

Control System Implementation

Hardware implementation



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Electronic Control systems are also:
Members of the Mechatronic Systems

- Concurrent design (Top-down approach?)
- Mechanic compatibility
- Solve the actual task
- Separating the control system design from the mechanic "target" is a risky business

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Printed Circuit Boards (PCBs) - #1

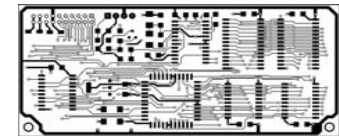
- Material requirements
 - Mech. stress
 - Electr. isolation (also at high frequency)
 - Thermal conductivity
- Materials used
 - Glass fiber dominating today
 - Ceramic materials for high thermal conductivity
 - Polymer materials for flexible PCB:s

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Printed Circuit Boards (PCBs) - #2

PCB manufacturing process (simplified)

- Copper foil attached (5-35 μm)
- Photo resistive coating
- Exposure with photo mask
- Develop pattern
- Etching



Conductive copper pattern remains on board

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Printed Circuit Boards (PCBs) - #3

- Through-plated via-holes connect the top and bottom layer
- Multilayer boards - same principle but thin layers pressed together. Then through-plated
- A lot of requirements can be met with modern PCB technology. *But it's important to specify!*

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Electronic systems exposed to Environmental Factors

- Mechanical stress
 - Direct forces and torque can usually be avoided
 - Acceleration might be more difficult to handle
- Temperature
 - Check the classification of your components. *Commercial, Industrial or (Military).*
- Humidity
 - Coating , encapsulating.
- EMC

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Analyzing the Control Task

- Task complexity
 - Understand the problem
 - Where is it possible to install control system parts
 - Centralized/ distributed control
- Speed requirements
 - Sensor/actuator time scheduling
 - Computational power requirements

A mutual understanding of Mechanical/Electrical design often gives the opportunity of solving a difficult problem by a minor redesign "on the other side"

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Possible Solutions for the control Task

- Discrete analog circuit
- Discrete digital circuit
- ASIC (Application Specific IC)
- Programmable logic IC (PLD or FPGA)
- Computing unit (microcontroller, DSP...)

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Discrete Analog Circuits - Opportunities

- Operational amplifiers (OP-amp)
 - Add, subtract
 - Filter
 - Derivative, integration
- Analog computation components
 - Multiplication
 - Logarithmic functions
 - Rms-detection...

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Discrete Analog Circuits - Summary

- +
 - Continuous operation
 - Fast (!) processing of analog signals
 - Cost effective
- - Logical conditions difficult to include
 - Interfacing problems
 - Experienced engineer required

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A multiplier for approx \$9



Low Cost Analog Multiplier

AD633

FEATURES
 4-Quadrant Multiplication
 Low Cost 8-Lead Package
 Complete—No External Components Required
 Laser-Trimmed Accuracy and Stability
 Total Error within 2% of FS
 Differential High Impedance X and Y Inputs
 High Impedance Unity-Gain Summing Input
 Laser-Trimmed 10-V Scaling Reference

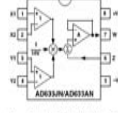
APPLICATIONS
 Multiplication, Division, Squaring
 Modulation/Demodulation, Phase Detection
 Voltage Controlled Amplifiers/Attenuators/Filters

PRODUCT DESCRIPTION
 The AD633 is a functionally complete, four-quadrant, analog multiplier. It includes high impedance, differential X and Y inputs and a high impedance summing input (Z). The low impedance output voltage is a nominal 10-V full scale provided by a biased Zener. The AD633 is the first product to offer these features in stockily priced 8-lead plastic DIP and SOIC packages.

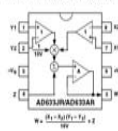
The AD633 is laser calibrated to a guaranteed total accuracy of 2% of full scale. Nonlinearity for the Y input is typically less than 0.1% and noise referred to the output is typically less than 0.1%.

CONNECTION DIAGRAMS

8-Lead Plastic DIP (N) Package



8-Lead Plastic SOIC (NS-V) Package



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What CPU do you need to emulate this?

(< \$6)



Low Level, True RMS-to-DC Converter

AD636

FEATURES
 True rms-to-dc conversion
 200 mV full scale
 Laser-trimmed to high accuracy
 0.5% maximum error (AD636HS)
 1.0% maximum error (AD636LS)

Wide response capability
 Computes rms of ac and dc signals
 1 MHz, -3 dB bandwidth, V_{rms} > 100 mV
 Signal crest factor of 6 for 0.5% error
 dB output with 50 dB range
 Low power: 800 pA quiescent current
 Single or dual supply operation
 Monolithic integrated circuit
 Low cost

FUNCTIONAL BLOCK DIAGRAM

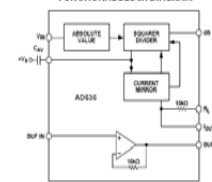


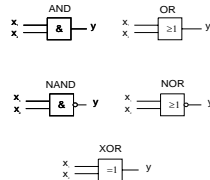
Figure 1.

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Discrete Digital Circuits

Gates, flip-flops, counters, registers...

- Simple logical problems
- Primary use today as support ("glue") to more advanced digital systems
- High speed applications



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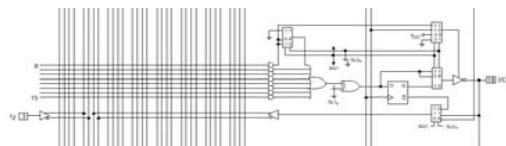
PLD - Programmable Logic Devices

- Logical function programmable. Several languages e.g. VHDL
- AND/OR -planes
- Pin mapping programmable
- Internal flip/flops makes internal state machines possible
- Comparable speed as discrete logic (often higher)

- Starts at discrete logic replacement at $< 1\$$ cost/unit
- Large devices with several sub-blocks and interconnection matrixes

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PLD structure example



GAL16V8 with a fraction of the programmable matrix and a macro cell

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FPGA

Field Programmable Gate Arrays

- Larger than PLD but the borderline is not absolutely clear
- Programmable logic structures
- Several development languages e.g. VHDL
- Can include (Flash) memory, DSP
- Design supported by large libraries (IP: Intellectual Property)
- E.g. a large FPGA can very well be used to implement a microcontroller

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ASIC

Application Specific Integrated Circuit

- Full freedom. Analog or digital or mixed signal.
- Design supported by large libraries (IP: Intellectual Property)
- Design at transistor level possible
- Only used in large scale production since development costs are high. However, price per unit is low.

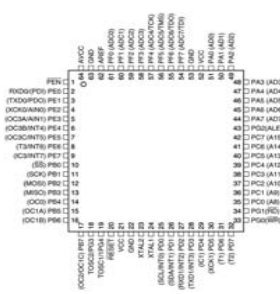
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Microcontroller

- Single chip computer. Complete system:
 - CPU
 - Memory
 - I/O devices including analog
 - Timer
- Few external components (if any)
- Low cost (< 1\$ and upwards)

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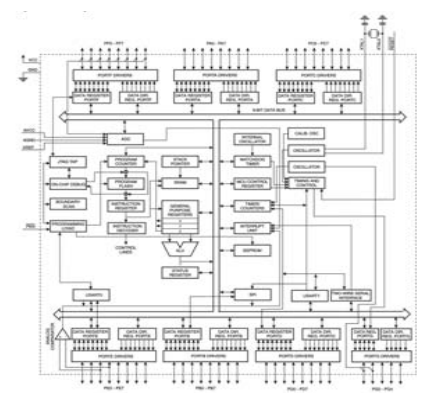
AVR ATmega128 - as an example



- ...
 - Up to 16 MIPS Throughput at 16 MHz
 - On-chip 2-cycle Multiplier
 - Nonvolatile Program and Data Memories
 - 128K Bytes of In-System Reprogrammable Flash
- ...
 - 4K Bytes Internal SRAM
- ...
 - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
 - Two Expanded 16-bit Timer/Counters with Separate Prescaler, Compare Mode
- ...
 - Real Time Counter with Separate Oscillator
 - Two 8-bit PWM Channels
 - 6 PWM Channels with Programmable Resolution from 2 to 16 Bits
 - Output Compare Modulator
 - 8-channel, 10-bit ADC
 - 8 Single-ended Channels
 - 7 Differential Channels
 - 2 Differential Channels with Programmable Gain at 1x, 10x, or 200x
 - Dual Programmable Serial USARTs
 - Master/Slave SPI Serial Interface
 - Programmable Watchdog Timer with On-chip Oscillator
 - On-chip Analog Comparator
- ...

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AVR ATmega128 - overview



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DSP

Digital Signal Processor

- Especially well suited architecture for signal processing (e.g. Filtering, FFT...)
- Few internal operations in each instruction gives a high execution rate
- The internal datapath can support a parallel execution at several stages.

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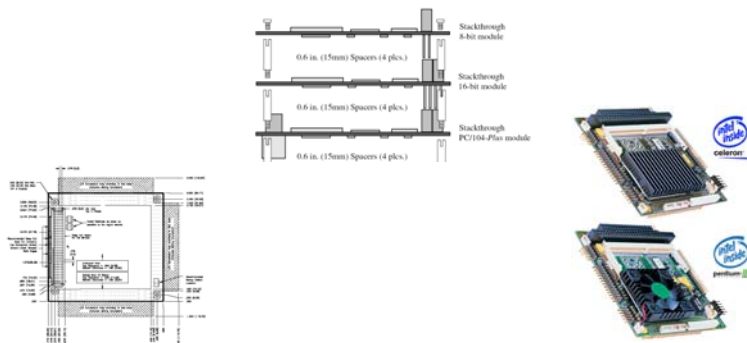
Embedded PC

- The success of the PC architecture gives several economical advantages
- Stability problems not due to hardware
- Several standards for embedded PC exists (e.g. PC104)
- It is also possible to use an "industrial PC box" without any peripheral devices but equipped with LAN- and fieldbus-connections

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PC-104 standard for embedded PC

<http://www.pc104.org>



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Various formats for embedded PC



Compact PCI

Free format
(PC104 host)

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Industrial PC – Product Example



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PLC Programmable Logic Controller

- The fundamental industrial control system of the latest decades
- Originally only logic control but nowadays analog I/O and PID-loops
- Programming languages (IEC 61131-3)
 - Ladder Diagram (LD)
 - Function Block Diagram (FBD)
 - Instruction List (IL)
 - Structured Text (ST)
 - Sequential Function Chart (SFC)



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Memory

- SRAM - Read/Write, Volatile, Static design
- DRAM - Read/Write, Volatile, Need cyclic refresh
- ROM - Read. Programmed in production
- PROM - Read, User programmable
- EPROM - Read, UV-Erasable user programmable
- EEPROM - Read, Electrically erasable
- Flash - Type of EEPROM

Rotating hard-disks are often avoided in embedded applications and replaced by disk-emulating EEPROM memories (Flash disk). Also in same housing (SSD).

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Analog signals

- D/A conversion
 - Multiplying converter
 - PWM + LowPass filter (low cost solution)
- A/D-conversion
 - Successive approximation (microcontrollers)
 - Flash (fast)
 - Dual slope (high accuracy, slow)
 - Sigma/Delta

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Sampling

- Sampling frequency is a critical factor
- The system has no idea what happened between the sampling instants
- Remember Nyquist frequency: $f_N = f_s/2$
(practically a factor 5-10 applied)
- Use filters

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Galvanic Separation

When?

- Connecting to power systems
- EMC problem reduction when connecting different systems
- Grounding problem elimination

How?

- Relays
- Optocouplers (LED - phototransistor)
- Opto-fiber
- Isolation Amplifier (analog)

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