Job #: 71729

Author name: Crols

Title of book: CMOS Wireless

ISBN number: 0792399609
CMOS WIRELESS TRANSCEIVER DESIGN
ANALOG CIRCUITS AND SIGNAL PROCESSING
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CMOS WIRELESS TRANSCEIVER DESIGN

by

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Heverlee, Belgium

SPRINGER-SCIENCE+BUSINESS MEDIA, B.V.
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Symbols, Conventions, Notations and Abbrevations

Conventions and Notations

The following notations are used for the subscripts of voltage and current signals to indicate their instantaneous, AC or DC value. The notation method of [Laker 1994] is used.

\[ I_{\text{OUT}} \] DC or average value of a current signal;
\[ I_{\text{out}} \] amplitude of the AC-component of a current signal in steady state;
\[ i_{\text{out}} \] instantaneous value of the AC component of a current signal;
\[ i_{\text{OUT}} \] total instantaneous value of a current signal, so \( i_{\text{OUT}} = I_{\text{OUT}} + i_{\text{out}} \).

When the unit dBm is used throughout this text, it is not used in its original definition of 0 dBm being equal to 1 mW in 50 Ω. Unlike in discrete realizations, integrated RF systems often use impedance levels that differ from 50 Ω. In order to allow a comparison with classical discrete RF design, the unit dBm is still used, however re-defined as the corresponding voltage level in 50 Ω systems. 0 dBm is thus defined as 223 mV\text{rms} independent of the impedance level. 20 dBm is equal to 2.23 V\text{rms}.

Bibliographic References

In this text, bibliographic references contain information on the first author, the publication source and the year of publication, possibly extended with an extra character when more than one publication of the same author has been published in the journal in the same year. In this way the reader finds already a lot of information on bibliographic references within the text. The full information can of course be found in the bibliography. An example is [Crols JSSC95a]. ‘Crols’ are the first five letters of the first author’s name. ‘JSSC’ is an abbreviation for the journal the reference was published in. ‘95’ is the year of publication and the character ‘a’ has been added to
avoid ambiguity with another bibliographic reference. A list of the most important abbreviations used for publication sources has been given below. The absence of such an abbreviation in a reference indicates that it refers to a book.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ACD</td>
<td>Analog Circuit Design</td>
</tr>
<tr>
<td>CASII</td>
<td>IEEE Transactions on Circuits and Systems II</td>
</tr>
<tr>
<td>CICC</td>
<td>proceedings of the Custom Integrated Circuits Conference</td>
</tr>
<tr>
<td>ESSC</td>
<td>proceedings of the European Conference on Solid-State Circuits</td>
</tr>
<tr>
<td>ISSCC</td>
<td>digest of technical papers of the International Conference on Solid-State Circuits</td>
</tr>
<tr>
<td>JSSC</td>
<td>IEEE Journal of Solid-State Circuits</td>
</tr>
<tr>
<td>VLSI</td>
<td>proceedings of the Symposium on VLSI Circuits</td>
</tr>
</tbody>
</table>
Symbols
The symbol convention given below is used in the circuit schematics throughout this text. Unless otherwise indicated, the bulk of nMOS transistors is always assumed to be connected to the ground and the bulk of pMOS transistors is always assumed to be connected to their source.
Abbreviations

This list gives the full description of the abbreviations used throughout the text.

ADC  analog-to-digital converter
AC  alternating current
AGC  automatic gain control
BB  baseband
BER  bit error rate
BPF  bandpass filter
CMOS  complementary MOS
CPU  central processor unit
DAC  digital-to-analog converter
dc  direct current
DDS  direct digital synthesis
DECT  digital European cordless telephone
DR  dynamic range
DSP  digital signal processor
EEPROM  electrically erasable programable ROM
FER  frame error rate
FFT  fast Fourier transform
FM  frequency modulation
FS  frequency shift
GaAs  gallium arsenide
GMSK  gaussian minimum shift keying
GSM  global system mobile
HDn  n<sup>th</sup> order distortion
HF  high frequency
I  in phase
IF  intermediate frequency
IMn  n<sup>th</sup> order intermodulation
IPn  n<sup>th</sup> order intermodulation intersection point
ISDN  integrated services digital network
LF  low frequency
LNA  low noise amplifier
LO  local oscillator
LPF  lowpass filter
LTF  linear transfer function
modem  modulator-demodulator
MOS  metal oxide semiconductor
MOSFET  MOS field effect transistor
NF  noise figure
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTA</td>
<td>operational transconductance amplifier</td>
</tr>
<tr>
<td>PLL</td>
<td>phase locked loop</td>
</tr>
<tr>
<td>PSD</td>
<td>power spectral density</td>
</tr>
<tr>
<td>Q</td>
<td>in quadrature</td>
</tr>
<tr>
<td>QPSK</td>
<td>quad phase shift keying</td>
</tr>
<tr>
<td>RBER</td>
<td>residual bit error rate</td>
</tr>
<tr>
<td>RF</td>
<td>radio frequency</td>
</tr>
<tr>
<td>RMS</td>
<td>root mean square</td>
</tr>
<tr>
<td>ROM</td>
<td>read only memory</td>
</tr>
<tr>
<td>ΣΔ</td>
<td>sigma-delta</td>
</tr>
<tr>
<td>SNR</td>
<td>signal-to-noise ratio</td>
</tr>
<tr>
<td>spec</td>
<td>specification</td>
</tr>
<tr>
<td>SSB</td>
<td>single sideband</td>
</tr>
<tr>
<td>SUSR</td>
<td>signal-to-unwanted-signal ratio</td>
</tr>
<tr>
<td>TDMA</td>
<td>time domain multiple access</td>
</tr>
<tr>
<td>transceiver</td>
<td>transmitter-receiver</td>
</tr>
<tr>
<td>VCO</td>
<td>voltage controlled oscillator</td>
</tr>
<tr>
<td>VGA</td>
<td>variable gain amplifier</td>
</tr>
<tr>
<td>Xtal</td>
<td>crystal</td>
</tr>
</tbody>
</table>
The world of wireless communications is changing very rapidly since a few years. The introduction of digital data communication in combination with digital signal processing has created the foundation for the development of many new wireless applications. High-quality digital wireless networks for voice communication with global and local coverage, like the GSM and DECT system, are only faint and early examples of the wide variety of wireless applications that will become available in the remainder of this decade.

The new evolutions in wireless communications set new requirements for the transceivers (transmitter-receivers). Higher operating frequencies, a lower power consumption and a very high degree of integration, are new specifications which ask for design approaches quite different from the classical RF design techniques. The integratability and power consumption reduction of the digital part will further improve with the continued downscaling of technologies. This is however completely different for the analog transceiver front-end, the part which performs the interfacing between the antenna and the digital signal processing. The analog front-end’s integratability and power consumption are closely related to the physical limitations of the transceiver topology and not so much to the scaling of the used technology. Chapter 2 gives a detailed study of the level of integration in current transceiver realization and analyzes their limitations.

In chapter 3 of this book the complex signal technique for the analysis and synthesis of multi-path receiver and transmitter topologies is introduced. With this technique, several new receiver and transmitter topologies are developed. An example is the low-IF receiver topology. The presented topologies all have in common that they combine the advantages of the classically used heterodyne architectures, i.e. a very good performance, with the advantage of a very good integratability.

Determining the building block specification for a new transceiver architecture is for RF designers mainly an experience-based process, resulting in long design cycles
and only a very gradual advancement of transceiver architectures. Here, in chapter 4, a formal methodology for the high-level design of transceiver architectures is presented. This methodology allows a structured and computer automatic high-level design, resulting in short design cycles and a fast evaluation of new transceiver architectures. The full high-level design of a low-IF / direct upconversion GSM transceiver front-end is presented in chapter 5.

A true full integration of a wireless transceiver requires that the analog front-end is integrated on the same die as the transceiver’s digital baseband signal processor. DSP’s use however standard CMOS technologies and these are less performant than the silicon bipolar and GaAs technologies that are used today for the integration of analog transceiver front-ends. Therefore, the integration of RF building blocks in CMOS is studied in chapter 6. Several chip realization are presented. In chapter 7 the capabilities of deep sub-micron CMOS used in combination with new highly integrated transceiver topologies for the implementation of wireless transceiver front-ends in the 1 to 2 GHz range is studied and demonstrated.

We also wish to express our gratitude to all persons who have contributed to the realization of this book and to the research described in this book. We would like to thank Prof. W. Sansen and Prof. H. De Man for carefully proofreading the manuscript. We would like to thank J. Craninckx, P. Kinget, M. Borremans and J. Janssens for their contribution made to this research. Our thanks also goes to the IWT (The Flemish Institute for Research in Science and Technology) for funding of the research.

Finally, we thank our families for their support and patience. Without it this research and this book would not have been possible.

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