EIT 50 YEARS

WHY DID I CHOOSE TO STUDY HERE

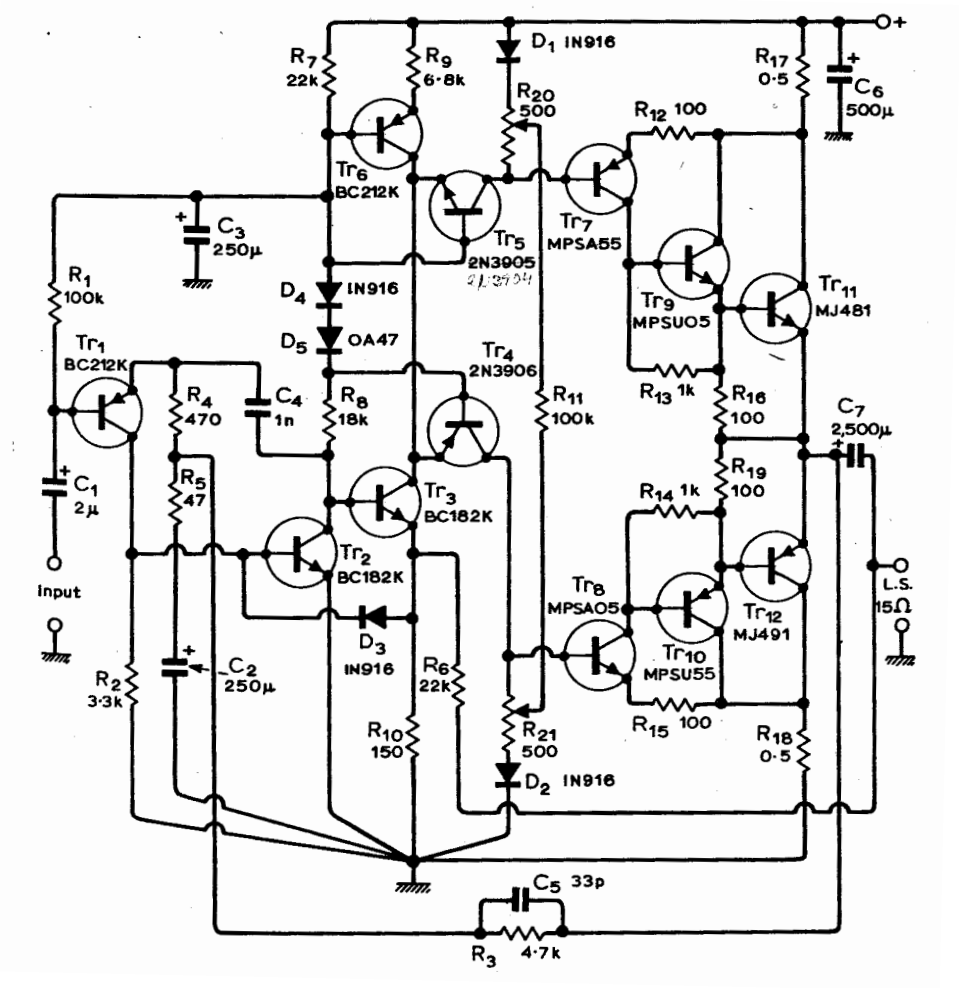
OR

→ LTH → ERICSSON → BLUETOOTH

SVEN MATTISSON

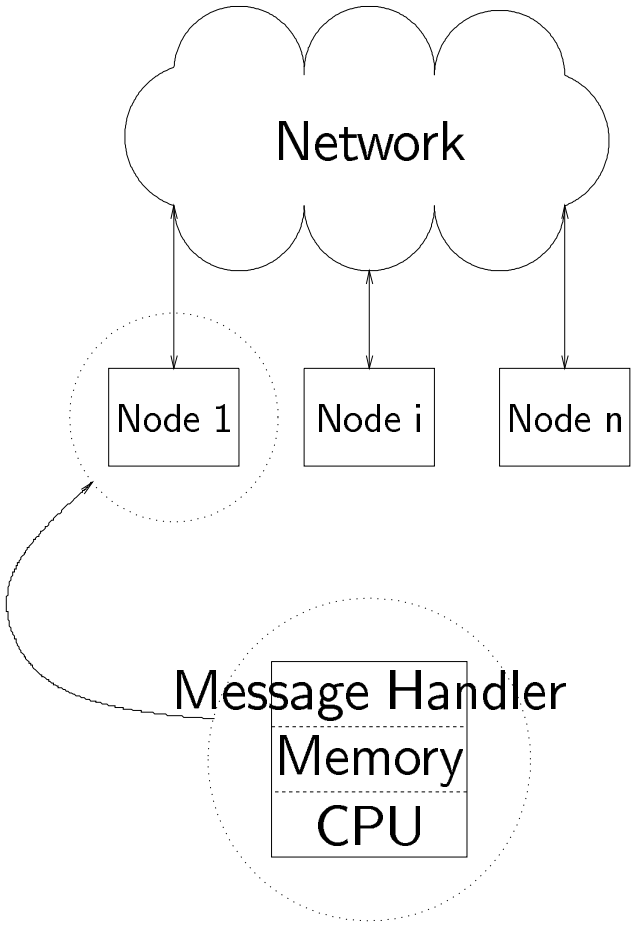
WHY EE AT LTH?

WHY EE AT LTH?


R7 22k
R9 6·8k
D1 IN916
R20 500
R17 0·5
C6 500µ
R12 100
Tr6 BC212K
Tr5 2N3905
Tr7 MPSA55
C3 250µ
R1 100k
D4 IN916
D5 OA47
Tr9 MPSU05
Tr11 MJ481
Tr1 BC212K
Tr4 2N3906
R4 470
C4 1n
R8 18k
R11 100k
R13 1k
R16 100
C7 2,500µ
C1 2µ
R5 47
Tr3 BC182K
R14 1k
R19 100
Tr2 BC182K
Input
Tr8 MPSA05
Tr12 MJ491
L.S. 15Ω
D3 IN916
Tr10 MPSU55
C2 250µ
R2 3·3k
R6 22k
R10 150
R21 500
R15 100
R18 0·5
D2 IN916
C5 33p
R3 4·7k

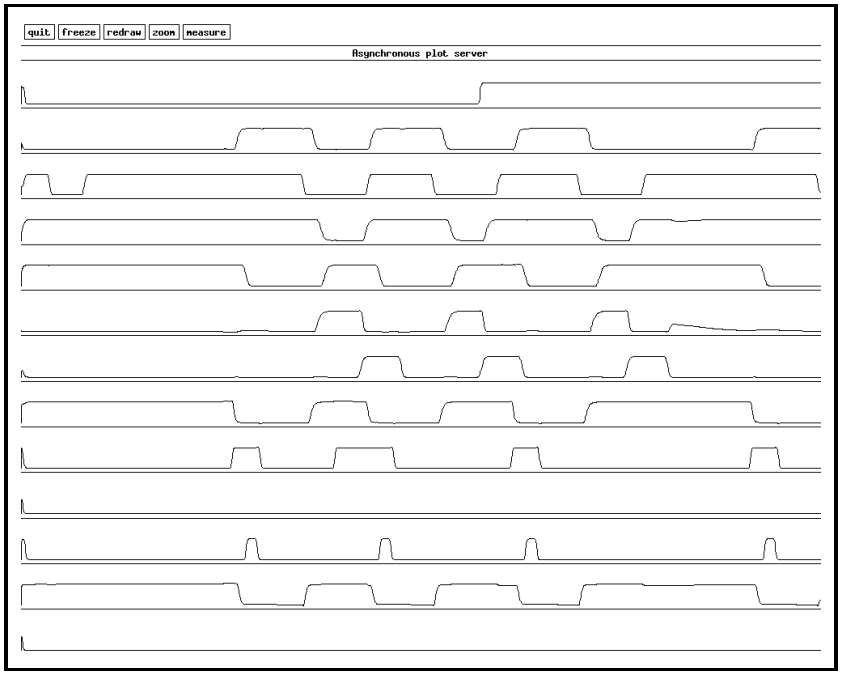
!

PHD AT LTH



- (teaching) assistant
  - applied electronics
  - analog design
- research
  - radar
  - ASICs
- Caltech
  - special student
  - research project

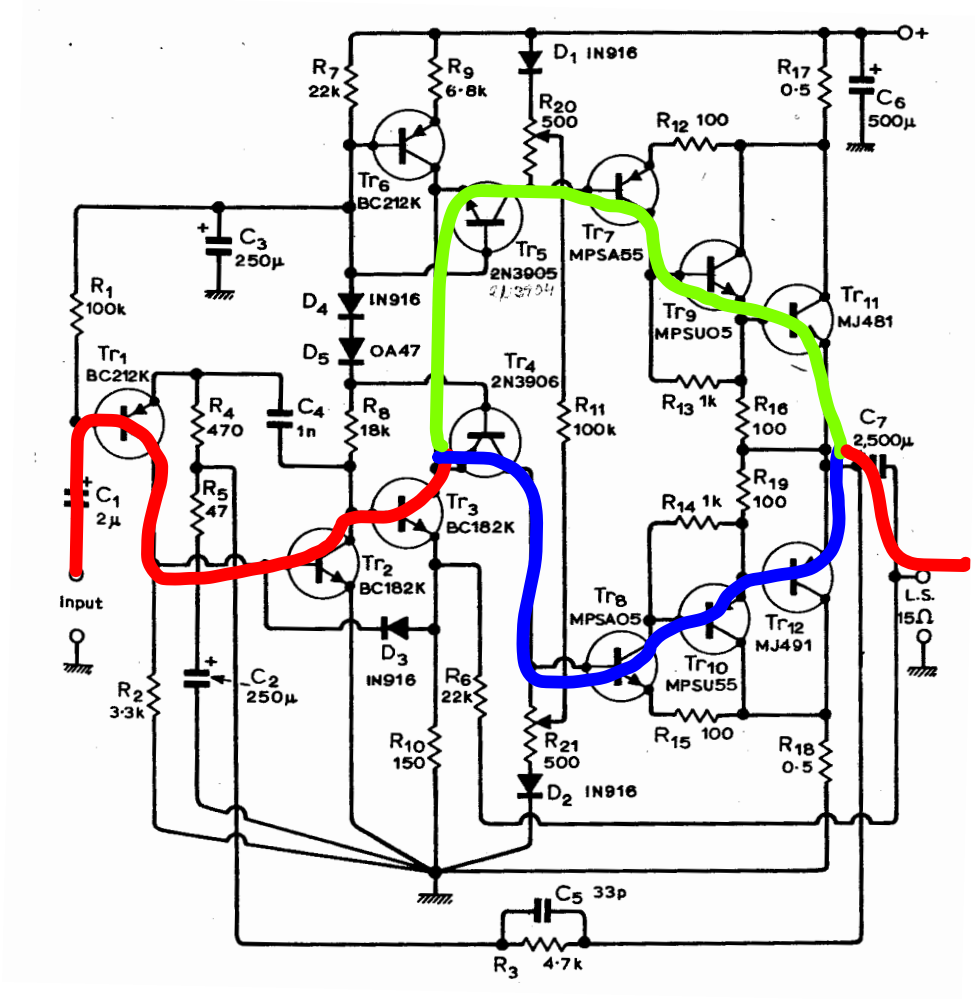
CONCISE



- 192-node multicomputer
- 87 times speedup
- 25000 MOS transistors
- 6 hours wall-clock time
- 21.8 days total CPU-time

Time-domain simulation of ASICs on many CPUs/computers

BLOMLEY AUDIO PA



A class B amplifier!

COW'S MEADOW TURNS INTO SCIENCE PARK

IDEON STARTED 1982 AT PÅLSJÖ MEADOWS

Gun Hellsvik, Nils Hörjel and Nils Stjernkvist in a rural setting 1982. Ericsson started cell phone development here in 1983.

THE ACADEMY HAS MANY NEIGHBORS NOW

Pålsjö meadows (and Brunnshög) are just memories now

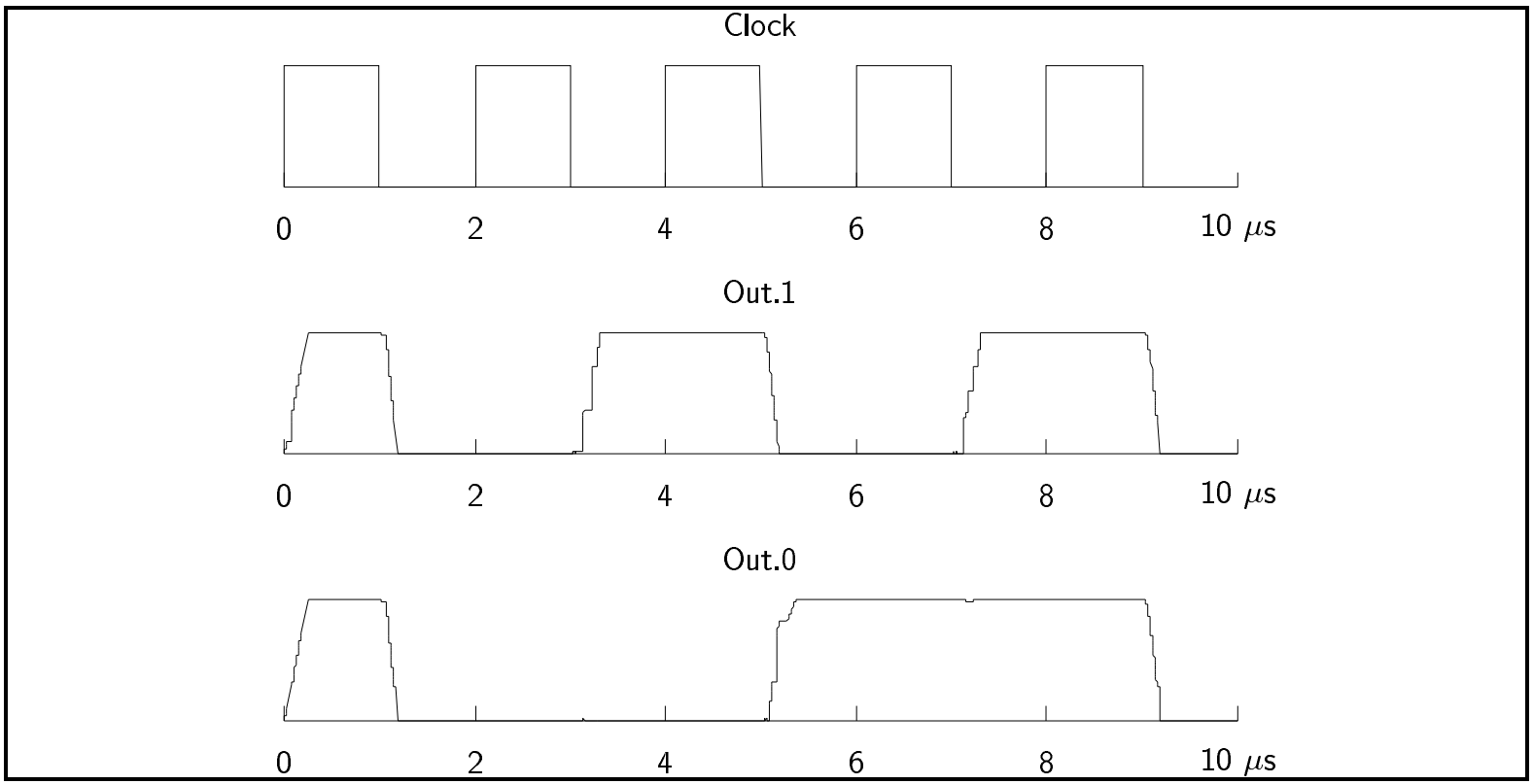
IDEON

- the first science park in Scandinavia, founded 1983
- businesses in mobile communications, information technology, pharmacology, biotechnology, ...
- 250 small companies today employing some 2500 people
- large companies, including Ericsson, ST-Ericsson och Sony Mobile Communications (more than 5000 active within mobile technologies)

80's cellphone

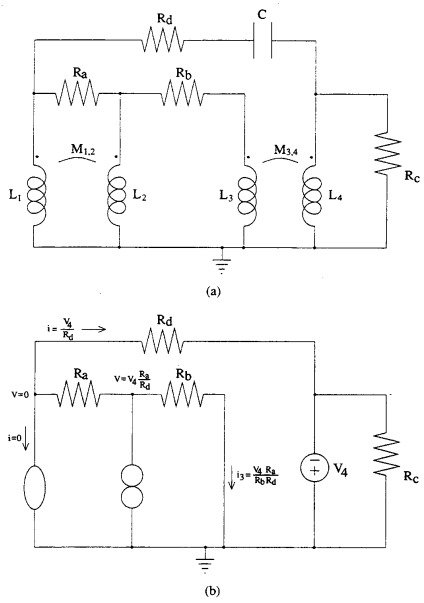
more recent head set

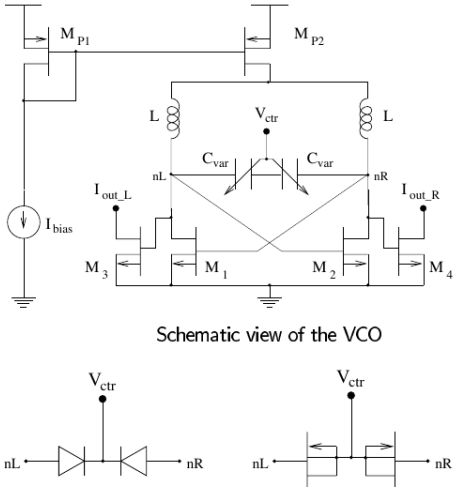
GRAD STUDENTS

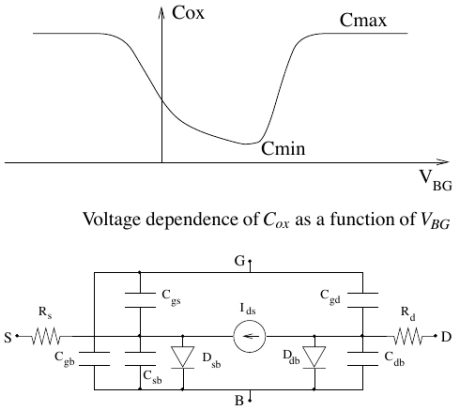


Caltech exchange, multi-computer donations, CAD tools

THEORY AND DEVICES

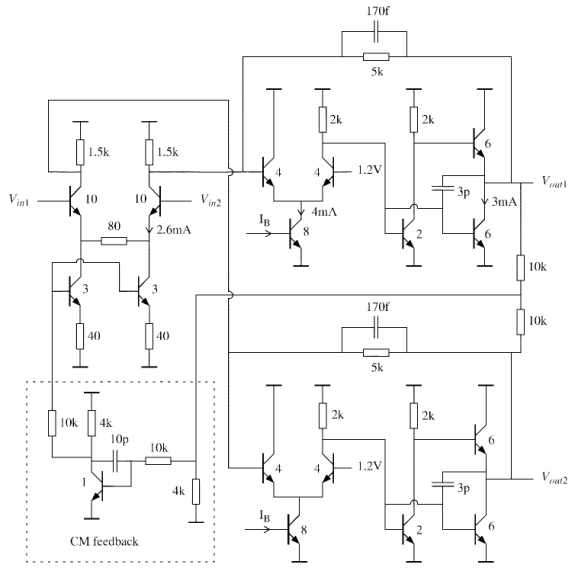




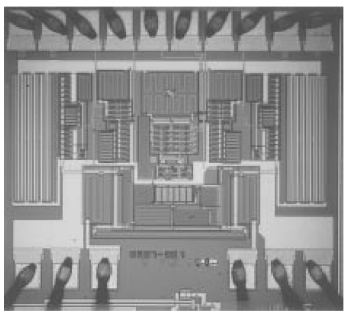


State-of-the-art VCO designs

RF ASIC DESIGN



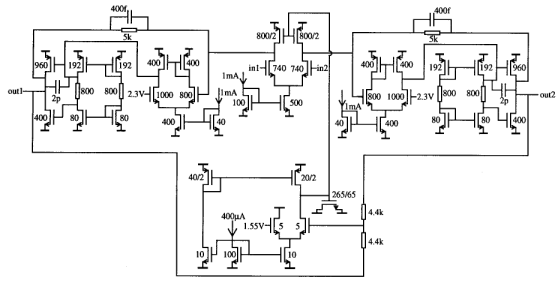
The entire schematic with parameters. The numbers at the transistors indicate number of unit devices used. Each unit device has a 15 × 1 μm emitter.



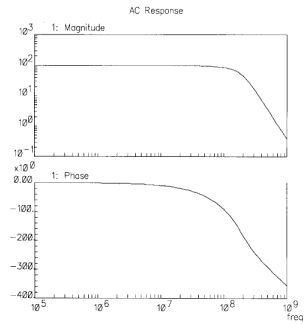
Die photo of the amplifier.

SOME SIMULATION AND MEASUREMENT RESULTS

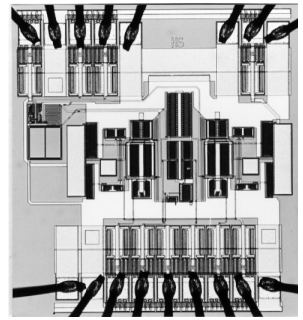
	Simulation	Measurement
Supply voltage	5V	5V
V_{cm} input range	1.2V-1.7V (nom. 1.4)	1.15V-1.8V (nom. 1.4)
Current consumption	26.7mA	24.4mA
Voltage gain	96	100
Bandwidth	160MHz	190MHz
IP3 (out) @ 20MHz, 10MHz	43dBV, 41.5dBV	42dBV, 40.5dBV
NF (R_s=2*100Ω) @ 10MHz	3.6dB	5.4dB +/- approx. 1dB



The entire schematic with device parameters. Unless specified, the transistor length is 0.8 μm.



Bode plot of the voltage gain with internal capacitive loading.



Microphotograph of the amplifier.

ultra low power → 60 GHz ASICs

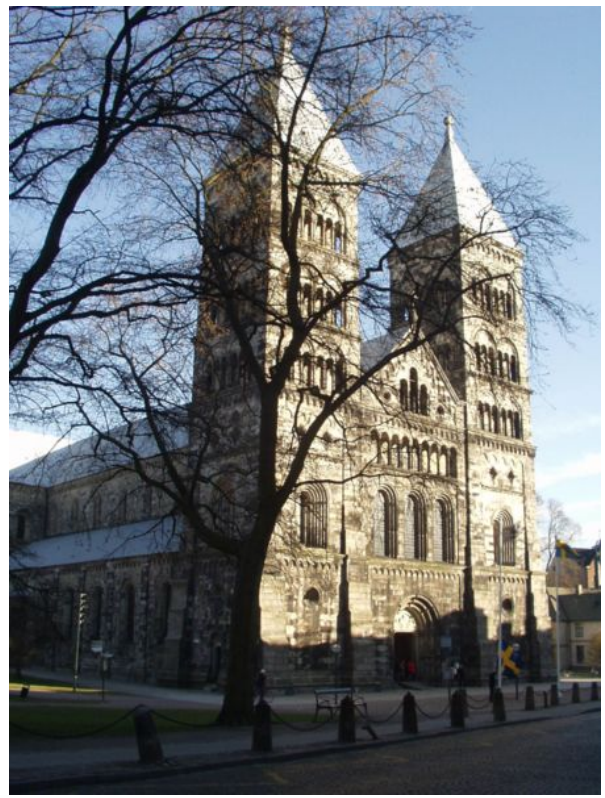
It all started in Lund in the mid nineties. . .

LUND

FOUNDED 990 BY HAROLD BLUETOOTH'S SON SVEN FORKBEARD

- full curriculum with 40000 students and 5500 researchers and staff
- research intense infocom and biotech industry

Lund university was founded 1666



The Cathedral, inaugurated 1145

THE BLUETOOTH OBJECTIVES

”wireless cable between. . .

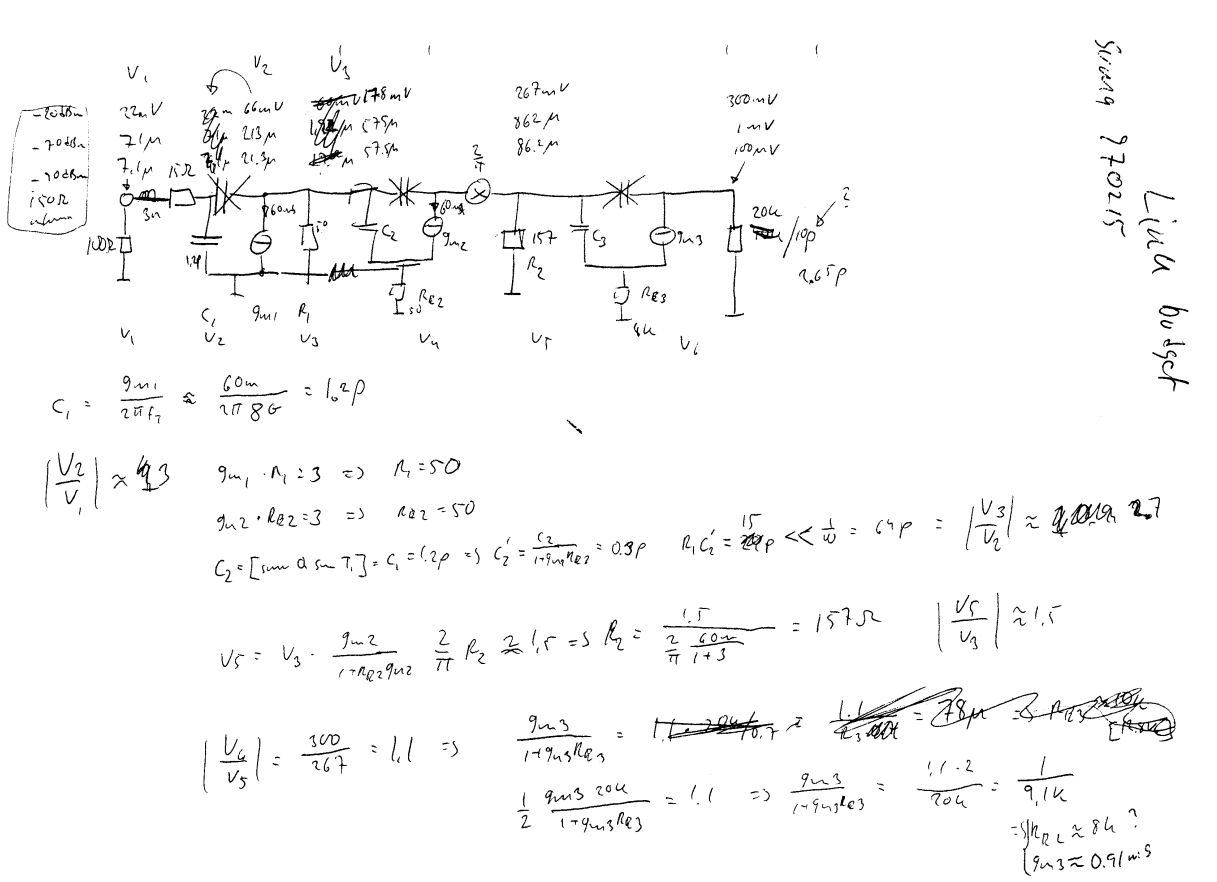
CABLE REPLACEMENT

"Design a radio that replaces a cable and its connectors. . . "

- targets
  - low volume
  - low manufacturing costs $< \$5$
  - low power consumption standby $< 1\,\mathrm{mW}$
  - safe and robust communication in the open ISM band
- challenges
  - efficient yet robust radio link
  - single chip integration

[project targets, 1995]

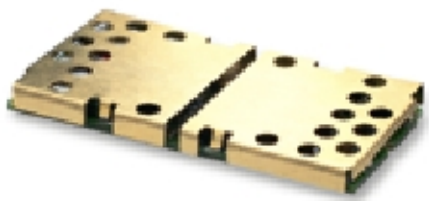
FIRST BT LINK BUDGET



Lucent BiCMOS

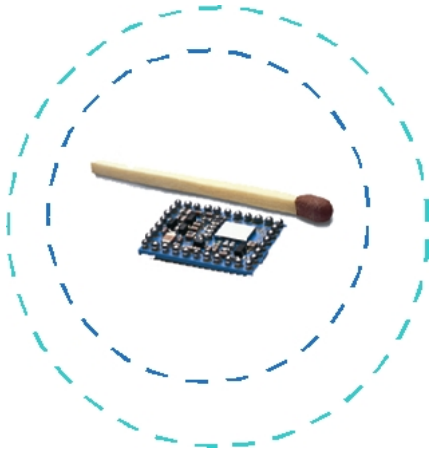
COST EFFICIENT RADIO TECHNOLOGY

- integrated on the same silicon die
  - radio
  - processor
  - I/O
  - memory
- large manufacturing volumes
- many suppliers
  - Ericsson
  - Lucent
  - Philips
  - Infineon
  - ...



KEY PERFORMANCE

Bluetooth version 1,0



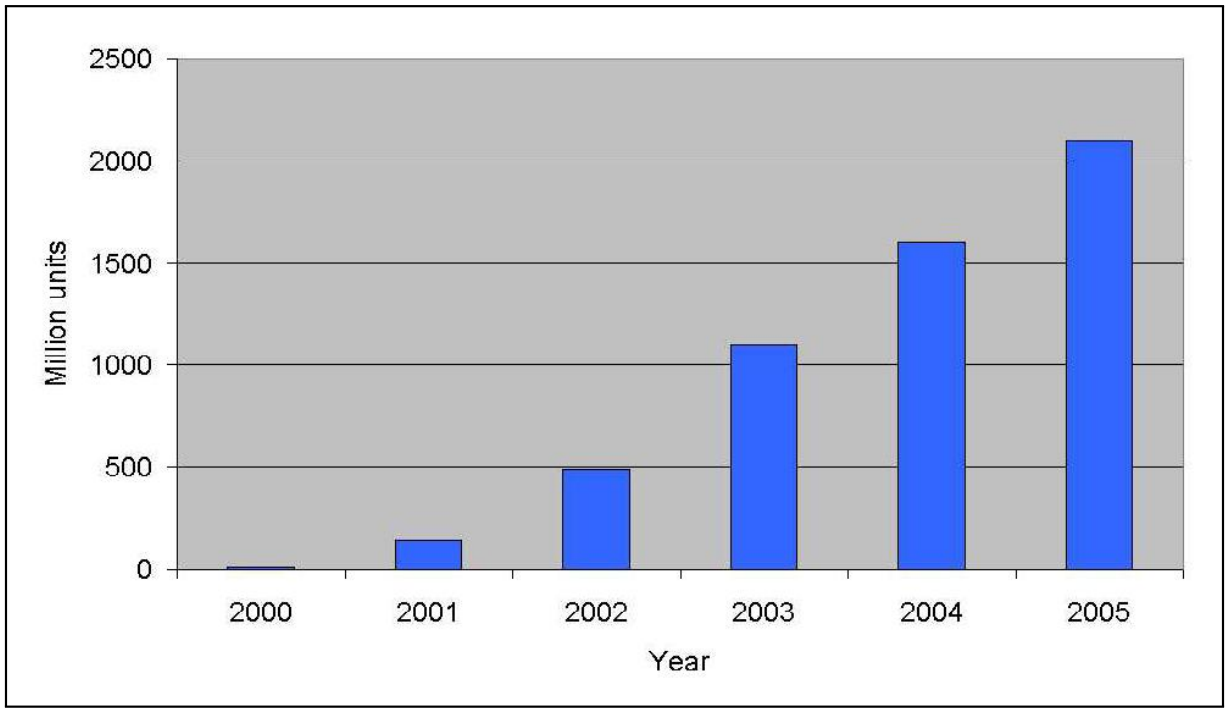
- radio in the open 2.4 GHz ISM band
  - global availability
- 10-100 m range, personal "bubble"
  - transmit power: $\leq$100 mW, =1 mW or $\lesssim$ mW
- 1 Mbit/s symbol rate
  - 2·115 kbit/s .. 56+721 kbit/s data rate
  - 1..3 simultaneous voice channels, 64 kbit/s
  - high speed variant under development ($\approx$ 10 Mbit/s)
- simultaneous voice and data

BLUETOOTH CONCEPTS

CIRCA 2000

SALES FORECAST

FROM 2000



Source: Merrill Lynch, 2000

. . . in reality it was a bit slower, but 2 billion units were shipped by 2008, only after 10 years, and 1.7 billions under 2011!

WHAT MADE BLUETOOTH POSSIBLE?

- co-design of hardware and system
- specification tailored for cost efficiency
- single-chip integration target
- attractive user scenarios, not requiring an infra structure
- competence in circuit design and telecommunication on site in Lund

BLUETOOTH PROJECT MILE STONES

1994: first vision of short range radio link

1995: concept studies and design starts

1997: Intel cooperation

1998: Bluetooth SIG founded
Ericsson, IBM, Intel, Nokia, and Toshiba

1999: Bluetooth specification 1.0 published
SIG augmented with 3Com, Lucent, Microsoft and Motorola

2000: first products on the market
Ericsson Licensing Technology started

BLUETOOTH TODAY

- new standards
  - version 3.0, high-speed mode
  - version 4.0, low-energy mode
- large volumes
  - 906 million cellphones sold 2010, almost all with Bluetooth
  - 171 million lap tops sold 2010, 77 % Bluetooth enabled
  - 50 million game consoles sold 2010, 62 % with Bluetooth
  - 40 million health- and medical appliances on the market 2011
  - $\frac{1}{3}$ of all new cars 2011 Bluetooth enabled, estimated at 70 % 2016

NEW OPTIONS FOR THE REGION...

- research centers
  - SoS, system design on silicon
  - EASE, embedded application software engineering
  - nano science
  - ...
- Mobile Heights and MH Business Center
- small as well as large companies
- MAX 4, ESS...

ERICSSON