Some basic design issues for RF power amplifiers as integrated circuits.

Introduction: This brief article presents, in cookbook fashion some basic considerations for the design rf power amplifiers using microtechnology. For background information on RF power amplifiers please refer to the RF power amplifier design fundamentals in our website located at http://www.signalpro.biz > engineer's corner.

Design considerations:

Technologies: RF power amplifiers are being implemented in a large number of technologies. Bipolar, SiGe, III-V technologies, GaAs (a perennial favorite), GAN, CMOS (with some reservations stated below) Most of these technologies are freely available from foundries and can be used for ASIC/RF IC and wireless IC implementations with confidence.

Some issues with CMOS technology that must be recognized are:

1) Highly doped substrates are common in CMOS. This results in poor quality passive elements. Inductors integrated in CMOS exhibit high loss.

2) Substrate interaction in a highly integrated CMOS IC also has a significant effect on RF CMOS design.

3) Transistor models for CMOS have been found to be only moderately accurate for RFICs/MMICs, and need to be improved for analog operation at RF frequencies. Large-signal CMOS RF models are critical to the successful design and operation of integrated CMOS RF power amplifiers.

4) Other issues to take into considerations are: Device parasitics, package, and bond-wire parasitics. These have a significant impact on power amplifier output and efficiency. 1 nH package pin inductance, at 2.4 GHz, has a reactance of 15 n. This reactance will cause problems for output matching.

Ground bounce is a performance-limiting factor for high power amplifiers.

5) The layout of RF power amplifiers (whether integrated or not) is one of the most significant performance effecting parameters for RF power amplifiers. The power device

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design itself is a major issue in most integrated designs while the choice of the power device is the issue in discrete designs.

6) The design of the power rail to the output stage is very important. The concern is the current flowing through it and the impact of ringing (badly designed power rail) can have from noise to latch up to a complete burn out. Diode protection of the power rails should be used.

7) SWR control needs to be seriously considered as even momentary bad SWR can cause destruction of the device and serious latch up problems which will destroy the device.

8) The design of the output pad in integrated devices is another issue that must be recognized. The output pad is where the connections of the PA output will be to the outside world. The parasitics associated with the pad in tandem with the parasitics of the bond wire or the bump and its extension on a trace will cause multiple problems as described above.

9) Design of the power pad has the same significant effects on the RF PA operation. It is of course, a given that the PA power pad will be separate from the power for the rest of the circuitry.

10) Interactions between the PA power and the rest of the circuitry's power pad. These interactions can cause problems from latch up to severe degradation of the performance.

11) Device I/O. This is an art and should be provided by the foundry. The reason is, it takes a significant amount of resources to design, characterize and qualify an I/O pad, specially if ESD protection is required. (Also see the paper on RF/MW ESD protected pads in the SPG website).

12) Other challenges such as noise, oscillation problems, thermal design are also of concern and need to be addressed at the outset. (See papers on these in the spg website>engineer's corner).

Conclusions: RF power amplifier design is more of an art than a science. Design tools do exist to assist the engineer to do this but they have some severe limitations. Behavioral modeling (see the spg website) for RF PAs, brass boarding (will only provide a functional equivalence to an integrated device) and tweaking (at one time the only resort for the design of MIC power amplifiers) are all legitimate techniques to use in the design of the RF/Wireless power amplifiers.

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