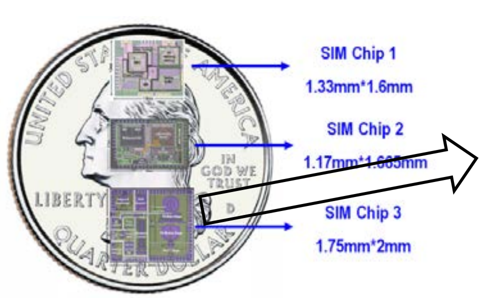
What are Integrated Systems?

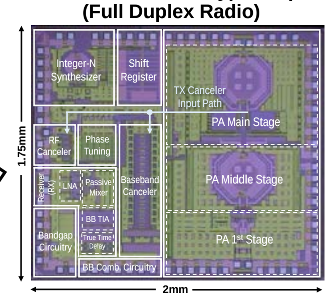
The application space for integrated devices is virtually unlimited. Circuits and sensors that are integrated on a single chip benefit from orders-of-magnitude reduction in cost, size and power as compared to discrete, board-level solutions of electronic systems. Example applications would include single-chip radios found in your phone and laptop, biosensors (neural interfaces, devices for spectroscopy, blood analysis, etc), control applications, to name a few. Those that have skills in designing these devices are typically in very high demand, both within industry and academia (faculty in the VLSI group are always on the lookout for grad students with good IC design skills).

Designing devices, both circuits and sensors, on a single chip demands skills across many disciplines including physics (device physics), signal processing, circuit design, good programming skills (for use in CAD tools), and math. The confluence of all these fields is what originally attracted me (Chris Rudell) to IC design, and I still find interesting to this day. As future systems become more complex and cross-layered, having a thorough understanding of what happens on a chip will benefit virtually anyone who goes into the area of designing electronic hardwaresystems. Below, you'll find a recent example of a prototype research chip(s) from UW. The device in the first set of figures contains an entire radio front-end, both the receiver and transmitter, which is capable of simultaneous transmitting and receiving on the same frequency (full duplex communication). At UW, we have three generations of this chip, shown on the left, set on a quarter, built in nanometer length dimension CMOS technology. An expanded picture of the chip at the bottom of the quarter, is shown in the center. Keep in mind, this chip contains a frequency synthesizer, low noise amplifier (LNA), power amplifier (PA), bandgap reference circuits, control and communication logic allowing an FPGA to talk with the chip, two adaptive cancellation filters and a complete receiver signal path, all within 2mm^2. On the right, you see the test board and lab setup (holds the experimental chip) including an FPGA to complete the system. To design such a system requires skills in IC design, embedded systems, programming and board design. A lot of these design topics are discussed along the Integrated Systems Concentration.

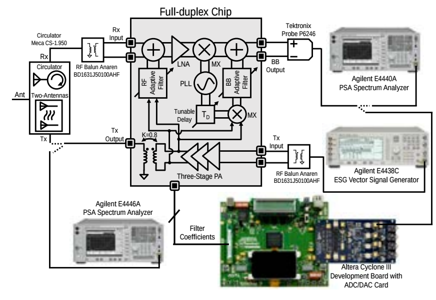
Three Generations of Full Duplex Radio Chips



TSMC 40nm Prototype Chip (Full Duplex Radio)



Full Duplex System

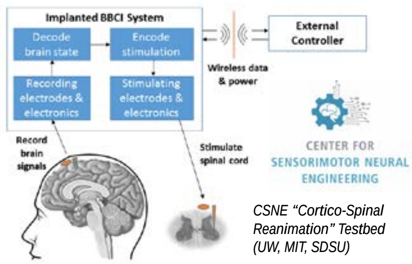


Another interesting application of integrated systems involves the use of chips for implantable (in vivo) neural interfaces. This application demands small size and ultra-low power electronics which is ideally addressed by integrating electronics on chip. Present day research is focused on techniques to integrate neural interfaces electronics on to one chip, easy to implant and low power. Example applications, system diagram, existing board-level solutions, and envisioned single chip solutions (right), shown below.

Deep Brain Stimulation

Source: Medtronic, Inc.

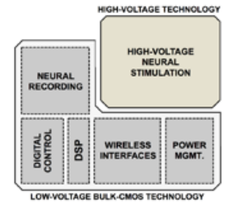
Bidirectional Brain Computer Interfaces



CSNE "Cortico-Spinal Reanimation" Testbed (UW, MIT, SDSU)

Integration of Bidirectional Brain Computer Interfaces

(ABOVE) High-voltage neural stimulation/recording system used by UW researchers [Zanos, 2011]



Student FAQs:

1) If I follow this new "Integrated Systems Concentration" will I be able to get a job as an IC designer after graduation (post BS EE)?

Ans: It's challenging (not impossible) to drop right into an IC design position after obtaining a BS in EE. In reality, it takes many years of education and practice in the industry, to get to the level of designing circuits and sensors for a chip. Likely the path to becoming an IC designer involves some graduate-level education (MS or PhD). However, there ***A LOT*** of jobs within the semiconductor industry where BS EE skills gained from this envisioned Integrated Systems Concentration will be valuable, such as validation engineers, signal integrity, device design, and product engineering. Moreover, if you are interested in continuing on to study integrated circuits and sensor design in graduate school, you will need the material covered in this concentration.

2) What knowledge do I need going into the new EE 332.

Ans: Not much, EE 215 and EE 233 might be enough. However, if you've had EE 331, that helps a lot. Students need a working knowledge of KVL, KCL, analysis of AC frequency response, voltage dividers, current dividers, resistive dividers, time domain response of RLC circuits and the concept of resonant LC circuits.

3) I've heard that analog IC design is being replaced by digital systems. As such, isn't the demand for engineers in this area fading?

Ans: Analog circuits have been replaced by digital electronics for the last 50 years. The immunity to noise found in digital circuits makes them an attractive alternative to analog electronics. However, as the speed of semiconductor devices increases, there are continually new analog applications being explored at very high frequencies (now in the mm-Wave band) where digital circuits are simply not fast enough. In addition, you may have heard the old expression that "we live in analog world" which is true, you don't see or hear 0s and 1s. As such, we always need an interface between the analog and digital worlds. Designing that interface is quite challenging and requires an engineer who has many skills related to chip design, signal processing and an understanding of sensor devices, mainly excellent fundamentals in many areas that this concentration will cover.

4) Friends tell me that the entire IC design industry is moving overseas. So, will there even be a future career for me if I decide to specialize in this area?

Ans: The fear of engineering jobs going overseas is something that almost every area of specialization struggles with at some point. There is no doubt that silicon fabrication houses in Asia are dominating the industry. In fact, it is likely becoming too expensive, to fabricate, in production, any electronics in the United States. With that said, Intel has just opened a new $7 billion fab in Hillsboro, Oregon. A lot of IC design is moving to Asia and India, but the high-end design appears to remain in the US. While that might change going forward, at a minimum, the higher end design problems will likely be split between the US, Europe, Asia, India and few other regions including the Middle East. It is more likely for a student starting off in IC design today, that they would change their career after 15 or 20 years because of burnout, rather than losing their job to an overseas company. It's a challenging job with demanding/stressful deadlines. As such, some designers look to move up, or transition to another easier careers...management, marketing, or designing less complicated electronic systems. However, I'm not aware of a single engineer in my area who lost their job because their group was shut down and moved overseas. Among my classmates that I graduated with from UC Berkeley, who had/have a career in IC design, about 1/2 of them are still working as silicon designers (this is after 20 years in the industry). The others have transitioned to business careers (become VPs), some now implement very large systems (one friend recently quit designing chips and is one of the lead designers at Google, for the latest Android Phone, "Pixel"), and lastly, a number of my colleagues simply retired after one or two successful startups (one classmate now manages his own VC fund). So, transitioning out of a career in IC design is quite easy as it is a fundamental area in Electrical Engineering, requiring skills that are easily translatable to many, many other careers in the high-tech world.

Is this field challenging? Yes, very demanding, but it can also be very rewarding!