



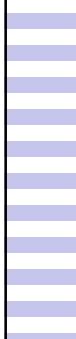
Technology Leadership Day 2004
Microelectronics in Medical Applications:

Very high performance DSP implementation for medical imaging

Rainer Fehr
Netmodule AG, Meriedweg 11
CH – 3172 Niederwangen
rainer.fehr@netmodule.ch

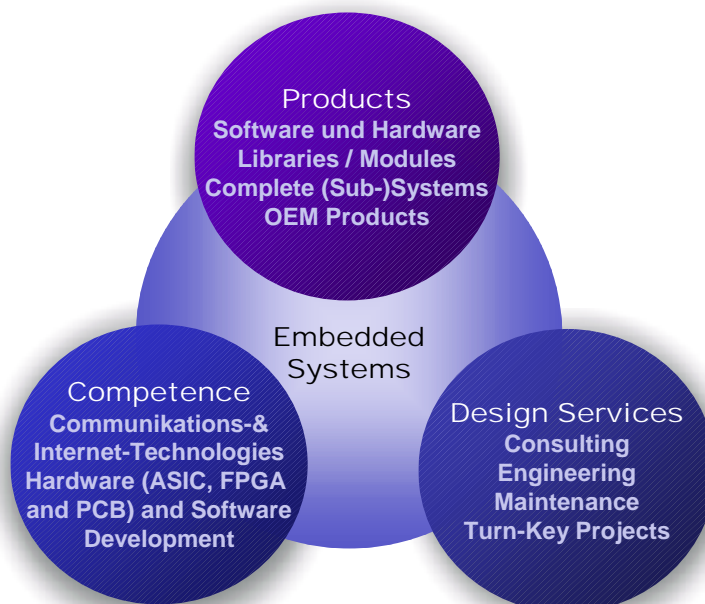


INITEC Methodology and Design Flow



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1.9.03: The Hardware Design Team of INITEC AG joined Netmodule AG



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Overview

Part 1: DSP Functions required for "Color Doppler" Imaging

- High sample rates
- Pre-filtering
- Frequency estimation by means of correlation
- Multidimensional post-filtering

Part 2: Comparison of standard DSP with FPGA-based solution

- Computing Power required
- Memory Bandwidth required
- Comparison TMS320C6413 versus Xilinx XC2V1500

Part 3: Description of actual FPGA implementation

- Characteristics
- Results

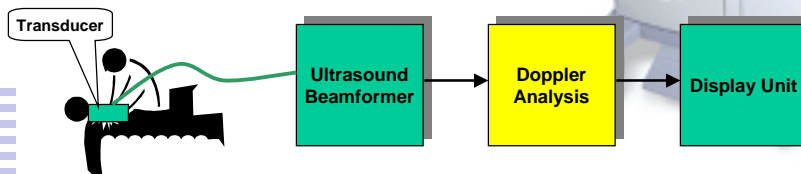
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System Overview

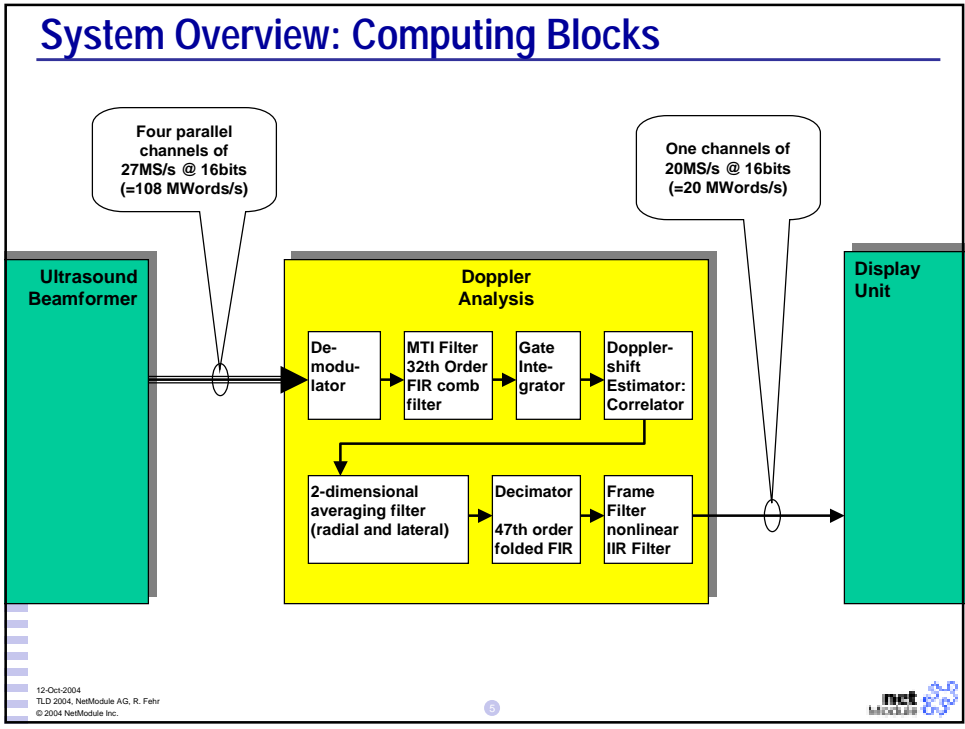
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System Overview: Computing Throughput

Function	Comment	Multiplications per sec. *10 ⁶	Additions per sec. *10 ⁶
Demodulator	Quadrature Demodulation	0	500
MTI	Complex FIR comb filter	2000	2000
Gate Integrator	Complex Running average	50	100
Doppler-shift estimator:	2 complex correlations and table lookup	250	500
2-dimensional averaging filter	2-channel radial filter + 2-channel lateral filter	100	250
Decimator	2-channel folded FIR	2000	2100
Frame Filter	2-channel IIR	60	100
TOTAL		4460	5550

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Comparison of Standard DSP with FPGA (1)

Example DSP:

Texas Instruments TMS320C6413

- Clock Rate: 500MHz
- 4000 MIPs
- Six ALUs(32/40 Bit)
- Two Multipliers 16x16
- L1/L2 Memory Architecture
4 Cache Memories (16kB,16kB,256kB,128kB)
- External Memory Bandwidth:
 $100\text{MHz} * 32\text{bit} = 3.2 \text{ Gb/s}$

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Comparison of Standard DSP with FPGA (2)

Example FPGA:

Xilinx XC2V1500

- Clock Rate: 163MHz
- System gates: 1.5 Mio
- 18x18bit Multipliers : 48
- On-chip Block RAM: 48*2.25kB
- External Memory Bandwidth: (in this application):
 $163\text{MHz} * 252\text{bit} = 41 \text{ Gb/s}$

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Comparison of Standard DSP with FPGA (3)

Item	TMS320C6413 Peak performance	Xilinx XC2V1500 Peak performance	Required for Doppler Analysis
Addition	3000 MOP/s	N/A	4460 MOP/s
Multiplication	1000 MOP/s	7824 MOP/s	5550 MOP/s
External Memory Bandwidth	3.2 Gb/s	41 Gb/s	41 Gb/s

TMS320C6413 ist the highest performance DSP available from TI.
The Parameters of the highest complexity Virtex II FPGA are:

Item		Xilinx XC2V8000 Peak performance	
Multiplication		28'000 MOP/s	
External Memory Bandwidth		~ 100 Gb/s	

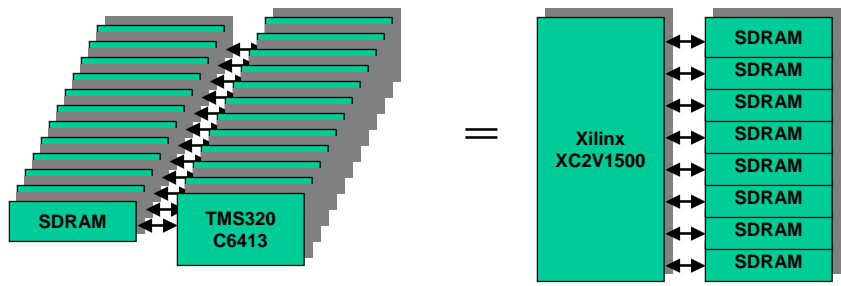
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Comparison of Standard DSP with FPGA (4)

The comparison result for this example of Doppler Analysis is:

- The limiting factor is the required bandwidth to the large external memories. The large memories are required because of the to 2- and 3-dimensional filtering of the image information.
- The second critical factor is the number of multiplications.



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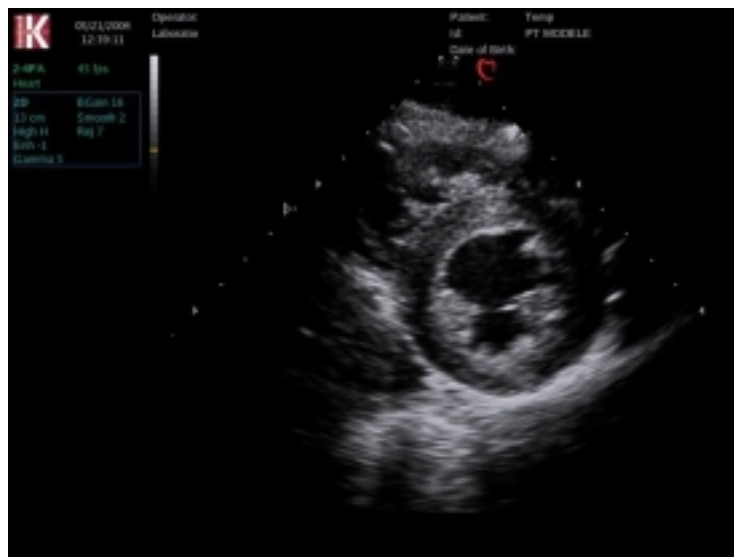
Actual FPGA Implementation: Methodology

- **Development of Signal Processing Algorithms:**
Matlab
- **Requirements Specification:**
Word document organized according to „Structured Analysis and Design“ Methodology
- **Implementation:**
VHDL '93 on Visual VHDL (Summit Design Inc.)
- **Verification:**
RTL Level Testbenches (Visual HDL)
 - Testbench contains a dedicated parser
 - Stimulus written using scripting language (ASCII file)
 - Testbench output is ASCII logfile
 - Partially selfchecking for easy regression testing
- **Synthesis:**
Synplify with HDL Analyst (Synplicity Inc.) and Synplify Pro
- **Place-and-Route:**
Xilinx Foundation
 - guided placement of clock elements and critical interface modules

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Heart: Mitral Valve, 2D-Image only

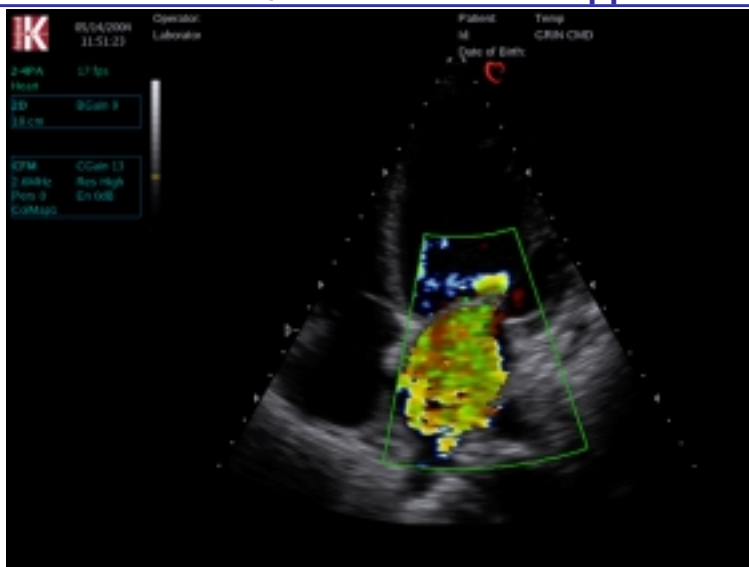


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Heart: Mitral Valve, with color flow Doppler

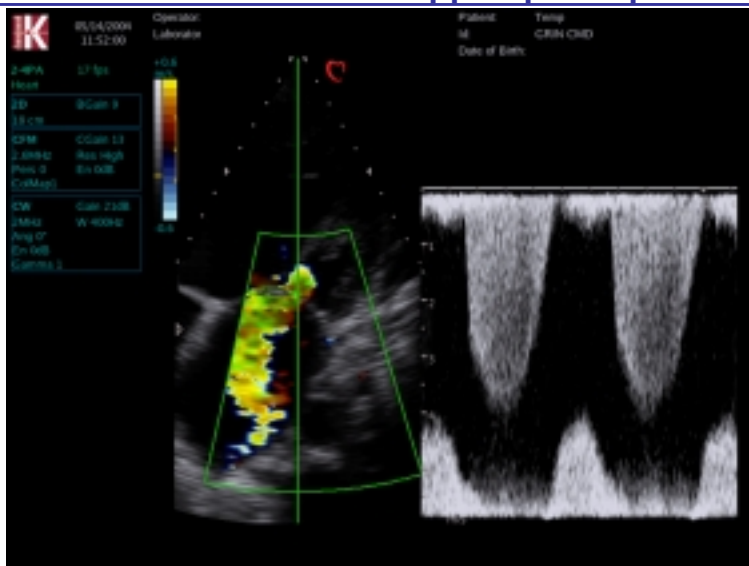


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Heart: Mitral Valve, color Doppler plus Spectrum



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Conclusion

- Digital Signal Processing for Doppler Blood Flow Analysis requires very high computing power and very large memory capacity and bandwidth.
- Standard DSP chips are not suitable for this application.
- Previous implementations were implemented on multiple PCB boards.
- A single-board solution was developed, where all signal processing algorithms were implemented in one single FPGA.



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Thank you!

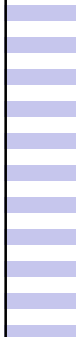
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<http://www.netmodule.com>

Email: info@netmodule.com

Tel: +41 31 985 25 10

Fax: +41 31 985 25 11



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