RF Power Amplifiers, Classes A Through S: How the Circuits Operate, How to Design Them, and When to Use Each

This tutorial is for “beginner” through “advanced” design engineers and their managers, concerned with designing any type of RF power-amplifier product, e.g., radio transmitter, or RF-power source for induction heating, dielectric heating, plasma generation, or illumination. Learn how all types of linear and nonlinear RF power amplifier circuits operate, how to design them, and when to use each, and be able to design manufacturable RF power amplifiers that work satisfactorily under all foreseen normal and abnormal operating conditions.

With at least ten lettered classes of RF power amplifiers, and several combinations of those classes, many engineers are confused about RF power amplifier design. The complexity of the subject is compounded by the fact that the RF power transistor acts *either* as a high-resistance current source *or* as a low-resistance switch, *or - in some amplifiers* - as a high-resistance current source during *part* of the “on” interval and as a low-resistance switch during *another part* of the “on” interval (so-called “mixed-mode” operation). The circuit topology does not define unambiguously the transistor operating mode or the amplifier class of operation - examples will be shown.

The tutorial will review

- Saturated (switching-mode) and unsaturated (“linear”) families of amplifiers - Classes A through S
- Transistor Utilization Factor defined as output power per transistor normalized for peak drain voltage and current of 1 V and 1 A, respectively for each class of operation
- BJTs, MOSFETs and MESFETs operating in current-source (“linear”) mode, in switching mode, and in “mixed-mode” operation
- Interactions between power transistor and external circuit, determining transistor and circuit operating conditions
- *Controlling* RF output amplitude vs. *modulating* information onto amplitude envelope
- Benefits and shortcomings of each circuit
- Overview of reasons for parasitic oscillation and how to ensure stability
- Suitable application areas for each circuit
- Linear amplifier *systems* using RF power amplifier circuits as building blocks
- Computer-Aided Design (“CAD”) of switching-mode RF power amplifiers

Nathan O. Sokal – Biography

Nathan Sokal received the 2007 Microwave Pioneer award from the IEEE Microwave Theory and Techniques Society “in recognition of a major, lasting, contribution ... development of the Class-E [high- efficiency switching-mode] RF power amplifier.” In 1989, he was elected a Fellow of the IEEE, for his contributions to the technology of high efficiency switching-mode power conversion and switching- mode RF/microwave power amplification. In 1965, he founded Design Automation, Inc., a consulting company doing electronics design review, product design, and solving “unsolvable” problems, for equipment manufacturing clients. Much of that work has been on high efficiency switching mode RF power amplifiers at frequencies up to 2.5 GHz, and switching mode dc-dc power converters. He holds eight patents in power electronics, and is the author or co-author of two books and about 130 technical papers, mostly on high efficiency generation of RF power and dc power. During 1950 to 1965 he held engineering and supervisory positions for design, manufacture, and applications of analog and digital equipment. He received B.S. and M.S. degrees in Electrical Engineering from the Massachusetts Institute of Technology, Cambridge, Massachusetts, in 1950. He is a Technical Adviser to the American Radio Relay League, on RF power amplifiers and dc power supplies, and a member of the Electromagnetics Society, Eta Kappa Nu, and Sigma Xi honorary professional societies.