Modern Computer Architecture

Lecture 12
embedded Applications, classical DSP, automotive (Tricore)
Embedded Systems on a Chip

• Microcontrollers
• Digital Signal Processors (DSP)
• Applications: Automotive
System On a Chip (SoC)

- Von-Neumann Model of a System:
  - Processor
  - Memory
  - Peripherals
- Traditionally: many individual components are used to compose a system
- Advances in silicon integration: allows to put all components onto a single piece of silicon
- Consequences:
  - no external wiring and system composition necessary
  - challenge to debug
  - each change requires a new chip
  - generic products with lots of functions
  - each implementation uses specific subset of available functionality
Components of a SoC

- Clock Generation
- Processor(s)
  - Microcontroller
  - DSP, FPGA
  - Generic CPU (ARM, x86)
  - Accelerators: Graphics, Encryption, Audio, Radio, etc.
- Memory
  - on-chip: very restricted
  - often: bus interface to external RAM (SDRAM, RAMBUS)
- Peripherals:
  - challenging to provide appropriate choice
  - USB, Firewire, Ethernet, CAN (automotive), video: LVDS and DP, I^2C (one-pin serial), and many more
  - analog: DAC, ADC, digital: GPIO, mechanical actors: PWM
  - Audio, Graphics, Radio, Timers, …
- Bus or Crossbar Switch
Microcontroller

- For control-flow intensive applications
- Lean CPU with no sophisticated OS
- consumes not much power and chip area
- low computational power

- typical applications:
  - coffee machine, washing machine
  - chip cards
  - remote control, etc.
  - automotive: ABS, etc.
  - watch, alarm clock
  - keyboard, mouse, scanner
  - network processor (TCP/IP)
• “Number Crunching”
• Two fundamental approaches
  – traditional DSP (example: Motorola 56K DSP)
    • audio processing (equalizer, echo/noise suppression, compression, filter)
    • modem
    • mobile radio (GSM)
    • mechanical engineering: ABS, ESP, engine control, suspension/break control
  – supercomputer on AA-battery
    • WLAN
    • DSL
    • mobile radio (UMTS, etc.)
    • digital oscilloscope
    • image processing
    • radar
• Harvard Architecture: separate memories for
  – code
  – data global
  – data x
  – data y

• CISC Design

• Execution Units
  – Program Control Unit (PCU)
  – Address Generation Unit (AGU) 2x
  – Arithmetic Logix Unit (ALU) with Multiply-Accumulate (MAC)

• Arithmetic
  – 8-bit operands (from ADC) with 0.8 or 1.7 fixed point
  – 16-bit operands (from ADC) with 1.15 or 0.16 fixed point
  – 40-bit accumulator as 8.32 fixed point
  – 56-bit accumulator as 8.48 fixed point
Functional Units of Traditional DSP

- **PCU**: “Zero overhead loop” (ZOL) as prefix to any instruction
  - “loop” a number of times, constant or register
- **AGU** generates memory address and increments pointer
  - adds an offset to address pointer (“stride”)
  - performs division modulo N (wrap array index)
  - can check for array boundaries
- **ALU/MAC**
  - performs multiplication and addition simultaneously
  - rationale: fixed point multiplier can easily add another number
  - observation: accumulator can be supplied late
• idiom: “loop mac”
  
  rep #ntaps-1
  mac x0,y0,a x:(r1)+,x0 y:(r4)+,y0

• can be used for vector primitives:
  – add/multiply vector/matrix
  – scalar product
  – FFT

• sequential execution of vector primitives
• transition to floating point data format (sometimes: double precision)
• concepts of traditional supercomputers:
  – parallelism
  – SIMD
  – VLIW

• Example: Texas Instruments C6x
• TriCore: combines features of microcontroller and DSP
• Industrial applications
  – Powertrain (engine control)
  – Safety (suspension and dampening systems)
  – Industrial & Multimarket (e.g. wind power station)
Infineon Aurix

Infineon Aurix Features

Performance
• Up to 3x TriCore CPUs
• TC1.6P up to 300MHz
• TC1.6E up to 200MHz
• DSP with up to two FLOPS
• Dedicated multicore extensions
• Power Generic Timer Module (GTM)
• Delta sigma converters

Safety Features
• Diverse lockstep with clock delay
• Access permission system
• Safety management unit
• Safe DMA
• I/O, clock, voltage monitor

Security Features
• Hardware Security Module (HSM)
• IP from chipcard market leader
• Immobilizer
• Tuning protection
• Secure software updates
• IP protection
• Component protection

Scalability
• 80-3x300MHz
• 256KB-8MB Flash
• 48KB-2.7MB SRAM
• ASIL Level from QM
• up to ASIL D
• HOT Package Option
• From Single Core to Triple Core

Connectivity
• Ethernet 100Mbit
• FlexRay
• High Speed Serial Link for Interprocessor Communication
• QSPI, CAN FD (flexible data rate), LIN
• Camera Interface (up to 16-bit)
• External ADC IF (up to 16-bit)
• External Bus Interface for Memory Extension

- Example: Infineon AUDO NG– F–Max
- Tricore \(\leftarrow\) “DSP”
- PCP2 \(\leftarrow\) “Microcontroller”
- temporal redundancy mode
- safety concept: certified SIL3 by TÜV SÜD on 09/27/2007

source: Infineon
Automotive Applications

Application Features

- Direct injection
- Scalable software-based knock detection
- Variable valve control
- Throttle and EGR control
- Turbo charging
- Catalyst after treatment
- Start/stop systems

source: Infineon
Bosch Direct-Injection Application

Technical Parameters:
- Pressure up to 1350 bar
- Five nozzles of 0.12mm each
- Quantities down to 1mm³ as minimum dosage
- Coil impedance < 0.4 Ω

Source: Infineon AP32029
Automotive Blockpraktikum

• Anmeldung
  https://uniworx.ifi.lmu.de/?action=uniworxCourseWelcome&id=422
• Blockpraktikum 01.10.2015 bis 09.10.2015
• 6 ECTS Punkte
• Arbeiten mit dem Infineon Tricore

Themengebiete:
• Mikroarchitektur
• Softwareentwicklung und Optimierung
• Sensoren und Aktoren
• Kommunikation mit CAN Bus
• Functional Safety, Formale Spezifikation und Verifikation