Big Things in Small Packages
Embedding an SDR Device in Today's Mobile Computing Platforms

Epiq Solutions
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Our Background

- Lifelong passion for building things
- Worked in wireless telecom industry for 11 years (1998 – 2009)
- First experience with GNU Radio back in 2005
- Co-founder of Epiq Solutions in 2009
- Big robot nerd

- System/Software engineer at Epiq since 2013
- Been working with SDRs for 7+ years
- Software lead on Epiq's Sidekiq/Maveriq products
- Supports GNU Radio on Epiq platforms
- Enjoys tinkering

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Some Observations

- The digital world keeps getting better...
  - Better CPUs:
    - Time increases → Transistor density goes up → CPU processing capability goes up → GNU Radio wins
  - Faster I/O Interfaces:
    - USB 3.0 and 3.1, PCIe x1/2/4/8/16 → More samples → GNU Radio wins
  - Feature-rich FPGAs:
    - Time increases → transistors get smaller → More LUTs, DSP blocks, block RAM → GNU Radio wins (+1 for RFNoc)
Some Observations

- **RF world** keeps shrinking...
- Direct conversion RF architecture led the parade
- Key contributions
  - Highly integrated LO solutions
    - Analog Devices ADF4350 in 2008
  - Fully integrated RF-to-bits transceivers
    - Lime Microsystems LMS6002d in 2010
    - Analog Devices AD936x in 2013
- The RF IC market is advancing at a rapid pace
- SDR world wins → GNU Radio wins

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So...What if...

- What if we wanted to blur the line between SDR and the mobile computing system?
- How can we merge them together?
- What are the practical issues?
- What does it mean for GNU Radio?
Where do we want to run GR?
Where do we want to run GR?

Everywhere, of course :-)
Focus on mobile use-cases, where we want the following...

- **Intimate electrical/mechanical coupling between host computer and SDR**
  - The smaller the SDR, the easier it is to integrate
  - Minimize cabling between host and SDR
  - Tighter coupling → More RF interference from host computer?

- **High throughput CPU ↔ SDR data transport**
  - Minimize CPU cycles needed for transport so GR can use them

- **Host computing systems with battery already integrated**
  - Power provided by host computing platform
  - Power efficiency of SDR is paramount

- **Integrated antenna availability**
  - Physics aren't on our side here
  - Ideally, integrated antenna + external antenna option
Solution Space

- USRP B210 from Ettus Research
- RTL-SDR from various vendors
- FunCubeDongle from FunCubeDongle
- Sidekiq MiniPCIe from Epiq Solutions
Why MiniPCIe is Interesting

• Can be used in LOTS of host computing systems
  – Desktop PCs (via PCIe->MiniPCIe adapter)
  – Laptops (internal MiniPCIe slot) or Expresscard slot (via adapter board)
  – Tablets (if slot is available)
  – Embedded computer boards

• Power and thermal dissipation provided by host slot (3W)

• High speed, low latency data transport
  – x1 PCIe (up to 5 Gbps theoretical) + USB 2.0 (up to 480 Mbps theoretical)

• Antennas often pre-wired in host for certain bands
  – Typically 700 MHz – 1 GHz, 1600 MHz to 2.2 GHz, 2.4 GHz and 5.0 - 5.9 GHz

• Very small...
  – ...and in general, small can be used in more places than big

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Example Integration Platforms

show-n-tell
gr-sidekiq (on github)
gr-sidekiq (on github)
Example benchmarks

- **Dell E6440 Laptop - PCIe (MiniPCle + Expresscard)**
  - 50 Msamples/sec Tx or Rx (unpacked)
  - 61.44 Msamples/sec Tx or Rx (packed)
  - 30.72 Msamples/sec Tx + Rx (unpacked)
  - Typical Sidekiq board temp: 55 deg C

- **Gateworks GW5410 – PCIe (MiniPCle)**
  - 50 Msamples/sec Rx, 45 Msamples/sec Tx (unpacked)
  - 61.44 Msamples/sec Tx or Rx (packed)
  - 22 Msamples/sec Tx + Rx (unpacked)
  - Typical Sidekiq board temp: 60 deg C (assumes minor thermal relief)
Antenna performance

• Systems with pre-integrated antennas can vary greatly
Antenna performance
RF interference from host

Internal laptop spurs below -110 dBm for the vast majority of the spectrum

Guess what the base CPU speed is?

(with an Intel Core i7-4610-M consuming 30+ Watts a few inches away!)

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What needs to improve?

- It ain't all roses
  - RF pre-selection is still a big challenge here (fighting physics again)
- Options for integrating external antennas
- Improvements in mobile CPUs to handle the firehose of samples from the radio
  - Leveraging mobile GPU, such as in Jetson TK1 and future Nvidia ARM offerings
The Future

- More card options coming on the market
- M.2 is leading the way
  - Smaller than MiniPCIe, more variants
  - Targeted at laptops/tablets
  - Smaller antenna ports (!)
  - Similar power consumption (~3W)
- Embedded platforms likely to stick with MiniPCIe for foreseeable future
- Sidekiq M.2
  - More FPGA fabric, more RF capabilities
  - Stay tuned for additional announcements
- RFIC world keeps improving
  - More dynamic range, wider bandwidths, more linearity
Conclusion

- Mobile computing platforms are getting smaller and more capable
- Very quickly making GNU Radio practical in small/mobile environments
- Small SDR platforms in MiniPCIe and M.2 form factors are helping pave the way for better integration
- The future is bright...
Questions?

Thank you!

Epiq Solutions
www.epiqsolutions.com

(oh...and we're hiring if you dig this stuff)

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