Embedded Systeme

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Dipl.-Ing. Hans Rieder

Fraunhofer Institut Zerstörungsfreie Prüfverfahren

www.izfp.fhg.de

fon: +49-681-9302-3862

rieder@izfp.fhg.de

Embedded Systems

- What is an embedded system ?
- What are typical embedded applications ?
- What is an embedded processor ?
- What are the problems of designing an embedded system ?

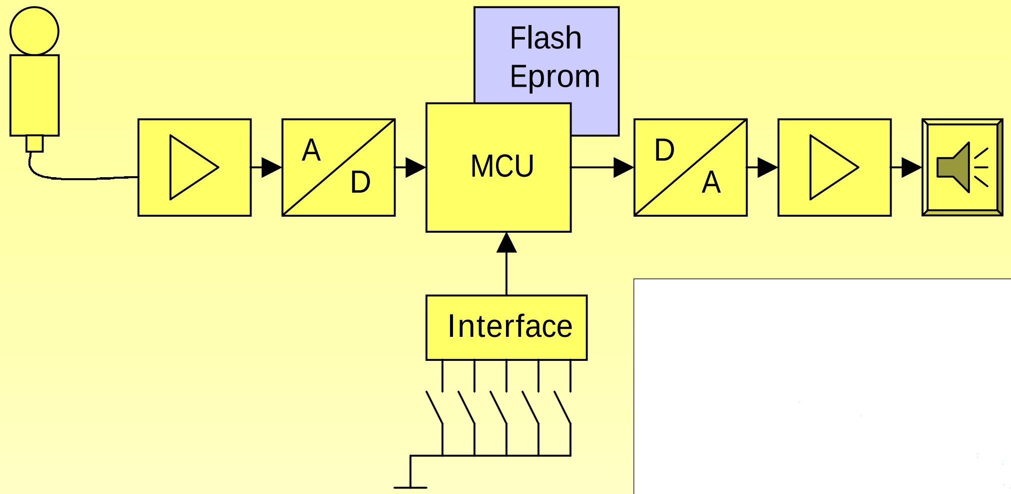
How many computers do you see each day ?

- Usual answer one or two, a computer at work and possibly a computer at home !

- In reality, most people use dozents of computers each day. These other computers, called Embedded processors, are built into various equipments such as radios, callular telephones, microwave ovens, copiers, cameras, controll systems, security systems, audio systems, and automobiles, and......
- We do not think of these processors as computers because we can not see this devices and because they play a supporting role in the complete function of the product of which they are a part.

What is an embedded system ?

- An embedded system is an intelligent device often inside a product, which interacts with the physically environment for complex measuring, controlling purposes and communication.
- An intelligent device is generally a small microcontroller, a microprocessor for higher functionallities or a special processors, for example a digital signal processor (DSP) with unique features for signal and data processing.



A simple MCU controlled embedded system

- Human Interface with display
- Integrated compression techniques
- Up to 200 different speech recordings
- fast select and play
- < 3.3 Volt and low power

Characteristics of embedded applications

- Complex interaction with physically environment by
  - sensors:
    - switch, temperatur, voltage, current, pressure, speed, distance, voice, weight, light, sonar, ultrasound, ...
  - actuators:
    - relays, motors, lamps, loud speaker...
  - human interface
    - keyboard, switch, voice, mouse, light pen, display, led, beeper, loud speaker, ...
  - special networking
    - I^2C, USB, CAN, SSI, Ethernet, Fire Wire, Fiber Optical Link, Profibus, Interbus, ...

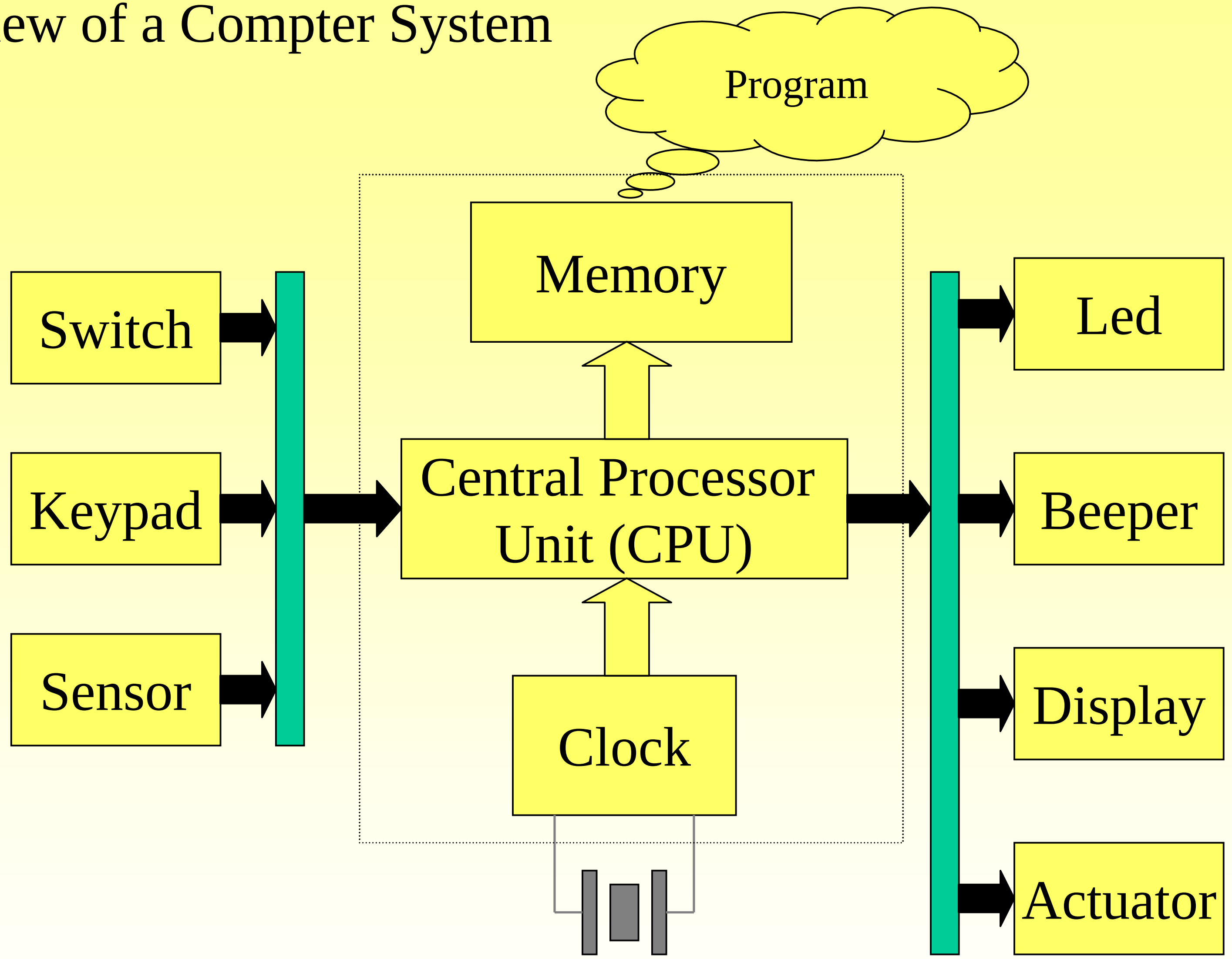
- In terms of volume, 90 % of the produced processor chips are used for embedded applications; only 10 % are used for personal and other general-purpose computers.
- The capabilities and the prices of embedded processors vary greatly. Kitchen appliances, such as coffee maker, use simple 4- 8-bit-processors (costs < 2 dollar). A programmable industrial robot may require a 16-bit processor ($20). More sophisticated devices such as communications switching equipment may use the 32-bit processors as those installed in the more powerful personal computers and servers (more than 1000 $)
- Automobile manufacturers currently are the largest users of embedded processors. A new car has an average of about 10 to 20 embedded processors to monitor and control ignition, fuel mixture, air conditioning, brakes, and passenger restraint systems such as different air bags. Additional contolle functions are for: light, suspension, traction, and navigation.

- In the future, auto manufacturers will use more powerful processors as a distributed network, that will be connected with fiber optics to reduce weight.
- Consumer electronic devices uses embedded processors. Think about how many appliances and entertainment systems contain digital displays and programming components to meet your desired use. Alarm wake-up-times, programmed radio stations, DVD player, HIFI devices all are made possible by embedded processors.
- An additional important market is the voice and speech processing for human interfaces.
- An further important market is in area or motion controle applications.

What is a microcontroller ?

- A microcontroller is one of the most basic forms of a computer device.
- In the somplest sense , microcontrollers produce a specific pattern of outputs based on current inputs and the instructions in a computer program.
- Microcontrollers are general purpose instruction executors.
- The <u>star</u> of the system is a program of instructions, that are provided by a human programmer.
- The program instructs the computer to perform long sequences of simple actions to accomplish useful tasks as intended by the programmer.

Overall View of a Compter System



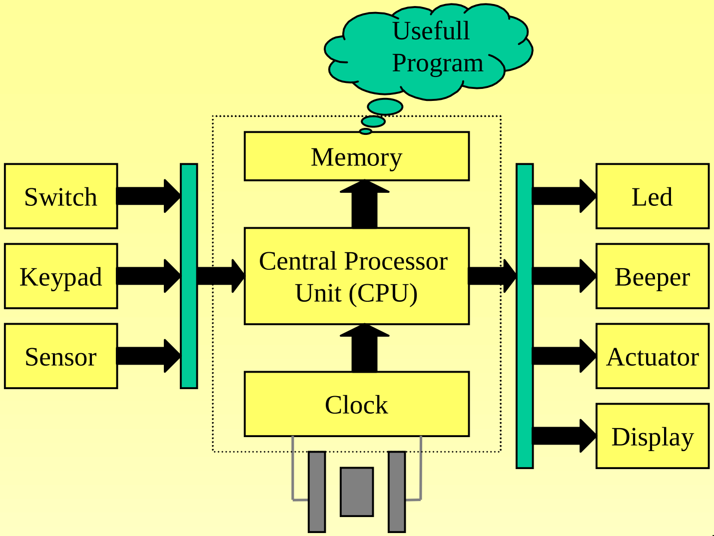
Microcontroller and Microprocessor

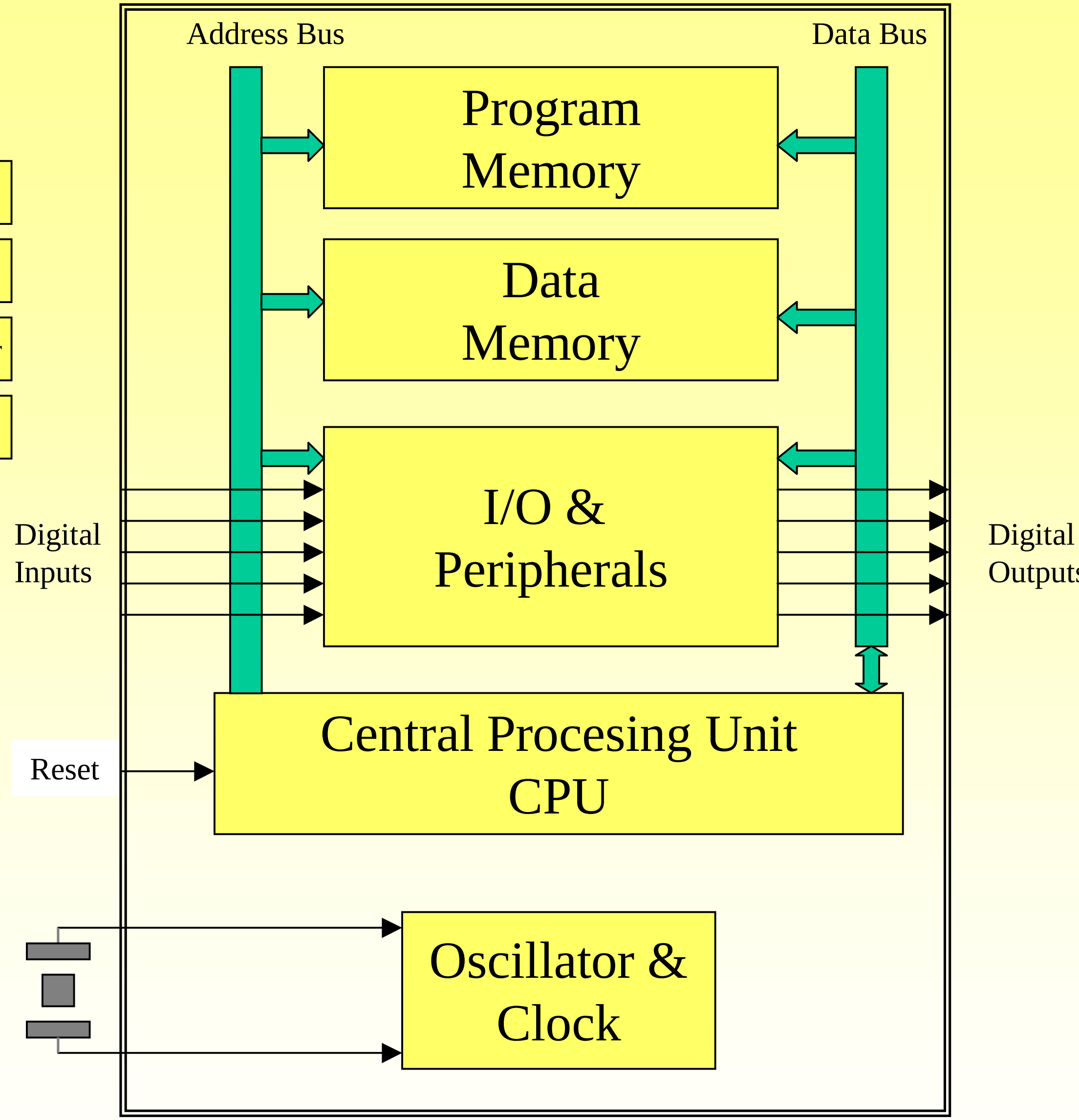
- A microcontroller can be defined as a complete, small computer system including a CPU, memory, a clock oscillator, and I/O on a single integrated circuit chip.
- When some of these elements such as I/O or memory are missing, the integrated circuit is more general called a microprocessor.
- The CPU in a personal computer is a microprocessor.
- The CPU in a mainframe computer is made up of many integrated circuits.

The amount of MCUs

Bit-Size	Turnover 1999 [billion $]	Market share %	1998-1999 %	Turnover 1998 [billion $]	Market share %
4 Bit	0,85	5,6	-5,7	0,9	10
8 Bit	5,4	54,7	8,7	5	55,5
16 Bit	2,8	28,4	0	2,8	31,3
32 Bit	0,82	8,3	174	0,3	3,3

Winner: 32 Bit Processor





Expanded View of a Microcontroller

General Description of an One Chip Microcontroller (Motorola Typ)

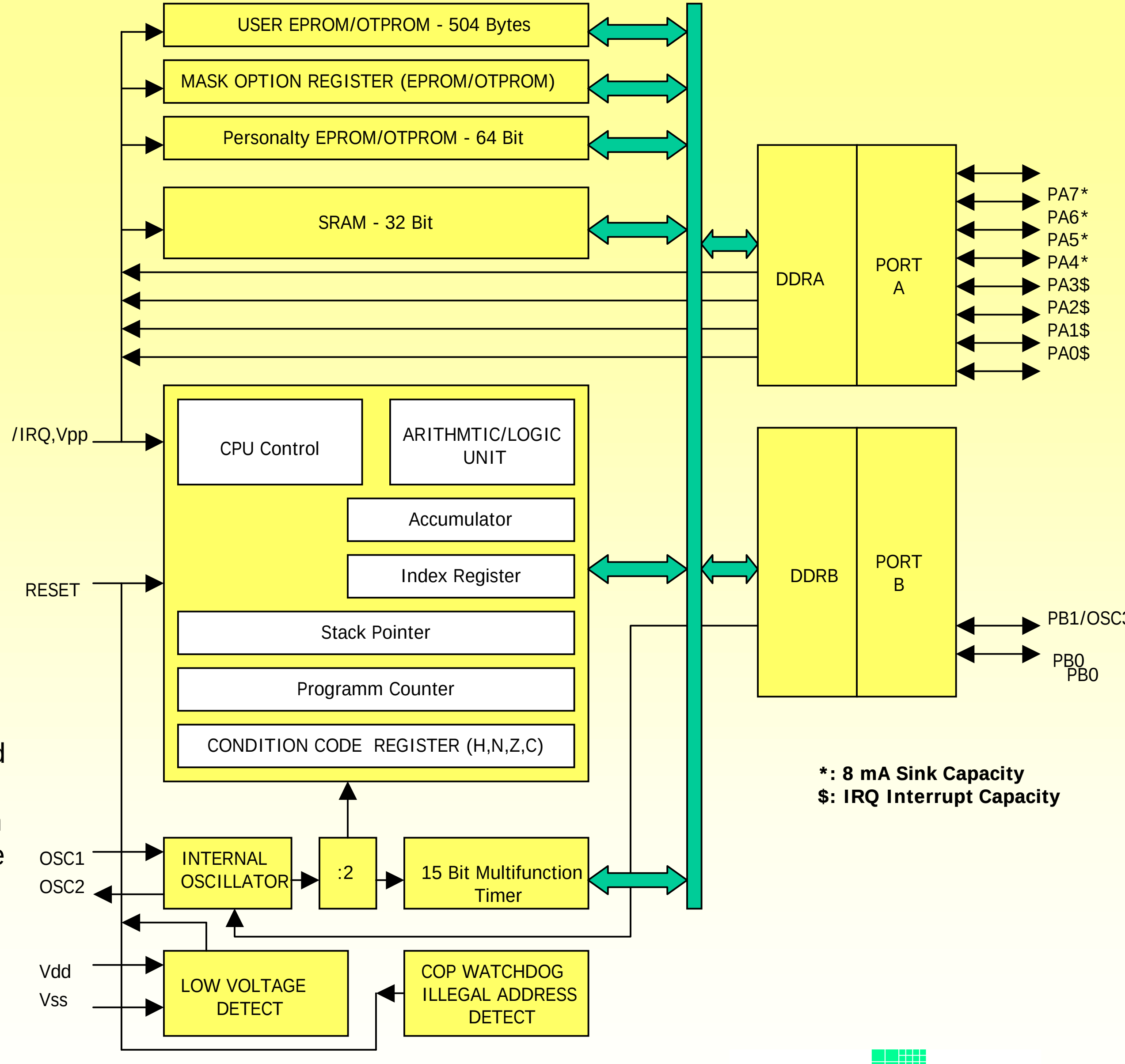
- The MC68HC705K1 is a member of low-cost, high-performance M68HC05 Family 8-bit-microcontroller units (MCUs). The MCU is based on the customer-specified integrated circuit (CISC) design strategy. All MCUs in the family use the popular M68HC05 central processing unit (CPU) and are available with a variety of subsystems, memory sizes and types, and package types.

- On chip memory of the MC68HC795K1 includes 504 bytes of erasable, programmable, ROM (EPROM). In Packages without the transparent windows for programm erasure, the 504 EPROM bytes serve as one-time programmable ROM (OTPROM).

Features

MC68HC705K1

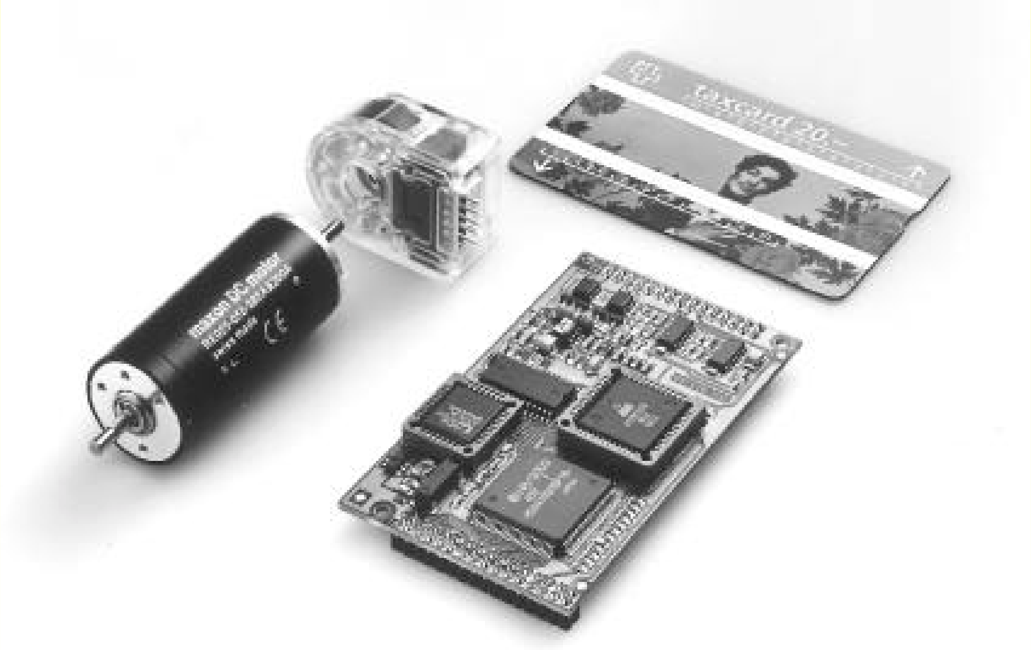
- Memory Mapped I/O
- 504 Bytes Erasable ROM
- 32 Bytes User Ram
- 64 Bit Personaltity Rom
- 10 Bidrectional I/O (SPullDown)
- 8 mA Sink Capability on 4 I/O
- External Interrupt on 4 I/O
- Hardware Mask and Flag for External Interrupt
- Fully Static Operation with no Minimum Clock Speed
- On Chip Oscillator (Crystal, Ceramic)
- Computer Operating Properly COP Watchdog
- 15 Bit Multifunction Timing (IRQ)
- Power-Saving Stop, Wait, Halt, and Data-Retention Modes
- 8 x 8 Unsigned Multiply Instruction
- 16 Pin Plastic Dual In-Line Package (PDIP)
- 16 Pin Small Outline Integrated Circuit (SOIC)
- 16 Pin Ceramic (Cerdip)



***: 8 mA Sink Capacity**
$: IRQ Interrupt Capacity

MIP-10 - MCU system for motion positioning

- Hitachi 16-Bit MCU and all peripherals for positioning a DC motor
- credit card size
- expandable to N axis by RS485 interface
- GUI for fast testing and DLLs for customer development



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How to select a Embedded Controller ?

- Costs per device (cheap if a high count of MCUs are ordered)

  (4 Bit < 0,50 $ per MCU for one million !)
- Integrated peripheral components

  (Different components and packages or customer specific solutions)
- Performance, best fit for the application with low costs
  - computational speed is not the main criterion
  - low power consumption with high speed
- Upgrade capability
- Integrated development tools incl. Simulation and Emulation
  - C or Assembler (time critical functions !)
  - Grafical User Interface (Labview, Mathlab, ...)
- Availability and delivery time

What is a DSP ?

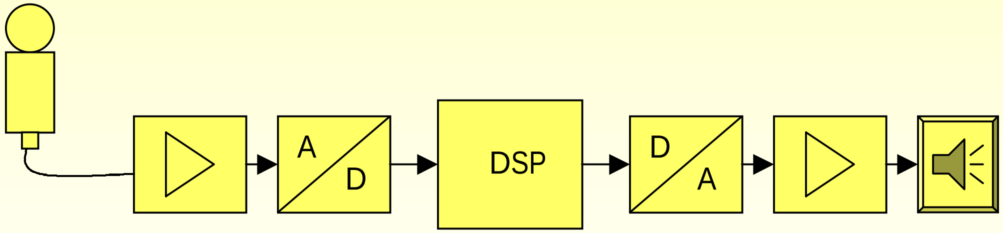
- A Digital Signal Processor can be defined as a programmable microprocessors specialized for extensive numerical computations for signal processing applications.

We can use electronic sensors to convert sound, pressure, light, temperature etc. to electrical signals with the aid of special electronic elements. We still have to change these signals into numbers to be passed to a digital computer for signal processing. This conversion process is called analog-to-digital, or A/D conversion.

The processing which we apply to the signal is realized by the digital computer and is thus called digital signal processing, DSP in the short form. In modern DSP systems generally a specially designed single chip microcomputer is used. These special chips are known as digital signal processors, or DSPs.

Once the signal has been processed by the DSP device it is still in the form of sequence of numbers. These numbers have to be converted back to an analog signal before being passed to an actuator (for example a loudspeaker). This process is called digital-to-analog, or D/A conversion.

It seems to be a simple process, but the problems are hidden in terms as signal bandwith, sample rate of conversion, filter algorithms, real-time, etc.



A simple example of a signal processing chain

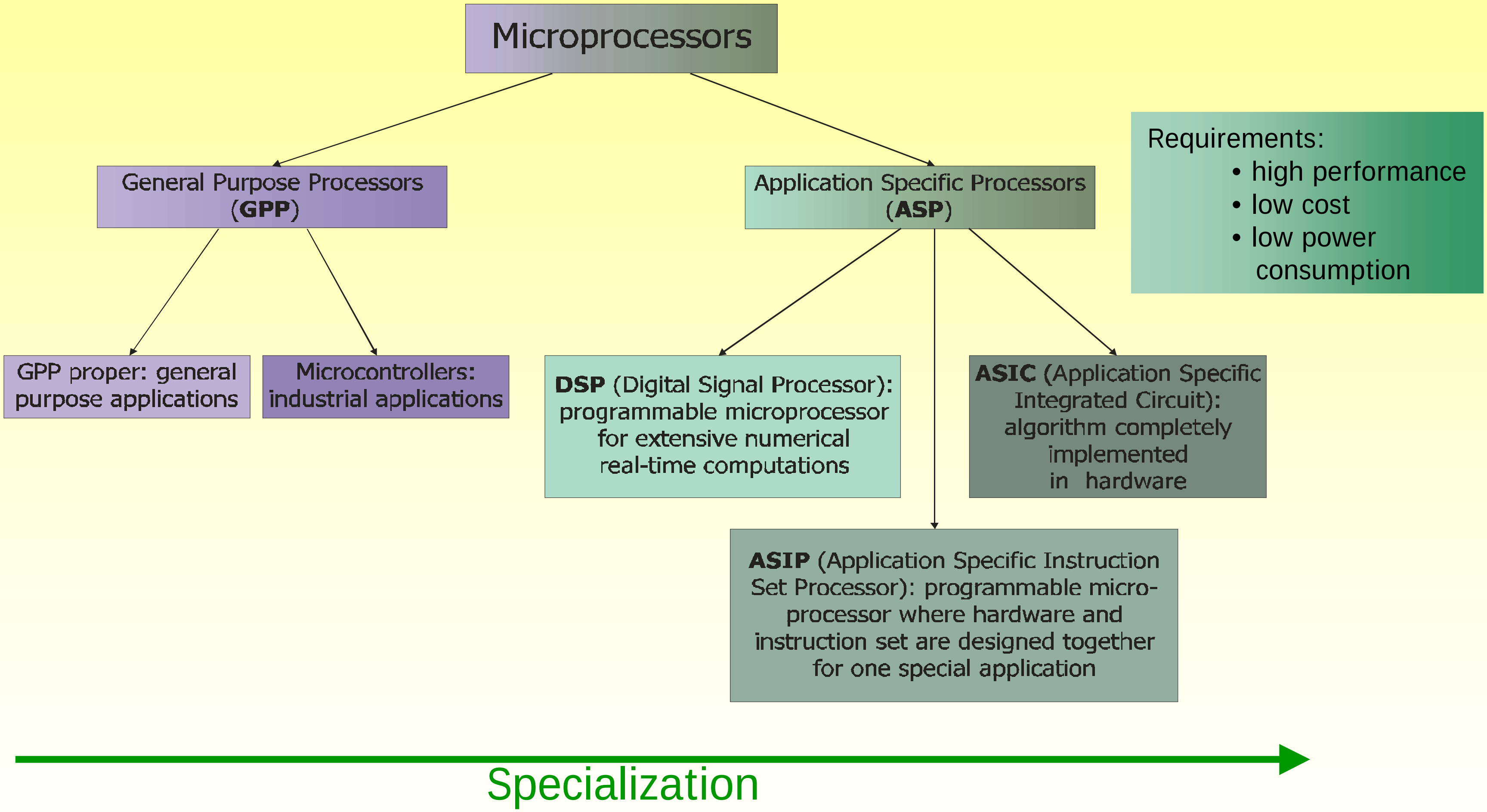
What are specific DSP applications ?

- Wireless handsets and personal communication systems
- Portable audio players
- Personal medical devices
- Digital cameras
- Internet/information purposes
- Power-efficient multichannel telephony systems
- Speech recognition and decoding
- Line or Acoustic Echo cancellation; noise cancellation and reduction
- Modulation and demodulation
- Image and audio compression and decompression
- speech encryption, decryption
- speech recognition, speech analysis
- industrial, automotive, consumer white goods and office market
- fast instrumentation and measurement devices

Characteristics: of DSPs

- Single Chip Devices
- Low power by low core voltage (1.8 Volt !)
- Multiply-accumulate units
- Multiple access memory architecture
- Specialized addressing modes: auto-modify addressing, circular addressing, bit-reverse addressing
- Fast interrupts
- Predicated execution in one cycle
- Hardware loops / zero-overhead loops
- Fast link busses for multiprocessing
- Restricted interconnectivity between registers and functional units

Classification of Microprocessors



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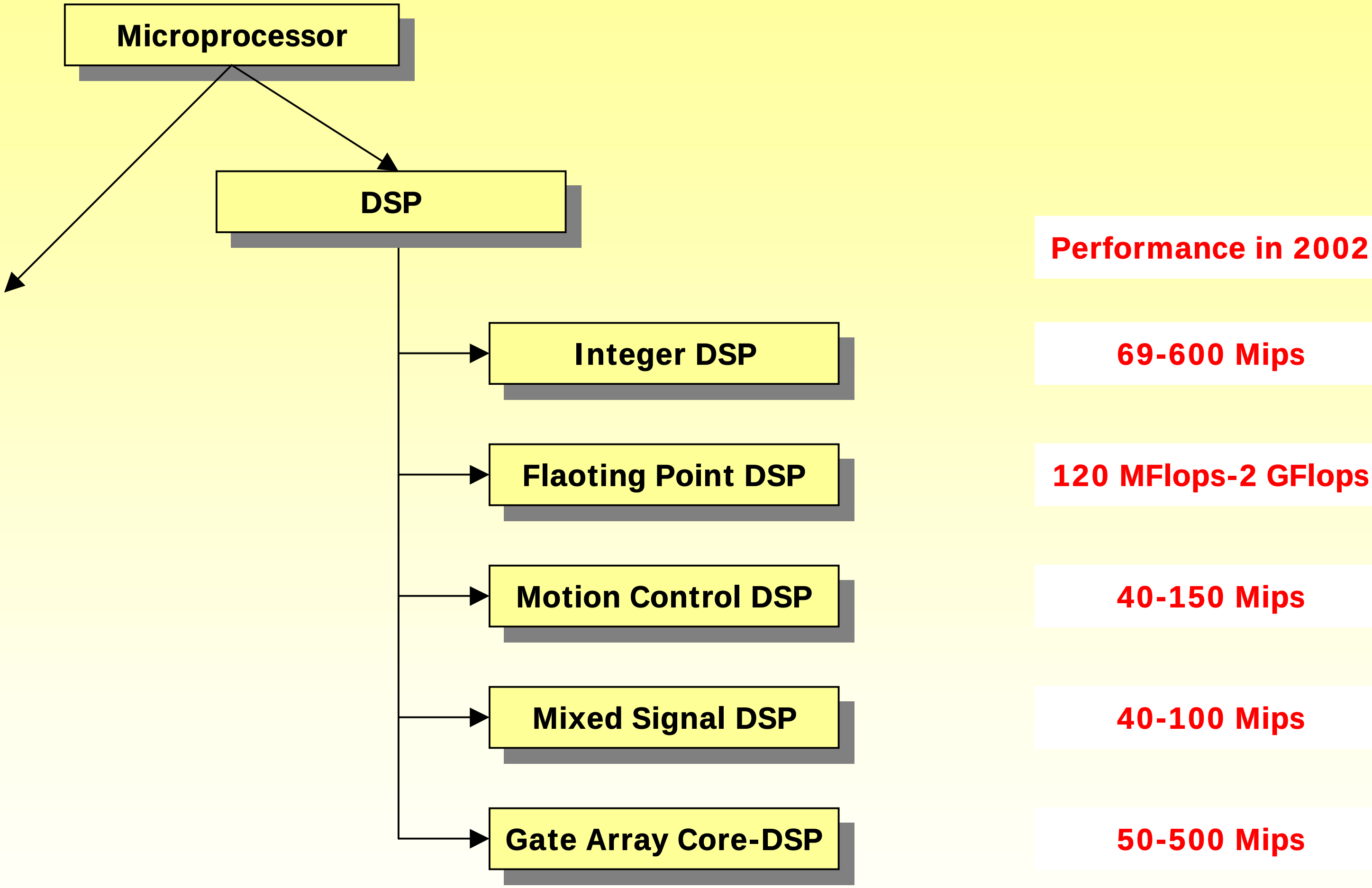
DSP vs. GPP: Some Figures

Die Size	
DSP	$3{,}9mm^2 - 60mm^2$
GPP	$\approx 100mm^2 - 345mm^2$ (HP PA-RISC 8000)

Prices (1997)		
Fixed-Point DSPs	Motorola DSP56812	7$
	TI TMS320C54x	25$ - 40$
Floating-Point DSPs	TI TMSC44	130$
	ADSP 2106x SHARC	64$ - 358$
General Purpose Processors	Pentium 200 MHz	509$
	PowerPC 604e 225 MHz	620$

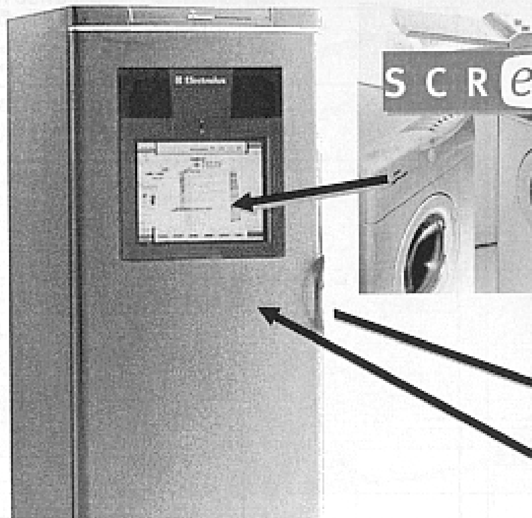
Classification of DSPs



EU Refrigerator Market Evolution

Electrolux

Without a DSP?



SCREENFRIDGE

- Food Management.
- Internal Communication.
- External Communication.
- News, radio, Home security.
- Digital Cook Book.

Electrolux brings you the refrigerator of the future.

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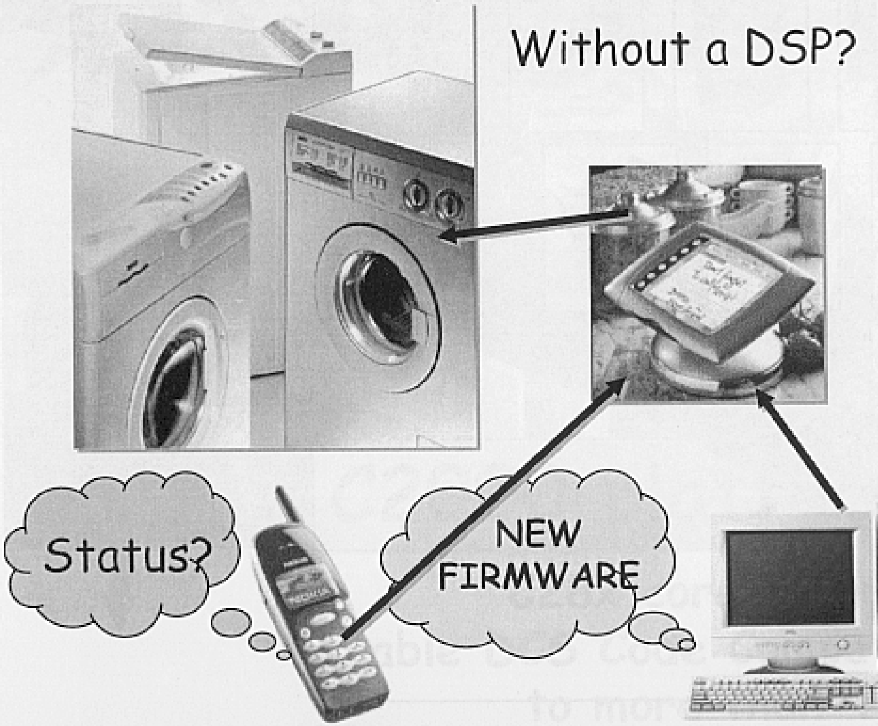
Texas Instruments

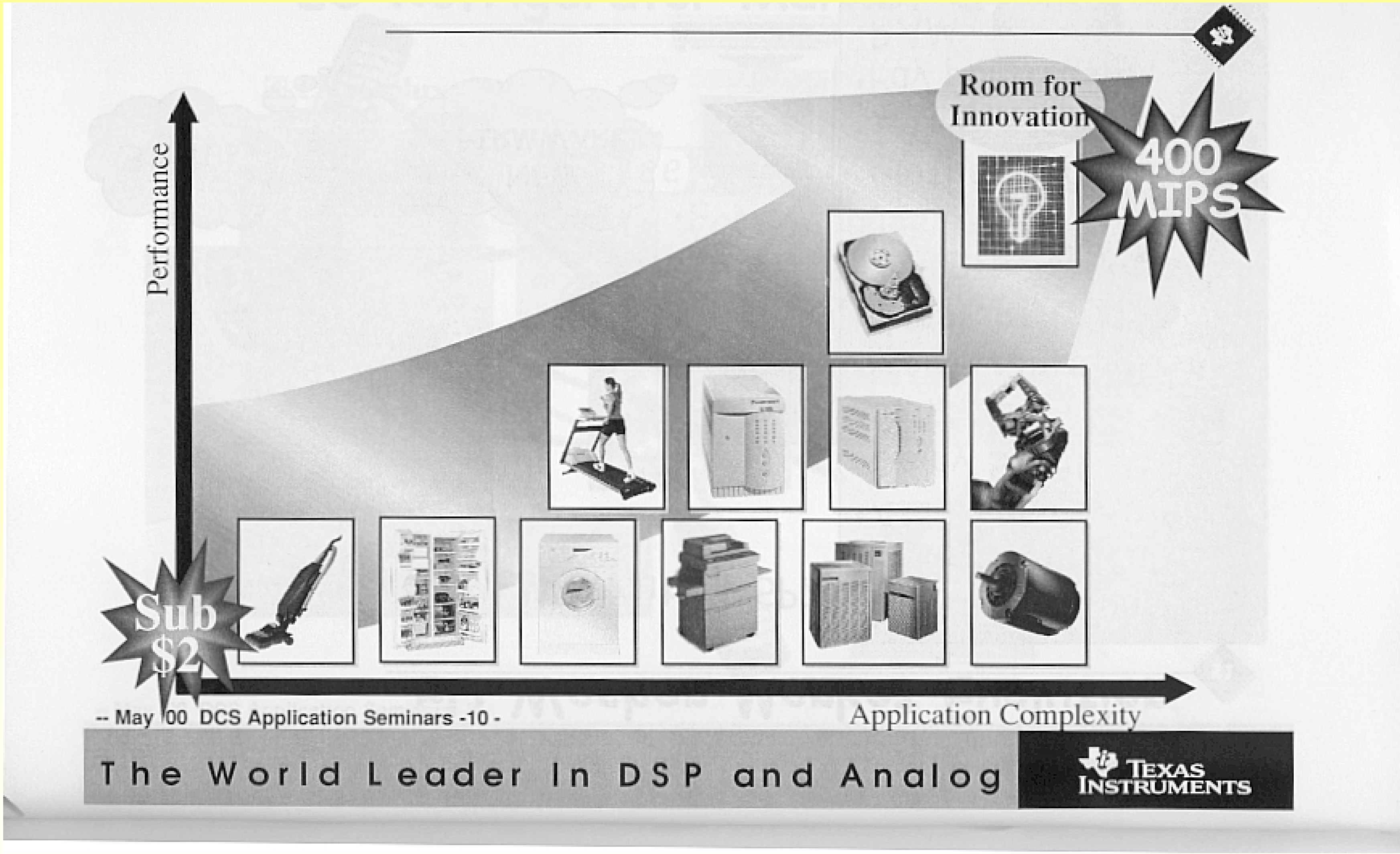
EU Washer Market Evolution



- Detergent Control.
- Balance Control.
- Anti-foam system.
- Delay Start.
- Class A.
- Noise cancellation.
- Constant torque.
- Smooth start.

...

- Clothes recognition.
- I.T.
- Pay per Wash.
- RAM (Remote Access Maintenance)


Room for Innovation
400 MIPS
Performance
Sub $2
Application Complexity
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The vision for DSP

Example Automotive:

„ In 2003, there will be 1.5 Billion electric motors digitally controlled. Eventually these 1.5 billion motors will translate into 1.5 billion DSPs“

Tom Engibous, Texas Instruments, March 98

The global market for general-purpose DSPs grew 25.5% to $4.4 billion in 1999 [Tempe Research Company].

CISC versus RISC

- Most computers have hundreds of commands in their instruction set and are reffered to as CISC computers for Complex Instruction Set Computing (or computers).
- However, studies have shown, that as much as 80 % of the processing is performed by a small number of frequently used instructions.

- Some manufactorers have designed CPUs based on RISC technology. RISC, which stands for Reduced Instruction Set Computing, involves reducing the instructions to only those that are most frequently used. Therefore, overall processing capabilities or throughput is increased.

Types of Processing

- The CPU in most computers processes only a single instruction at a time. The CPU waits until an instruction completes all four stages of a given machine cycle, which are fetch, decode, execute and store, before beginning work on the next instruction. With pipelining, a new instruction is fetched as soon as the preceding instructions moves on to the next stage. This mechanism leads to faster throughput because by the time the first instructions is in the fourth and final stage of the machine cycle, three other instructions have been fetched and are in different stages of the machine cycle.

- Some CPUs, called superscalar CPUs, have two or more pipelines that can process instructions simultaneously.

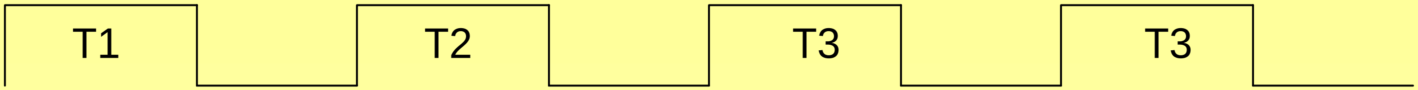
Pipelining

- With conventional CPUs, an instruction moves through the complete machine cycle before the next instruction is started.

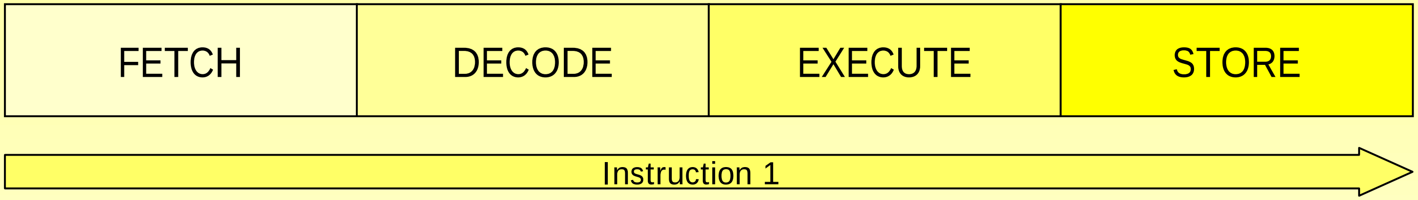
  In general a machine cycle consists of several clock pulses.

- With pipelining, the CPU starts working on another instruction each time the preceding instruction moves to the next stage of the machine cycle. In this pipelining example, three other instructions are partially completed by the time instruction 1 is finished. Some CPUs have more than one pipeline. In each cycle an instruction will be finished.

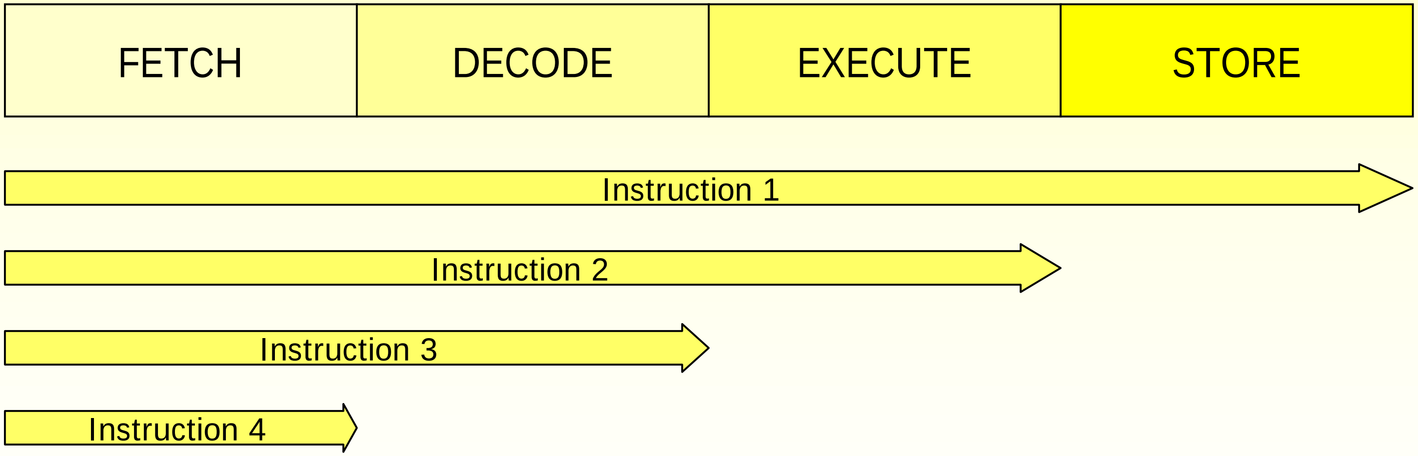
  Example: DSP-SHARC has three pipeline stages.



MACHINE CYCLE (without pipelining)



MACHINE CYCLE (with pipelining)



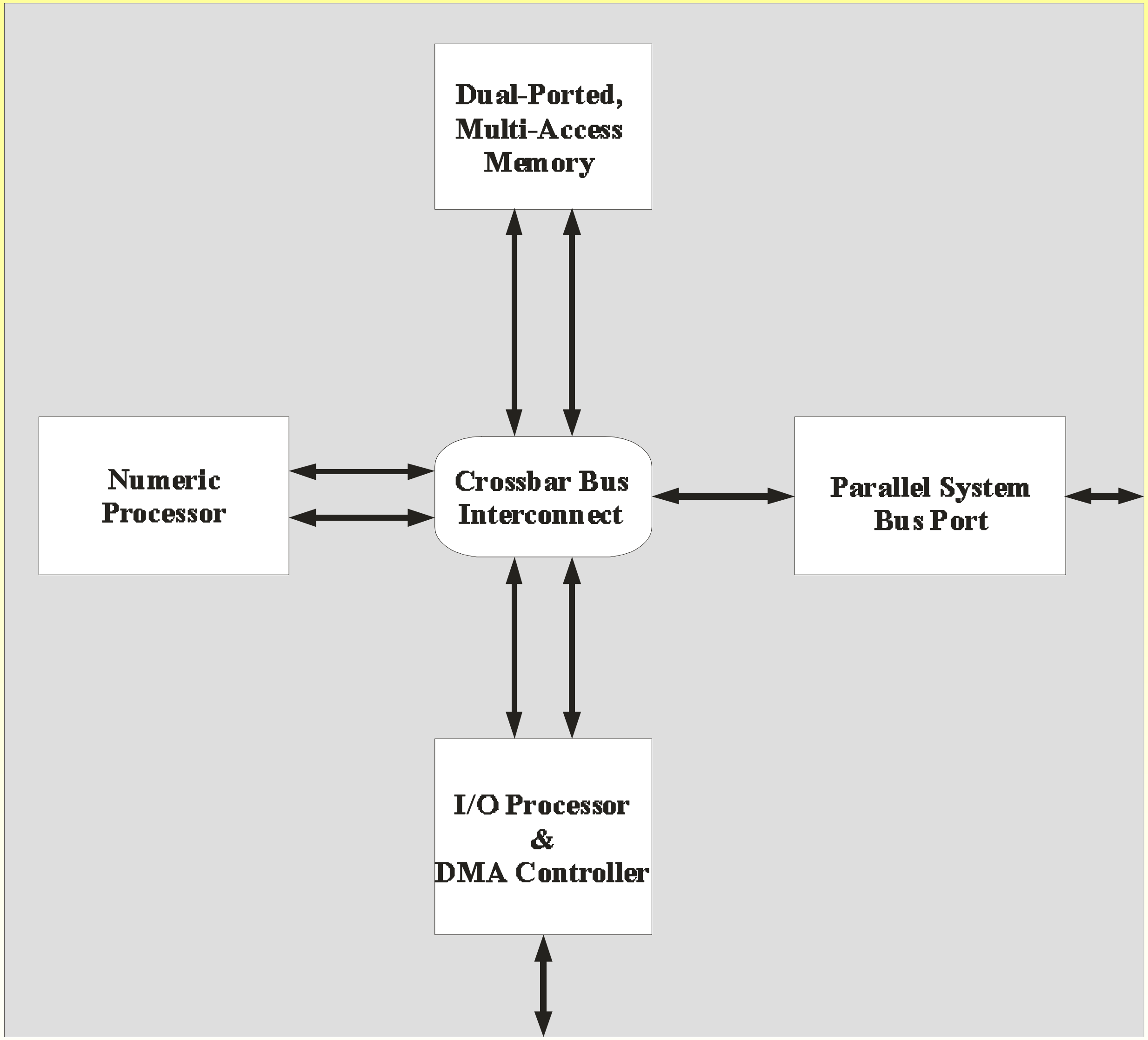
Parallel Processing

- Another way to speed up processing is to use more than one CPU in a computer device. This method involves the use of multiple CPUs, each with its own memory. Parallel processors divide up the problem so that multiple CPUs can work on their asigned portion ot the problem sumultaneously.
- High power DSPs are generally prepared for multiprocessing.
- Problems:
  - The used method of connectivity (shared memory, buses, fast links, network)
  - Parallel processors require special software that can recognize how to divide the algorithm and bring the results back together again.
  - Scheduling of different actions on N nodes
  - Dataprocessing versus communication time

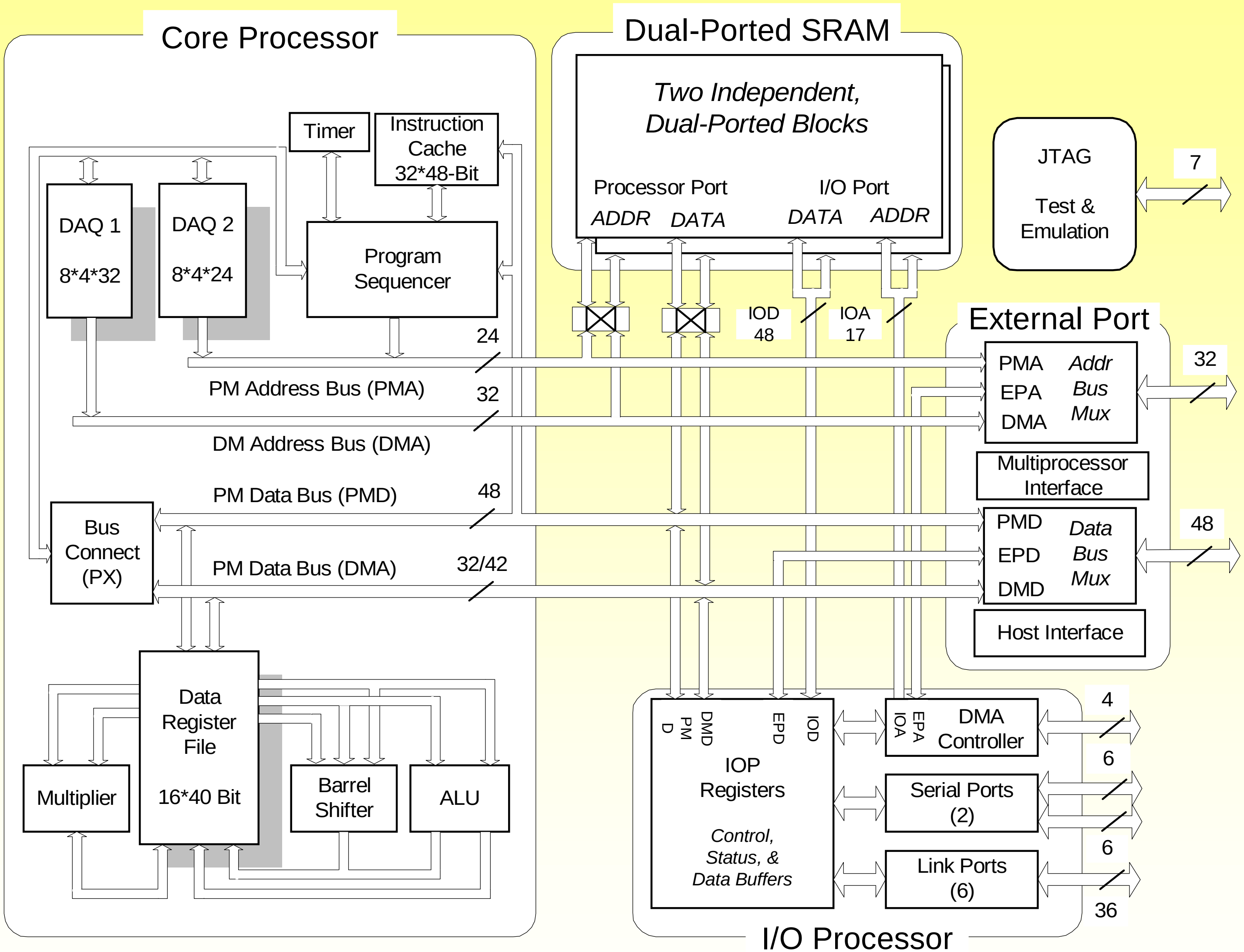
DSP SHARC

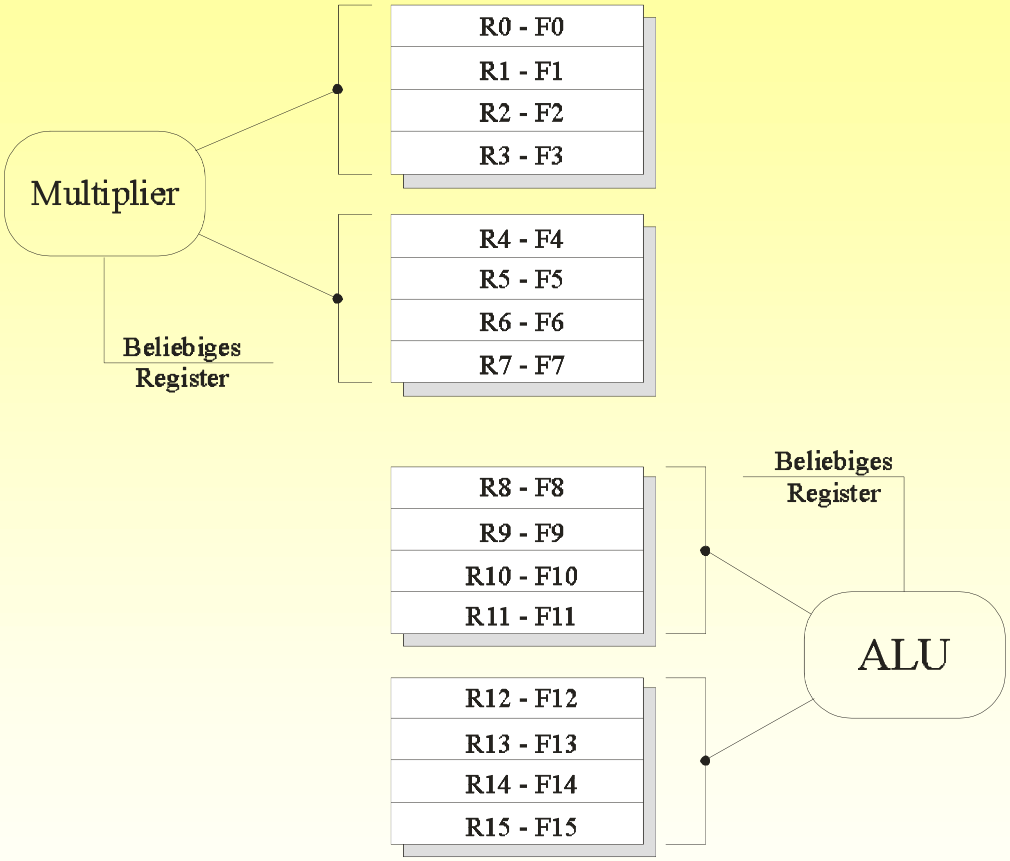
The ADSP-2106x SHARC (**S**uper **H**arvard **Ar**chitecture **C**omputer) has extensive numerical power for signal processing applications. All instructions are executed in one cycle. With the dual-ported on chip SRAM and the integrated I/O peripherals, as SSI interface, 4 Bit-Link interface, direct-memory-access and fas interrupt logic, it is a powerfull single chip processor. Four independant busses and a high speed crossbar switch are integrated.

- 120 Mflops / 80 Mips
- 2 MBit Dual-Port-RAM (intern)
- 6 parallel Link-Ports (40 MByte/s)
- 2 Serielle Schnittstellen (40 MBit/s)
- Host-Interface
- Interface for multiprocessing of up to 6 DSPs
- External Hardware-Interrupts
- I/O Signals


Dual-Ported,
Multi-Access
Memory
Numeric
Processor
Crossbar Bus
Interconnect
Parallel System
Bus Port
I/O Processor
&
DMA Controller

SHARC Core Processor



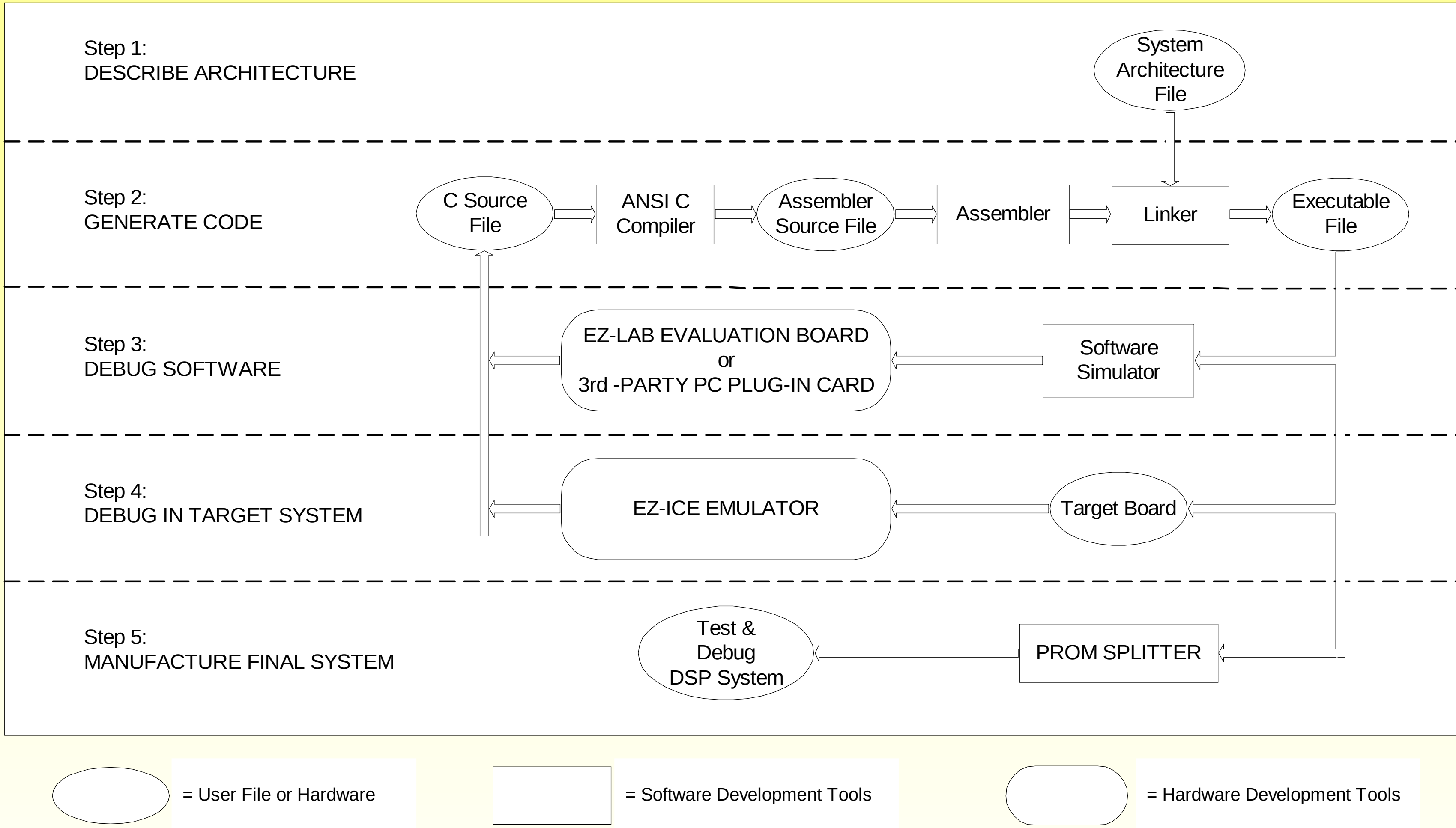


Register Rx: 32 Bit Integer
Register Fx: 32 Bit Floating Point
Shadow register for fast context switching

Example:

F3 = F3 * F2, F8 = F10 + F12;

Example: FFT.asm



Development Environment

DSP Development Tools for SHARC DSP

Debugger and Simulator

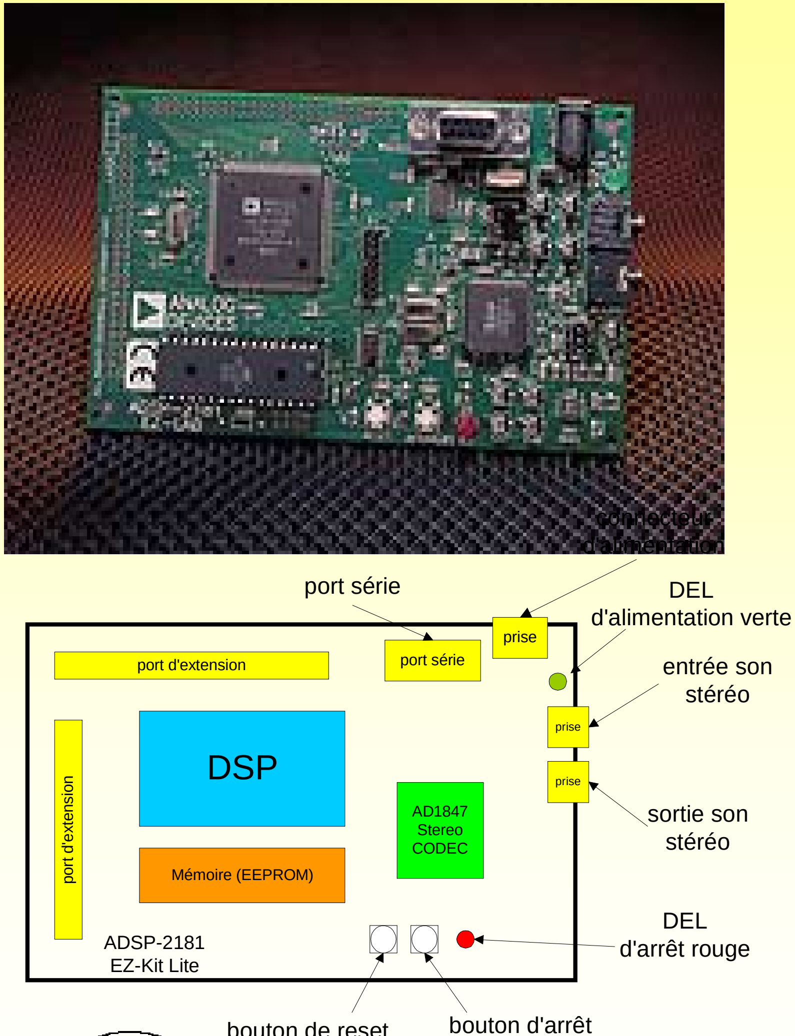
- View source files in C, Assembly, or mixed C and Assembly
- Profile and trace instruction, execution of C and Assembly programs
- Set watch points (conditional breakpoints) on processor register and stacks, and program and data memory with:
  - inclusive or exclusive memory ranges
  - read and write of any value or a specific value
  - stack overflow and underflows
- Create custom register windows
- Simulate Standard I/O, interrupts, and streams

Integrated Development Environment

- Define all projects and tool configurations through Property Page dialog boxes
- Set project-wide or individual file settings for debug or release mode project builds
- Create source files using an integrated, full-featured editor with syntax highlighting, drag and drops and bookmarks

Example: VisualDSP

EZ-KIT Lite - DSP based system



Description :

DSP based system for audio, voice and other applications

- Audio
- Speech recognition
- Filter (FIR, IIR, Cepstrum,...)
- FFT, Wavelet, ...
- Simulation
- Automated systems (PID, ...)

Sensors	Data Acquisition	Memory	Processor	Output	Actuators
Voltage, Current	A/D	RAM	Micro-processor	D/A	Loud-speaker
Temp-erature	Codec	Dual Port RAM	Micro-controller	Digital	Relay, Led Lamp
Light, Pressure, Noise	Digital	Multi Port RAM	DSP	Display	Switch
Audio, Ultrasound		Shared RAM	Transputer	SSI/SPI	Motor
Position, Velocity Acceleration		Fifo	Core-Processor	CAN, Profibus	....
Human Interfaces			Multi-Processor System	Network (Ethernet)	
....				Bus-Interfaces	

A more generall view to different functional blocks for signal processing for nondestructive testing devices.

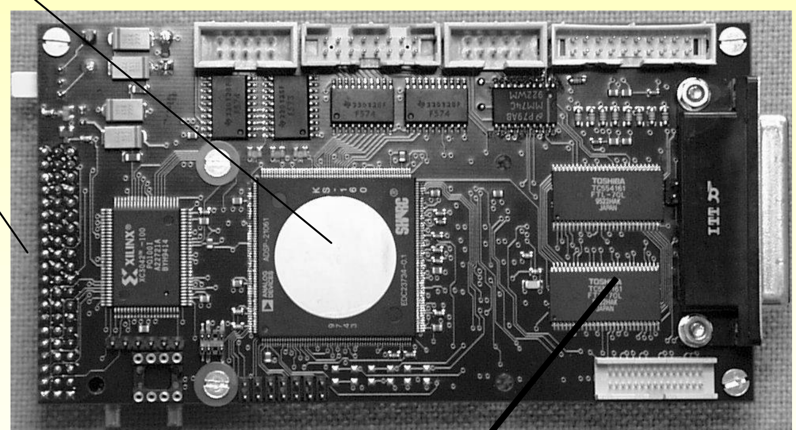
A DSP based embedded system for straylight measurement (IZFP 1999)

Different interfaces as SSI, RS485, Keypad, LCD-Display

SHARC DSP

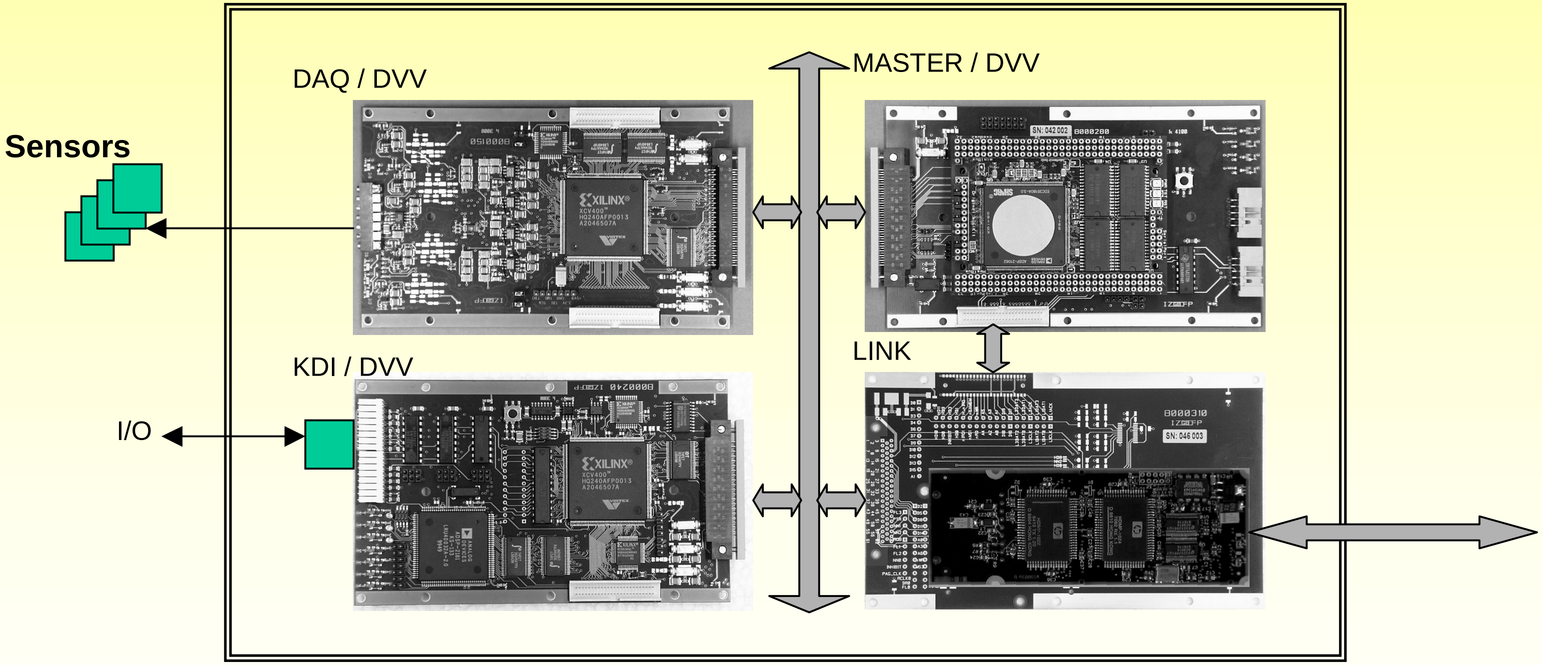
Expansion

RS-232

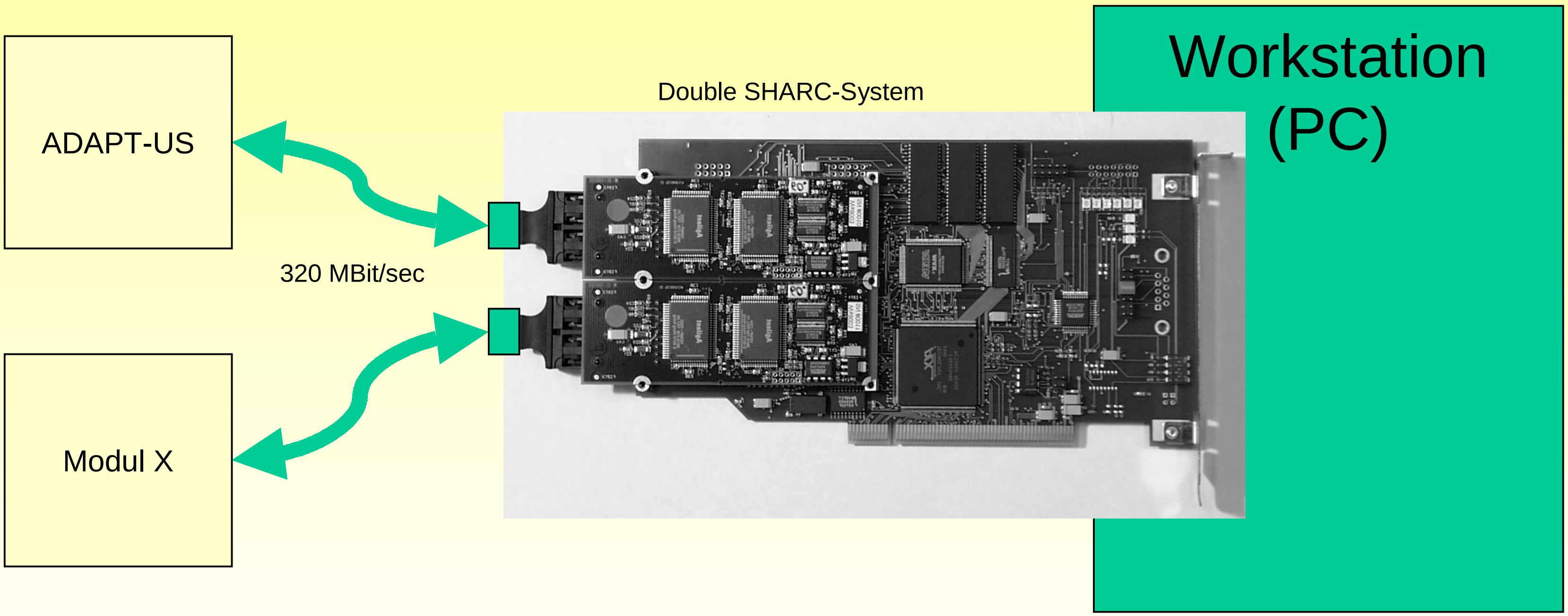


Extern Memory

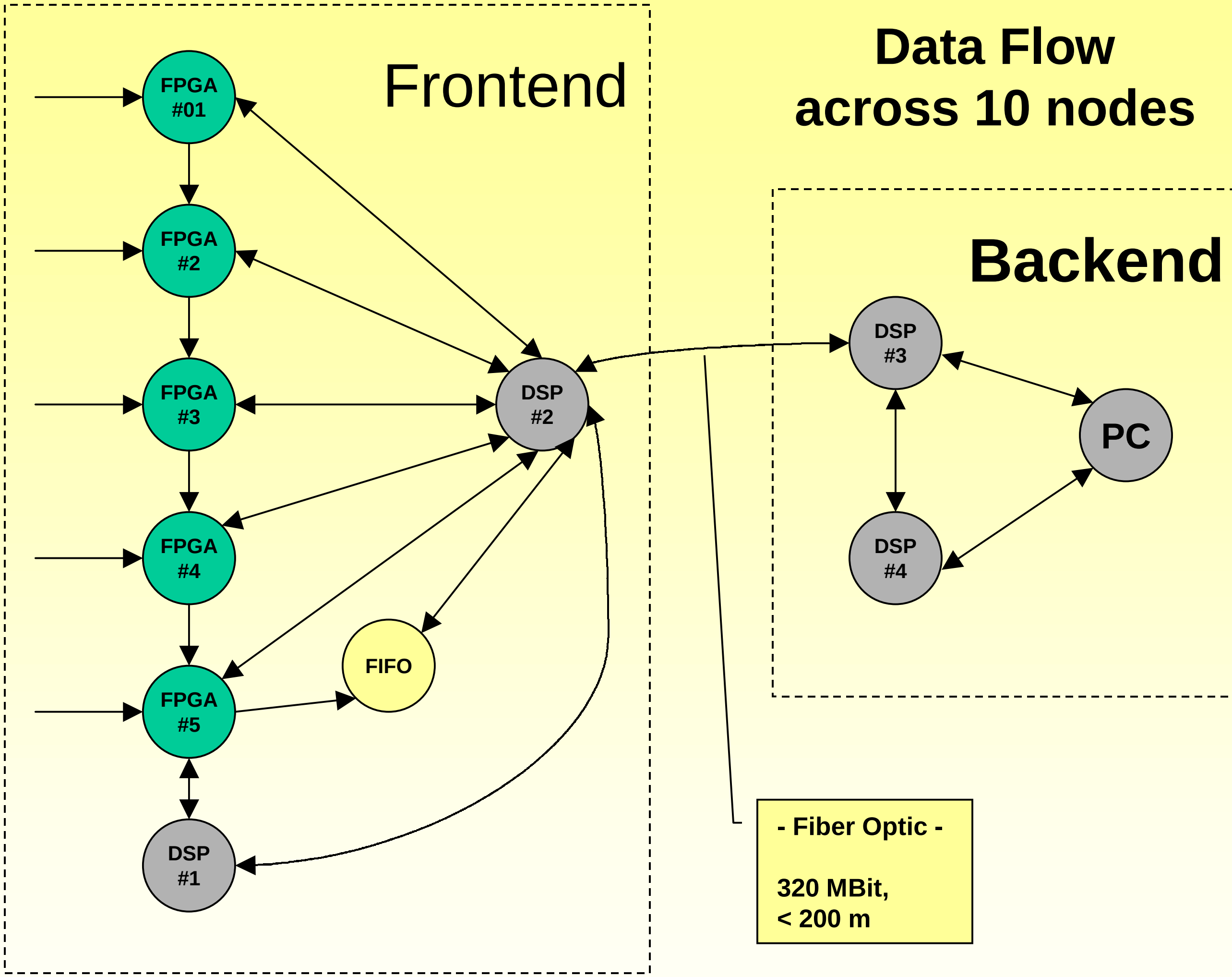
ADAPT-US: Multichannel Ultrasonic Embedded System



ADAPT-US: Standard-PC



Data Flow across 10 nodes



Next week

- Topologies
- Networking
- Interfaces