Discrete RF Semiconductors: Alive and Well

By Rick Cory, Skyworks Solutions, Inc.

In the early 1980s, I was faced with a choice. I was working for a small microwave diode manufacturer as a test engineer, happily integrating stand-alone test equipment into systems controlled by first-generation IBM personal computers. My division vice president walked into my office one morning and said, in a rather abrupt manner, “Our applications engineer just quit. You are the closest thing to him we have, so you are our new applications engineer as of right now.” He vanished as suddenly as he had entered, leaving me wondering what just happened and whether it was good or bad for my family and me.

Commercial RF/microwave integrated circuits (RFICs) were establishing a credible toe-hold at the time, to the extent that the prevailing conventional wisdom held that discrete RF semiconductors were on a sure, quick path to obsolescence. My gut reaction told me that my new assignment had placed me on an inescapable one-way trip to the unemployment office, so I sought career advice from some more experienced colleagues. The very small majority of those whom I consulted advised me to make the shift into RF discrete diode applications engineering, the most prescient of whom told me that as a test engineer I was really “just a computer programmer, who are a dime a dozen” (his words – not mine!) and that if I was able to become a reasonably good RF/microwave applications engineer, I could “write my own ticket” (he was a tad optimistic on that point). He said that discrete RF/microwave semiconductors were going to be around for a long time.

Fast-forward to 2009. The market for discrete RF/microwave semiconductors is not just alive and well, it is as healthy as any in the electronics industry, and is weathering the current recession very well indeed.

The capabilities of RFICs have advanced and improved by orders of magnitude. For example, complete radio transceivers, that would have been as large as a shoe box in the 1980s, which utilize very complex modulation and multiple access technology, are being produced as chips much smaller than a breath mint -- in billions-of-units quantities for cellular telephones and for wireless local area networks. Indeed, several multi-standard cellular telephone handsets contain multiple RF transceivers, each of which is specialized for specific communications standards such cellular telephone systems including GSM, WCDMA, et al, as well as personal and local area network standards like Bluetooth™ and the 802.11 wireless local area network family of standards. All this technology is packaged into a volume smaller than a deck of playing cards, with LCD displays, GPS receivers, multi-megapixel digital cameras, and QWERTY keyboards occupying most of that space.

Even with such remarkable and admirable advances in RFIC technology and capability, the market for discrete RF/microwave semiconductors is thriving and for several good reasons. Discrete, single function semiconductors are versatile. An RF switch can be designed using RFIC field effect transistor technology, but PIN diodes can much more readily be configured in various circuit topologies to meet specific power handling, insertion loss and isolation requirements “on the bench.” An RFIC switch is what it is: if it satisfies technical requirements it probably takes significantly less PCB space and is likely less expensive than the discrete-PIN-diode equivalent. However, if some aspect of RFIC’s performance is found to be lacking, it cannot be quickly adapted to meet specifications. A new RFIC must be designed, a process that can easily take 18 months or more.

The output frequency of a voltage controlled oscillator (VCO) is controlled by varying the capacitive reactance of a semiconductor junction in response to a tuning voltage. Monolithic RFIC VCOs have been developed that work quite well, but their frequency vs. tuning voltage curves are restricted as a result of the practical limitations that wafer processing capabilities impose on the performance of the variable capacitance element in the circuit. The RFIC designer must avoid the use of processing techniques that are beneficial to the realization of a specific capacitance vs. voltage characteristic, but deleterious to the performance of the components in the remainder of the VCO circuit. Discrete tuning varactor diodes can be produced with many different capacitance vs. voltage characteristics, since the diode designer is free from many of the restrictions in wafer processing methods under which the RFIC designer must labor.

The measurement of signal levels is required in most radio communications systems, to control automatic gain control circuitry, measure transmitter output power in order to ensure compliance with communications standards or government regulations, and more. Very clever RFICs have been developed, such as demodulating logarithmic amplifiers, which rival the performance of the simplest of RF discrete diodes -- the

Schottky junction diode. The RFICs can offer wide dynamic range and somewhat customizable transfer functions, but this is at the cost of power consumption from the system power supply, often on the order of several milliamperes at 3 to 5 Volts.

Schottky diode detectors could not be much simpler to implement: the simplest version consists of a single Schottky diode, a capacitor, a resistor and possibly RF choke, configured as a simple half-wave rectifier. No external DC power supply is required. Silicon Schottky diodes with different barrier heights, such as very low (often called a “zero bias detector” barrier height), low, medium and high barrier diodes are available. The barrier height is proportional to the forward voltage of the junction, so the lowest barrier height is well suited for detection of very low power RF signals, the high barrier diode is readily able to handle large RF signal amplitudes, with the low and medium barrier diodes’ power detection and handling capabilities falling in between.

As my colleague predicted, I have had the very good fortune to be gainfully employed as an RF discrete semiconductor applications engineer since that strange day in 1982, save for a brief period when I attempted to perform that same function in support of RFICs. Contrary to the aforementioned prevailing wisdom of the 1980s, the market for RF discrete diodes has steadily increased, quite handily so. For example, in 2008 Skyworks Solutions alone produced several hundred *million* discrete RF diodes, which found their way into systems from cellular telephone handsets and base stations to garage door openers to military and homeland security communications. This number probably exceeds the number of diodes produced for the entire worldwide market by all manufacturers in 1982. With the new markets for RF/microwave discrete semiconductors such as medical implants and wireless sensor networks, the robustness of the military/homeland defense market, and the pleasantly surprising tenacity of the cellular communications market, the future looks promising. I cannot wait to see what happens next!

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