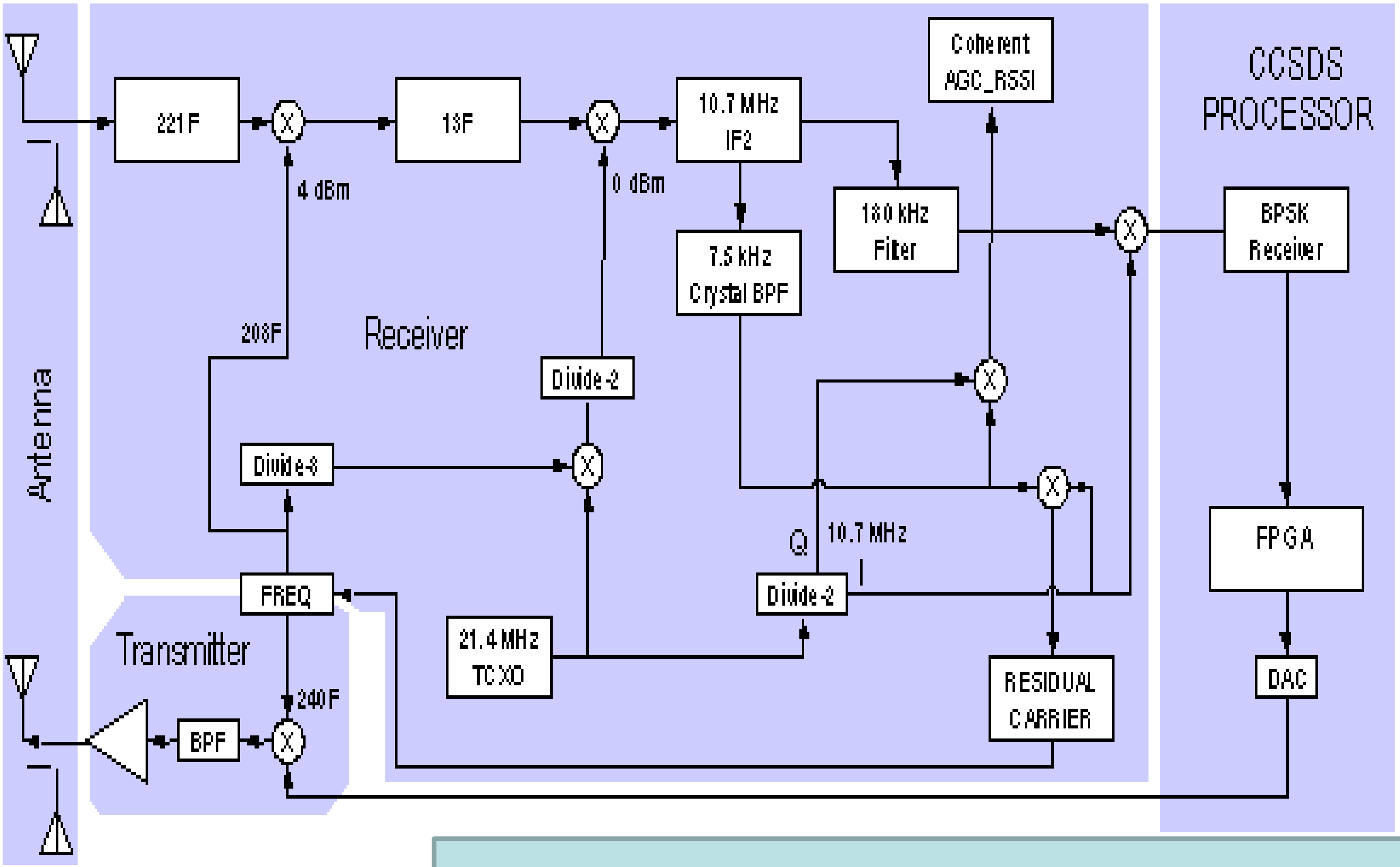
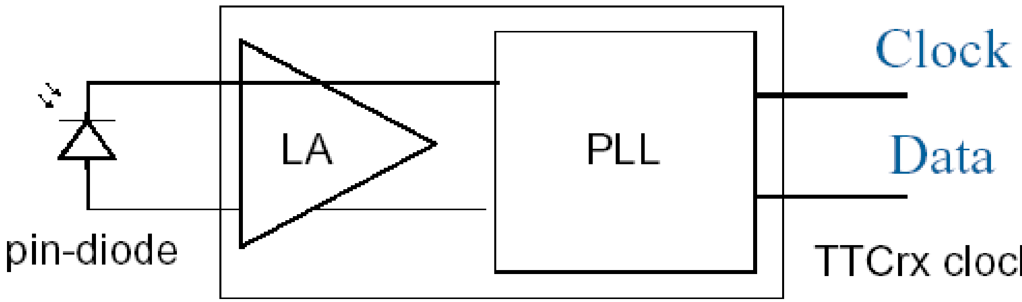
Telemetry Tracking and *Communication* (*TT&C*) *System*



CCSDS: Consultative Committee for Space Data Systems

TTC-Rx



TTCrx clock and data recovery part

Clock deskew function

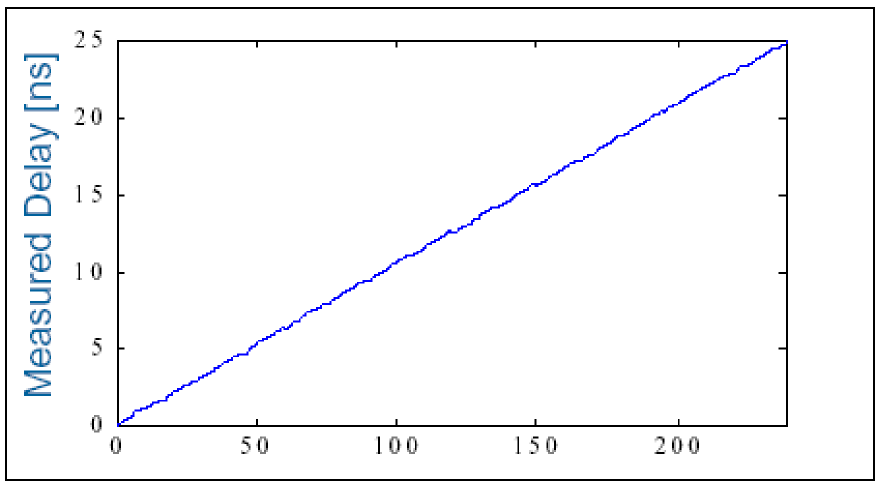
Δ = 104.8 ps

σ_{diff} = 48 ps

pp_{diff} = ±162 ps

σ_{int} = 80 ps

pp_{int} = ±185 ps



Delay tap

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

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

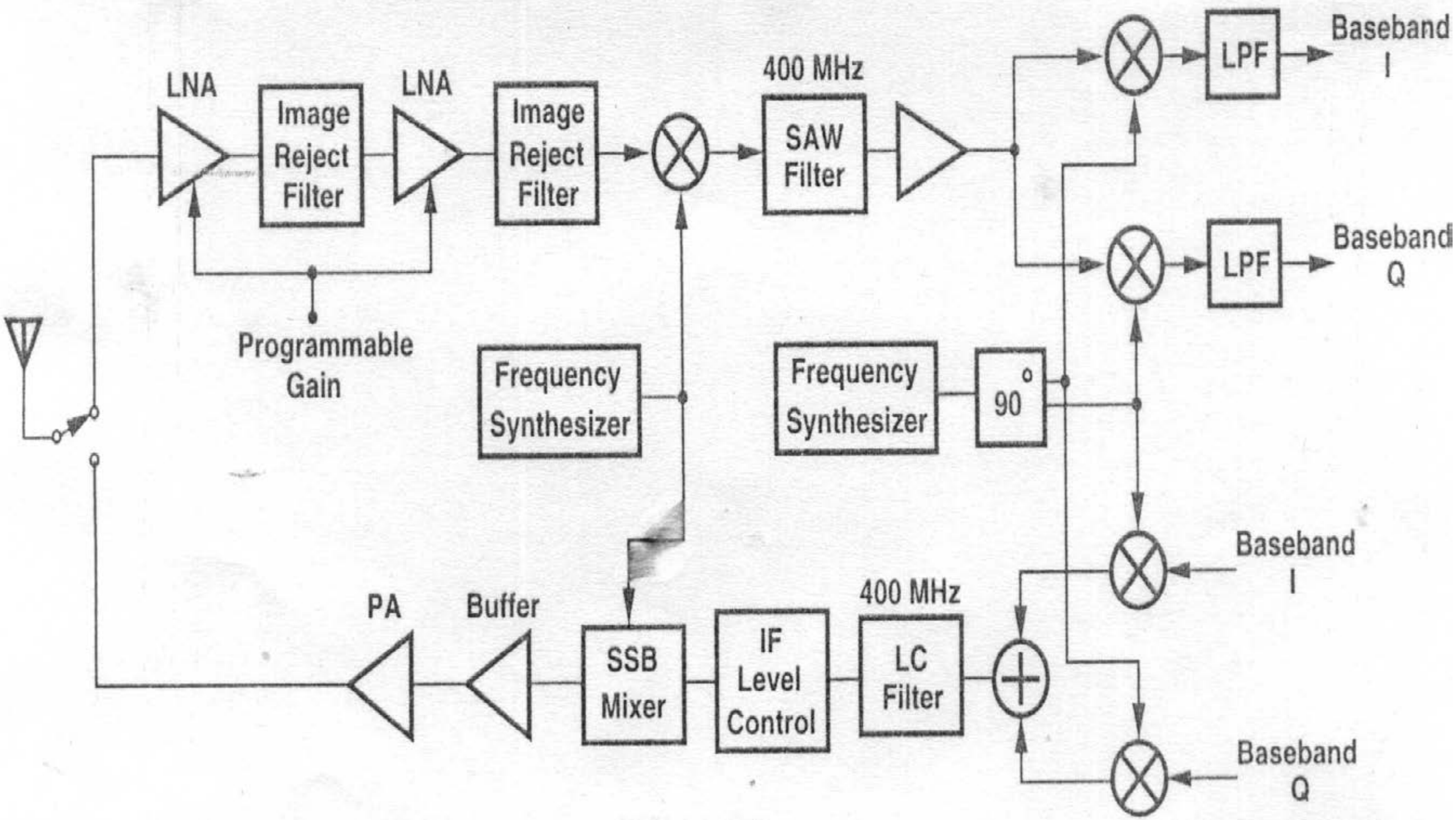
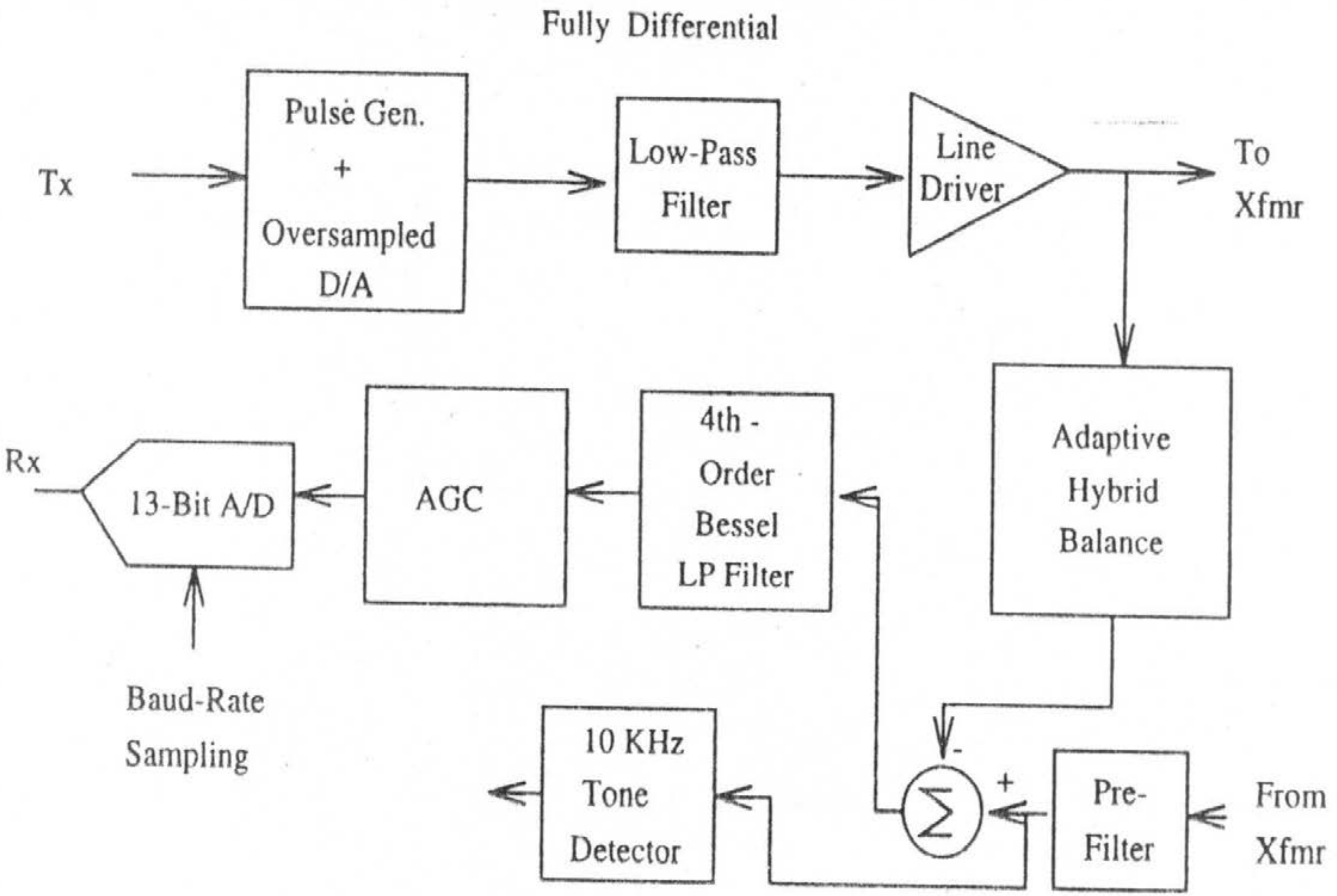


Figure RF section of a cellphone [1]



FIGURE

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

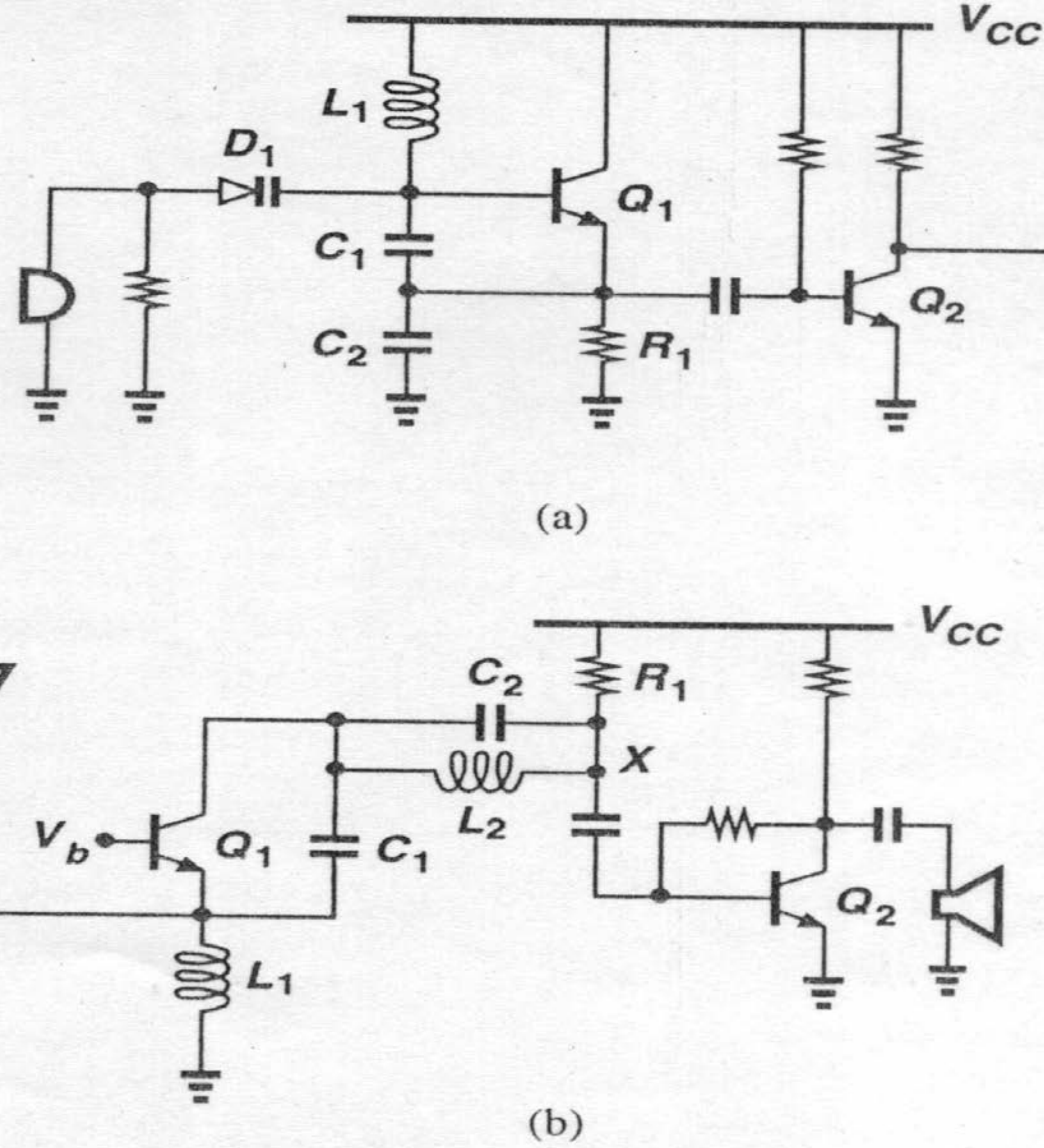


Figure (a) FM transmitter, (b) FM receiver.

RF Circuits

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

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

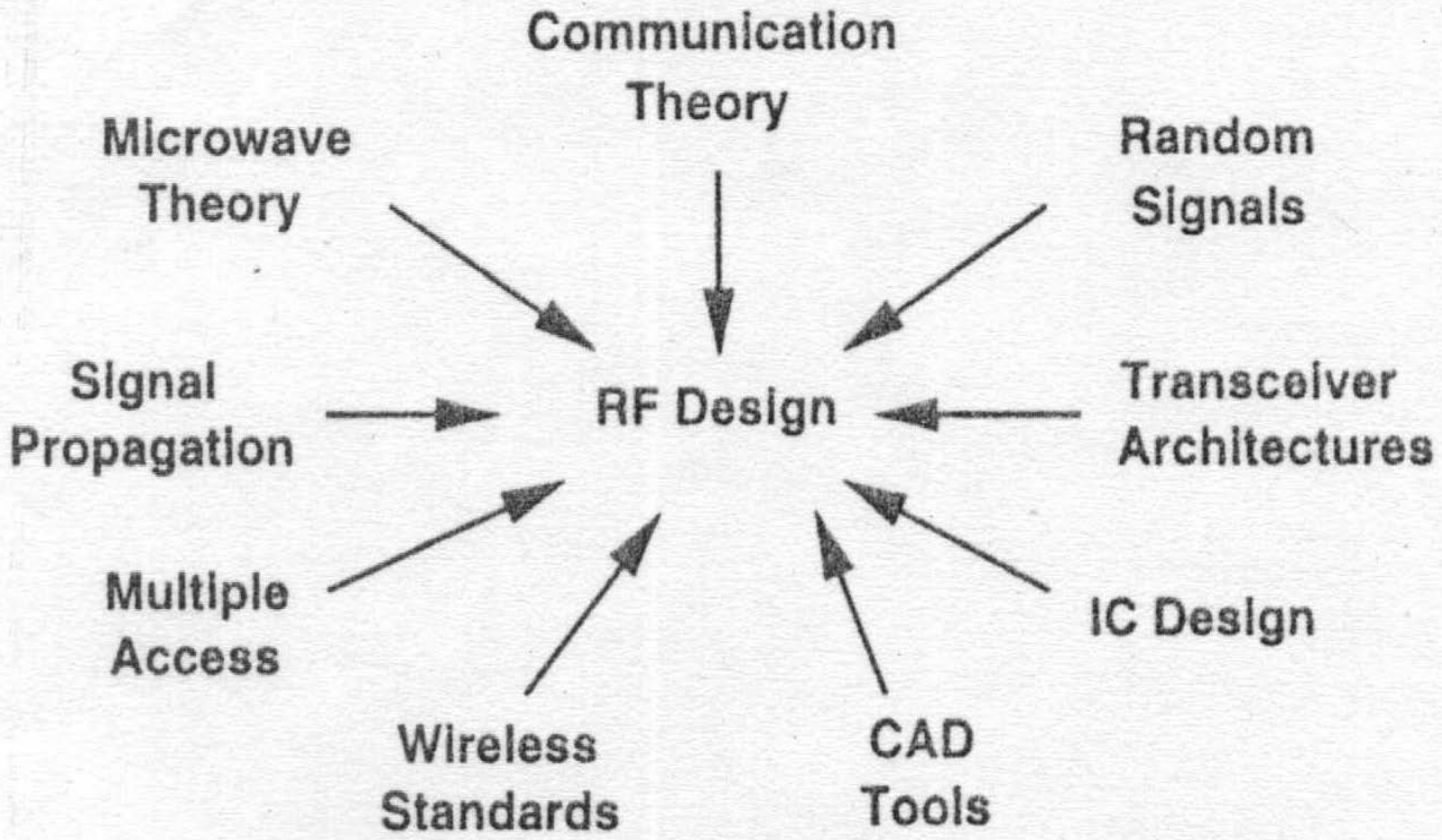


Figure Disciplines required in RF design.

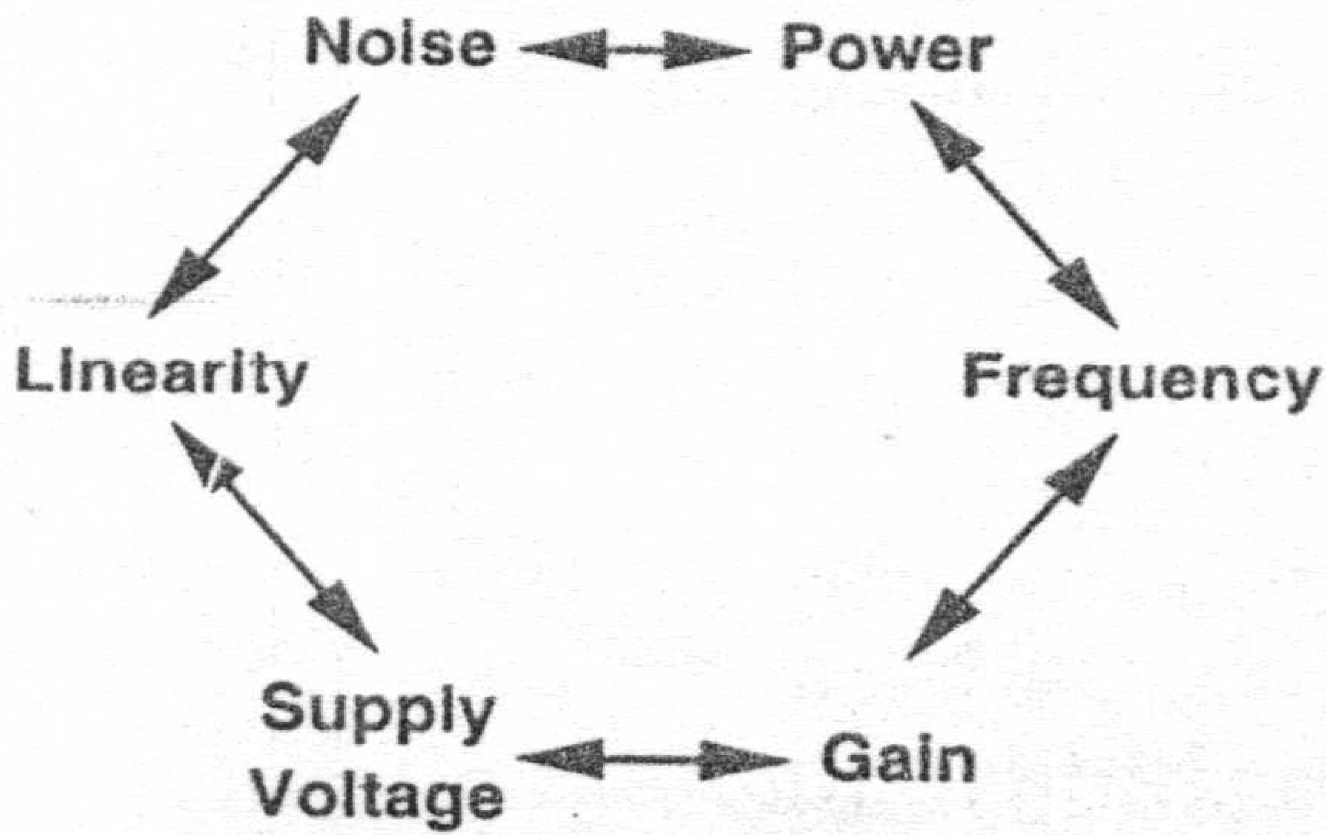


Figure RF design hexagon.

CMOS for Wireless applications(IBM Process)

- Digital Systems' Integration with Analog and RF blocks for realizations of Systems:

  Bluetooth and WLAN

  Set-top Box Transceivers

  IF and Baseband part of Radios

Challenges for Mixed Signal CMOS …1

- Different performance requirements for analog and digital parts of the chip
- A CMOS Technology, optimized for low power digital requirements, often is worse from the analog performance point of view
- Short Channel Effects
- V_{DD} Scaling/Breakdown Voltages
- Transistor mismatch- worsens with scaling
- Nonlinearity of CMOS-based analog circuits
- Substrate coupled noise and Flicker Noise
- Modeling Issues– NQS effects etc. at RF frequencies

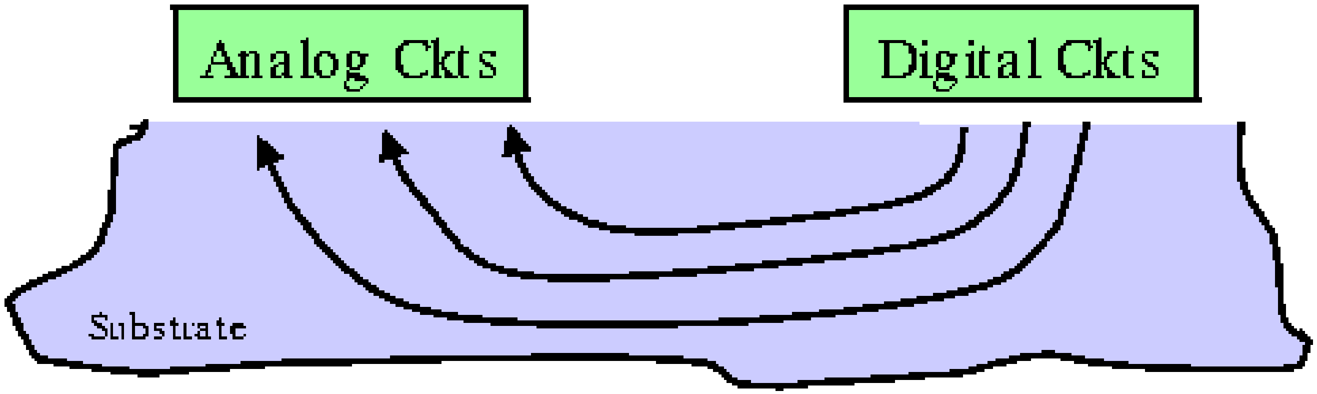
Challenges for Mixed Signal CMOS …2

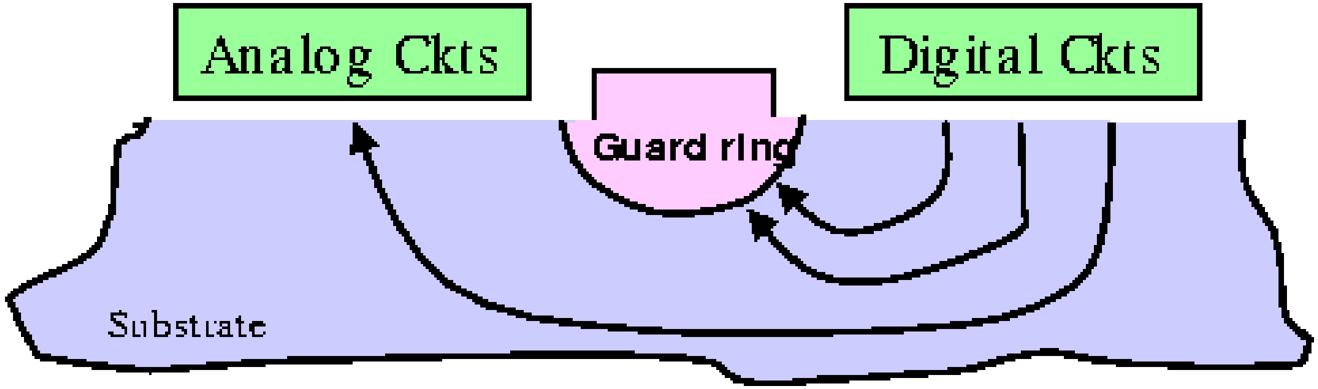
- Digital Design continues to benefit from CAD-tool advances

- Analog circuit design still remains a hand-crafted art.
  - Larger percentage of the die area analog circuits occupy
  - Design time

- Cost of mixed-signal chips: The analog part costs approximately two-and-half times to do in 0.18-micron as it did in 0.35-micron (Source:Cypress MicroSystems) because it doesn't shrink as much as digital. So if the analog is a significant part of the chip area, one is paying two-and-a-half times as much for that part of the chip.

Substrate Coupling – Mixed Signal



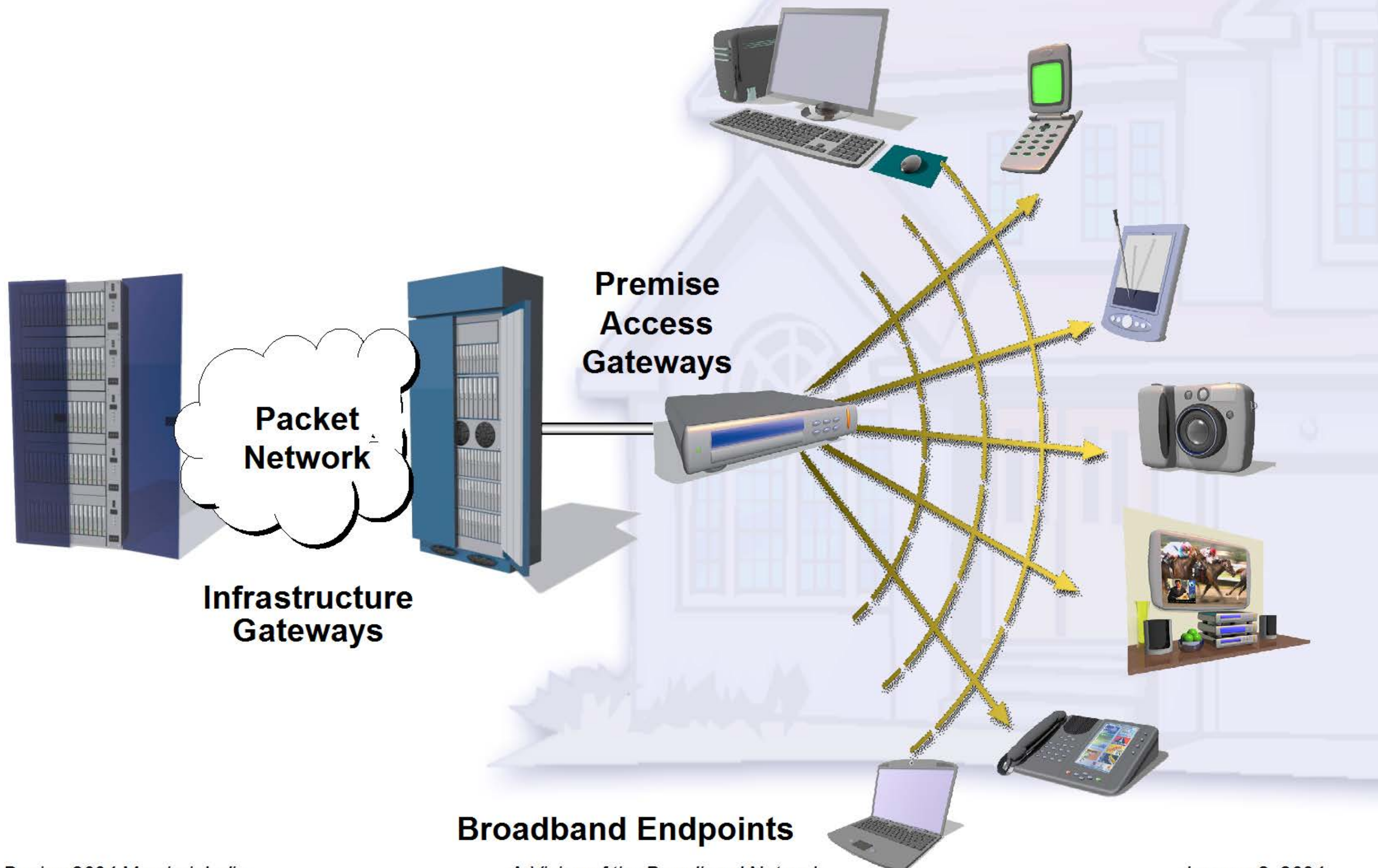


SOI

Analog and Mixed-Signal Technology—Enablers of the Broadband Revolution

Courtesy : Dr Bill Witowsky ,Texas Instruments

Broadband Network



Drivers of Broadband Growth & Impacts

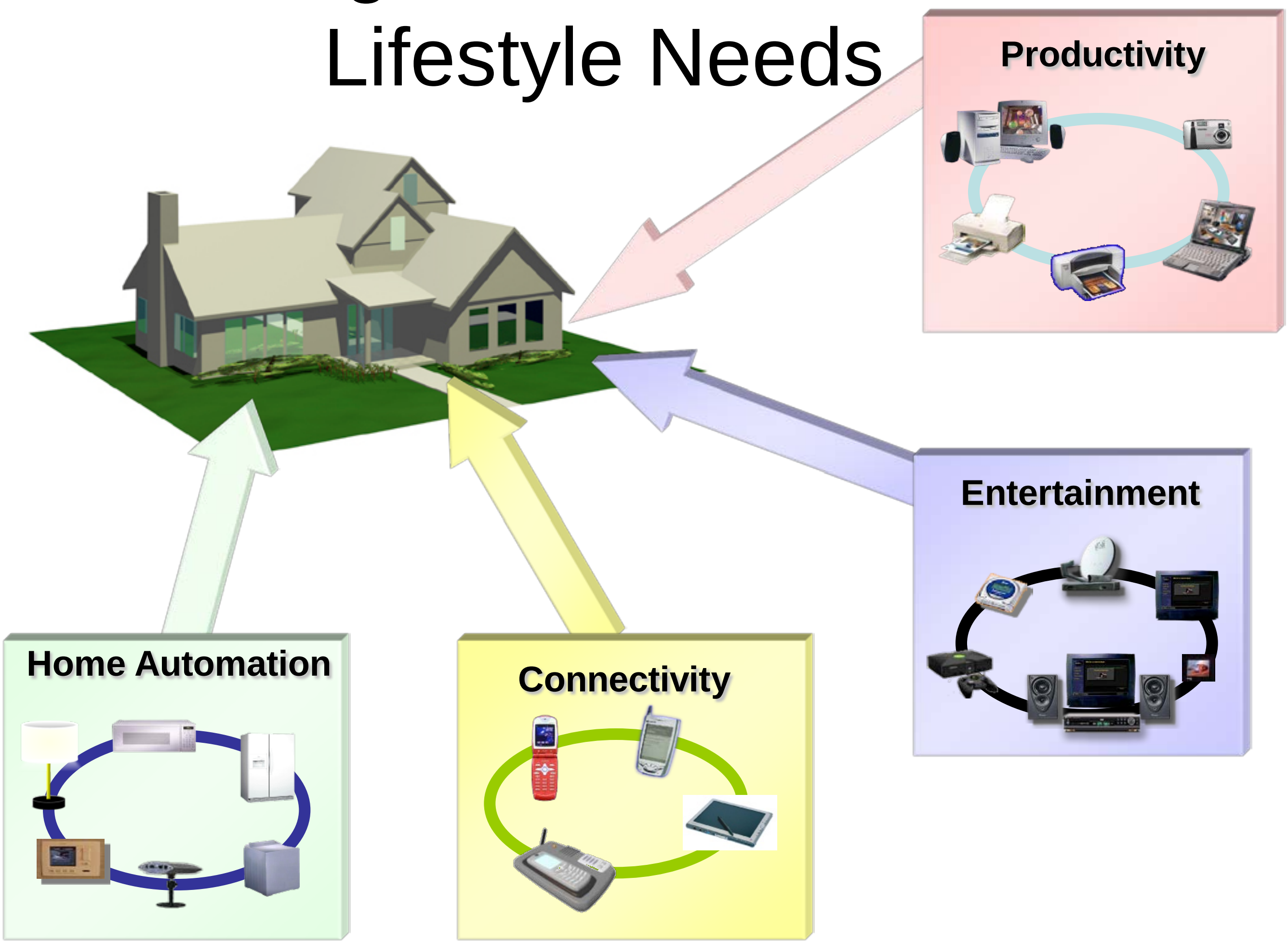
Drivers

- Demand for High Speed Connections, Streaming Video and Audio
- Home Networking: Multiple PCs and Internet Appliances in the Home
- Multiple Services Delivered to Multiple Endpoints, Providing Information, Communication, Entertainment and Home Control
- Consumer Requirement for Ease of Use
- Shift from PC World to Embedded World

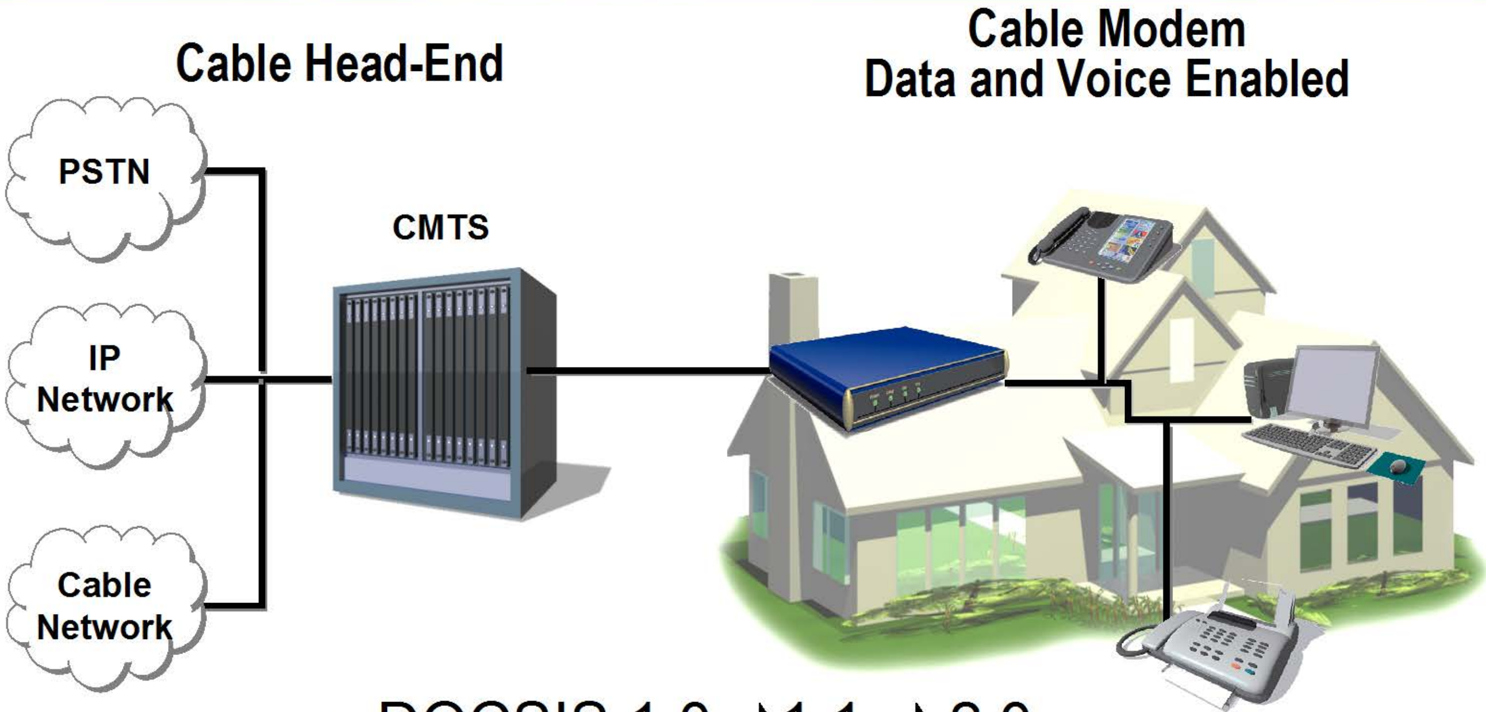
Impacts

- More Bandwidth Consumed per Home
- QoS Needed End-to-End
- Network Capable Consumer Electronics Devices
- Video/Audio Distributed In-home
- Various Internet Appliances, End Points & Services through the Home Network
- Improved Security to Protect Consumer, Provider & Content
- Seamless Interoperability for Networked Devices Required
- RG Key Enabler

The Evolving Networked Home Meets Lifestyle Needs



Cable Network Evolution



- DOCSIS 1.0 ➡ 1.1 ➡ 2.0
- PacketCable
- CableHome

Video

- **Large spectrum of applications**
- **Multiple standards, Resolutions**
- **Infrastructure starting to get in place**

MPEG1/MPEG2

WMV9

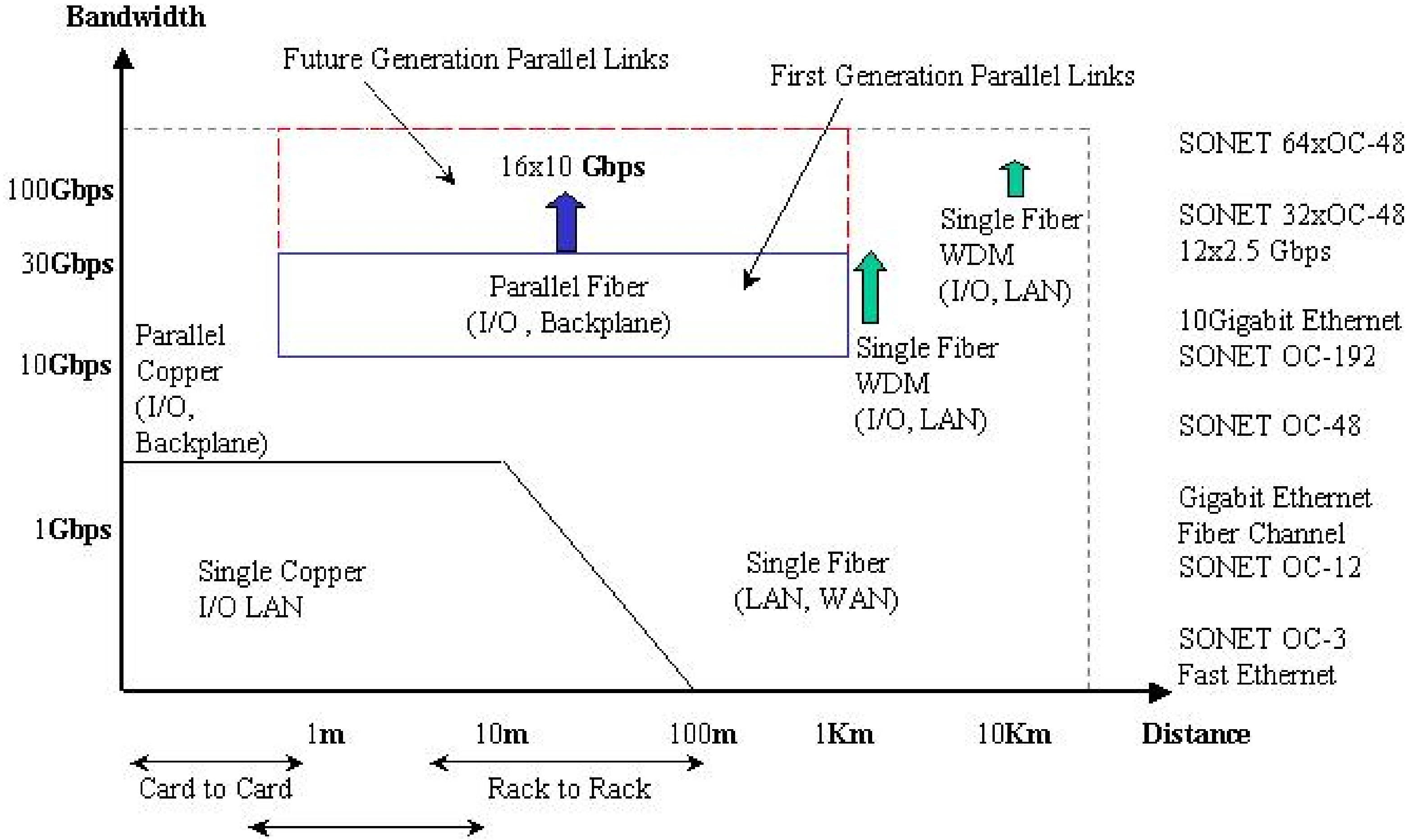
H.264

DivX 3/4/5

CIF, VGA, D1, HDTV

Video communications over IP will be as simple at making a phone call

Data Communication Links (Binary)

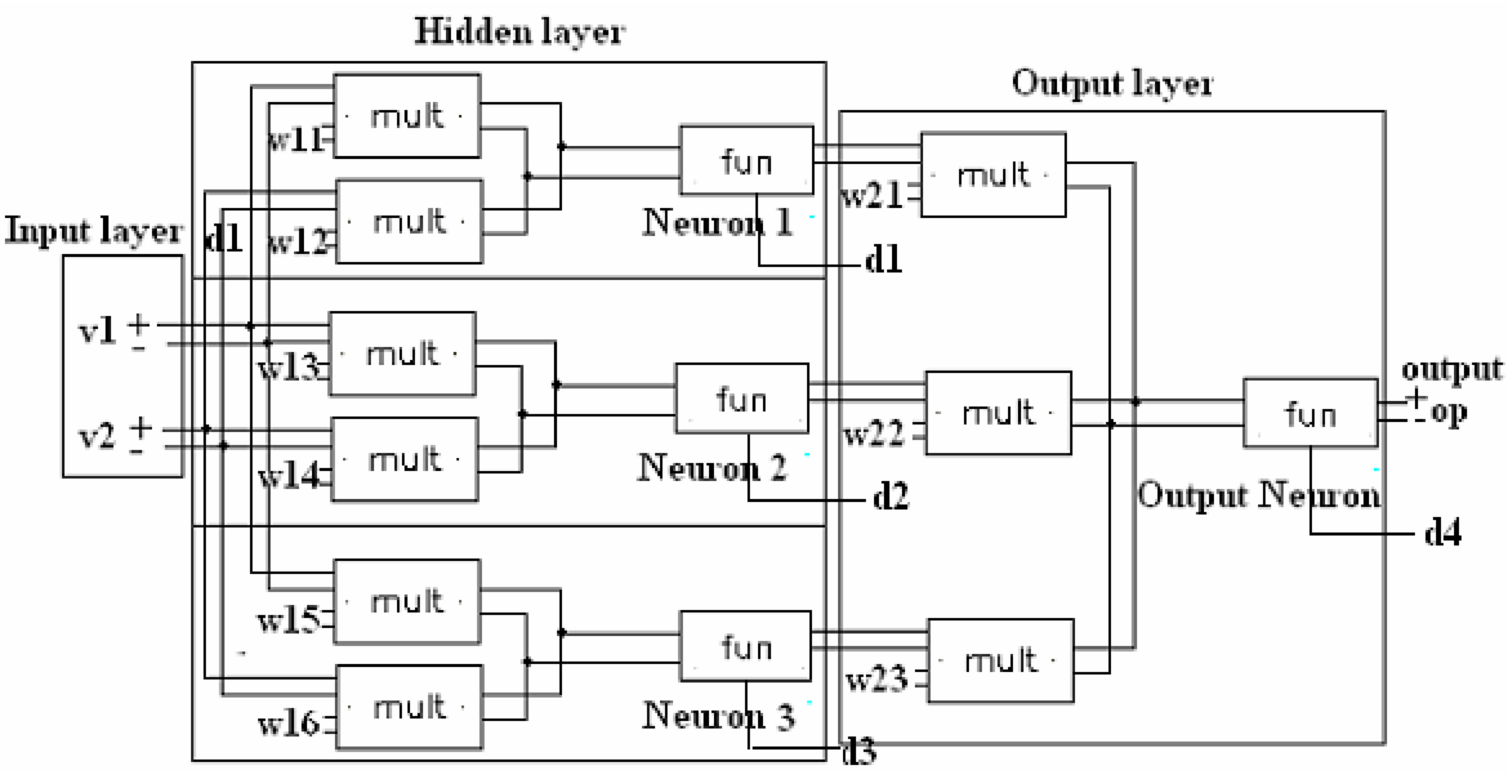


Ref.Georgia Institute of Technology

Summary on Broadband

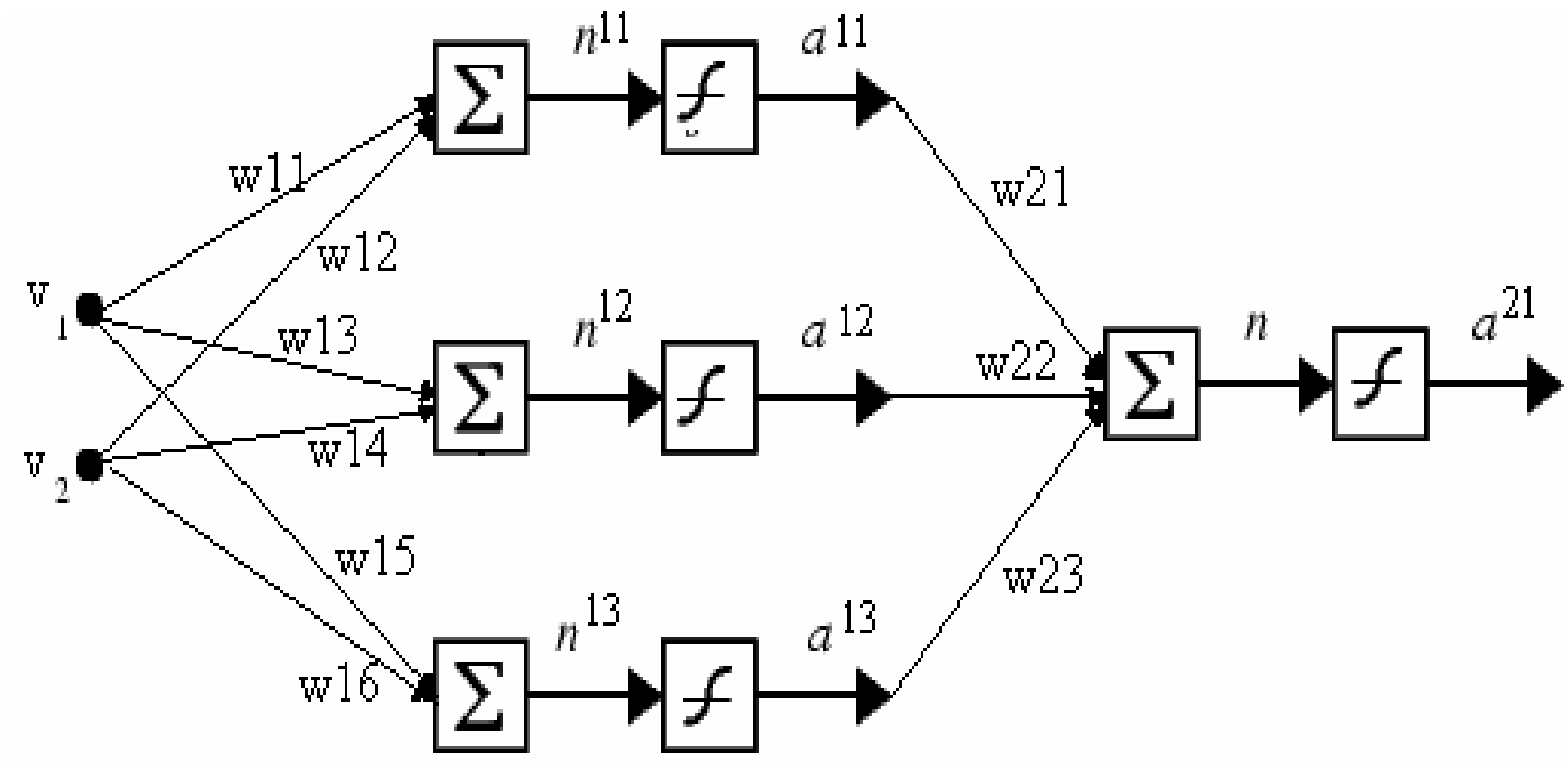
- Strong Growth in Broadband exists today fueled by Consumer demand for Broadband Content and Services.
- Broadband access is evolving from high-speed, always on internet to the connected home.
- Broadband connectivity is enabled by System On a Chip (SOC) and the emergence of Broadband Endpoints
- Broadband is changing the way we live, work, and play.

Implementation of the Neural Architecture using Analog Blocks

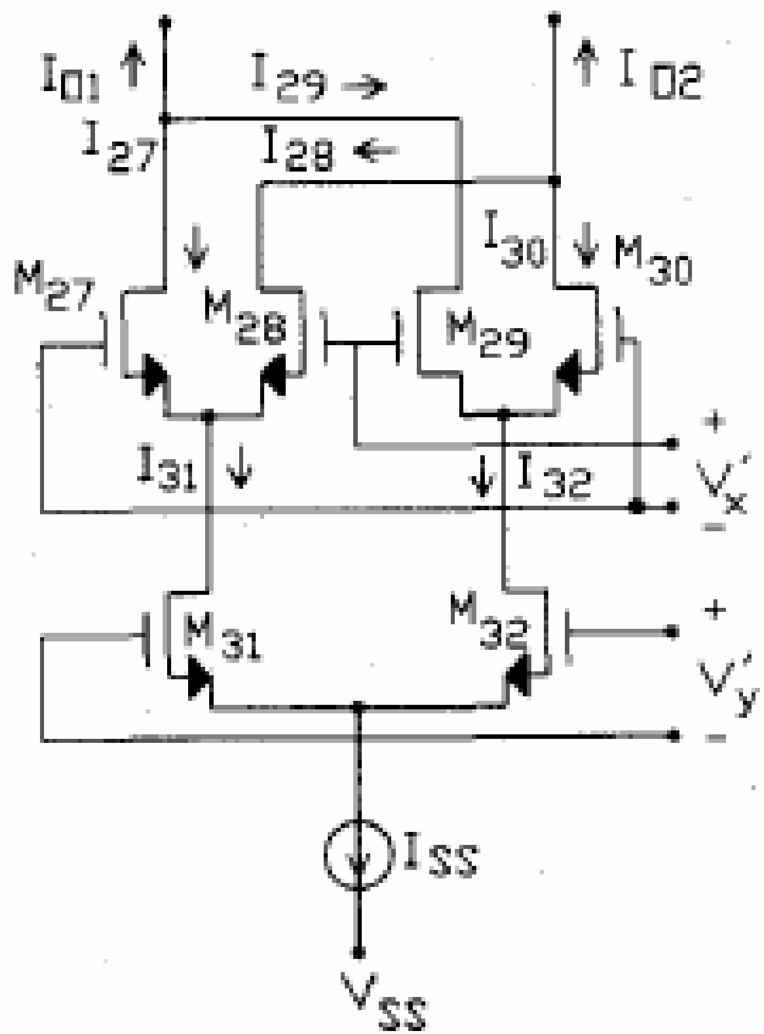


Mult: Gilbert Multiplier; Fun: Neuron activation function with Diffamp output

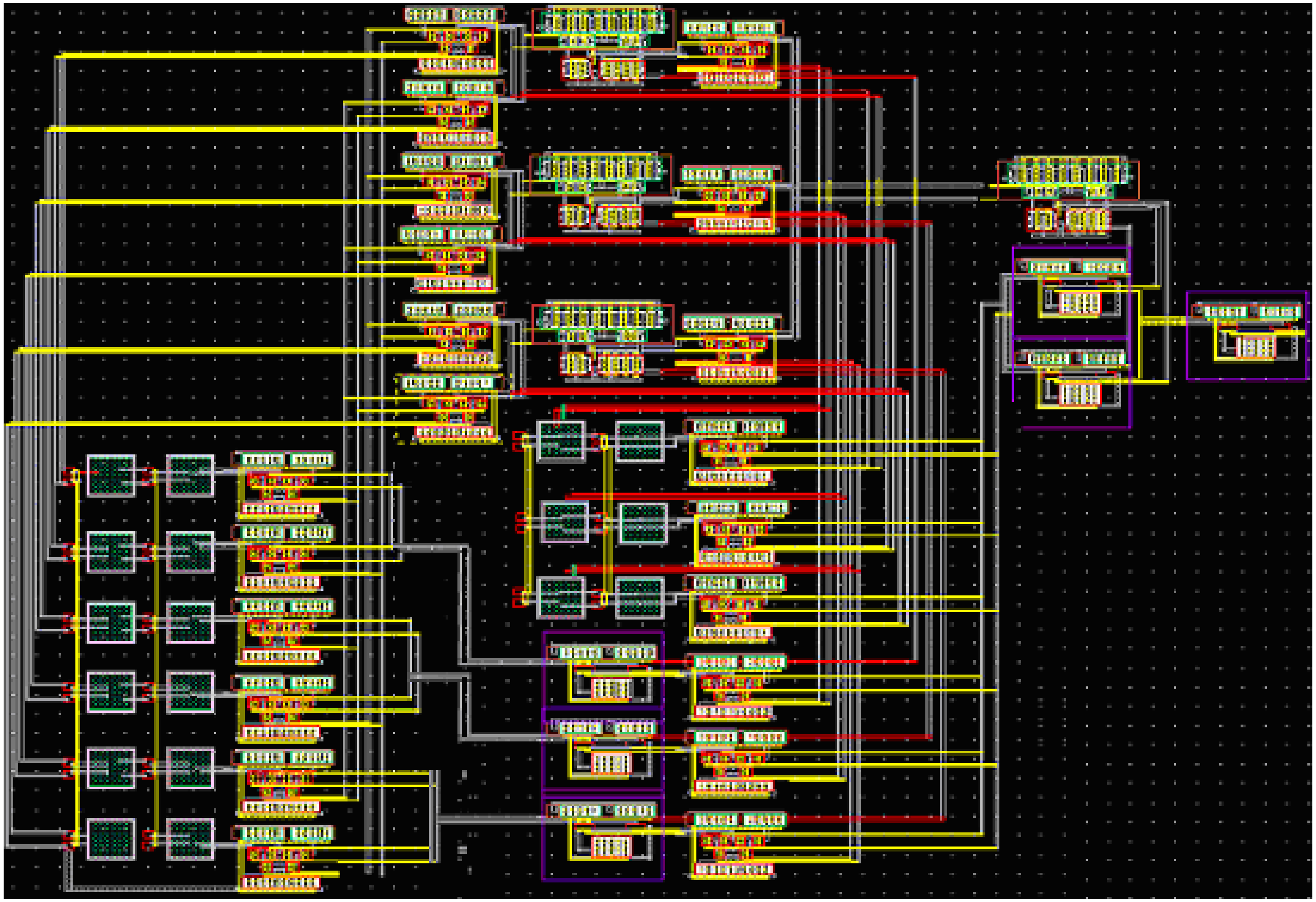
Multiple Layers Neural Network



Analog Multiplier (Gilbert Cell)



Layout of 2:3:1 neural architecture



VARIOUS APPLICATIONS of Analog ICs/Systems

- **Applications in** automotive guidance**,** robotics, and remote sensing require sensors for processing visual motion that are small, consume little power, and work in real time.
- Because image irradiance is a continuous function of time, asynchronous circuit implementations are preferable to clocked implementations. The latter introduce temporal aliasing artifacts that can significantly compromise time sensitive computations, such as those associated with optical flow.

Kramer et al

Analog Processing

- Analog processing is more economic in terms of **silicon area** and **power** than digital processing of comparable complexity and thus makes higher pixel densities possible.
- Its main drawback is its *lack of precision*, but high-precision motion processing is often not possible anyway, because of noisy input

  data and fundamental computational problems associated with the estimation of the velocity field from the optical flow

Kramer et al

Motion Sensors

- Analog VLSI motion sensors that incorporate the photoreceptors and the processing circuitry on a single chip

Kramer et al

Analog VLSI Systems for Image Acquisition and Fast Early Vision Processing

- The work at **MIT** is concentrated on ***early vision tasks***, *that is, tasks early in* the signal flow path of animal or machine vision.
- The goal is to determine how the advantages of Analog VLSI**—high speed, low power, and small area**—can be exploited and its *disadvantages—limited accuracy, inflexibility, lack of storage capacity, and long design and debugging times*—can be minimized
-

JOHN L. WYATT et al

Mohammed Ismail’s Analog VLSI research At Ohio University

Circuits for Communication, RF CMOS, multimedia, Instrumentation, Sensors, Medical, and Automotive Electronics

- ***A project completed recently focused on the design of a CCD imager interface CMOS chip with a CDS(Correlated Double Sampling), AGC and A/D converter for Camcorder***
- ***Ongoing and near term projects include chip design solutions for multi-standard wireless applications:***
- ***The research spans the RF parts(LNAs, Mixers, I-Q generators and buffers), baseband parts including channel select filters, variable gain amplifiers and high speed data converters, and frequency synthesizers parts including design of low phase noise VCOs and PLLs.***

A Temperature Compensated Array of CMOS Floating-gate Analog Memory

- A programmable analog memory, floating-gate (FG) transistors are widely used in many adaptive learning systems and

  neural systems
- How does it work?--------

Analog IC Market
A Strategic Overview and Opportunity

Content

- **Analog IC market**
- **Characteristics of analog companies**
- **Strategic considerations**
- **Opportunity in analog IC market**
- **Summary**
- **Author of this survey :Khanh Le**

Analog IC Market Drivers

- Automotive electronics
- Consumer electronics
- Energy
- Mobility
- Security
- Healthcare

Sources: IC Insights, Aug 2010,

Maxim Feb 2011

Courtesy: Khanh Le

Analog IC
Market Characteristics

- Market Characteristics
- Analog Market 2008-2012 ($B)
- Closely correlated with semiconductor market cycles
- Double digit growth – 10% average(**CAGR 2010-2016)**
- $42B in 2010 (30% 15 growth from 2009)
- $45.2B in 2011 growing to 0 $74.9B in 2016
- Period :2008-2016

(Source: Databeans, 2011)

Courtesy: Khanh Le

Analog IC Market Ranking

- 5 companies hold 43% market share and top 10 companies over 60% market share
- Disruptive change: TXI's acquisition of NSC

Company	2010 Rank	2010 $ M	2010 % Share
Texas Instruments	1	6,190	14.6
ST Microelectronics	2	4,291	10.1
Infineon Technologies	3	3,328	7.9
Analog Devices	4	2,482	5.9
Maxim IC Products	5	1,936	4.6
Others		24,058	56.9

Courtesy: Khanh Le

Analog IC Market Segments

	Application Specific	General Purpose
•	Analog ICs that perform specific functions: Timing Control, RF TRX, Touch sensors, LED & Display Drivers	Analog ICs that fit into multiple applications: amplifiers, ADC/DAC , Comparators etc
Analog Market Main Segments – 2011	**26.3 Billion $**	**18.8 Billion $**
Analog Market Main Segments - 2016	**40.3 Billions**	**32.9 Billion $**

Courtesy: Khanh Le

Analog IC Market Environment

- **A**nalog IC companies compete through:

(1) Special product design skills (2)Breadth of products

(3) Extensive worldwide distribution and support network

(4) Competitive price

- Smaller companies focus on specific products:

Asia - Leadtrend (power management), Richtek (power management, LED drivers, etc.), Niko, Power Analog Micro (high voltage), GMT (audio, switches, power management), Taiwan Semiconductor (discrete, voltage regulators, opamps), Sitronix (LCD drivers), Silicon Mitus (power management)

Courtesy: Khanh Le

Analog IC Applications Areas

- Audio and Video
- Clock and Timing
- Data Conversion - $3.8B in 2010
- Energy Measurement and Metering
- Interface
- LED Lighting
- Power Management - $9.1B in 2010
- Signal Conditioning
- Thermal Management and Sensors
- Wireless and RF

Courtesy: Khanh Le

Analog IC Applications by Industries

- **Applications by industry segments**:

Automotive

Communications

Computing and Storage

Consumer Electronics

Industrial

Medical

- **Very diverse products:**

Texas Instruments 30,000 products

Linear: 7,500 products NSC: 12,000 products

Maxim: 6,500 products

Courtesy: Khanh Le

Analog IC Process Technologies

- **Very diverse process technologies, optimized for analog and frequently specific product**

Bipolar (amplifiers, RF, regulators, power management, discrete)

BiCMOS, BiMOS (RF, amplifiers, power management)

DMOS, VMOS, etc. (High voltage)

CMOS (amplifiers, data converters, power management)

SiGe (RF) , SiGeC (UWB)

GaAs (RF)

Courtesy: Khanh Le

Each industry segment requires specific analog or mixed-signal technologies

- Consumer electronics: Touch screen, LED drivers, display drivers, NFC, video, audio codec, etc.
- Industrial: LED lighting, energy monitoring, RF, ADC, line drivers, etc.
- Automobile: Sensors, ADC, line drivers, audio codec, etc.
- Computer and Storage: HDMI, SATA, Thunderbolt, etc.
- Communications: GbE, 10GE, 40GE, timing control

Courtesy: Khanh Le

Characteristics of Analog IC Companies

- Major trend:

  Higher integration

  Multiple analog functions onto one chip

- Leaders are :

  Broadcom and

  Maxim

Courtesy: Khanh Le

Characteristics of Analog IC Companies

- Very profitable
- High operating margins

(Linear: 52.4%, ADI: 30%, Maxim: 26.4%) and

- Gross margins (TI: 53.6%, NSC: 68.3%, Linear: 77.6%)
- High P/E ratios (Linear: 15.3, ADI: 14.7, Maxim: 31)
- Resource-intensive
- Large companies have thousands of application engineers (e.g. TXI, NSC, Maxim, etc.)
- Extensive network of direct sales, distributors and sales reps.

(P/E Ratio: price-to-earnings ratio)

Courtesy: Khanh Le

Characteristics of Analog IC Companies

- **Diverse set of products and customers**
- **Tens of thousand of products and hundred of package types**
- **Tens of thousand of customers at all volume levels**
- **Hundreds of distinct applications in each market segments**
- **Longer product life cycles than many other IC types**
- **Very low ASP ($0.48) but very high volumes (88 Bu)**
- **Most large companies own fabs – esp. TI, NXP, LLTC, MXIM, etc.**

Own recipes and optimized processes

Leverage process R&D across products

Depreciated fabs keep cost low

Courtesy: Khanh Le

Strategies of Analog IC Companies

- **Maxim**
- **Strategy: integration, innovation, and balance**
- **Market focus: automobile, HD infrastructure, energy, mobile, security, and healthcare**
- **Linear Technology**
- **Strategy: broad-based supplier, quality**
- **Market focus: communications, industrial and automobile**
- **Zarlink**
- **Strategy: grow with network evolution and healthcare**
  - **Market focus: timing and line driver for networking, wireless for healthcare**
- **National :Strategy: broad base supplier of high performance, energy-efficient analog and mixed signal products**
- **Market focus: growth areas – LED lighting, portable medical, renewable energy, communications infrastructure and personal mobile device**

Courtesy: Khanh Le

Strategic Considerations

- Opportunities
- Growing appetite for analog chips in major industry segments
- Consolidation re-started with TI's acquisition of NSC in April 2011
- Several potential acquisition targets exist in US and elsewhere
- Threats
- Current partners of TI, STMicro, ADI, etc. will block entry or limit playing field

Courtesy: Khanh Le

Application-Specific Analog Opportunity

- **Application-specific Analog** sees increasing share in the IC content of DVD, mobile devices, DTV/STB etc.

Example: A i-Pad either with no 3G or 3 G costs around $ 225/- & $ 260/- in US Market.

The *Analog share is around $ 55/- (20 to 25 %)*

- **Great Opportunity for Other innovative startups and smaller analog IC companies**

Courtesy: Khanh Le

Viable Market Strategy

- **Differentiate with --**

  Innovative designs,

  Analog performance,

  System-friendliness, and

  Custom packages to meet requirements of applications

- **Focus on growing segments--**

  Cellular wireless RF – Transceivers, Power amplifiers

  Power management – Chargers, Supply control, LEDs,

  Wi-Fi, GPS, Bluetooth, NFC, etc. Transceivers and Controllers

Courtesy: Khanh Le

Potential Growth: Power Management

- **Power management semiconductor market** (ICs and discretes) :
  - ***$31.4B in 2010,***
  - ***$36.2B in 2011***
  - ***13% growth rate next 4 years***
- **Driven by**
  - ***Portable consumer Devices***
  - ***Alternative energy systems***

Courtesy: Khanh Le

Potential Growth: Wireless

- **Wireless Products:**
  - **5 Billion units by 2014**
- **Wi-Fi :**
  - 3.8 Billion units,
  - $10B revenue

Courtesy: Khanh Le

In Nut Shell

- **Large and consolidated Analog IC market**
  ***(US$ 42 Billion*)**
- **It's a horizontal market with large number of application segments and customers**,
  Low ASP (US$ 0.48) and
  Huge unit volumes (88Billion units)
- ***Application-specific analog is an attractive segment for entry by innovative start-ups***

Courtesy: Khanh Le

Wireless and Mobile Electronics Drive Solid Analog IC Market Growth

- **Key Issues :**
- ***Will the analog IC market rebound occur to the same extent as the overall semiconductor market?***
- ***Will analog ICs remain viable in the future, or will they be displaced by digital products?***
- ***Is the market becoming increasingly application-specific?***
- ***Will multi-market devices lose their share of the market?***
- ***Where is the best opportunity for growth in analog ICs: power, signal processing or interface?***

Courtesy: Khanh Le

Analog Integrated Circuits Market to 2016 Electric Vehicles and Portable Medical Equipment Segments to be Main Source of Future Growth

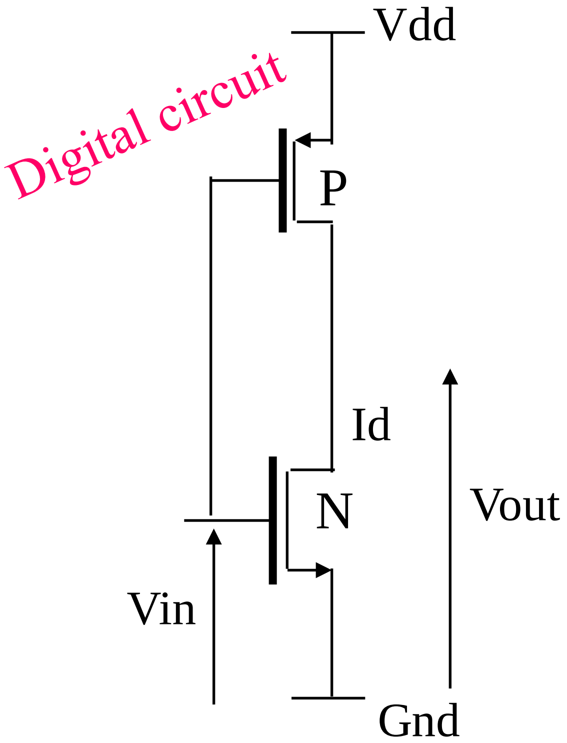
Unstoppable Rise of the Smartphone Will Drive Analog Integrated Circuit Market

Analog ICs are used in a wide range of applications including third and forth generation (3G/4G) radio base stations and portable device batteries.

ANALOG VLSI DESIGN

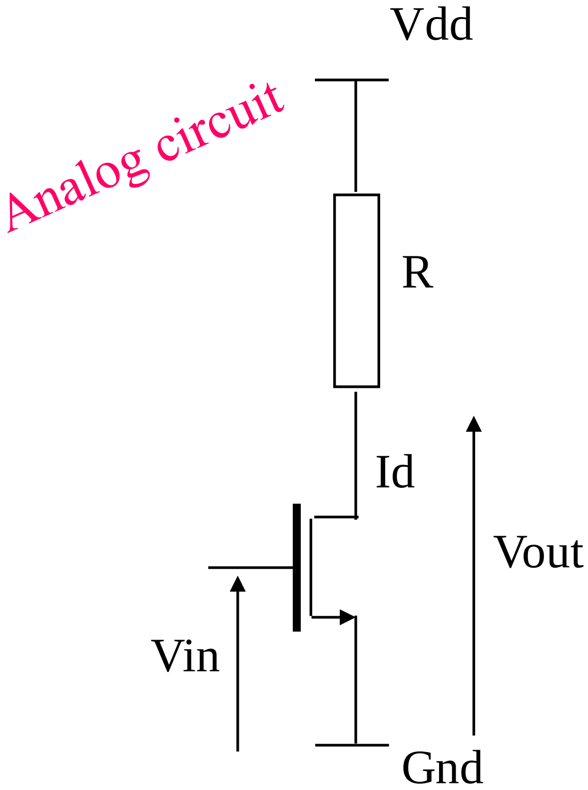
Principles, Techniques, Building Blocks

1- Introduction to analog circuit



Vin=Gnd (0) or Vdd (1)
Vout = Vdd(1) or Gnd(0)

NON LINEAR SYSTEM

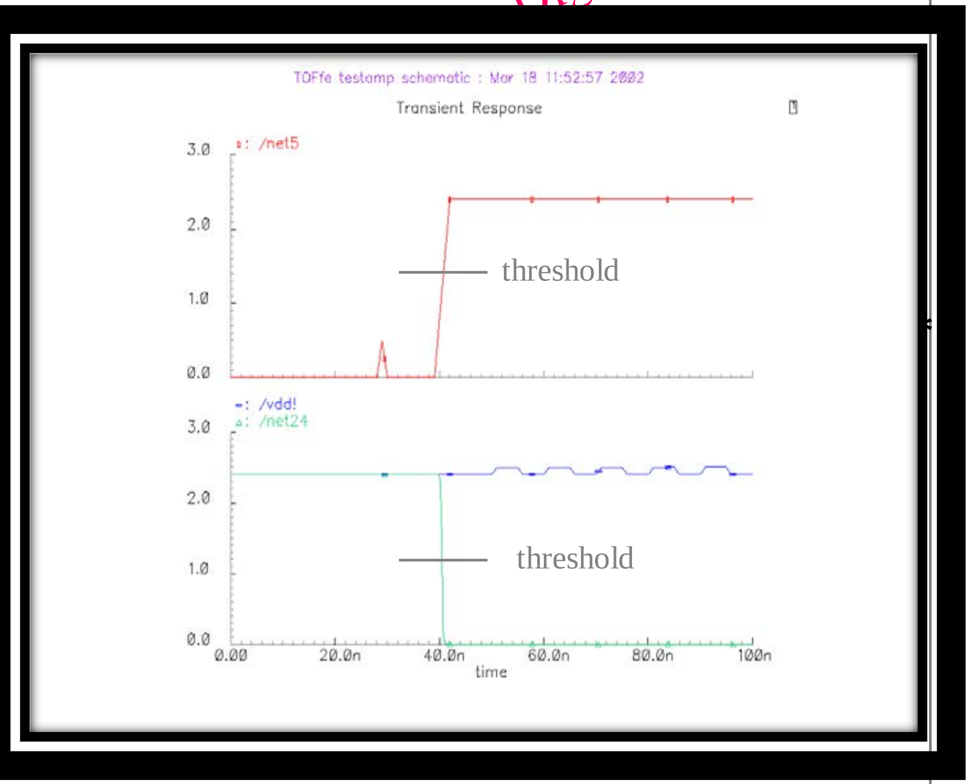


Vout=f(Vin)
Vin and Vout can take any value between Vdd and Gnd

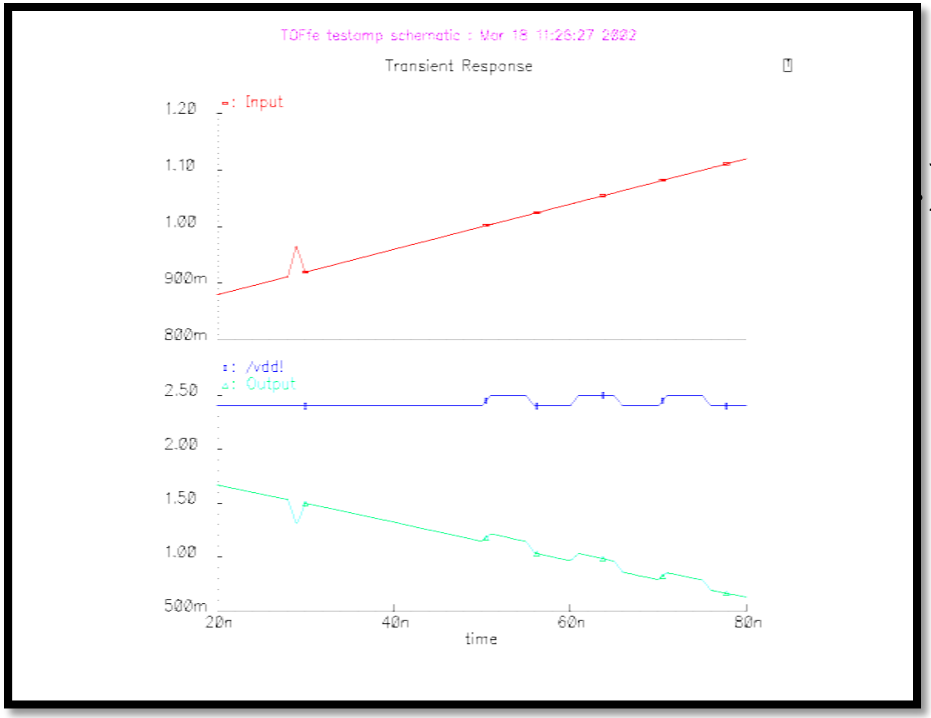
LINEAR SYSTEM

Introduction to Analog circuit

Digital circuit



Analog circuit



* = up to certain limits !

** = function of max. signal range versus noise level

General Design Issues

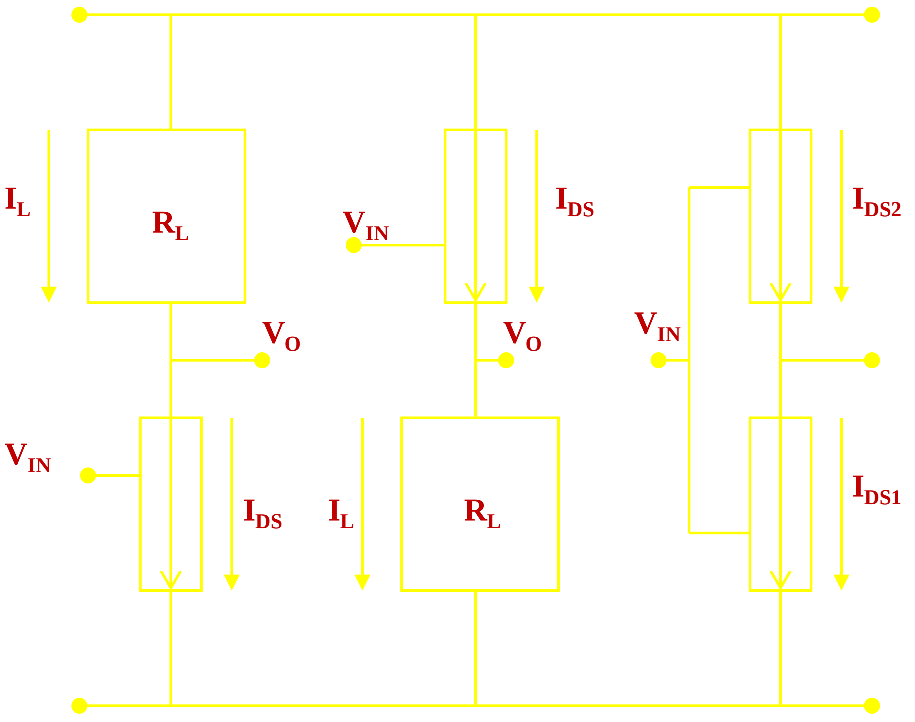
DIGITAL

- Irradiation results in additional speed degradation (Vt drift, mobility degradation)
- Power consumption change before/after irradiation not under control (design dependant)
- SEU is an issue

ANALOGUE

- All aspects of "analogue" functions are affected by radiation : noise, offsets, stability, BW, operating point
- Control over biasing voltages or currents (when possible) allows some compensation of radiation effects
- SEU (generally) not an issue

Generic Representation of an amplifier



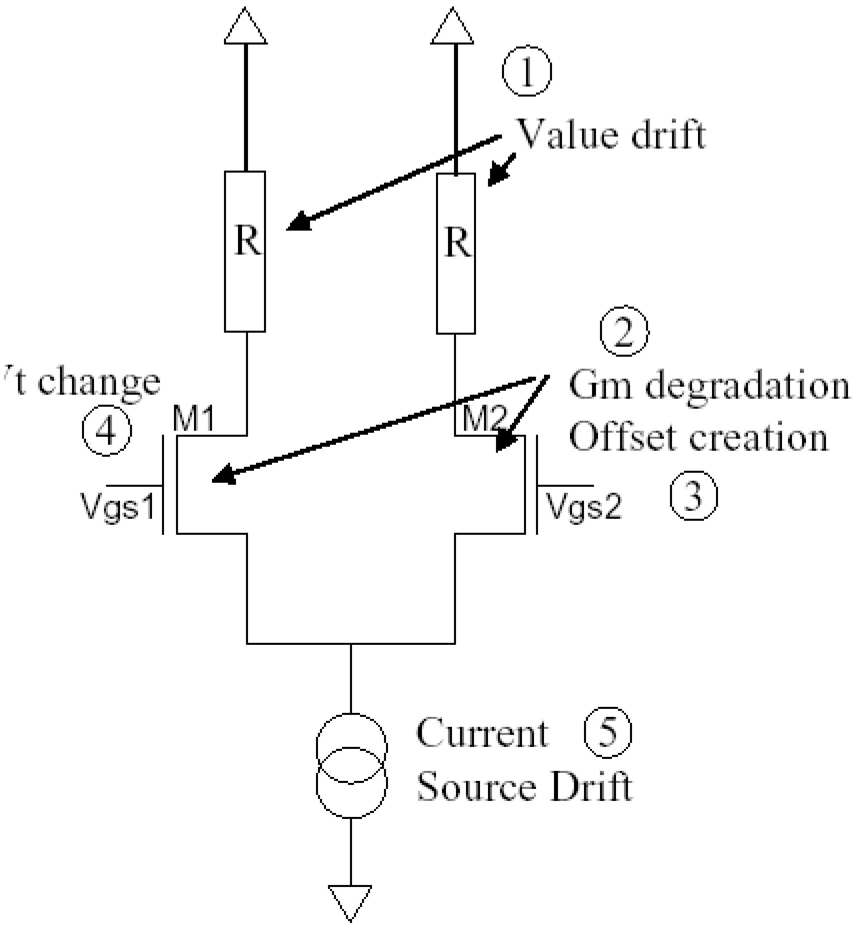
Analog design needs to consider:

- Handling of positive and negative signals (dual rail)
- Biasing is very important
- Linearity is essential
- Lower noise tolerance
- Lower drift
- Unavailability of standard cells
- Difficulty in realizing low voltage and low power circuits

Main parameters in design are:

- Transconductance, g_m
- Output resistance, R_O
- Input referred noise
- Frequency response- bandwidth

Analog Design Issues



1 4 5 = Operating point loss

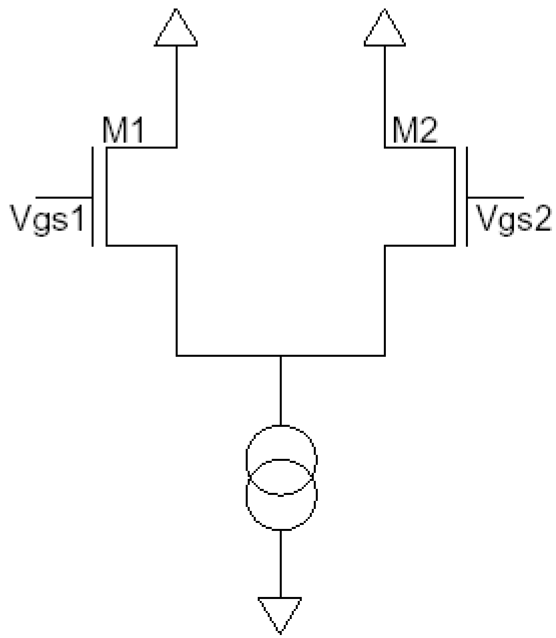
3 = Offset Increase

2 5 = Noise change

1 2 5 = BandWidth Change

Analog Design Issues

Amplifier offset



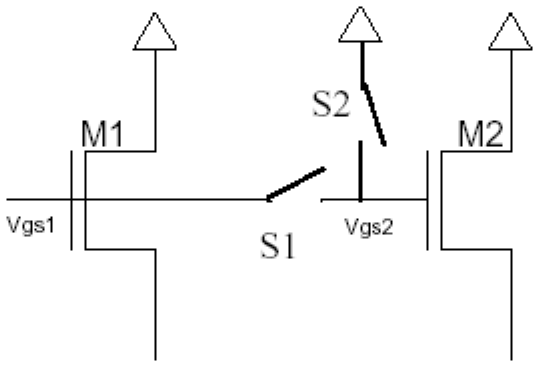
If during operation under irradiation, Vgs1 is almost always less than Vgs2, Vt drifts for M1 or M2 are different :

Large input offset creation

This situation is frequent for comparators, used for input level detection, threshold discrimination, etc ...

Analog Design Issues

Current mirror switching :



Vt drift on M2 depends on S1/S2 status during irradiation :

M2 current is different from M1 current
if S2 closed, S1 open during irradiation

Noise in Analog Devices/Systems

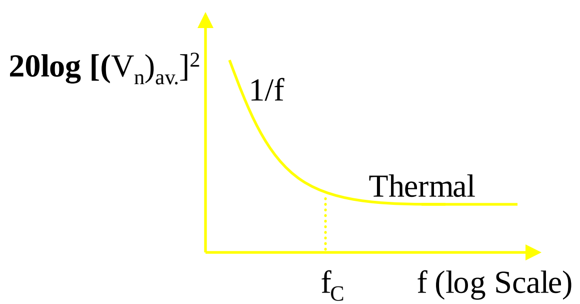
Types of noise:

(i) Thermal noise: $S_v(f) = 4kTR$ V²/Hz.

(ii) 1/f noise: Mobility fluctuations <=> D_{it}.

Flicker noise corner frequency

$$f_C = \frac{kg_m}{C_{ox}W.L}\frac{3}{8kT}$$

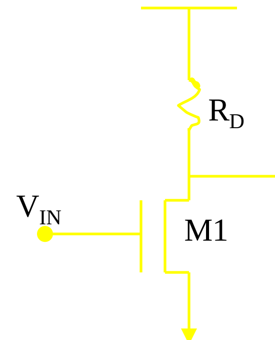


Clearly scaled down devices increase 1/f noise.

Noise in Amplifier

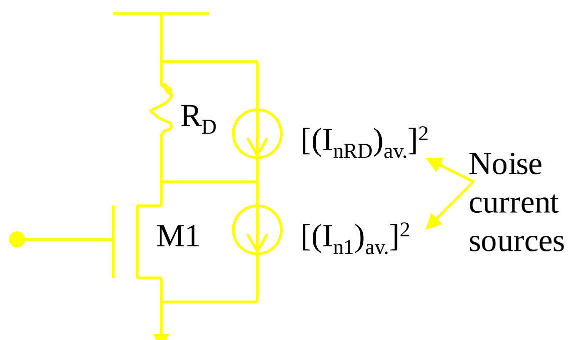
$$\overline{I^2_{n^{th}total}} = 4kT\left(\frac{2}{3}g_m\right)\times(Bandwidth)+4kTR_D\times(Bandwidth)$$

$$\overline{I^2_{n_{1/f}}} = \frac{k}{C_{ox}W.L}\frac{1}{f}g_m^2$$



$$\overline{V^2_{n_{total}}} = \left(4kT\frac{2}{3}g_m+\frac{4kT}{R_D}+\frac{k}{C_{ox}W.L}\frac{1}{f}g_m^2\right)R_D^2$$

$$g_m \cong \sqrt{2\beta^1\left(\frac{W}{L}\right)I_D}$$



Noise in amplifier

Clearly short channel devices lead to higher noise in amplifiers. If A_v is the gain of the amplifier ($=g_m R_D$), input referred noise

$$\overline{V_{n_{in}}^2} = \overline{V_{n_{out}}^2} / A_v^2$$

$$\overline{V_{n_{in}}^2} = 4kT\frac{2}{3g_m} + \frac{4kT}{g_m^2 R_D} + \frac{k}{C_{ox}W.L}\frac{1}{f}$$

Design Modifications:

- Increase V_{dd} or tune I_{bias} - stabilize DC biasing
- Design for comfortable PM, use Miller and pole-zero compensation - stability
- Constant-gm architecture - stability
- Use differential structures and offset compensation schemes. - offset
- For comparators design for high gain so that any degradation would not effect much its operation.

Is Analog VLSI Design Dead?

- No, not true at all !
- Total analog chip sales for 2006 $ 48 billion, 2007 ~ $55 billion
- 10% increase over previous year, growth predicted for next 3 years
- Raw transducer output in most systems is analog in nature
- Although very small %age of total chip area is analog, still a

  need for good design practice since analog component may be the limiting factor on overall system performance
- Days of pure analog design are over, majority of systems are integrated with increased functionality in digital domain
- Will attempt to introduce some hierarchy - use building block approach as for digital
- **Bottom Line: Ability to design both analog and digital circuits and understand interactions between the 2 domains adds dimension to your design portfolio**

Analog Building Blocks

- Basic Blocks include
  - Current Sources
  - Current Mirrors
  - Single Stage Amplifiers
  - Differential Amplifiers & Op Amps
  - Comparators
  - Voltage References
  - Data Converters
  - Switched Capacitor Circuits

CMOS Technology

- MOS Market dominates worldwide chip sales (>85%)
- Total MOS sales 2010/2011 ~ $ 500 billion (Electronics : 3.0 Trillion)
- Illustrates strength of CMOS technology - feature sizes now < 045nm
- True system-level integration on a chip i.e. converters, filters, dsp processors, microcontroller cores, memory all reside on one die
- >800 million transistors/chip
- Decreases in feature size cause some complexities:

  Layout issues more important

  Modeling is a key issue

  Parasitic effects significant

  Power dissipation issues challenging (BiCMOS, VDD-hopping, etc)

Improvement Trends

- Functionality (e.g. non-volatility, smart power)
- Integration Level (e.g. components per chip, Moore's Law)
- Compactness (e.g. components/sq cm)
- Speed (e.g. microprocessor clock in MHZ)
- Power (e.g. laptop or cellphone battery life)
- Cost (e.g. cost per function, historically decreasing)

Available from scaling & tech improvements over last 30yrs

Future Trends: **International Technology Roadmap for Semiconductors (ITRS)**

- S/C industry has become a global industry in the 90's: manufacturers, suppliers, alliances, world wide operations. Since 1992 Semiconductor Industries Association (SIA) has produced a 15year outlook on major trends in the s/c industry **(ITRS)**
- Technical challenges identified
- Solutions proposed (where possible)
- Traditional is reaching fundamental limits
- New materials must be introduced to further extend scaling limits

Way to go:

- System In a Package (SiP
- P-SoC (Performance System-on-a-Chip): integration of multiple silicon technologies on a chip
- Nanotechnology
- Neuromorphic Systems - emulate natural signal processing (circuits operating in subthreshold/weak inversion)

ITRS: Technology Working Groups (TWG’s)

Purpose: To provide guidance, host and edit workshop in following areas

- Design
- Test
- Process Integration, Devices, Structures
- Front End Processes
- Lithography
- Interconnect
- Factory Integration
- Assembly & Packaging
- Cross Cutting Working Groups in environment, safety, defect reduction, metrology, modeling/simulation

ITRS: Example of Key Lithography-Related Characteristics

Year	99	2002	2004	2008
DRAM pitch	180nm	130nm	110nm	70nm
MPU Gate Length	140nm	100nm	70nm	45nm

What is S-o-C (system on a chip)?

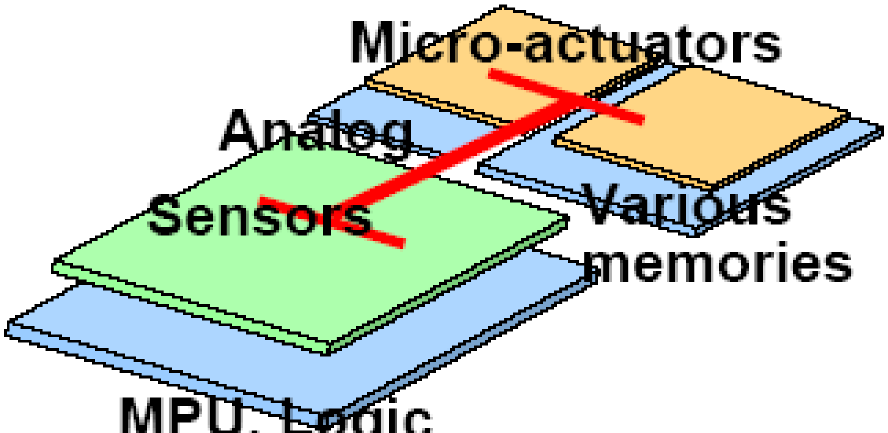
- S-o-C chips are often mixed-technology designs, including such diverse combinations as embedded DRAM, high-performance or low-power logic, analog, RF, esoteric technologies like Micro-Electro Mechanical Systems (MEMS) , optical input/output.
- Time-to-market for particular application-specific capability is key
- Product families will be developed around specific SoC architectures and many SoC designs customized for target markets by programming part (using software, FPGA, Flash, and others).
- Category of SoC is referred to as a *programmable platform*. The design tools and technologies needed to assemble, verify, and program such embedded SoC’s will present a major challenge over the next decade.

Interconnect Working Group

- Function of interconnect is to distribute clock and other signals and to provide power/ground
- Requirement for interconnect is to meet the high-speed transmission needs of chips despite further scaling of feature sizes.
- As supply voltage reduced, cross-talk an issue, near term solution is use of thinner copper metallization to lower line-to-line capacitance.
- Although copper-containing chips introduced in 1998, copper must be combined with new insulator materials. Introduction of new low κ dielectrics, CVD metal/barrier/seed layers, and additional elements for SoC, provide process integration challenges.
- Emerging system-in-a-package (SiP) and system-on-a-chip, or SoC
- For long term, material innovation with traditional scaling will no longer satisfy performance requirements. New design or technology solutions (such as coplanar waveguides, free space RF, optical interconnect) will be needed to overcome the performance limitations of traditional interconnect.

Future Chips 2014→

Possible electronic system in 2014



- Sensors/actutors
- 0.035μm 3.6G Si FET's with VTH & VDD control
- Locally synchronous 17GHz clock, globally asynchronous
- Chip / Package / Board system co-design for power lines, clocks, and long wires (super-connect)

Challenge

VLSI Design in 2012

Designing a map of 10m wide roads for a world atlas

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- Many of Prof. Razavi's papers & Books
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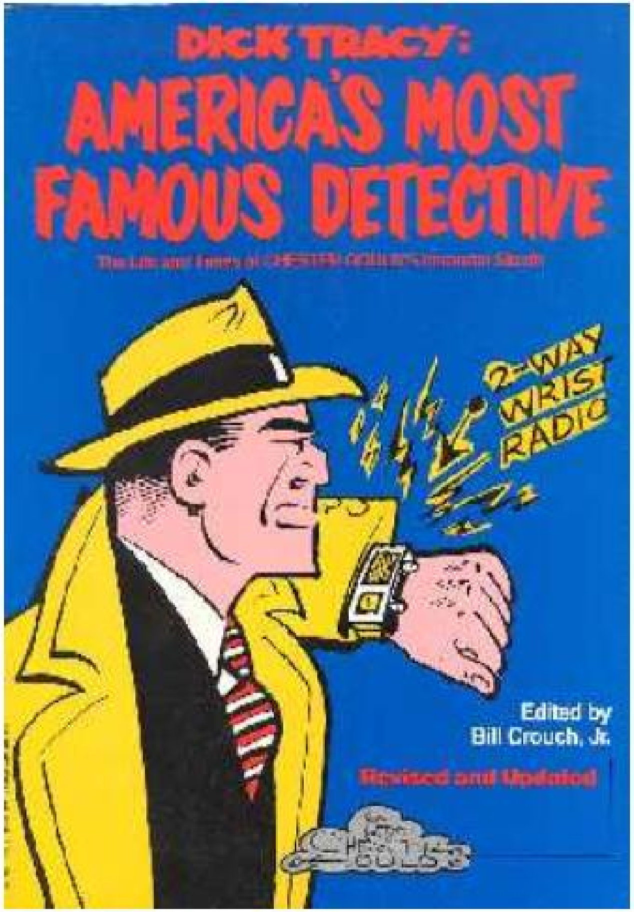
- SONY Corporation
- Ismail & Faiz work on analog Design
- J.Baker's papers and Books
- *www.slideshare.net/* **Khanh Le**

When will Dick Tracy's Watch be Available ?



Ultimate Nomadic Tool in Broadband Age

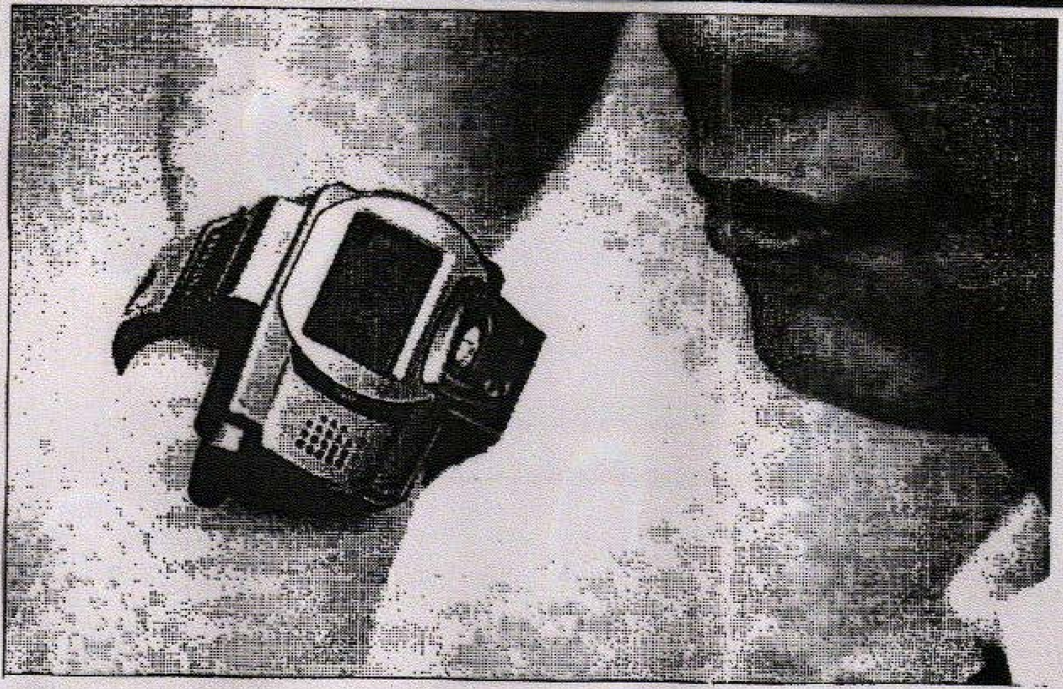
- Two-way Communication
- Language Translation & Interpretation
- e-Secretary
- Camera
- Music
- Electronic Money

Two-way Wrist Communicator

Calling Dick Tracy

Without question, the star of the show was a prototype wristwatch terminal that will have Dick Tracy and his wrist radio turning over in his comic book grave. The device, which is smaller than a bar of soap, allows users to send and receive video via a built-in screen and camera.

Driving Forces



This picture dated March 25, 99 shows Samsung's world's first ever Watch phone-To be marketed in April 1999. Weighs 39 grams, battery can last for conversation up to 90 minutes, size: 6.7cm x 5.8cm x 2cm.

Economical Factors
Competition
Creativity

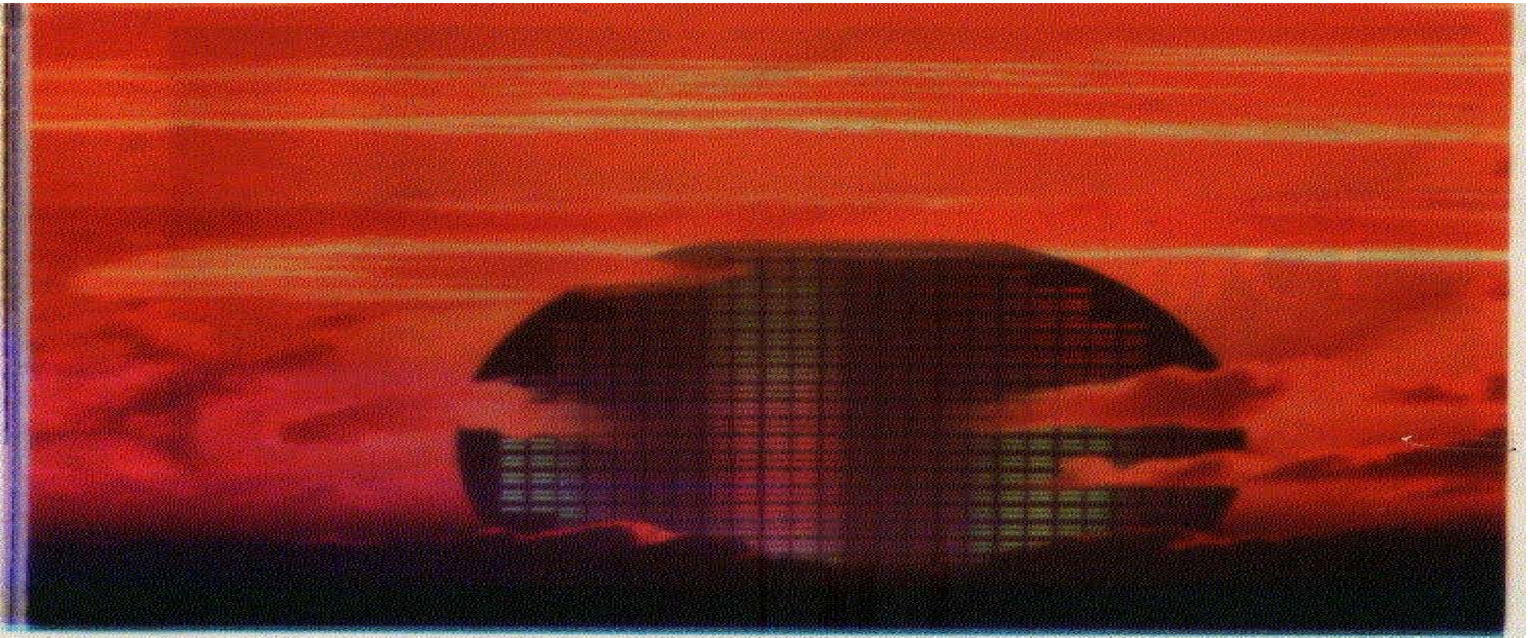
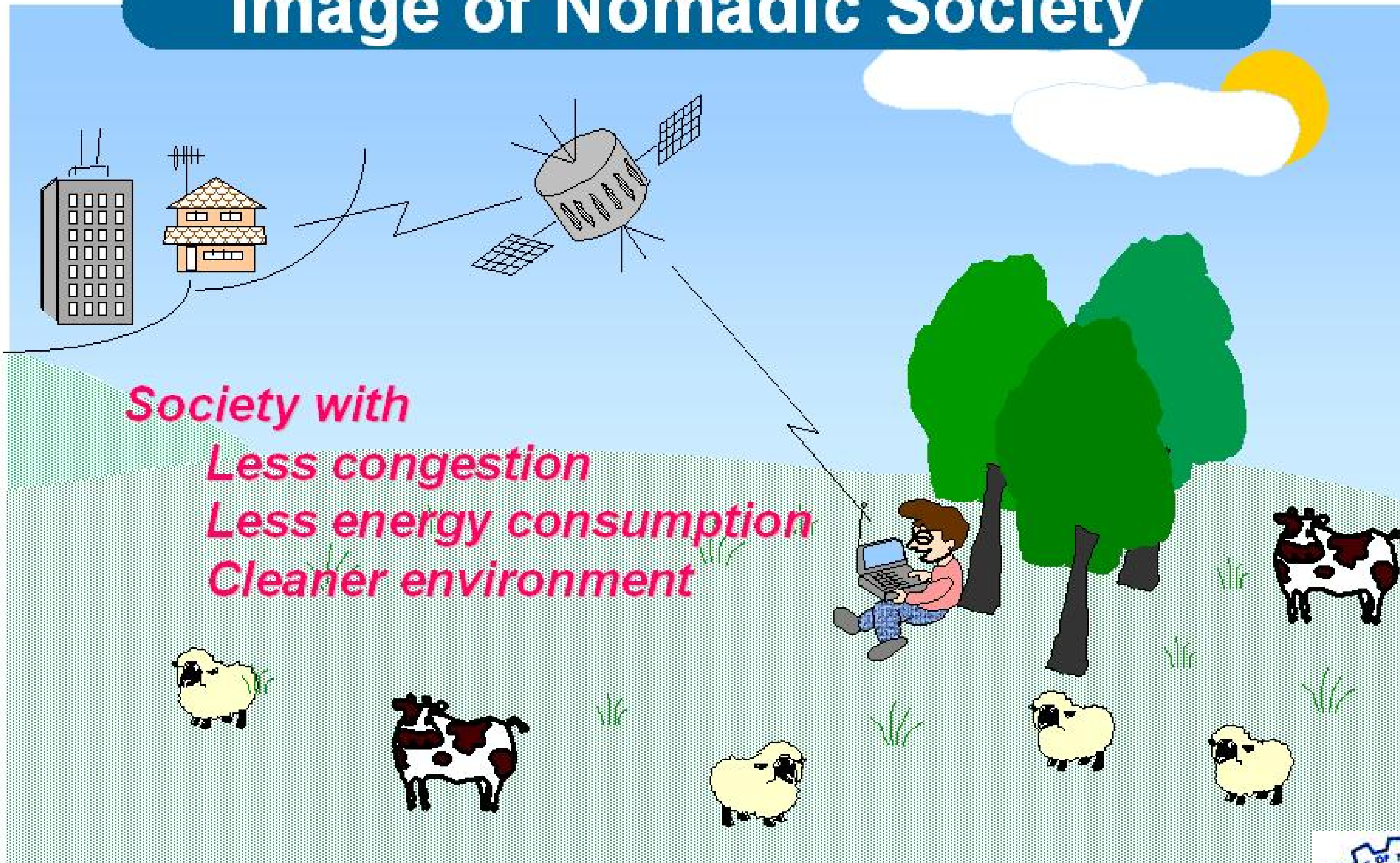


Image of Nomadic Society



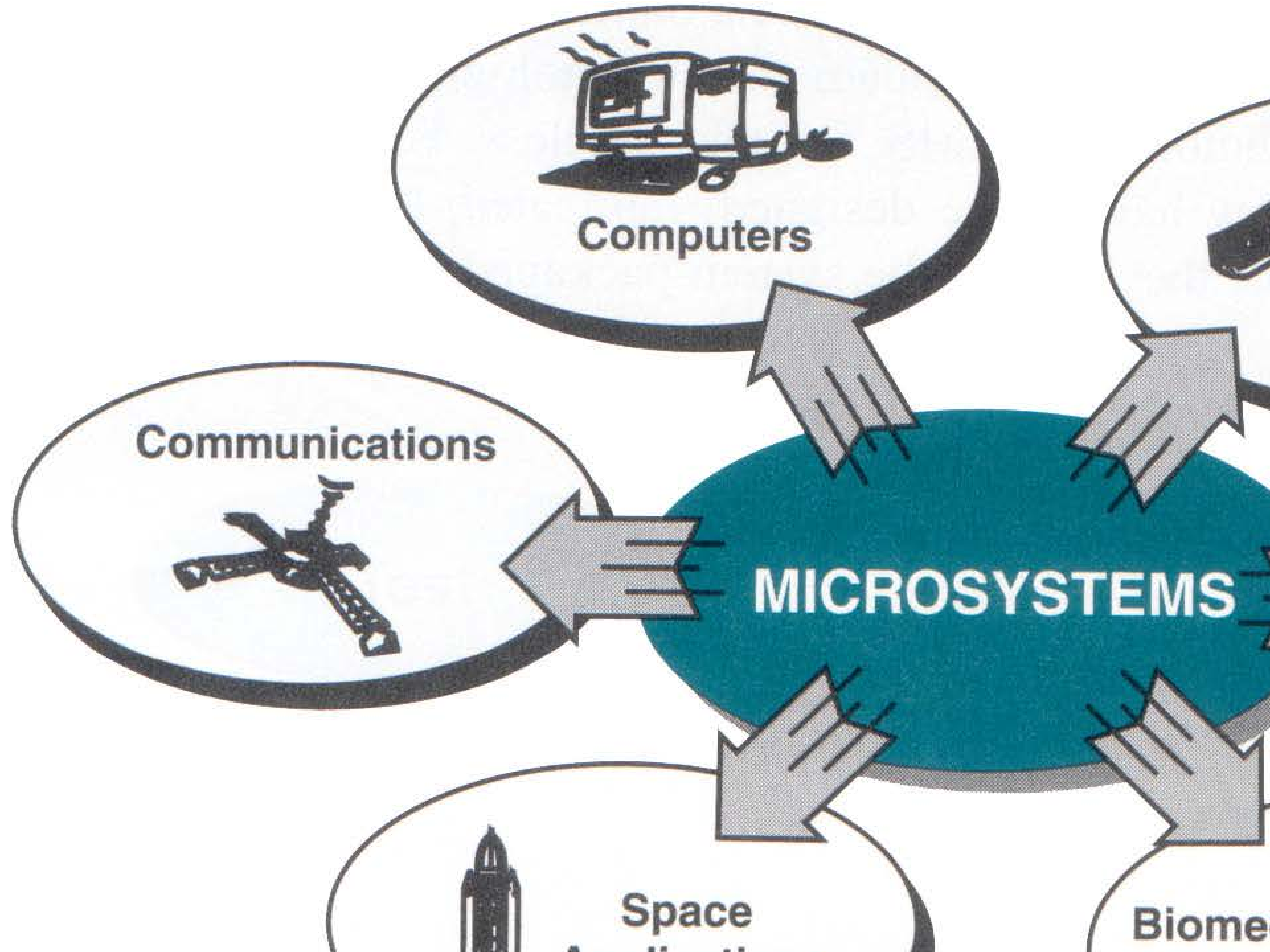
Society with

- Less congestion
- Less energy consumption
- Cleaner environment

“Executives might make the final decisions about what would be produced, but engineers would provide most of the ideas for new products. After all, engineers were the people who really knew the state of the art and who were therefore best equipped to prophesy changes in it.”

The Soul of a New Machine, Kidder, pg 35

THANK YOU



Computers
Communications
MICROSYSTEMS
Space
Biome