CMOS Analog VLSI Design

EE: 618

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CMOS Analog VLSI Design, EE 618, Spring 2012

Professor: Prof. A.N.Chandorkar,

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- **Electrical Engineering Department**
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- **Class Timing: 11.00 am –12.30 pm**
- **Venue EEG 401(CDEEP Studio)**
- **Class Hours: Wednesday and Friday**
- **Credits: 6 credits**
- **Objectives: Course deals with Basic theory of Analog Circuits, Design principles and techniques for analog IC's blocks implemented in CMOS technology. Although analog design appears to be much less systematic than digital one, This course will try to get some idea of good design principles to simplify process.**

Course content

- Introduction to Analog VLSI and mixed signal issues in CMOS technologies. Basic MOS models, SPICE Models and frequency dependent parameters. Basic NMOS/CMOS gain stage, cascade and cascode circuits. Frequency response, stability and noise issues in amplifiers. CMOS analog blocks: Current Sources and Voltage references. Differential amplifier and OPAMPs' design. Frequency Synthesizers and Phased lock-loop. Analog Interconnects. Analog Testing and Layout issues. Low Voltage and Low Power Circuits.

Course Text & Materials:

1. **Design of Analog CMOS Integrated Circuits by B.Razavi, McGraw Hill**
2. **CMOS Circuit design, Layout & Simulation by Baker, Li & Boyce, IEEE Press, 1998**
3. **Analysis and Design of Analog Integrated Circuits, Gray, Hurst, Lewis and Meyer, John Wiley & Sons, 2003**
4. **Analog VLSI Signal and Information Processing, Ismail and Faiz, Mc Graw-Hill**
5. **Specified journal & conference papers**

Examination Schedules

Spring Semester Exam Dates:

Quiz/Cum Test : Around 20th August 2012

Test -1 : In September End, 2012

Mid-Sem. Exam: 10th to 15th September 2012

End-Semester Exam: Fourth week of November 2012

All Examinations except

Mid-semester and End-semester Exams will be from

8.45 PM to 10.45 PM slot in

GG 001 and GG 002

Home assignments submission as per announced dates time to time.

Grading Policy :

Total of 4 Exams:

Quiz, Test, Mid-Semester and End-Semester

Weightage in % : 8 +10+22+ 45 = 85

AND some Design Home Assignments

Weightage: =15%

PLUS 5 to10 % Total bonus on

Attendance (80 % Min), Sincerity, Sheet-preparation and excellence in Exams.

TOTAL : 100 % (105 to110 in actual number)

Do & Don’t for This Course

- No laptops or Internet appliances can be used during lectures or exams.
- No late work accepted. All assigned work is due at the beginning of class or t assigned place by TAs.
- Neither the final exam. nor final project if any will be returned at the end of the semester. However Corrected End semester answer-books can be shown on demand.
- Regularly being tardy for lectures, reaching late for lectures, leaving in the middle of lectures, or earlier from lectures is unacceptable. Attendance pays even in extra marks.
- **Cheating or plagiarism** will result in an automatic “**FR**” grade in the course (so do your own homework and projects!)

Organization of the talk

- Introduction
- Why Analog? Which are Analog issues and why CMOS?
- Basic Analog Design with CMOS
- Analog Systems

Organization of the talk

- Low Power-Low Voltage Analog
- Layout of Analog circuits
- Conclusion and future directions

Introduction

VLSI of present era

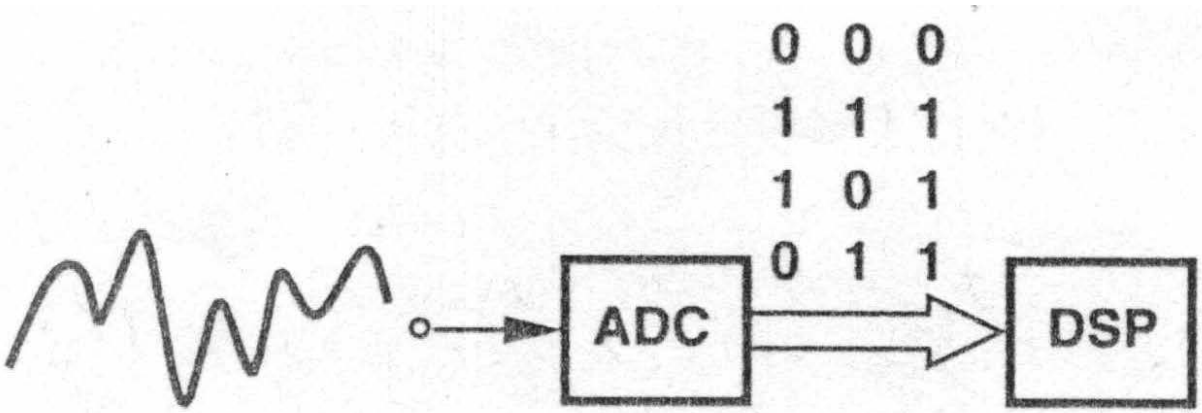
- Technology challenges:
  - CMOS/BICMOS/BIPOLAR
  - Silicon, Si-Ge, SiN and compound semiconductors and their combinations
- Market needs
  - Wireless Systems
  - Optical Systems
  - Sensors
  - High speed microprocessors
  - High speed memories
- Analog designs are like custom designs
- Power-speed is the challenge

Why Analog?

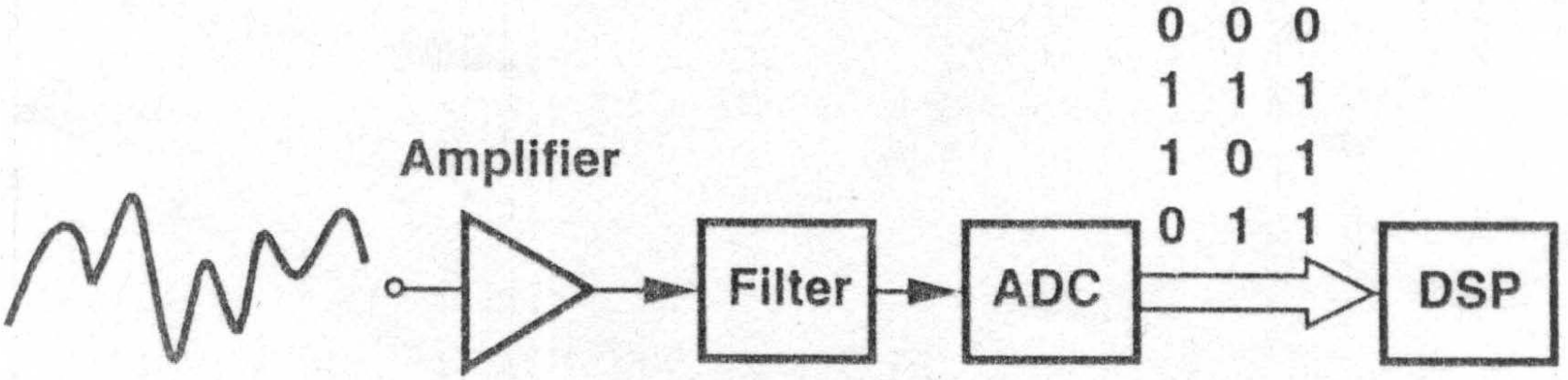
- Some digital system designers predicted in 1980, the “death of analog era”. But 2000 onwards, one sees increased stress on analog design.

Some Answers

- Nature is analog and hence at least “front-ends” will be Analog followed by A to D converters and later to DSP. (See Figs. ahead)



(a)



(b)

Figure (a) Digitization of a natural signal, (b) addition of amplification and filtering for higher sensitivity.

Why Analog?

- Sensors of all kind, e.g. mechanical, optical, and thermal give electrical transduced signal in μV, and susceptible to noise.

Signal processing thus needs low noise amplification, filtering and A to D conversion.

Why Analog?

- Digital data transmission on a long distance leads to “distraction”. Hence analog kind of trans-receiver will be needed.
- Data from HDD is extremely “weak” in separating “1” and “0”. Amplification is thus necessary.
- Wireless receivers receive very “weak” signals from antenna. Hence amplification is needed.

Why Analog?

- Microprocessors and memories with ultra high speeds use clocks/signals across large area chip. Non-ideal interconnects, parasitics of devices and package lead to “transmission-line” effects in signal flow.

Sense amplifiers of memories are essentially Analog Devices.

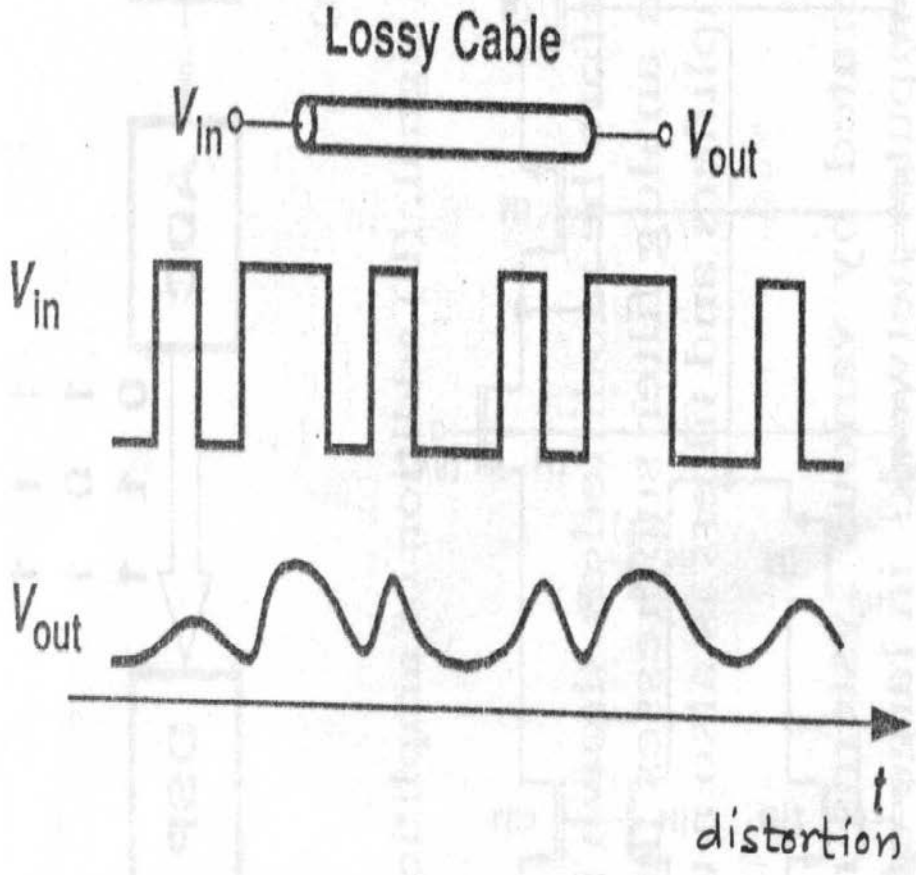


Figure Attentuation and
of data through a lossy cable.

Why Analog?

Question:

Is analog design more difficult than digital design?

Answer: Yes!!!

- Digital Design
  - Large noise margin
  - Trade-off between power and speed (and area) only
- Analog needs multi-dimensional trade-offs between
  - Power, speed (frequency), gain, precision (drifts), power supply voltage

Why Analog?

- Analog circuits are more sensitive to

  “Noise and cross-talk”

- Second order “Device” parameters affect analog function strongly than the digital one.
- Automation in design is very very difficult: even layouts need manual interventions.
- Modeling and simulation pose biggest challenge

--→>>>**An Analog designer is a Smart guy who uses Experience and Intuition to use simulators**

Why Analog?

- Technology for analog, though not the best possible, but more suitable for digital applications.
- CMOS is the best bet for digital circuits and hence analog too should get implemented on CMOS.

What is Analog VLSI Design?

- Analog IC design is the successful implementation of Analog circuits and systems using Integrated circuit technology.
- Unique Features of Analog IC Design:
- Geometry is an important part of the design
- Electrical Design Physical Design Test Design
- Usually implemented in a mixed analog-digital circuit
- What is Analog VLSI Design?
- Analog is 20% and digital 80% of the chip area
- Analog requires 80% of the design time
- Analog is designed at the circuit level
- Passes for success: 2-3 for analog, 1 for digital

- **Analog and Mixed Analog-Digital Integrated Circuits**

- **Analog Systems**

Amplifiers, Filters, Comparators, Oscillators, Multipliers, PLL, Voltage/Current References, Sample-And-Hold Circuits, A/D and D/A Converters, High speed IO Interface, DC-DC converters

- **Analog VLSI Design Automation**

Layout Techniques, Simulation Techniques, AHDL, Analog IP

- **Analog Signal and Information Processing Applications**

Telecommunication, Multimedia, Automotive Electronics, Biomedical Electronics, Consumer Electronics, Neural Networks, Sensing and Sensor Networks, Space and Military Electronics

- **Digital Circuits and Digital Signal Processing**

Mixed-Signal VLSI Chip

- Mixed digital/analog : “core” is analog and I/O is digital, e.g. neural signal processors.

  (See Fig.)
- Comparison of analog and digital VLSI

  (See Fig.)

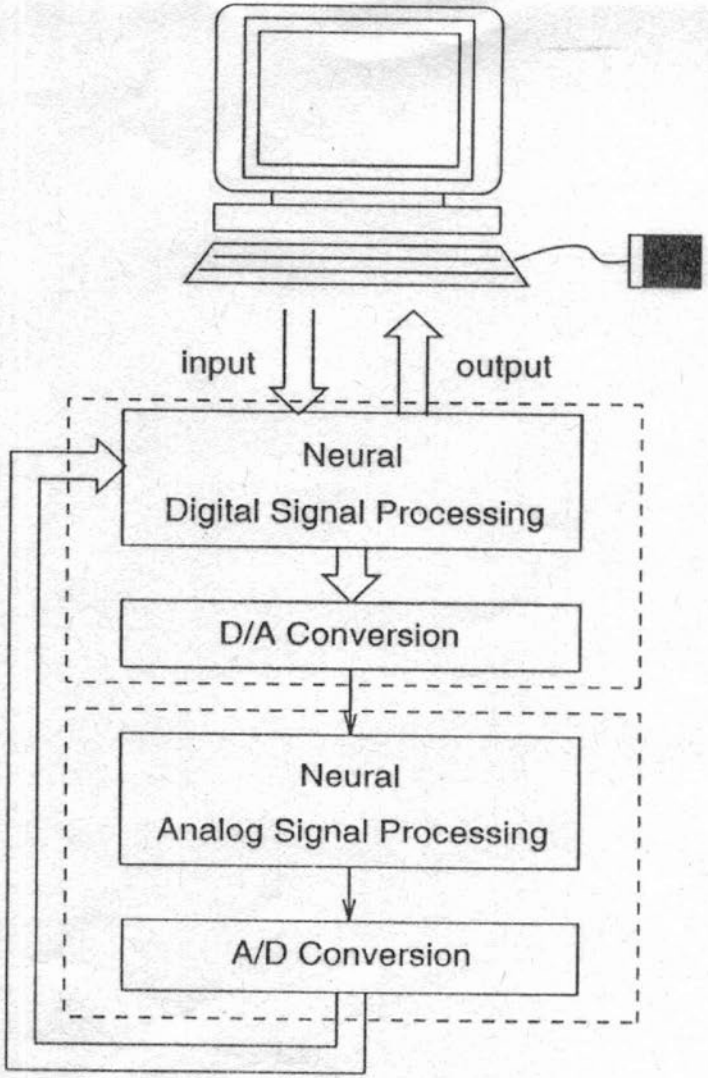


FIGURE
A mixed-signal neural processor for image data compression [2]. The digital part is a VQ codebook generator and consists of a host interface and timing control, a vector address handler, an input vector, a codebook, and a self-organizing trainer. The analog part is a neural-based vector quantizer and consists of a synapse matrix, current summing neurons, sample-and-hold circuits, WTA cells, and a digital encoder.

TABLE

Comparison of analog VLSI with digital VLSI in terms of cost, power, and computation density. (©1998 BYTE

ANALOG VLSI VS. DIGITAL VLSI

Analog VLSI is strikingly superior to digital technology in terms of cost, power, and computation density. (Estimated by Federico Fuggin.)

	Cost (MCS*/$)		Power (MCS/watt)		Computation density (MCS/ft^3.)	
	1991	2000	1991	2000	1991	2000
Conventional digital	0.002	0.1	0.1	10	0.2	10
Special-purpose digital	0.1	4	10	10,000	10	1,000
Dedicated digital	5	200	500	50,000	40	3,000
Dedicated analog	500	20,000	50,000	5,000,000	4,000	4,000,000
Human brain	10^{9}..		10^{10}		10^{11}	

* MCS=A million connection updates per second.

** This calculation assumes that the cost of a human brain is $10,000,000.

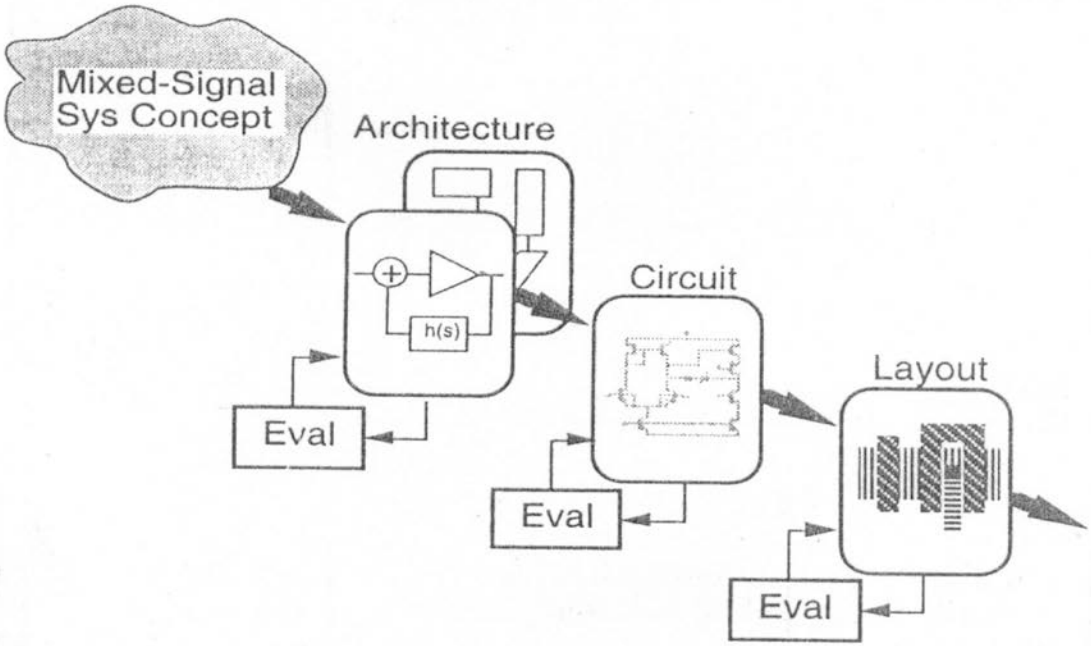
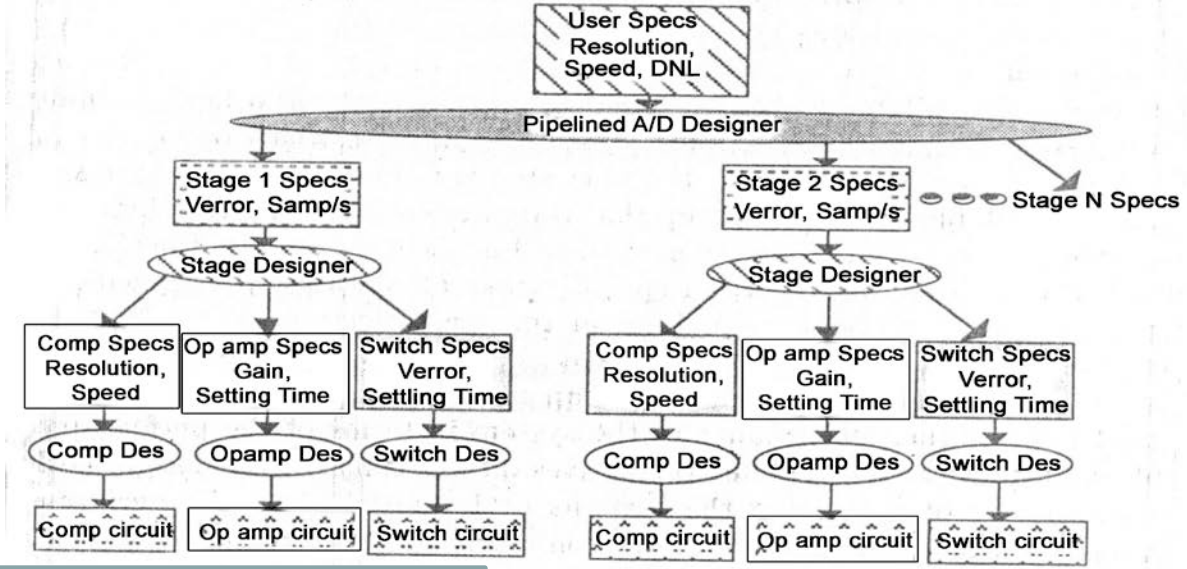


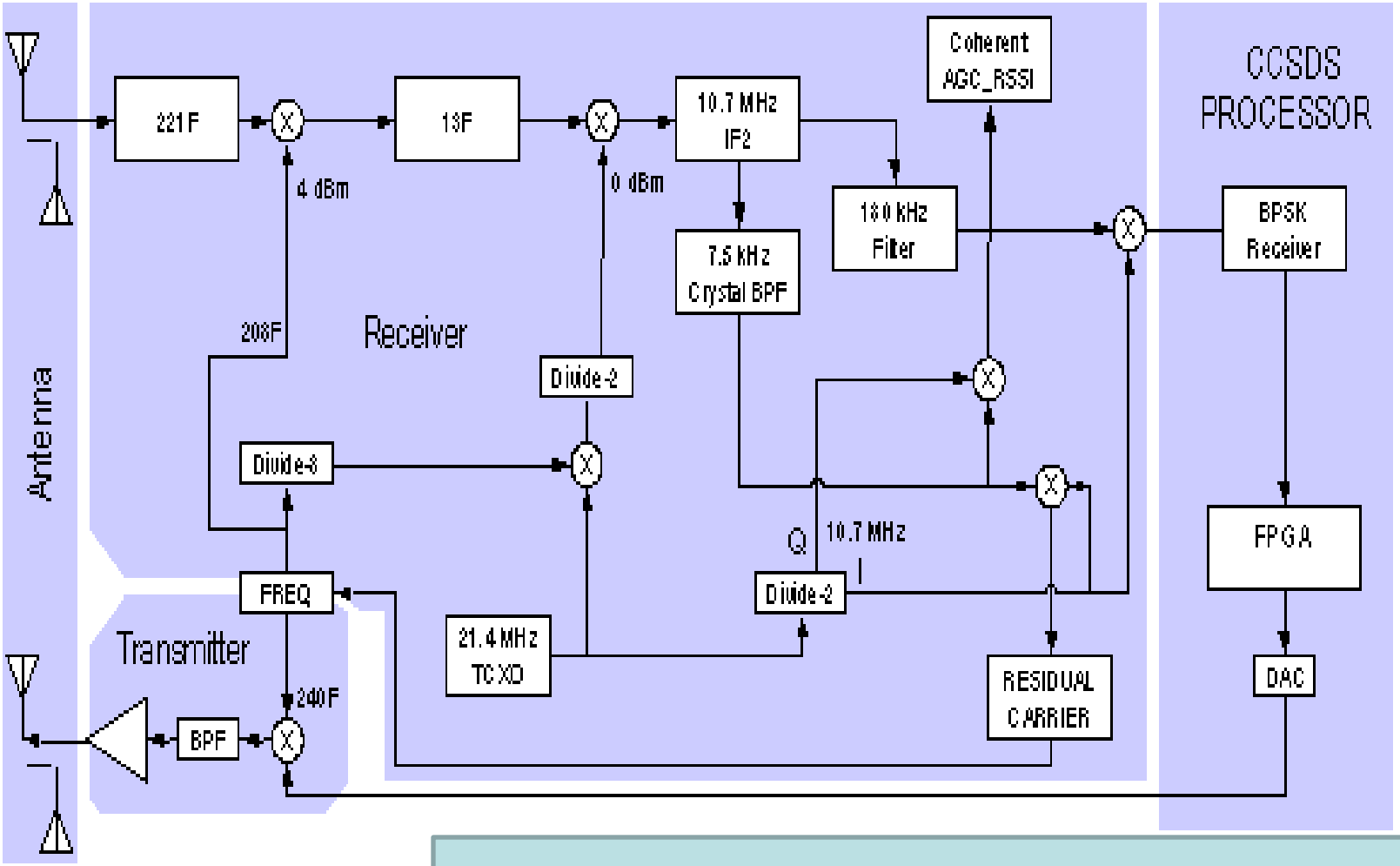
FIGURE
First-order decomposition of Analog System design process.



of a pipelined A / D converter.

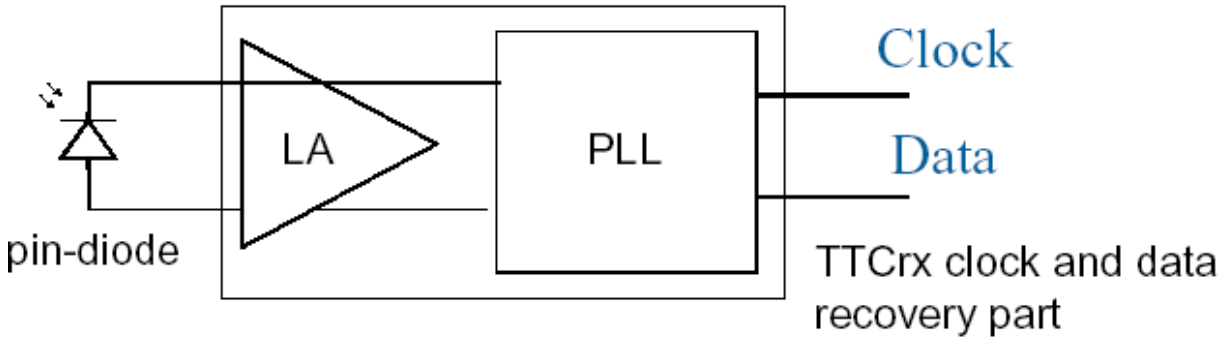
Ismail & Faiz

Telemetry Tracking and *Communication* (*TT&C*) *System*



CCSDS: Consultative Committee for Space Data Systems

TTC-Rx



Clock deskew function

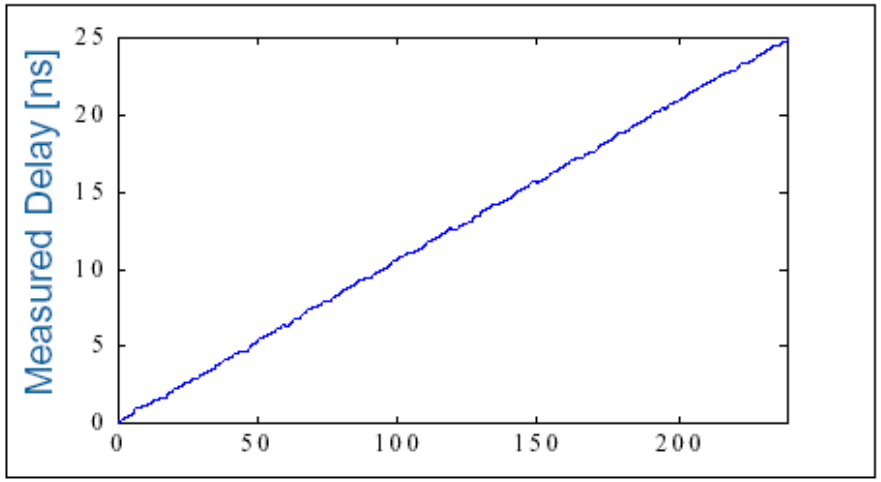
Δ = 104.8 ps

σ_{diff} = 48 ps

pp_{diff} = ±162 ps

σ_{int} = 80 ps

pp_{int} = ±185 ps



Why RF CMOS?

Cost – Submicron CMOS, driven by microprocessor
and memory, is cheaper and more widely available
than advanced bipolar IC technology

High levels of integration

Low Power

"If CMOS can do it, it will" – proprietary technologies
undesirable unless there is substantial

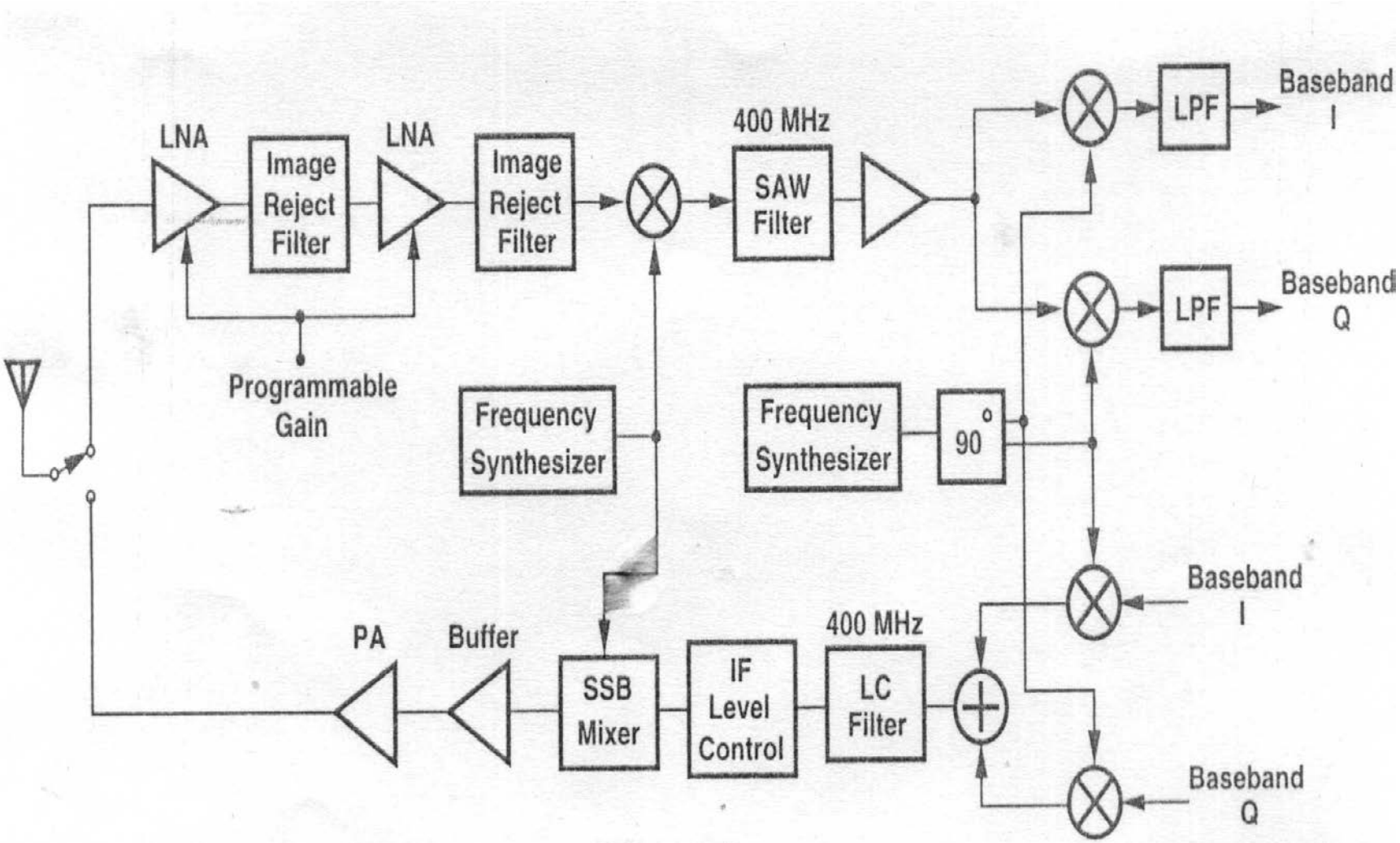
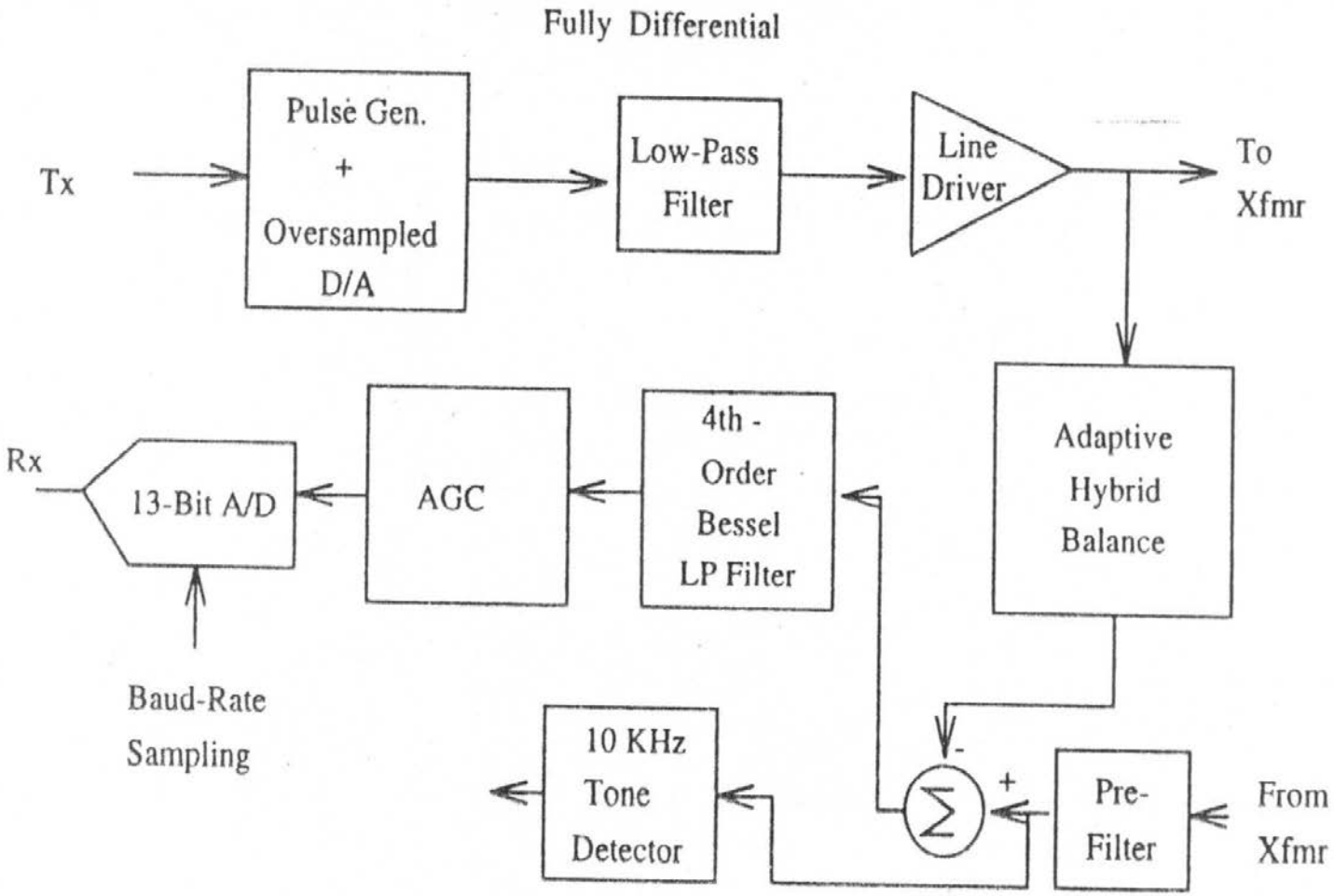


Figure RF section of a cellphone [1]



FIGURE

U-Interface analog front end for ISDN [1].

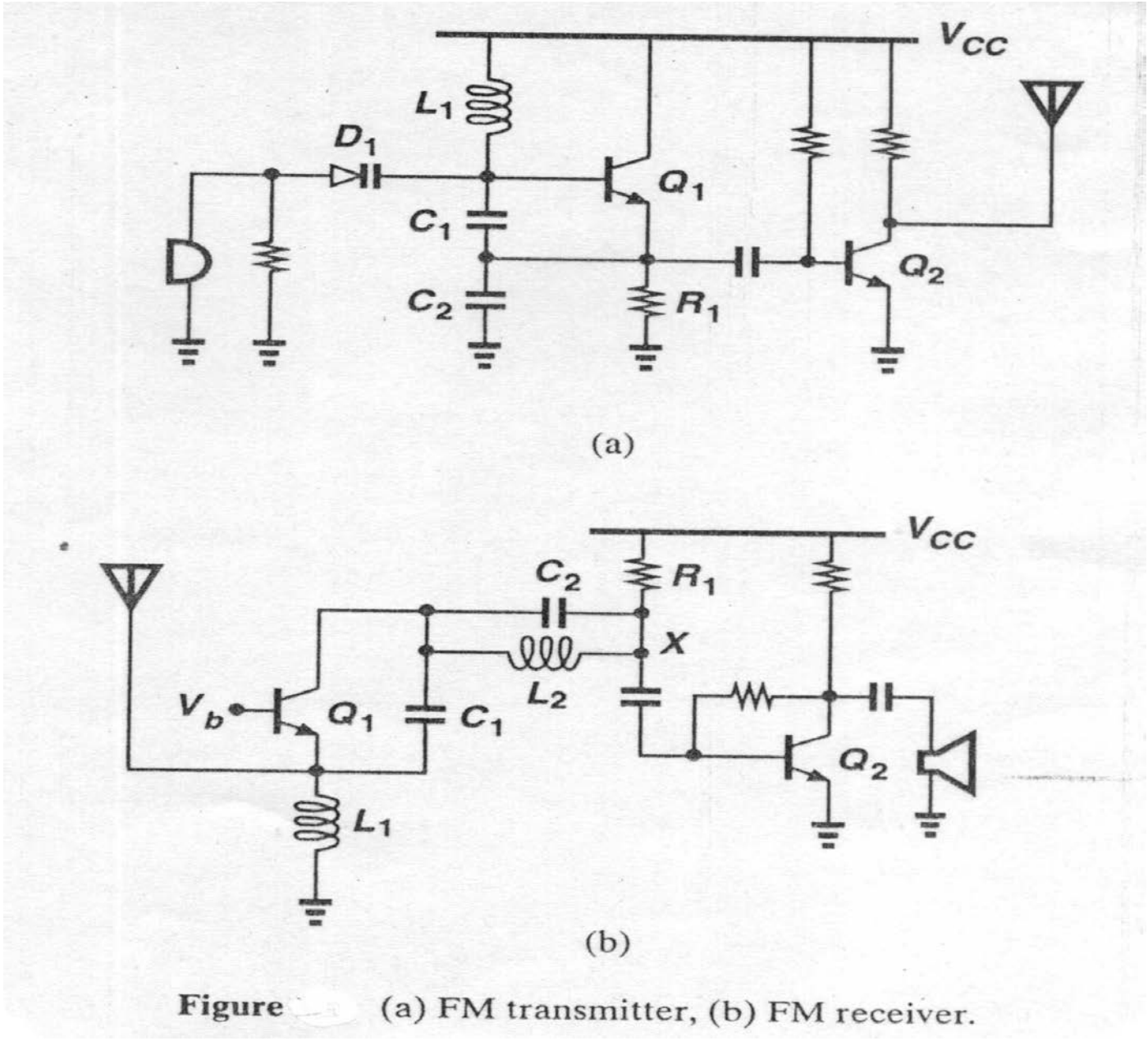


Figure (a) FM transmitter, (b) FM receiver.

RF Circuits

Modern Communication systems like MOBILE communication, WLAN, GPS system are examples.

The trade-offs in RF Design are shown in two viewgraphs