Introduction to The FR4IC Project

Two difficulties with common semiconductor processes for teaching, learning, and practicing RFIC Design in 2013 are:

1. Very long time delays between completing an initial design and having actual silicon to test.

2. Industry standard simulation, layout, and validation tools are prohibitively expensive and model libraries are exclusive.

However, once acquired, the basic knowledge and skills required of an analog or RFIC designer may be easily transferred between processes. A skilled CMOS designer quickly comes up to speed on a BiCMOS process, and a GaAs RFIC designer can attend, understand, and contribute to a design review for RF CMOS. What is needed for education, practice, and resume building is an IC process that enables quick-turn designs using accessible and open-source tools.

One way to meet these goals is to change the way we think about FR4. Rather than treating it as a printed interconnect structure, approach FR4 as a planar substrate upon which we build an integrated RF circuit—exactly the same way we treat a Silicon or GaAs substrate. We then proceed through the usual semiconductor design, simulation, layout, parasitic extraction, LVS and DRC, Critical Design Review, fabrication, bench evaluation, compliance matrix, redesign, fab, test etc. steps exactly as with one of the usual semiconductor processes, but much faster and cheaper.

If we think of FR4 as an IC process rather than simply a cheap circuit board material, we open up the door to a world of IC design and practice that permits us to develop and hone advanced RFIC skills. A major advantage of FR4 is that it is large, and we can build scale models of microwave ICs at frequencies where test equipment is highly capable and accessible. It is particularly convenient to use a scaling factor of 25, so that microns on a GaAs die become mils on our FR4 scale model. A 100 micron bond pad on a 1 mm square GaAs die scales to a 100 mil bond pad on a one inch square FR-4 die. Scaling frequencies by 25 permits us to build VHF circuits in the 30 to 300 MHz range that are scale models of GaAs and Silicon circuits in the commercially important 750 MHz to 7.5 GHz range. The 30 to 300 MHz VHF range includes 3 amateur radio bands, where the FCC encourages experiments with different power levels, digital and analog modulation schemes, and propagation modes.
A second major advantage of scale model RFICs on FR4 in the Amateur Radio Bands is that such circuits are, by definition and law, off the company books. They are ideal for open-ended experiments, designs that test unusual, creative ideas, and explorations of the relationship between analytical models, circuit and electromagnetic simulations, and bench measurements. These explorations are critical for student education, and practice/resume building for professionals. Data collected on FR4 circuits in the amateur bands simulated using LTSpice is freely available for your next interview presentation or IMS Conference paper. In the modern era where everything you do on GaAs or Silicon includes someone’s intellectual property, the free development and exchange of ideas is a welcome breath of fresh air.

The word “practice” has been used several times. Engineering students may recoil at the prospect of doing the same problem again and again until they are really good at it, but impatient students make rotten designers. Design is an art form, and artists practice. Experienced RFIC designers have a portfolio of work to lean on when approaching a new design. The use of open source material for practice is routine in every field except semiconductor design.

Consider an aspiring violinist with dreams of performing the Tchaikovsky Violin Concerto in D. The semiconductor industry approach would be to rent a concert hall, hire a symphony orchestra, open the sheet music, and get to work. With careful budgeting and a gifted violinist, that might be done for a million dollars—about the cost of a CMOS mask set. But violinists practice alone, building their skills on challenging material such as the Bach Solo Violin literature and the Paganinni Caprices. Having developed the necessary transferable skills, the technically difficult sections of the Tchaikovsky may be addressed with a few months of solo practice under the guidance of a skilled teacher, followed by a few rehearsals with the full orchestra in the concert hall.

Finally, FR4 circuitry is valuable in its own right. Electrical engineers who can design complex circuitry on FR4 using standard components are at the heart of successful companies from startups to major multinationals. The ability to go from a sketch to a working prototype in a week is a profoundly useful capability for any engineer working on practical problems that someone cares about. The FR4IC Project provides a path to build and practice that skill set, and portfolio material for entry into the world of IC design on Silicon and GaAs.