A Heterogeneous SoC for Bluetooth LE in 28nm

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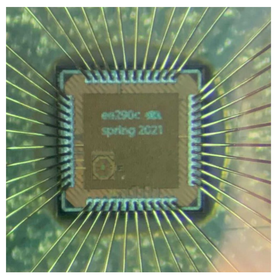
Motivation

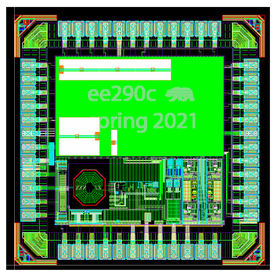
- Create a system-on-chip (SoC) (dubbed OsciBear) featuring:
  - RISC-V 32-bit 5-stage in-order scalar processor
  - AES accelerator
  - BLE 1M baseband-modem
  - 2.4 GHz radio front end (RFE) transceiver
  - On chip power regulation and distribution
- Tape out in 14 weeks with 19 students (4 Ph.D students, 6 masters students, and 8 undergraduates)
- Demonstrate Berkeley-developed agile hardware tools and flow
- More about UC Berkeley's tapeout course can be found at https://ucb-ee290c.github.io and here:

Verification

Chip Photos

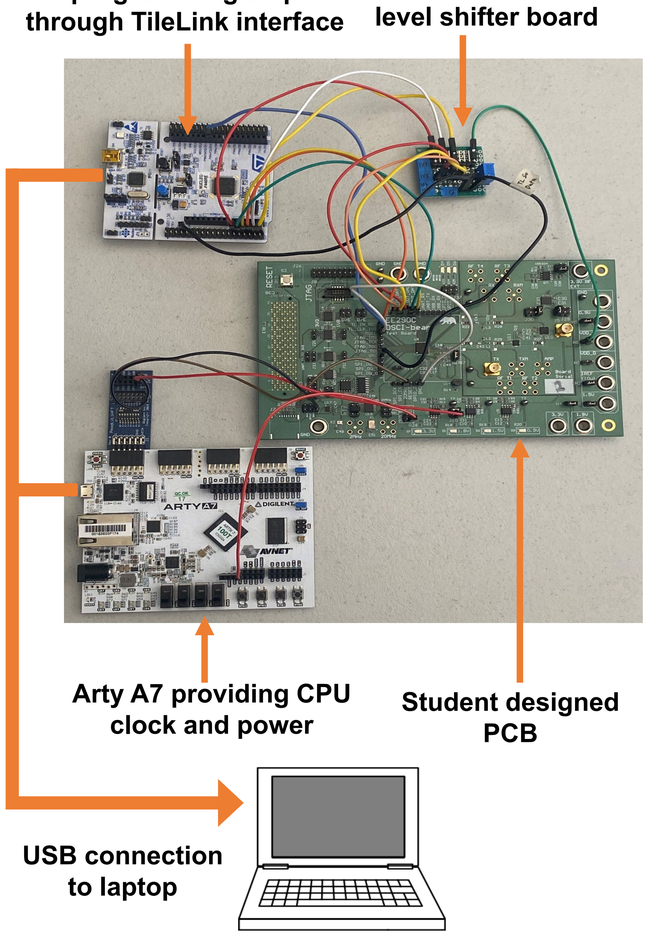


Wirebonded Die



Chip Layout

Demonstration Setup



Chip Architecture

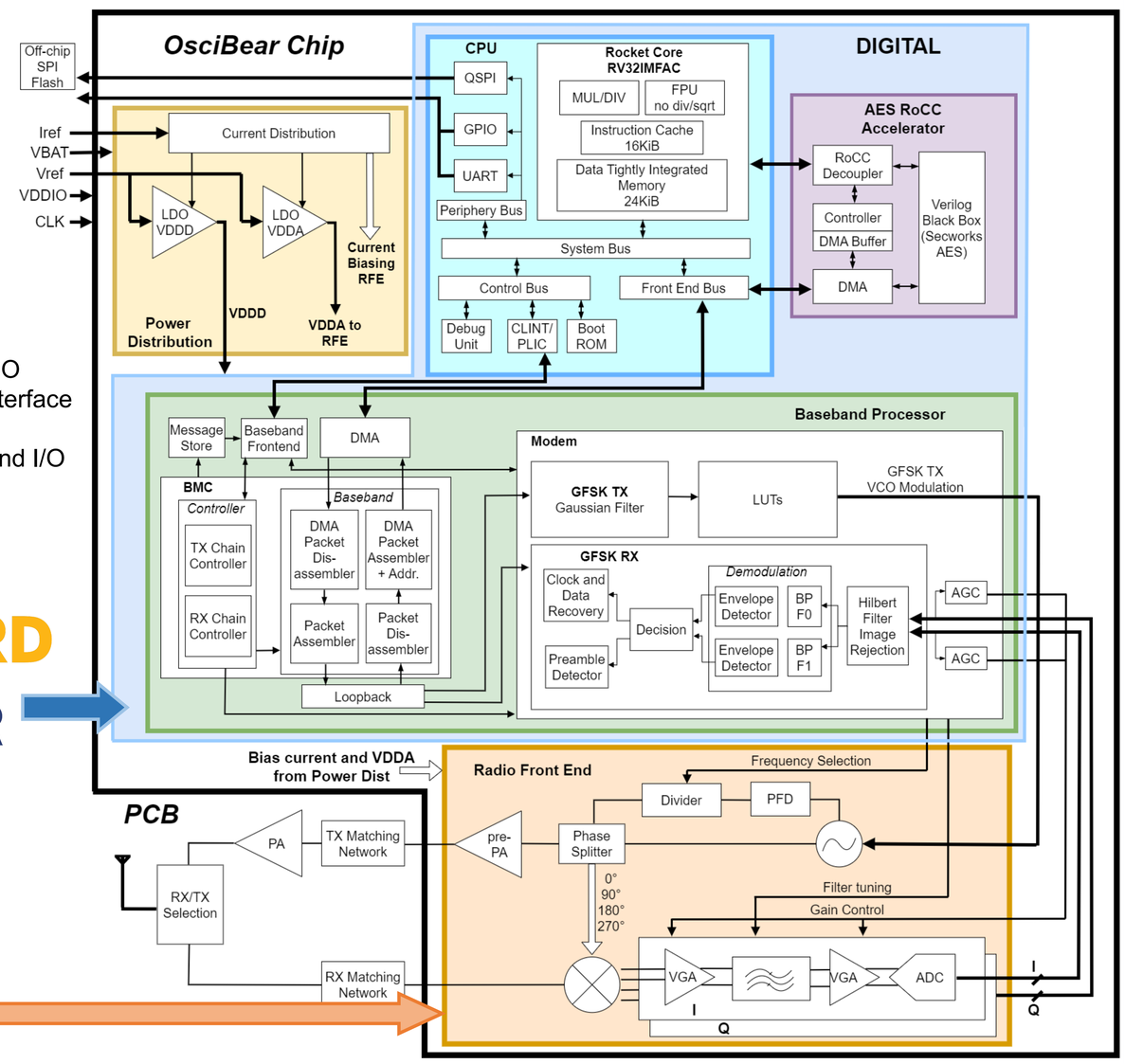
Chip Specs

- Digital Components
  - Compute
    - RV32IMAFC Core
    - Interrupt Controller
    - UART and TSI peripherals
  - Digital Baseband
    - TX/RX packet control
    - Digital RF tuning constants
- Analog Components
  - Radio Front End
    - Low-IF receiver architecture
    - TX and LO generation through VCO
    - Digital GFSK modulation tuning interface
  - Power Regulation
    - Three domains – analog, digital, and I/O
- <10mW of static power
- 74% density on digital portion of chip

Research Infrastructure

Digital CHIPYARD, HAMMER, CHISEL

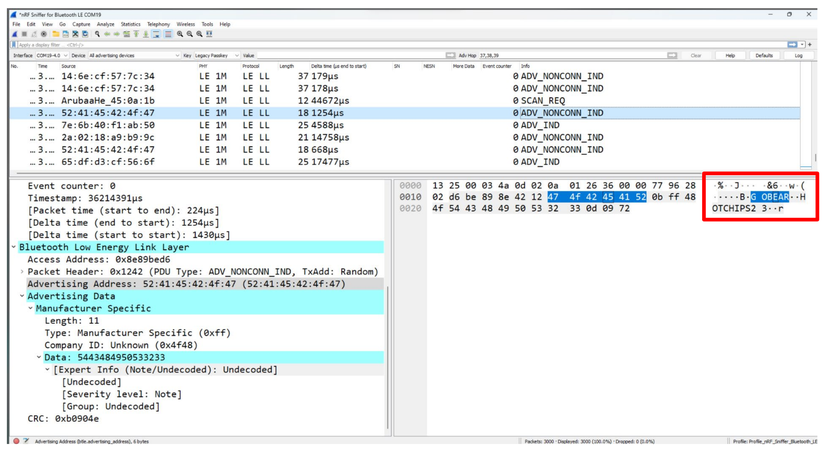
Analog BAG Berkeley Analog Generator (ADC Only)



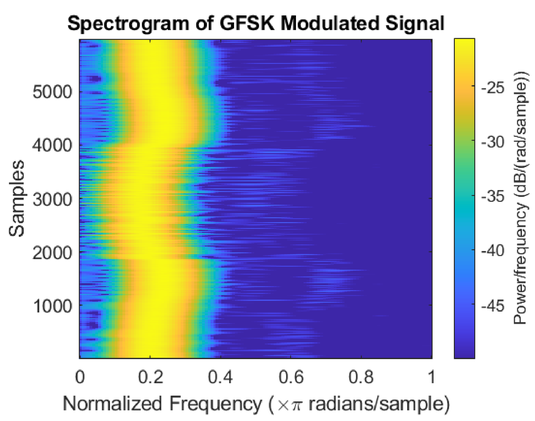
Bluetooth LE Transmit and Receive Measurements

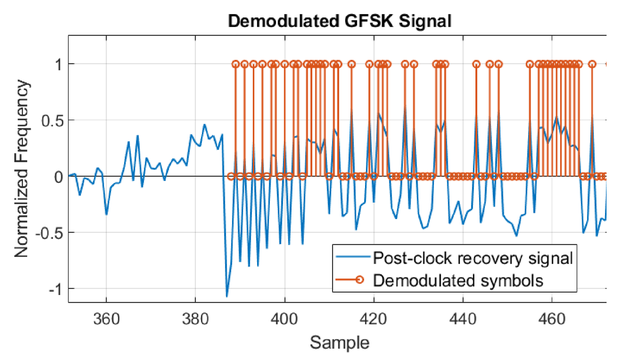
- Transmit packet decoding done two ways:
  1. Software Testing
     - Transmitted RF signal mixed down off chip
     - IF signal demodulated in software showed preamble, access address, and payload
  2. Commercial (Nordic nRF52DK) receiver
     - LO calibrated to BLE channel 38 (advertisement)
     - Packet transmitted periodically with commercial receiver configured as sniffer
- Receiver tested from PCB antenna port to differential output of final VGA (pre-ADC)

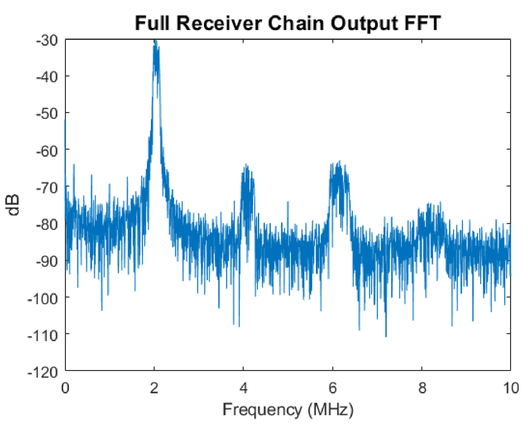
Radio Measurement Summary	
TX Frequency Modulation Range	~250 kHz
TX Power 1 meter away	-55 dBm
RX Chain SNDR (pre-ADC)	24.87 dB



Commercial receiver decoding correctly formed packet sent with "GOBEAR HOTCHIPS23" as payload







Acknowledgements

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