RF Circuit Design References

By Peter Delos

Proficiency in the RF circuit design profession requires significant awareness of many areas of electrical engineering. Acquiring foundational material and digesting the engineering principles involved is a lifelong undertaking. For engineers entering the RF profession it is not always clear where to begin. Fortunately, many well written references have been published over the last few decades. The purpose of this note is to outline some of the important references with comments on their contributions. The intention is to provide a starting point for working engineers entering the RF arena, as well as a useful reference list for seasoned RF engineers.

Effort was placed on providing references that provide a comprehensive foundation through books, some IEEE papers, and many working-level application notes. As a disclaimer to the compiled reference list, there is no way to include every possible reference book or famous paper. Any detailed design or study in a particular topic will lead to additional material not cited here.

**Introductory Material:**
If you are brand new to RF, these books can provide a practical foundation with easy to read descriptions.


**RF and Microwave Principles:**

[3] Pozar, “Microwave Engineering,” Wiley, 2011. This is a famous reference and is up to the fourth edition. It requires a background in field theory, and brings EM principles into microwave applications.


[6] Gandhi, “Microwave and Engineering Application,” Pergamon Press, 1981. This is a college textbook that complements, and in some ways is more practical, than Pozar.


Signal and Communication Theory: These first two books are college level textbooks, heavy in math, but provide some of the fundamental theory taught at the university level.


These references break down the basics of modulation and are well written:


**Receiver Architectures**


Murphy et al, “A Blocker-Tolerant, Noise-Cancelling Receiver Suitable for Wideband Wireless Applications,” JSSC, 2012. This received Best Paper Award at the time. Murphy outlines and includes many references for noise-cancelling receiver architectures. These methods may change how receivers are done in the future.

Waveform Generation


Modern waveform generation begins in the Direct Digital Synthesizer (DDS). Next it is followed by an up-conversion stage. The up-converter is conceptually a mirror of the receiver, but with different considerations. Much has been written on receiver design; less literature exists on the upconverter aspects of waveform generation. For this, the designer can refer to the mixer, filter, and amplifier references.

Phase Locked Loops

Brillant, “Understanding Phase Locked DRO Design Aspects,” Microwave Journal, 1999

Oscillators

Kurzenknabe, “Practical Considerations in Specifications of High Stability Crystal Oscillators,” Piezo Crystal Company (Now Vectron), exact date unknown, probably ~1990. This is a great reference for anyone buying crystal oscillators.

Noise

“Fundamentals of RF and Microwave Noise Figure Measurements,” Agilent Application Note AN57-1. This originated as a Hewlett-Packard note and is the place to start on noise figure. The fundamental theory is described along with measurement techniques.
Maas, “Noise in Linear and Nonlinear Circuits,” Artech House, 2005

Phase Noise: Although this could be considered a subset of noise, it is so important in RF it that is given its own section.

“Phase Noise Characterization of Microwave Oscillators, Phase Detector Method,” Agilent Product Note 11729B-1. Another note originated by Hewlett-Packard and is the place to start on phase noise. It is online along with several other phase noise application notes.
Rubiola, “Phase Noise and Frequency Stability in Oscillators,” Cambridge University Press, 2008. One of the few textbooks on the subject, a lengthy set of references are cited and online lecture notes are also available.

Some famous phase noise papers:
Mixers

Frequency translation is a fundamental to RF. The methods, limitations, and additional filtering required should be understood.


Harmonic Rejection Mixers may become a fundamental building block in the future. The concept of minimizing mixing spurious through emulating LO signals with reduced harmonics can become practical with highly integrated RFIC design. One recent paper is cited, and other also exist.


Filters

Three famous books provide the foundation for much of the modern filter theory in use today.

Matthaei, Young, Jones, “Microwave Filters, Impedance-Matching Networks and Coupling Structures,” Artech House, 1980


OpAmps

A working knowledge of operational amplifiers is fundamental to electrical engineering. Several references from major semiconductor companies are cited.


Audio Amplifier Design

With the exception of parasitic impact, discrete circuit design techniques applied in audio are closely related to RF and IC design. The Self and Cordell books outline the essentials of discrete solid state audio design, and the O’Conner book provides a detailed design guide to tube based guitar amplifier design.


RF Amplifiers


RF Power Amplifiers


Walker (editor), “High Power GaAs FET Amplifiers,” Artech House, 1993. This is a good collection of material from multiple important authors.

Data Converters

[53] Kester, “Analog-Digital Conversion,” Analog Devices, 2004. This is a weighty book that includes a historical perspective, architectures, sampling theory, specifications, and user considerations. The information from many other application notes is included in this reference.

IC Design

[54] Gray et al, “Analysis and Design of Analog Integrated Circuits,” Wiley, 2009. This book is referenced routinely in many IEEE papers on RFIC design. It has been a valuable resource for both the university level and the working engineer for many years. It is now up to the fifth edition.


[57] Sedra, Smith, “Microelectronic Circuits,” Oxford Press, 2009. This has been a college textbook for several decades now and is up to the sixth edition.

[58] Razavi, “Fundamentals of Microelectronics,” Wiley, 2014. Razavi is a prolific writer. He has many other books worth considering, also. This is his latest and outlines a foundation in IC design as the title indicates.

Transistor Properties

Most circuit books have a chapter or two on transistor principles. Sometimes it is good to have a book dedicated to the topic at a practical level without going too deep into semiconductor physics.


[60] Ashburn, “SiGe Heterojunction Bipolar Transistors,” Wiley, 2003. A comprehensive treatment of bipolar transistors; covering properties, modelling, and how they are made. This also provides a good historical perspective of improvements over the decades of development.


Printed Wiring Board Layout


Power Supplies and Regulation

Much literature exists on power supply design. For the RF designer it is more important to be versed in the topologies and concepts of linear and switching regulator design, since not typically working specifically in this area. For this reason, several application notes readily available on the internet are cited and only one book.


[67] “Basic Concepts of Linear Regulator and Switching Mode Power Supplies,” Linear Technology Application Note

[68] “Basic Linear Design, Chapter 9, Power Management,” Analog Devices


Low noise RF performance starts with low noise DC power. Two application notes are cited:

[70] Teel, “Understanding Noise in Linear Regulators,” Texas Instruments Application Note
Digital Signal Processing: Some knowledge of signal processing after the A/D capture is very useful to aid in understanding specification requirements flowed to the RF systems.

Radar: Radar is its own specialized application. However, many RF engineers will work on something related to radar at some point in their careers. These references are old, but many of the system-level approaches in use today were worked out years ago and are just being implemented with modern methods.

Antennas: Antenna theory is fundamental to RF. The above references are geared toward RF electronics and signal processing. A completely separate list could be compiled on antennas.

Tutorial Websites

The volume of information online is incredible. Learning through this method is encouraged and a good balance to written books or papers. Many great application notes are available from semiconductor companies, RF component companies, and test equipment companies, and research institutions. A few websites are listed which bring a unique contribution to the volume of available online material.

Areas Not Covered

The following areas are not referenced specifically but are also an important aspect of the RF engineering profession. These include:
1) **Programming:** Every engineer needs some programming fluency. Programming should be an aid, not a hindrance.

2) **CAD Tools:** CAD tools have progressed to an amazing level in our lifetimes. Circuit simulators, EM modelling, PWB and IC layout tools have made things possible that otherwise wouldn’t exist. Learn the CAD tools in use at your facilities and help bring the latest tools into your departments.

3) **Mathematics:** While electrical engineering college curriculum is heavy in math, later, as working engineers, it is easy to forget. Keep some old college books around, and review the basics periodically.

**Acknowledgement & Final Comment**

The author would like to thank the engineers who reviewed this compilation and contributed to the list of titles provided. The above list is by no means complete. It is geared towards providing a foundation and a starting point. If this can provide some help for others, then it was worth the time to compile.

**About the Author:**

Peter Delos is a lead RFIC Engineer in the Lockheed Martin Microwave Center at the Moorestown, NJ, facility. He received his BSEE from Va Tech in 1990 and MSEE from NJIT in 2004. He began his career as an electrical field engineer gaining experience in many types of systems, electrical problems, and a foundation in the electrical engineering profession. In 1997, he accepted a position with Lockheed Martin in Moorestown, NJ, and began Receiver/Exciter/Synthesizer design. Mr. Delos has both worked in and led many design teams on highly integrated RF and mixed signal designs. The quest for high performance in reduced footprints led to detailed RFIC designs, and in 2012 he was transferred to the Lockheed Martin RFIC Design Center.