Recent Developments in RF Power Device Technology

Developers of new RF power devices have different goals, depending on the frequency, power level, linearity, cost, duty cycle, efficiency, and other environmental and performance factors. Recent years have seen rapid changes in the technologies used for RF power, as new applications present new requirements.

LDMOS is Dominant for Linear Applications

In the frequency range of 500 MHz to 2 GHz, silicon LDMOS is the overwhelming choice for high power linear applications such as wireless base stations and digital television transmitters. Earlier, silicon bipolar was used in non-linear and mildly-linear systems (e.g. AMPS), while GaAs power devices gained the early lead in linear systems. Neither of these technologies had the combination of cost and performance required for more advanced systems (e.g. CDMA and DTV).

The capabilities of LDMOS for providing the necessary performance using low-cost silicon die were known, but practical issues in fabrication, thermal effects and aging required significant development effort to overcome. As reported in this and the previous issue of this magazine, accurate modeling and simulation of LDMOS devices is essential. The model developed for the Cree Microwave devices is a good example of the depth of the work required to obtain maximum performance for demanding applications

Now, LDMOS power devices are being produced in very large quantities by large and small companies, including not only Cree Microwave, but Freescale Semiconductor (formerly Motorola Semiconductor), Infineon, Advanced Power Technology, PolyFet RF Devices and others.

Handset PA Device Evolution

As a high-volume application, the handset market has driven development of RFIC power amplifiers. Similar to LDMOS in the power arena, these lower-power amplifiers experienced an evolution from silicon bipolar to GaAs MESFETs and now to GaAs HBT and its variations, mainly InGaP.

Companies like RF Micro Devices, WJ Communications (through its acquisition of EiC), Hittite Microwave, Sirenza Microdevices and others provide GaAs HBT power amplifiers to handset makers.

Silicon-germanium technology has also been developed for handset applications, but presently has a much smaller share of the market than GaAs HBT. SiGe has done much better in 2.4 GHz WLAN and other unlicensed device applications.

Silicon Bipolar Still Has Applications

Silicon bipolar has current density characteristics that have not been matched by other technologies. This makes them suitable for short-pulse, high power applications such as TACAN and IFF, plus other avionics applications and some electronic countermeasures systems. Long-pulse applications have used derated bipolar transistors, but LDMOS devices are now gaining ground in these applications in military and avionics systems.

Silicon bipolar is also used, along with other device types, in driver applications and low-level amplification. The low cost of fabrication and the relative unimportance of achieving high efficiency makes this technology useful. There are many bipolar and BiCMOS devices being produced.

RF Power at HF through VHF

Both legacy and modern communications systems are in operation at frequencies from the low-kHz range through VHF. For these applications, several power device technologies are used. Silicon bipolar is still in use over all of these frequencies, but in ever-smaller quantities. Newer technologies are now used in different portions of this segment of the spectrum.

At frequencies up to a few MHz, power FETs with very low ON-resistance and high current handling are used in broadcast and navigation radio transmitters, and in switching power supplies. Extremely high efficiencies can be achieved (90% and better) at these frequencies in non-linear (e.g. CW and pulse-width modulated) applications. Class D/E and other variations on switch-mode amplifiers are the dominant circuit types, and have been continually improved since their introduction in the mid-1970s.

In the HF and low-VHF range (roughly 2 to 150 MHz), RF power FETS using various forms of gate trench fabrication have been dominant. Certainly the best known of these devices is the venerable “Motorola MRF-150,” which has been copied, modified, adapted and improved by several other companies.

With single devices providing up to 150 watts RF power output, and with parallel development of transmission-line combining and transformer technology, amplifiers with power output of several kilowatts are common. The development of magnetic resonance imaging (MRI) systems gave this technology a huge boost in the 1980s, which continues today.

ISM-Band Industrial RF Power

Industrial RF for heating, plasma generation, laser driving and other non-communication uses is a big application area. Classic HF/VHF power FETs like those noted previously are still used in many systems, but there has been a clear evolution to a less-expensive FET derived from the common lower-frequency power FETs. Previously, the high gate and drain capacitance of power FETs made it difficult to use them above 1 or 2 MHz. Successful efforts to refine the structure have created a new family of switch-mode power FETs that are optimized for applications into the tens of MHz and higher. Two companies dominate this niche: Advanced Power Technology and IXYS.

In Development

There are several new technologies being explored for new applications. We’ve chosen two for special mention: wide band gap devices and silicon carbide.

Gallium arsenide was the first wide band gap material to be explored, and it has been highly successful, but only after a significant period of development and market “shakeout.” Recently, InGaP and InP have reached a similar level of successful development. Gallium nitride and several other materials are being studied intensely for emerging applications at frequencies above 5 GHz.

Silicon carbide is still early in its development, but it has the promise of higher power density, which can mean either smaller power devices, or lower die temperatures for longer life and higher reliability. Thermal issues are extremely important in power devices, some of which may be solved by SiC.