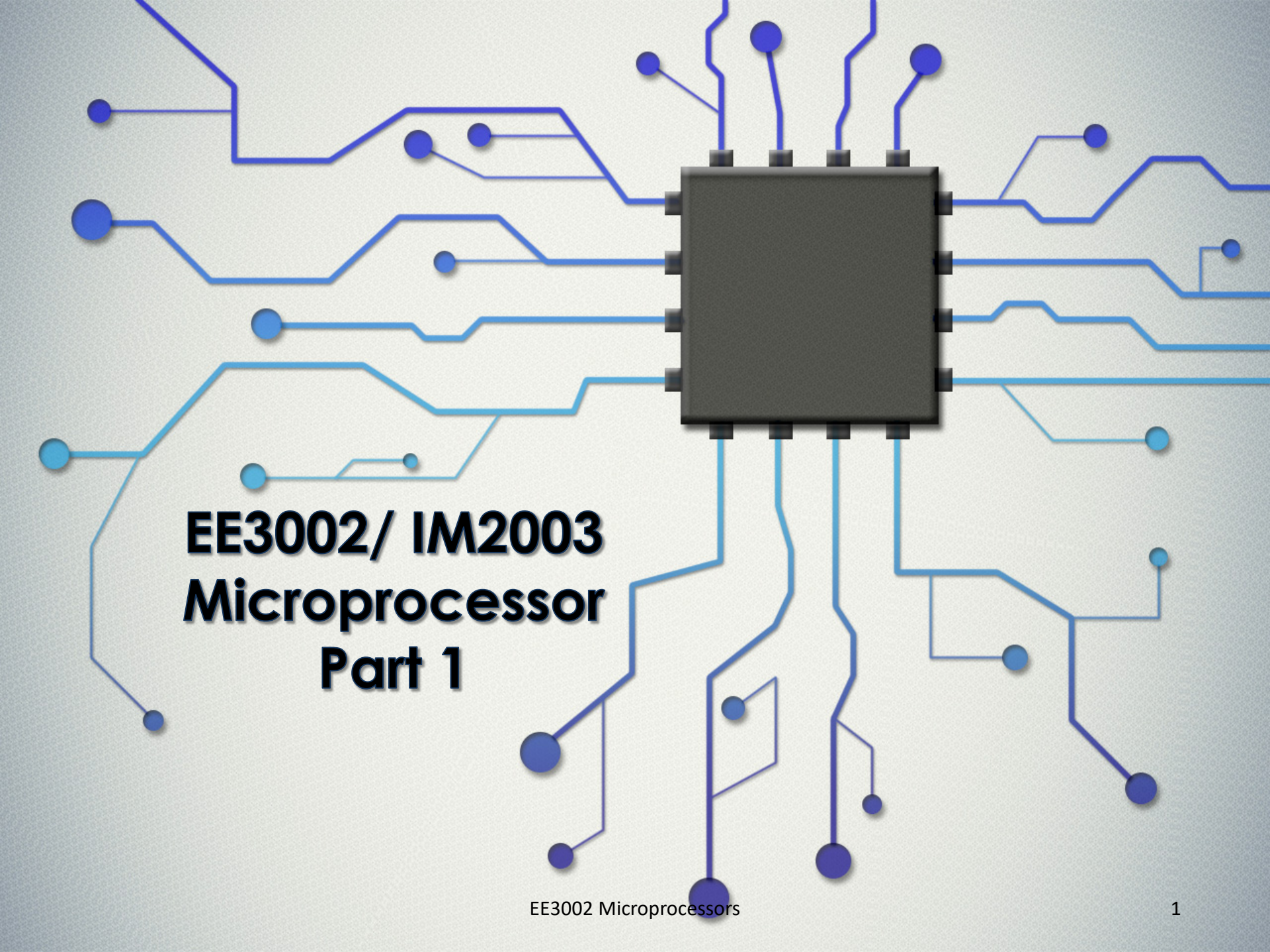


EE3002/ IM2003 Microprocessor Part 1

Course Objectives

- Understand what is a Microprocessor.
- Know the internal workings of an ARM processor.
- Ability to program an ARM processor in assembly and C language.

Course Structure

- 13 weeks of lectures (~ 3hrs/week)
- 26 hours of Tutorials
- 2 laboratory sessions of 3 hrs each
- 2 quizzes
- Course grade will be based on

➢ Final examination (60%)

➢ Quizzes (20%)

➢ Laboratory (20%)

Course Coordinator & Instructors

Coordinator

- Dr. Chan Chee Keong
- Telephone : 67905377
- Email : eckchan@ntu.edu.sg

Tutors

You will be assigned a tutor throughout the semester

Text and References

TEXTBOOK

- William Hohl, ARM Assembly Language Fundamentals and Techniques, CRC Press, 2009 (ISBN 978-1-4398-0610-4).

REFERENCES

- Daniel W. Lewis, Fundamentals of Embedded Software with the ARM Cortex-M3, Prentice Hall, 2012.
- Andrew Sloss, Dominic Symes and Chris Wright, ARM System Developer's Guide: Designing and Optimizing System Software, Morgan Kaufmann (Elsevier) 2004.
- David A. Patterson, John L. Hennessy, Computer Organization and Design: The Hardware/Software Interface (ARM edition), 4th edition, Morgan Kaufmann 2011.

Introduction to Microprocessor

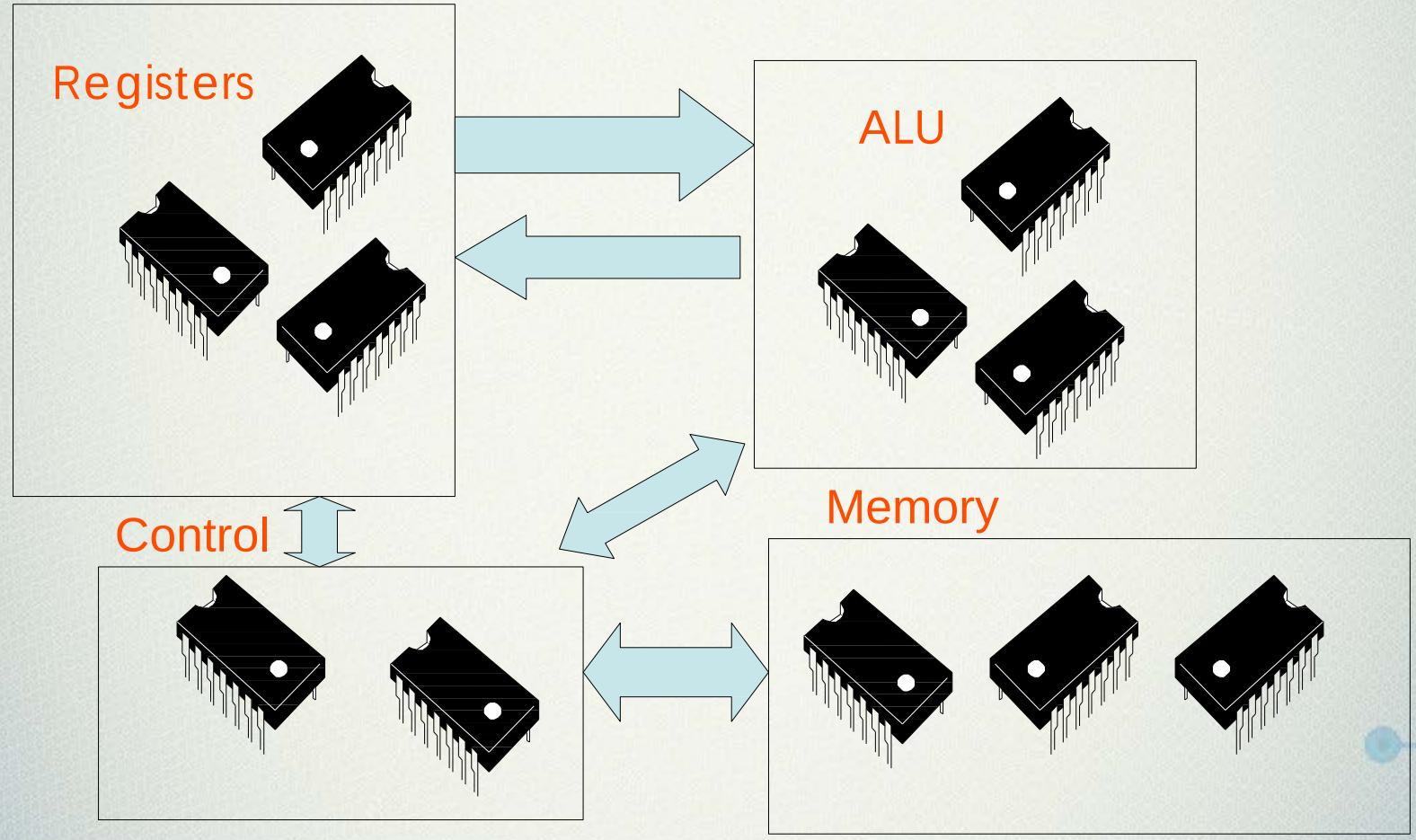
- Microprocessors are used in Computers and Embedded Systems.
- Embedded systems : microprocessors are transparent to the users e.g. in an ATM.
- Microprocessor based systems are widely used in home appliances and industrial systems.
- A Microprocessor is a programmable chip that can perform logical, arithmetic and control operations.

Microcontrollers

- Microcontrollers are Microprocessors integrated together with some Memory and I/O peripherals on a single chip, resulting in lower chip count.
- Peripherals integrated includes parallel I/O port, clock generation circuitry, serial I/O port, ROM and RAM.
- Hence it is easier to use a microcontroller for simpler applications.
- Microcontrollers can be very low cost (sub dollar) and can be very useful.

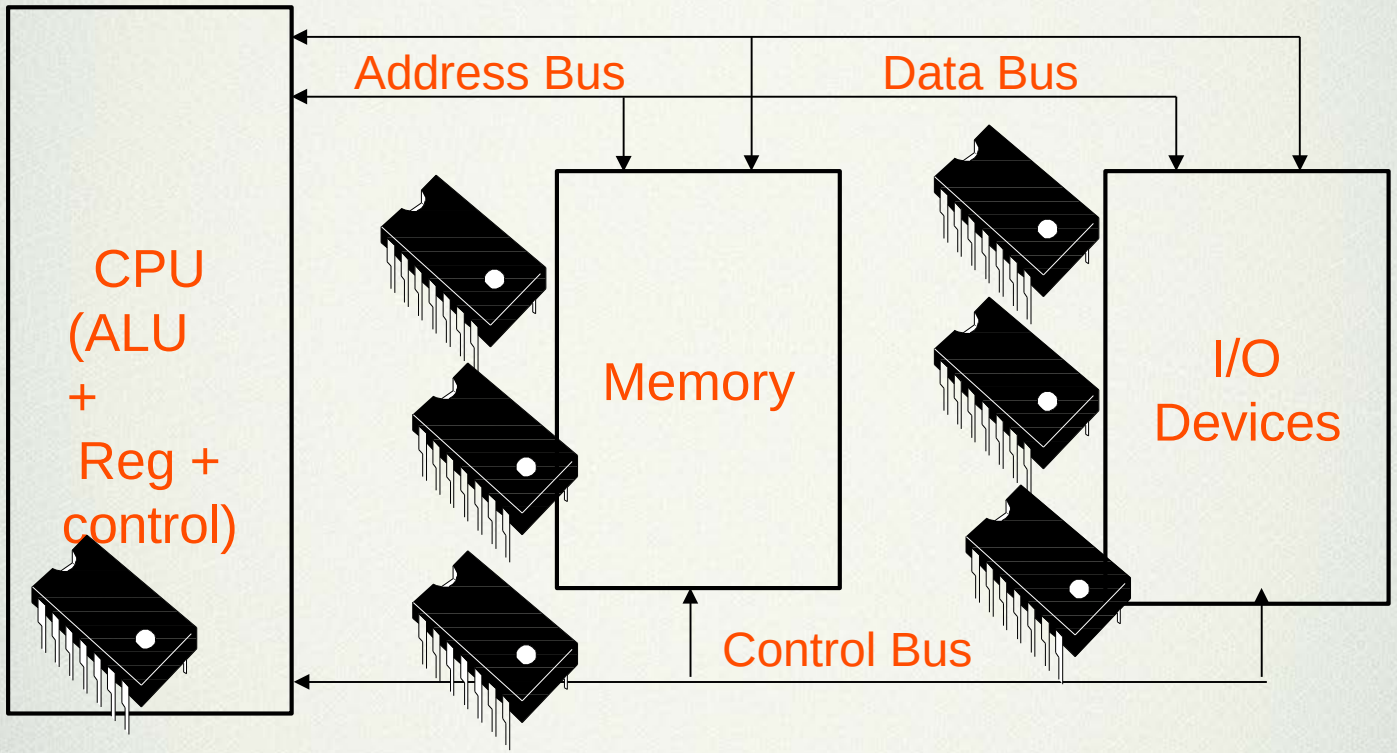
Processor Integration

Early computers had many separate chips for the different portions of a computer system



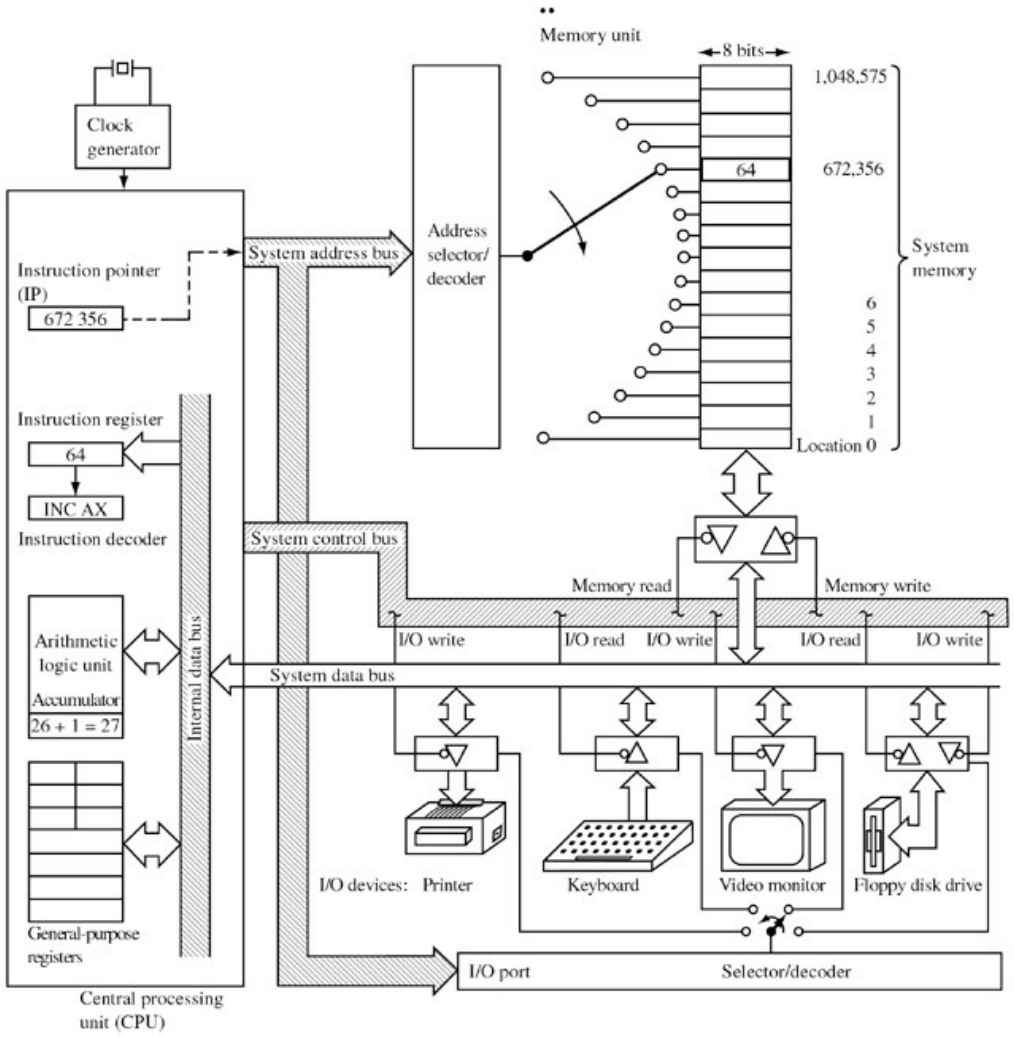
Microprocessors

First *micro*processors placed control, registers, Arithmetic logic unit in one integrated circuit (one chip).



CPU – Central Processing Unit

FIGURE 1-1 The stored program computer consists of three units: the CPU, memory, and I/O devices.



Microcontrollers

Microcontrollers integrate all of the components (control, memory, I/O) of a computer system into one integrated circuit. Microcontrollers are intended to be single chip solutions for systems requiring low to moderate processing power.

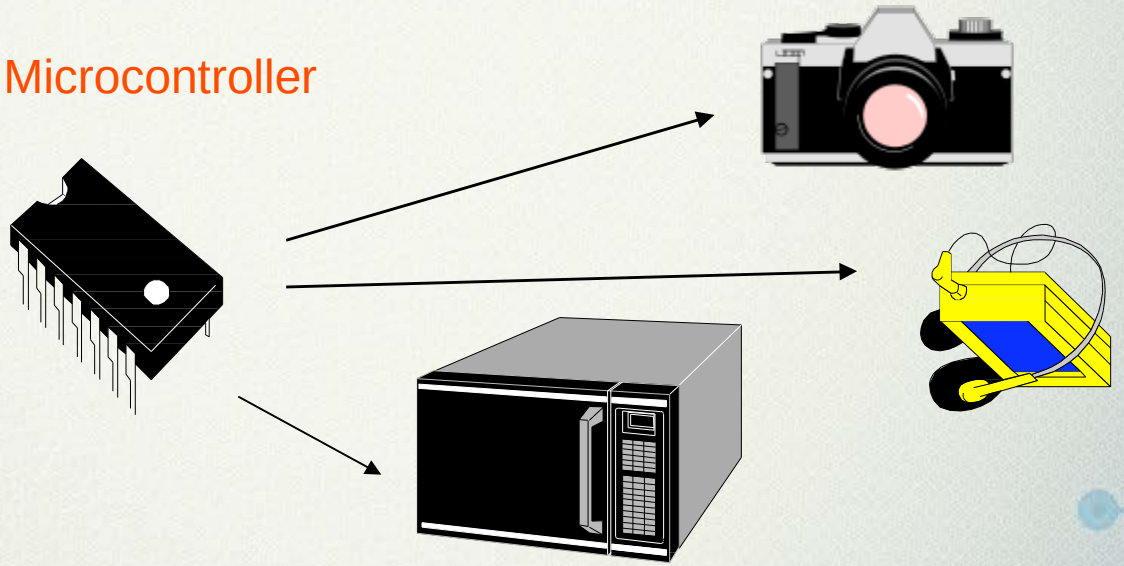


FIGURE 1-6 Microcontrollers are often called “hidden computers.” In this picture there are 14 different microcontrollers. (Reprinted courtesy of Intel Corporation and Microcomputer Solutions.)

Definitions (Recap)

Microprocessor – A CPU on a single chip containing registers, ALU, instruction decoder, addressing logic, internal busses, and control logic. Typically it cannot be operated in a standalone manner.

Microcontroller – A complete computer system on a chip containing a CPU, memory, IO/interface controllers, timers, and other specialized circuitry. Typically it can be operated in a standalone manner.

Embedded System – A system or device that has a dedicated computer as one of its subsystems. Examples are cell phones, MP3 players, household appliances, etc. They may contain microcontrollers or embedded general purpose processors.

Real-time System – A system or device that is required to respond to external events within a specified time period.

Other Families of Microprocessors

- **INTEL** - Dominant in laptops and desktops
  - History : 4-bit 4004 (1971), 8-bit 8080 (1973),16-bit 8086 (1978), 32-bit 80486 (1989), 64-bit Pentium (1993)
  - **MOTOROLA** – Popular in the past.
  - History : 8-bit 6800 (1973), 16-bit 68000 (1980), 32-bit 68020, PowerPC by AIM (1992)
  - **AMD, ZILOG, NATIONAL, NEC etc**

ARM® Processors

Processors Market

In 2007:

- 13 billion microprocessors were shipped.
- 3 billion are based on the ARM architecture embedded processor.
- 150 million are for the PC, notebook, and workstation.

By February 2008:

- 10 billion ARM-based processors have been produced.

In 2010:

- 10 billion ARM-based processors have been shipped that year alone.

A Bit of ARM History

- Originally conceived to be a processor for the desktop system (Acorn®)
- now entrenched in embedded markets
- First well-known product
- Apple®'s Newton™ PDA (1993) base an ARM6 core

- Significant breakthrough
- Apple®'s iPod® (2001) based on an ARM7 core

ARM Ltd

- Founded in November 1990
  - Spun out of Acorn Computers
- Designs the ARM range of RISC processor cores
- Licenses ARM core designs to semiconductor partners who fabricate and sell to their customers.
  - ARM does not fabricate silicon itself
- Also develop technologies to assist with the design-in of the ARM architecture
  - Software tools, boards, debug hardware, application software, bus architectures, peripherals etc

ARM Processor Architecture

- ARM stands for “Advanced RISC Machine”.
- based on Reduced Instruction Set Computer (RISC) architecture
  - trading simpler hardware circuitry with software complexity (& size)
  - but latest ARM processors utilize more than 100 instructions

RISC Philosophy

Original RISC design (e.g., MIPS)

- aims for high performance through
  - reduced number of instruction classes
  - large general-purpose register set
  - load-store architecture
  - fixed length instructions
  - Pipelines
- enables simpler hardware; hence, scalable to higher operating frequencies

ARM Processor

ARM processor

- targeted for embedded applications as a processor embedded for system-on-chip devices
- not a pure RISC architecture (e.g., supports both 16-bit and 32-bit instruction sets)

Also emphasizes the following:

- high code density
- low power consumption
- small die size
- cost effectiveness

Biggest market for ARM-based processors

- mobile phones and smart phones

ARM Powered Products

ARM Partners

The ARM processor is not sold as a processor chip but as a hardware IP license.

Licensees add their own logic and customized peripherals and then manufacture the silicon processor chip.

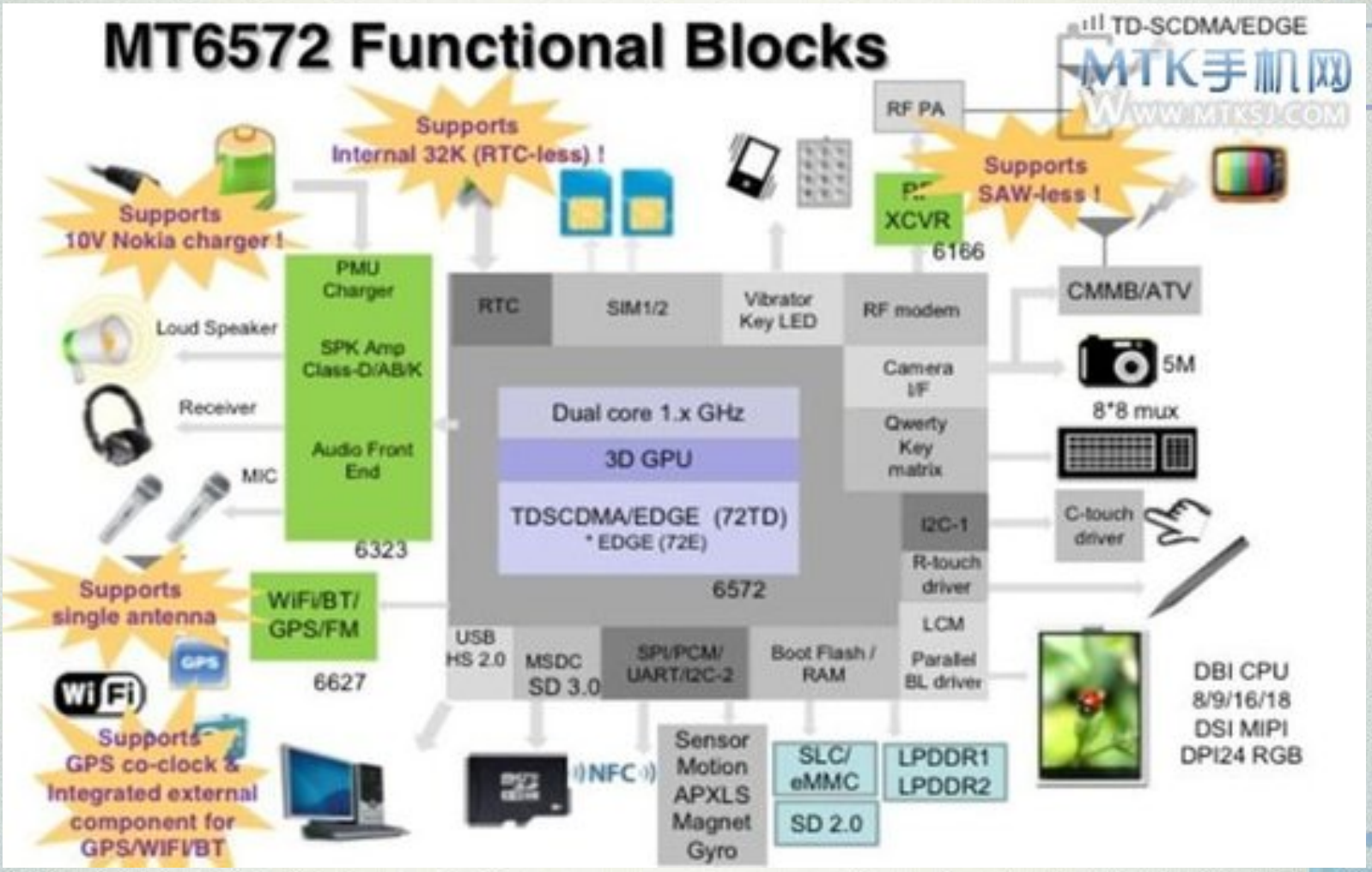
- typically sold as ASIC/SOC for embedded applications

Some of the present and past licensees (ARM calls them Partners) include:

- Texas Instruments, Philips, Analog Devices, Qualcomm
- Intel (StrongARM® and XScale®)
- Atmel – its processor is used on the ARM9 board

ARM Partnership Model

ARM System-On-Chip (SOC)



ARM Processor Main Features

- Typical ARM processors:
- run at a relatively slow clock cycle (few hundred MHz).
- [But new and upcoming family, like the dual-core Cortex™-A9 Osprey is capable of achieving up to 2 GHz clock.]
- 32-bit instructions, with extension to support 16-bit Thumb® & Thumb-2 instructions.
- single unified memory address space (i.e. all peripherals and I/O are accessed like normal memory, at certain specific memory locations).
- relatively low power consumption.

ARM Processor Families

a) ARM7TDMI family (E.g. NXP's ARM7)

- Based on ARMv4T architecture with 3-stage pipeline
- supports the 16-bit Thumb instruction set
- supports the JTAG Debugger
- includes a fast Multiplier to support DSP algorithm
- supports the In-Circuit Emulation interface

b) ARM9TDMI family (E.g. Atmel's ARM9)

- Based on ARMv4T with Harvard cache architecture
- 5-stage pipeline
- ARM920T is based on ARM9TDMI with a memory management unit (MMU)

ARM Processor Families (cont'd)

c) ARM9E family (E.g. Intel's XScale)

- Based on ARMv5E architecture
- Enhanced with DSP instructions
- Hardware support of Java™ bytecodes execution

d) ARM10 family

Based on ARMv5E with MMU

e) ARM11 family

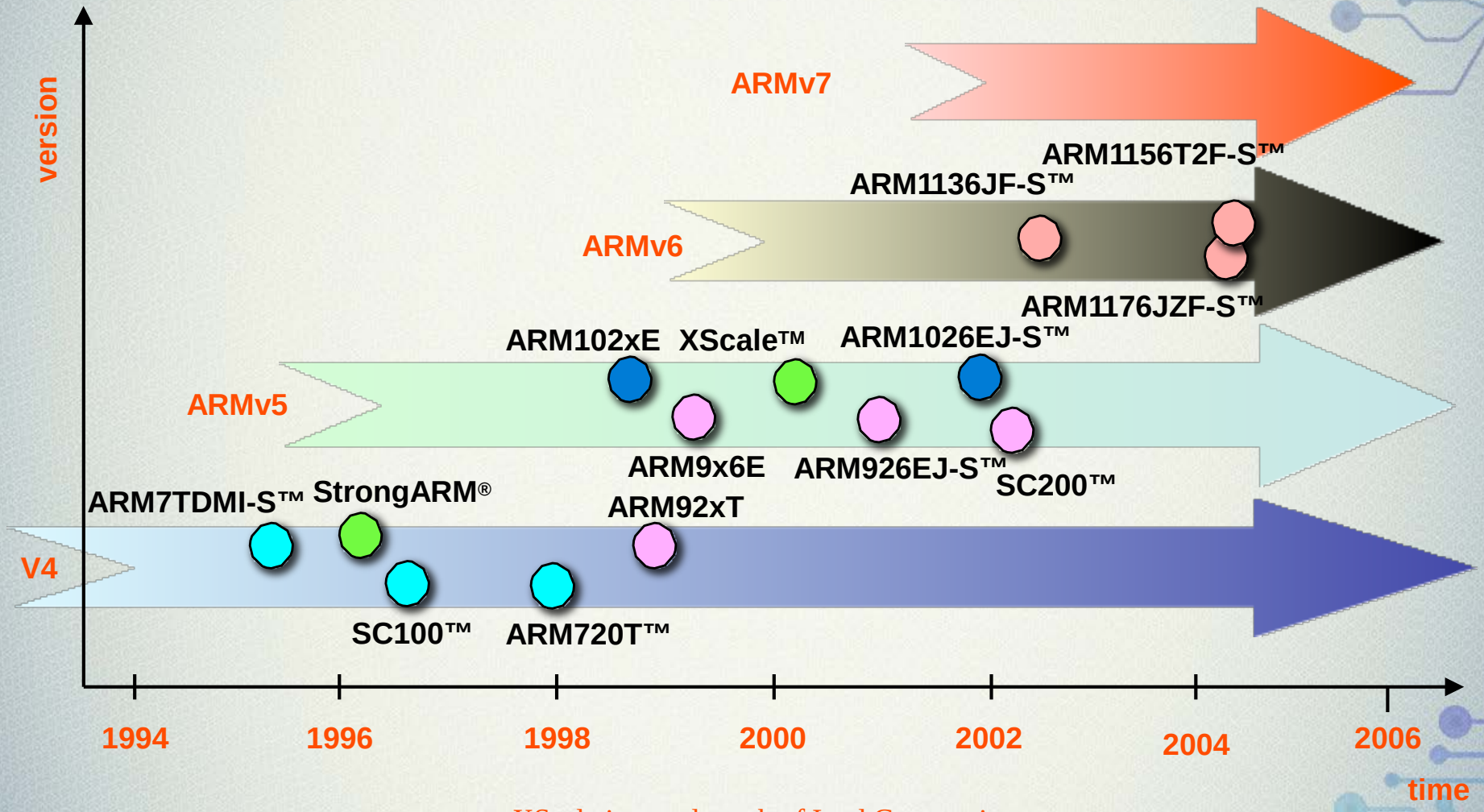
- Based on ARMv6 architecture
- Supports SIMD instructions

ARM Processor Families (cont'd)

f) Cortex families

- Based on ARMv7 architecture
- Supports the new Thumb-2 instruction set
- Cortex-A: For complex OS based applications
- Cortex-R: For real-time embedded applications
- Cortex-M: For deeply embedded, microcontroller type cost sensitive applications
- Only executes Thumb-2 codes

Architecture Revisions

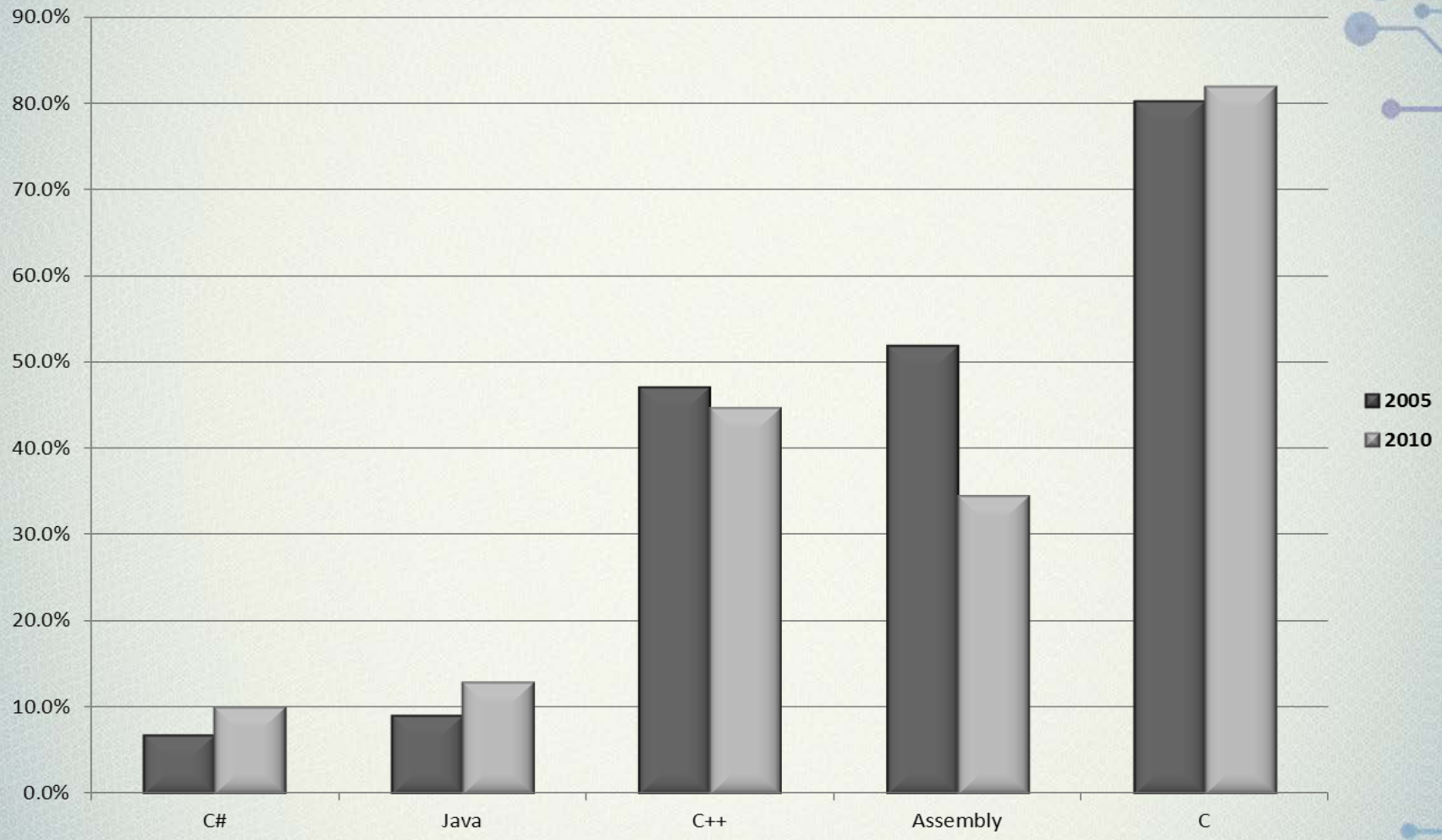


XScale is a trademark of Intel Corporation

Data Sizes and Instruction Sets

- The ARM is a 32-bit architecture.
- When used in relation to the ARM:
  - **Byte** means 8 bits
  - **Halfword** means 16 bits (two bytes)
  - **Word** means 32 bits (four bytes)
- Most ARM's implement two instruction sets
  - 32-bit ARM Instruction Set
  - 16-bit Thumb Instruction Set
- Jazelle cores can also execute Java bytecode

Programming languages used in embedded designs



Development Tools

- There are many development tools for ARM based processors.

- For this course, we will use Keil µvision 4.
  - Keil is an ARM company.
  - Keil tools are widely used.
  - Keil supports different microprocessors.
  - Lastly, Keil µvision 4 has a freeware version

Summary

- General purpose computer vs. Embedded System.
- Microprocessors vs. Microcontrollers.
- History of ARM processor