

SEC204

Computer architectures and low level 程序代写代做 CS 编程辅导 programming



Vasiliос Kelefouras

Email: v.kelefouras@plymouth.ac.uk

WeChat: cstutorcs

Website:

Assignment Project Exam Help

<https://www.plymouth.ac.uk/staff/vasilios-kelefouras>

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Computer Architectures – Last Pieces of the Puzzle

程序代写代做 CS编程辅导

2

Too many puzzling words

- x86, RISC, CISC, EPIC, VL

Harvard architecture

- SIMD

- Microcontrollers, ASIC, ASIP

FPGA, GPU, DSP

- Pipeline, vector processing,

superscalar, hyper-threading,

multi-threading

- Heterogeneous systems



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

Let's put them in order

https://tutorcs.com



Outline

程序代写代做 CS编程辅导

3



- Different computer architectures – classified regarding purpose
- General Purpose Processors
- Application Specific Processors
- Coprocessors / accelerators
- Multi-core processors
- Many-core processors
- Simultaneous Multithreading
- Single Instruction Multiple Data
- Heterogeneous Systems

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

程序代写代做 CS编程辅导



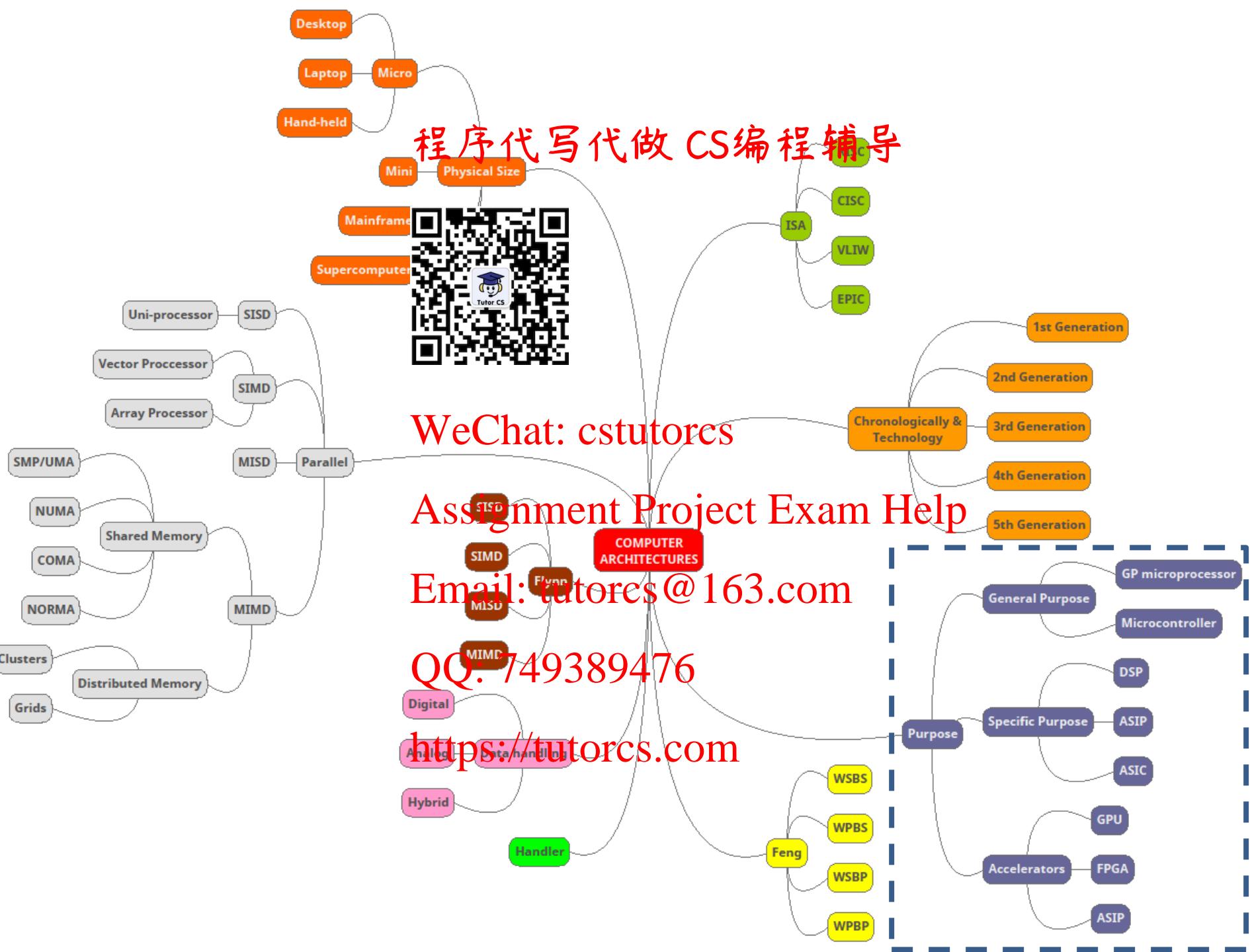
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



Computer architectures – classified regarding

程序代写,代码做(1) 编程辅导

5



Fig.1. CPU market analysis

Computer architectures – classified regarding

程序代写
作业代做
CS编程辅导
(2)

6

1. General Purpose Processors



2. Specific Purpose Processors

WeChat: cstutorcs

3. Accelerators, also called co-processors

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

General Purpose Processors (GPP)

程序代写代做 CS编程辅导

7

- They are classified into:

1. **General purpose microprocessors** - general purpose computers, e.g., desktop PCs, laptops



- Very powerful CPUs, e.g., Intel, AMD and now Arm too
- Superscalar and Out of Order, big cache memories, lots of pipeline stages

2. **Microcontrollers** - Embedded systems

- Less powerful CPUs, e.g., ARM, Texas Instruments
- They are usually designed for specific tasks in embedded systems
- They usually have control oriented peripherals
- They have on chip CPU, fixed amount of RAM, ROM, I/O ports
- Lower cost, lower performance, lower power consumption, smaller than microprocessors
- Appropriate for applications in which cost, power consumption and chip area are critical

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

GPP - General Purpose Microprocessor

程序代写代做 CS编程辅导

8

- General Purpose Microprocessors
 - They are designed for general purpose computers such as PCs, workstations, Laptops, notepads etc.
 - Higher CPU frequency than microcontrollers
 - Higher cost than microcontrollers
 - Higher performance than microcontrollers
 - Higher power consumption than microcontrollers
 - General purpose processors are designed to execute multiple applications and perform multiple tasks



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

GPP – Microcontrollers

程序代写代做 CS编程辅导

9



Fig.2. Microcontrollers

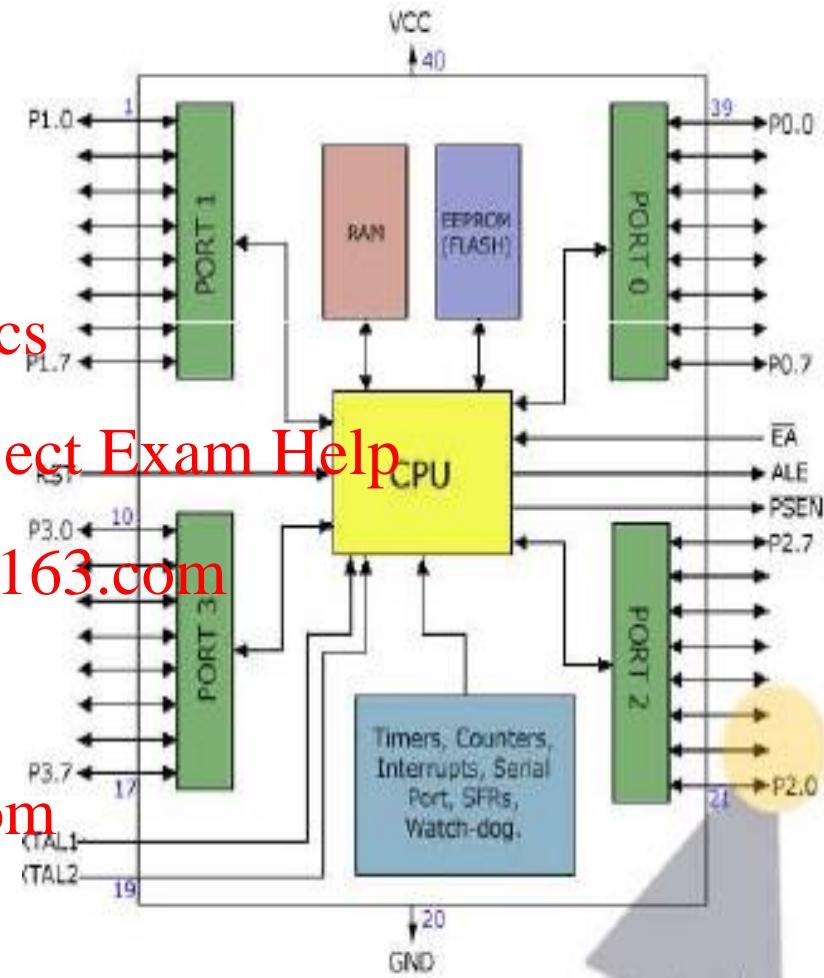


Fig.3. Components of
the Microcontroller

Application Specific Processors (1)

程序代写代做 CS编程辅导

10

- General purpose processors offer good performance for all different applications but specific processors offer better for a specific task



- Application specific processors emerged as a solution for

- higher performance

WeChat: cstutorcs

- lower power consumption

- Lower cost

Assignment Project Exam Help

- Application specific processors have become a part of our life and can be found almost in every device we use on a daily basis

Email: tutorcs@163.com

- Devices such as TVs, mobile phones and GPSs they all have application specific processors

- They are classified into <https://tutorcs.com>

1. Digital Signal Processor (DSPs)

2. Application Specific Instruction Set Processors (ASIPs)

3. Application Specific Integrated Circuit (ASICs)

Digital Signal Processors (DSPs)

程序代写代做 CS编程辅导

11

1. **DSP:** Programmable microprocessor designed for extensive real-time mathematical computations



- specialized microprocessor with its architecture optimized for the operational needs of digital signal processing
- DSP processors are designed specifically to perform large numbers of complex arithmetic calculations and as quickly as possible
- DSPs tend to have a different arithmetic Unit architecture;
 - specialized hardware units, such bit reversal, multiple Multiply-Accumulate (MAC) units etc
 - Normally DSPs have a small instruction cache but no data cache memory

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutors@163.com

QQ: 749389476

<https://tutorcs.com>

Application Specific Instruction set Processor (ASIP)

程序代写代做 CS编程辅导

12

2. **ASIP:** Programmable microprocessor where hardware and instruction set are designed together for a specific application



- Instruction set, micro controller, and/or memory system are customised for an application or family of applications
- Usually, they are divided into two parts: static logic which defines a minimum ISA and configurable logic which can be used to design new instructions
- The configurable logic can be programmed and extend the instruction set similar to FPGAs
- better performance, lower cost, and lower power consumption than GPP

WeChat: cstutorcs
Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Application Specific Integrated Circuit (ASIC)

程序代写代做 CS 编程辅导

13

3. ASIC: Algorithm completely implemented in hardware

- An Integrated Circuit is designed for a specific line of a company – full custom
- It cannot be modified – it is produced as a single, specific product for a particular application only
- Proprietary by nature and not available to the general public
- ASICs are full custom therefore they require very high development costs
- ASIC is just built for one and only one customer
- ASIC is used only in one product line
- Only volume production of ASICs for one product can make sense which means low unit cost for high volume products, otherwise the cost is not efficient
- **There is a lot of effort to implement an ASIC – there are specific languages such as VHDL and Verilog**



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Building an application specific system on an embedded system (1)

程序代写代做CS编程辅导

14

Consider that we want to build a application specific system. We choose:

1. GPP

- Functionality of the system is exclusively build on the software level
- it is not efficient in term of performance, power consumption, cost, chip area and heat dissipation



WeChat: cstutorcs
Assignment Project Exam Help
Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

2. ASIC:

- No flexibility and extensibility

3. ASIP:

- a compromise between the two extremes
- used in embedded and system-on-chip solutions



Fig.4. Comparison between Performance and flexibility

Building an application specific system on an embedded system (2)

程序代写代做CS编程辅导

15



Table 1. Comparison between different approaches for Building Embedded Systems [1]

	GPP	ASIP	ASIC
Performance	Low	High	Very High
Flexibility	Excellent	Good	Poor
HW design	None	Large	Very large
SW design	Small	Large	None
Power	Large	Medium	Small
reuse	Excellent	Good	Pure
market	Very large	Relatively large	Small
Cost	High	Medium	Volume sensitive

Accelerators - coprocessors

程序代写代做 CS编程辅导

16

- Accelerators / co-processors used to perform some functions more efficiently than the CPU



- They offer

WeChat: cstutorcs

- Higher performance

Assignment Project Exam Help

- Lower power consumption

- High Performance programming

Email: tutorcs@163.com

- But they are harder to program

QQ: 749389476

<https://tutorcs.com>

Field Programmable Gate Arrays (FPGAs)

程序代写代做 CS编程辅导

17

- FPGAs are devices that allow us to create our own digital circuits
- An FPGA (Field Programmable Gate Array) is an array of logic gates that can be hardware-programmed to fulfill user-specified tasks
- FPGAs contain programmable logic components called "logic blocks", and a hierarchy of reconfigurable interconnects that allow the blocks to be "wired together".
WeChat: cstutorcs
Assignment Project Exam Help
Email: tutorcs@163.com
- An application can be implemented entirely in HW
- The FPGA configuration is generally specified using a hardware description language (HDL) like VHDL and Verilog – hard to program
QQ: 749389476
<https://tutorcs.com>
- High Level Synthesis (HLS) provides a solution to this problem. Engineers write C/C++ code instead, but it is not that efficient yet

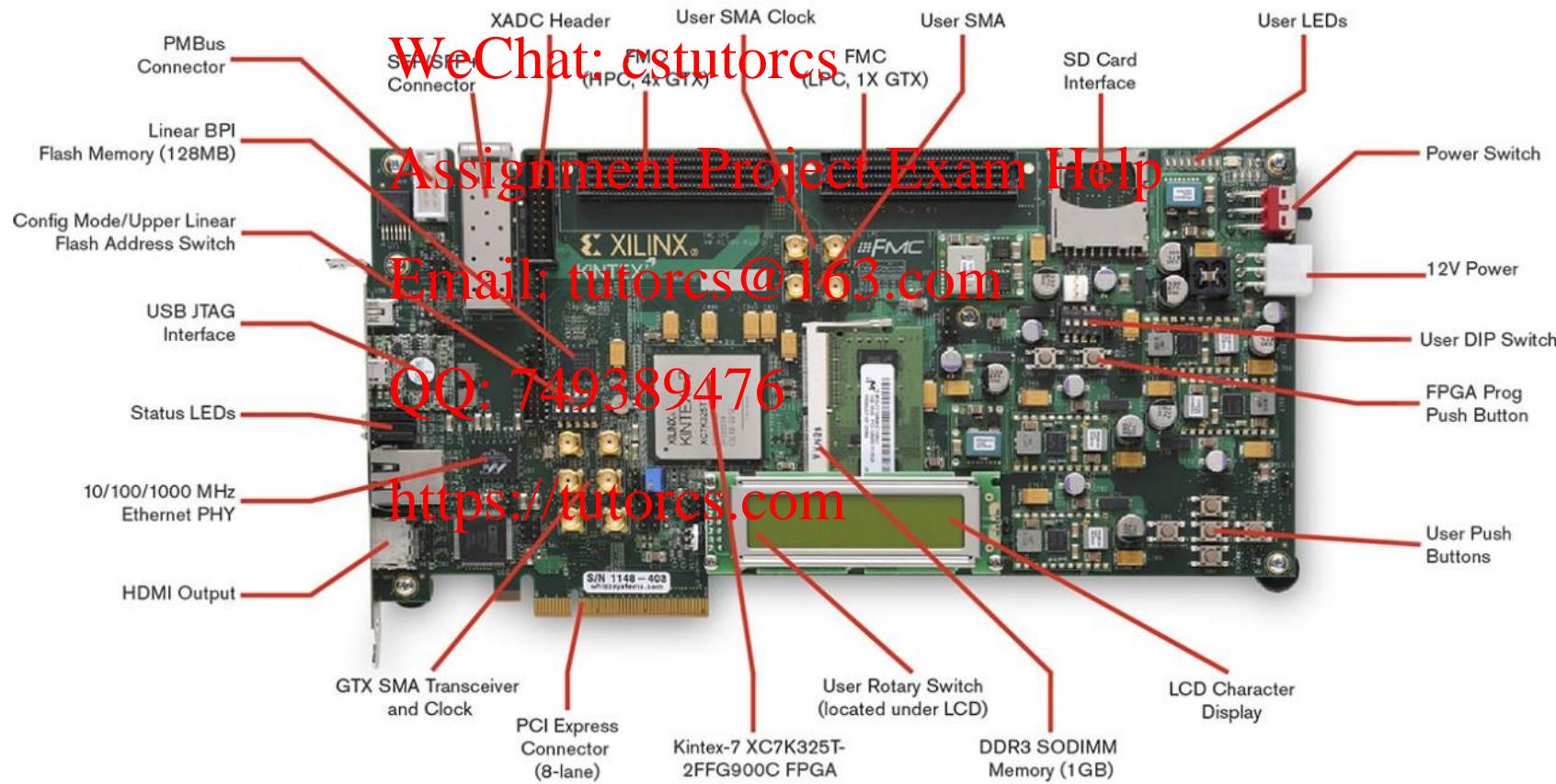


FPGAs (2)

程序代写代做 CS编程辅导

18

- FPGAs come on a board. It is connected to a PC and programmed. Then, it can work as a standard component



FPGAs (3)

程序代写代做 CS编程辅导

19

- Unlike an ASIC the circuit configuration is not set and you can reconfigure an FPGA as many times as you like!



- Creating an ASIC also costs potentially millions of dollars and takes weeks or months to create.

WeChat: cstutorcs

- However, the recurring cost is lower than the cost of the FPGA (no silicon area is wasted in ASICs)
- Assignment Project Exam Help
- ASICs are cheaper only when the production number is very high

Email: tutorcs@163.com

- Intel plans hybrid CPU-FPGA chips

QQ: 749389476

<https://tutorcs.com>

GPUs (1)

程序代写代做 CS 编程辅导

20

□ Graphics Processing Unit

- The GPU's advanced capabilities were originally used primarily for 3D game graphics. But now capabilities are being harnessed more broadly to accelerate computational workloads in other areas too

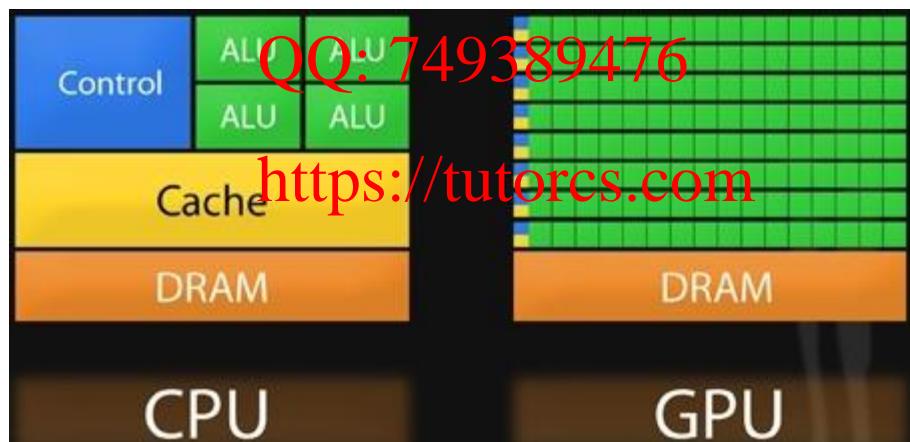
- GPUs are very efficient for

- Data parallel applications
- Throughput intensive applications - the algorithm is going to process lots of data elements

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com



GPUs (2) – why do we need GPUs?

程序代写代做 CS编程辅导

21



Tesla zu-series
Tesla 20-series

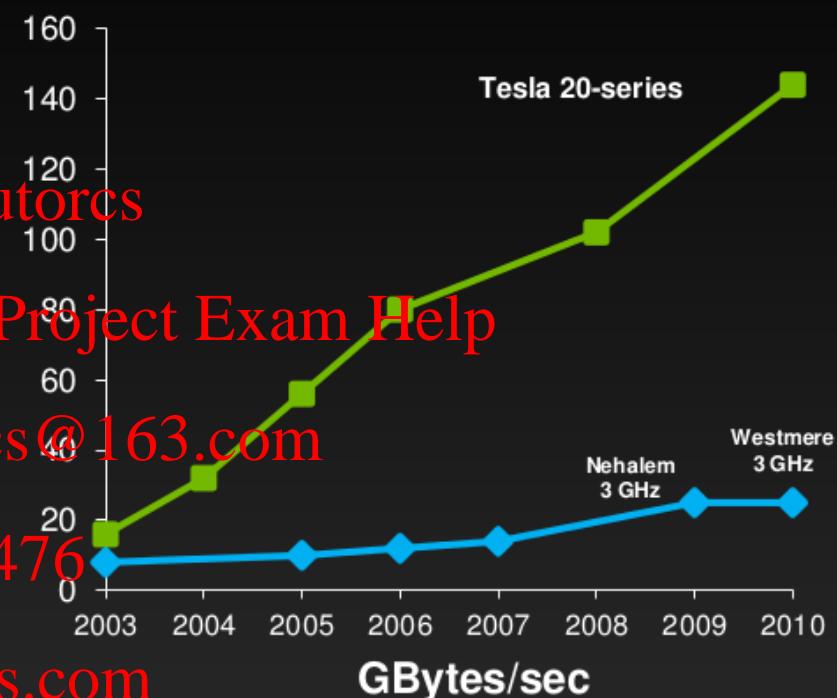
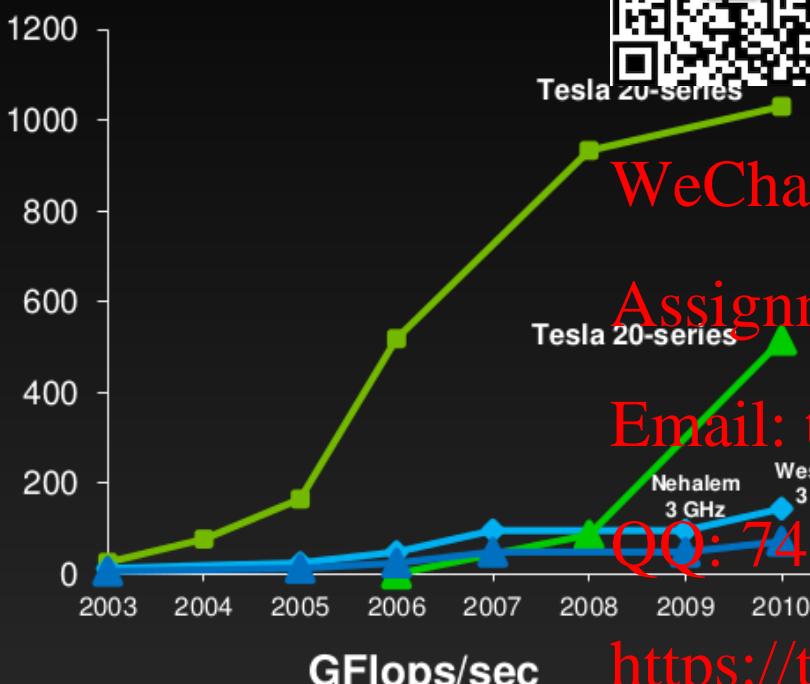
WeChat: cstutorcs

Tesla 20-series

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476



Single Precision: NVIDIA GPU
Double Precision: NVIDIA GPU

Single Precision: x86 CPU
Double Precision: x86 CPU

NVIDIA GPU
X86 CPU
ECC off

<https://tutorcs.com>

GPUs (3)

程序代写代做 CS编程辅导

22

- A GPU is always connected to a CPU – GPUs are coprocessors
- GPUs work in lower frequencies than CPUs
- GPUs have many processing elements (up to 1000)
- GPUs have smaller memories
- OpenCL is the dominant open general-purpose GPU computing language, and is an open standard
- The dominant proprietary framework is Nvidia CUDA

QQ: 749389476

<https://tutorcs.com>



Schematic of Nvidia GPU architecture

程序代写代做 CS 编程辅导

23



Multi-core CPUs

程序代写代做 CS编程辅导

24

- Multiple cores on the same die sharing memory using a shared cache
- Typically from 2-8 cores
- Both cores compete for the same hardware resources
- Both cores are identical
- Every core is a superscalar out of order CPU



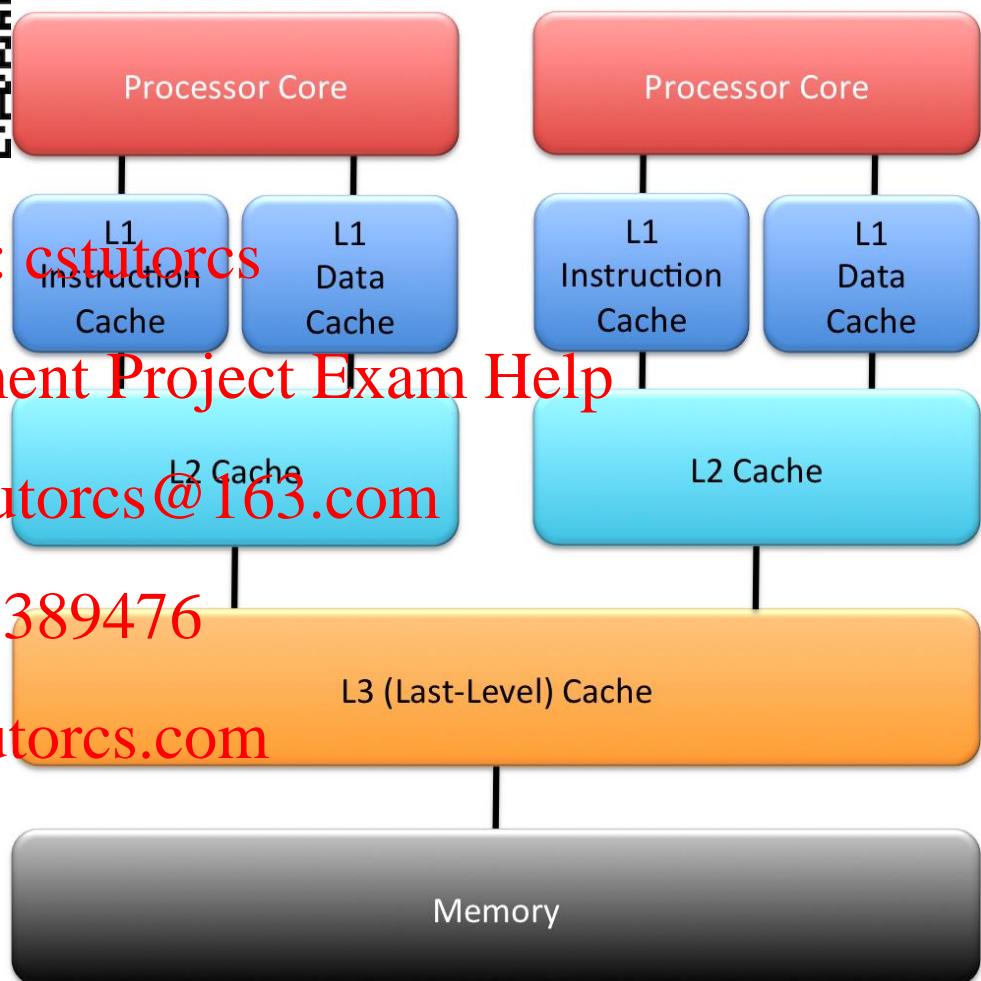
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

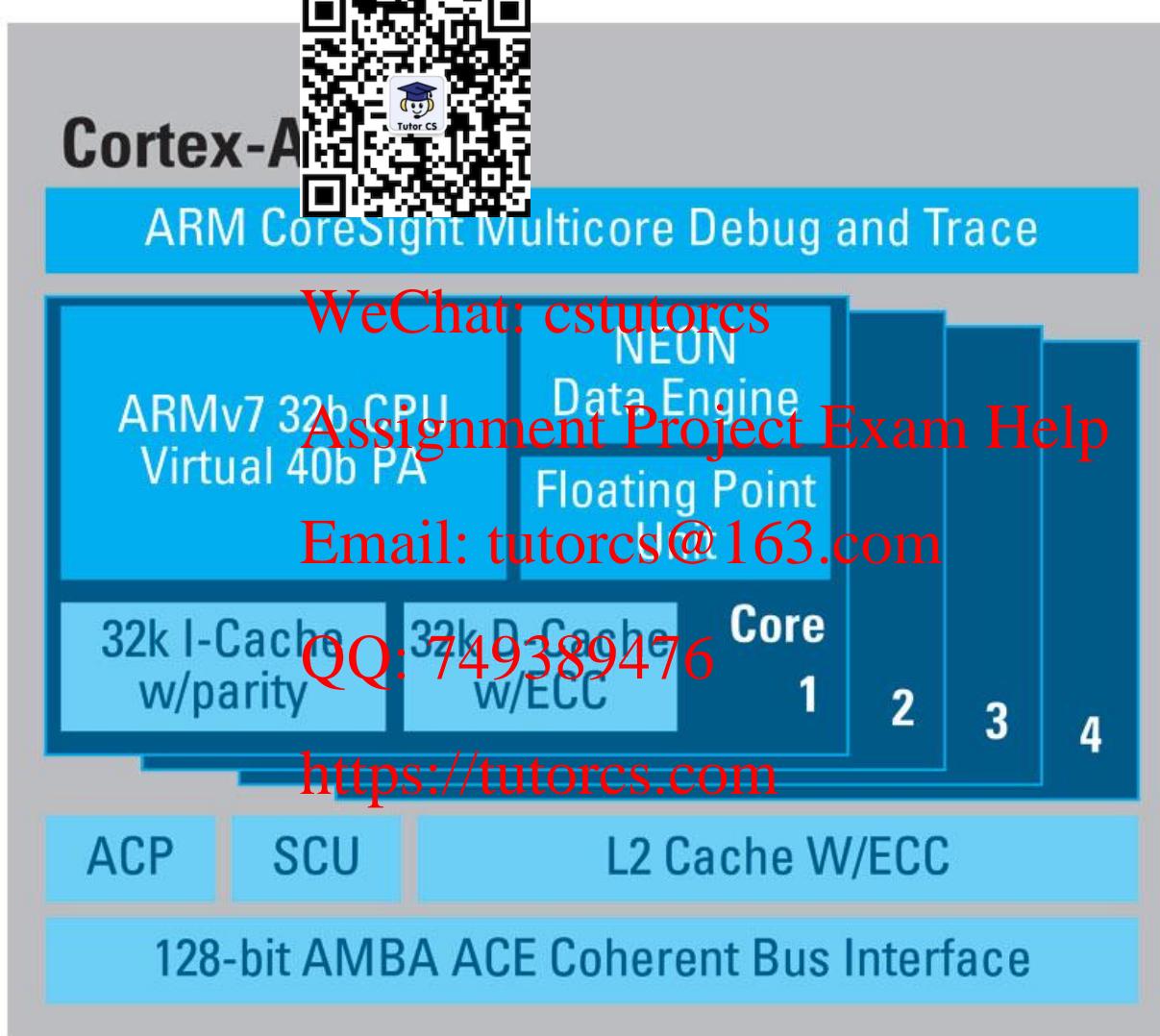
<https://tutorcs.com>



Multi-core CPUs – ARM Cortex-A15

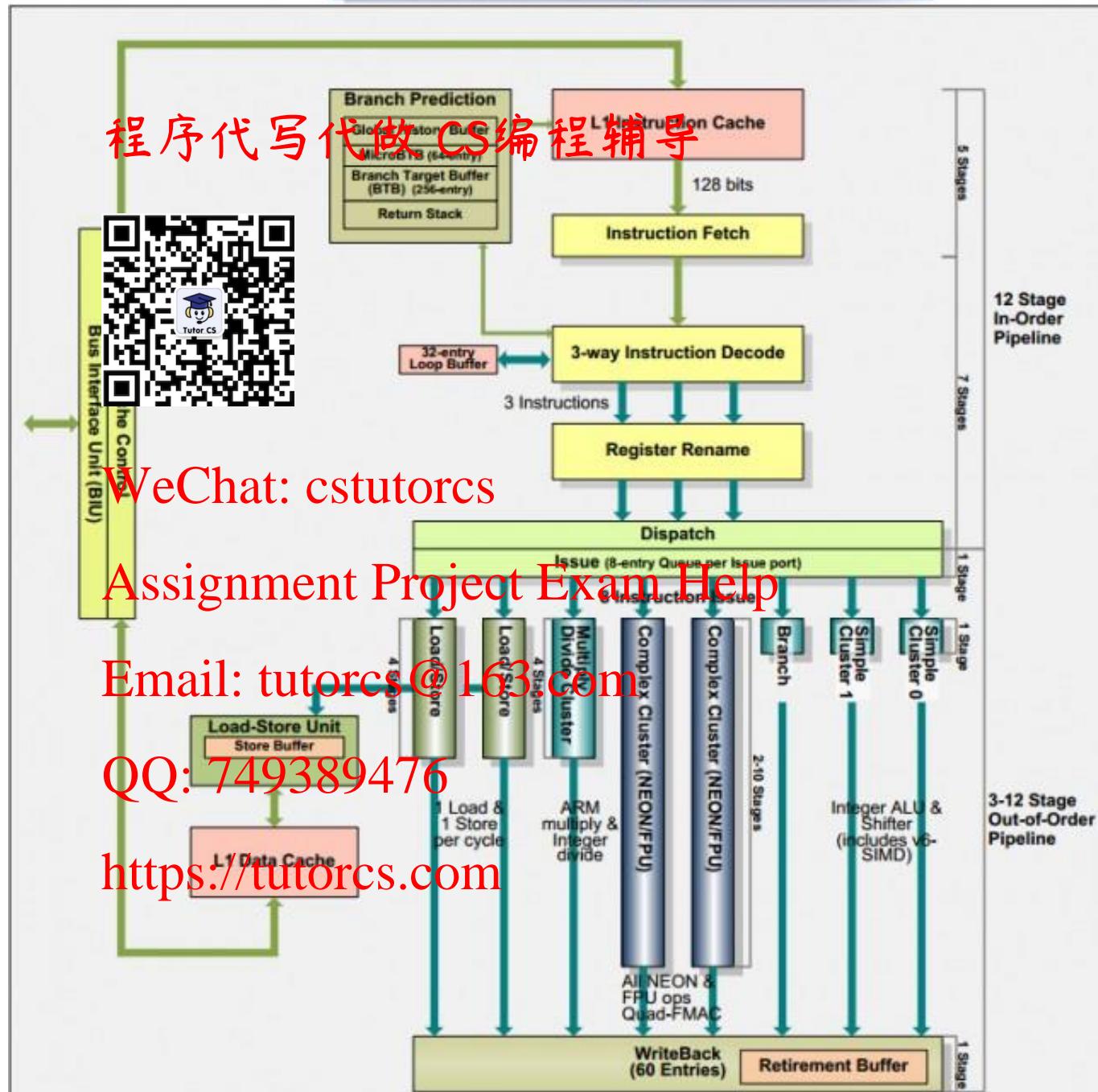
程序代写代做 CS编程辅导

25



ARM Cortex-A15

ARM Cortex-A15 Block Diagram



Multi-core CPUs - Intel i7 architecture

程序代写代做 CS编程辅导

27

- In the figure below there is a photograph of an Intel i7 CPU, where four CPU cores and the GPU reside in the same chip.



Many core Processors – Intel Xeon Phi

程序代写代做 CS编程辅导

28

- They are intended for use in supercomputers, servers, and high-end workstations
- 57-61 in-order simpler than i7 cores
- 1-1.7 Ghz
- 512bit vector instructions
- each core is connected to a ring interconnect via the Core Ring Interface



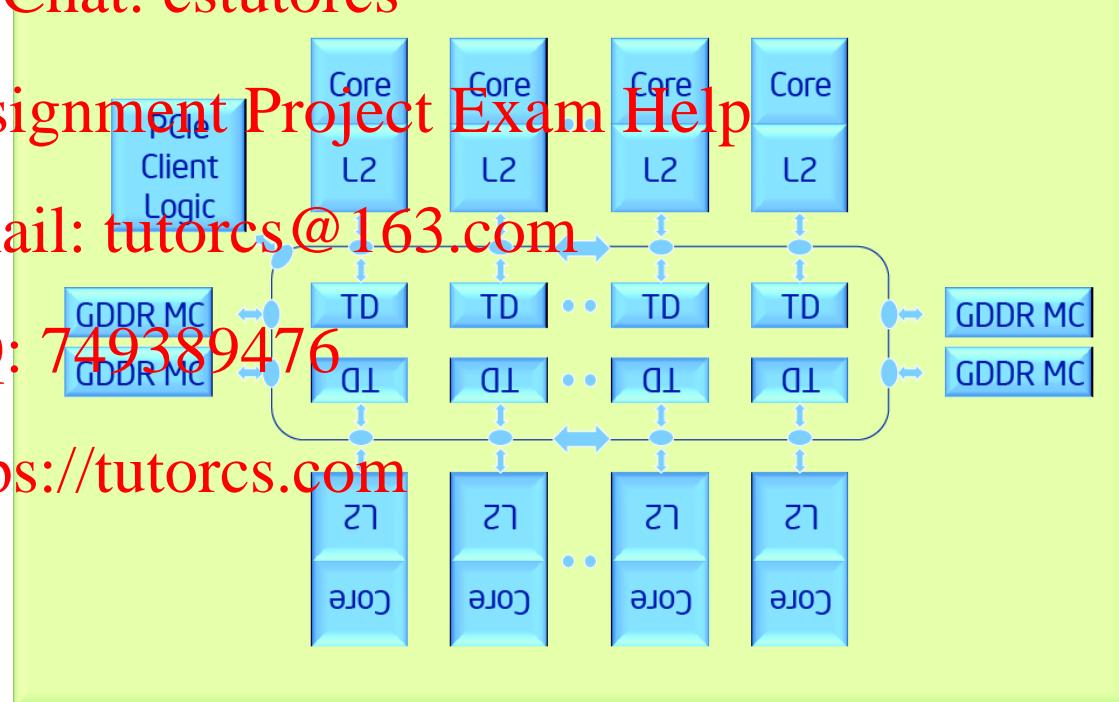
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

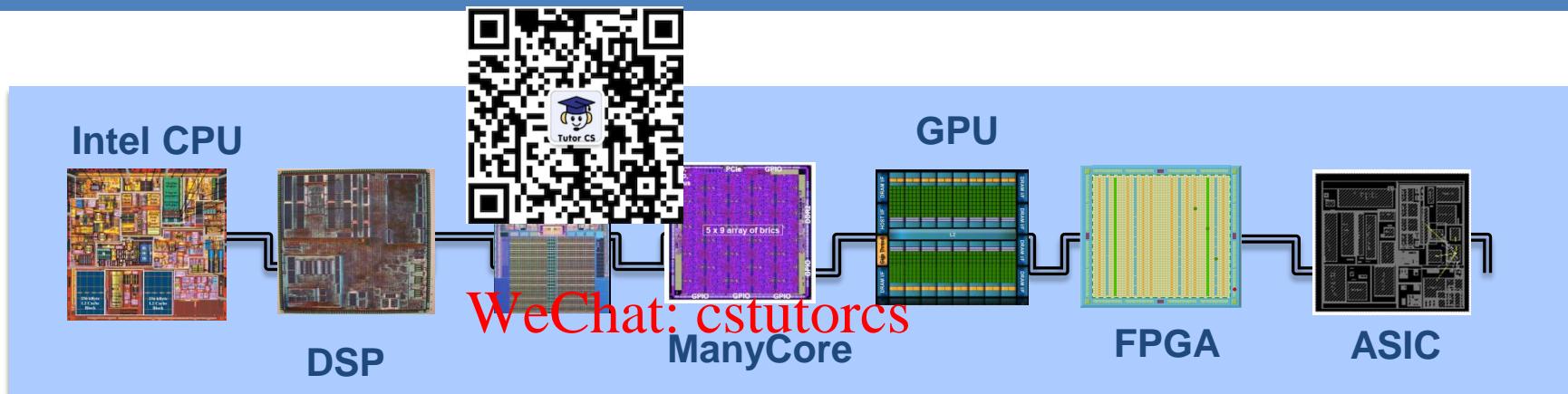
<https://tutorcs.com>



Comparison

程序代写代做 CS 编程辅导

29



Assignment Project Exam Help



CPU:

- Market-agnostic
- Accessible to many programmers (Python, C++, Verilog)
- Flexible, portable

QQ: 749389476

- Somewhat Restricted Market
- Harder to Program (VHDL, Verilog)
- More efficient than SW
- More expensive than ASIC

<https://tutorcs.com>

ASIC

- Market-specific
- Fewer programmers
- Rigid, less programmable
- Hard to build (physical)

Superscalar and Out of Order is not enough (1)

程序代写代做 CS编程辅导

30

- The approach of exploiting superscalar execution is seriously weakened by the fact that **only programs don't have a lot of fine-grained parallelism in them**



- Because of this, **CPUs normally don't exceed more than 3 instructions per cycle** when running most mainstream, real-world software, due to a combination of load latencies, cache misses, branching and dependencies between instructions

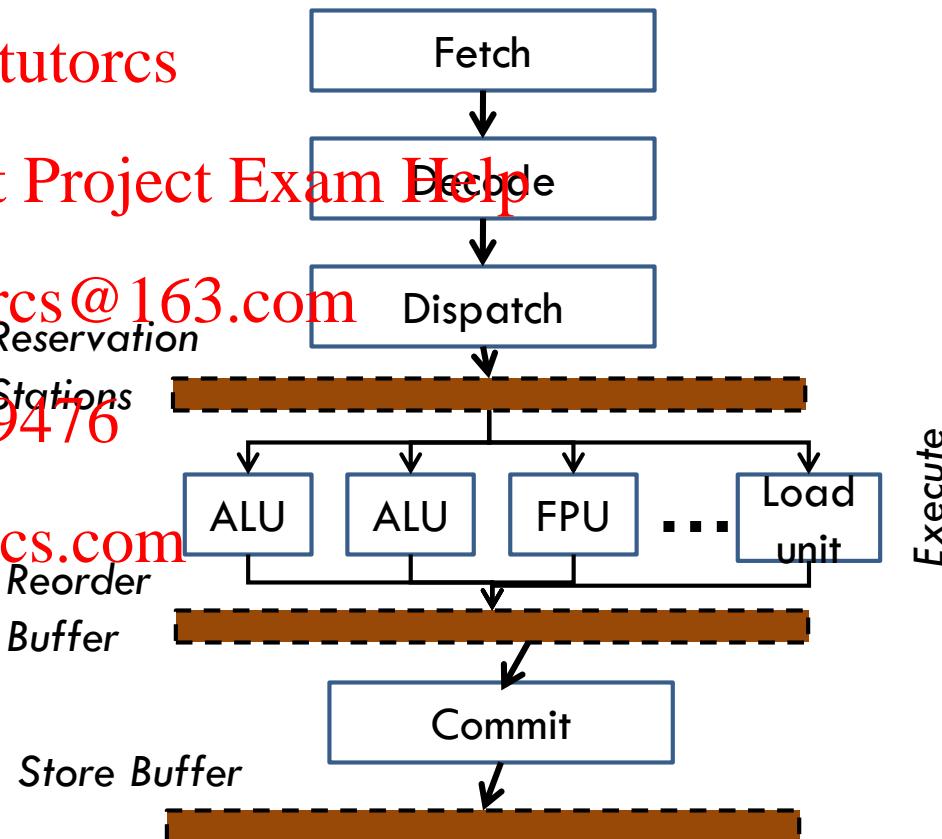
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



Superscalar and Out of Order is not enough (2)

程序代写代做 CS 编程辅导

31

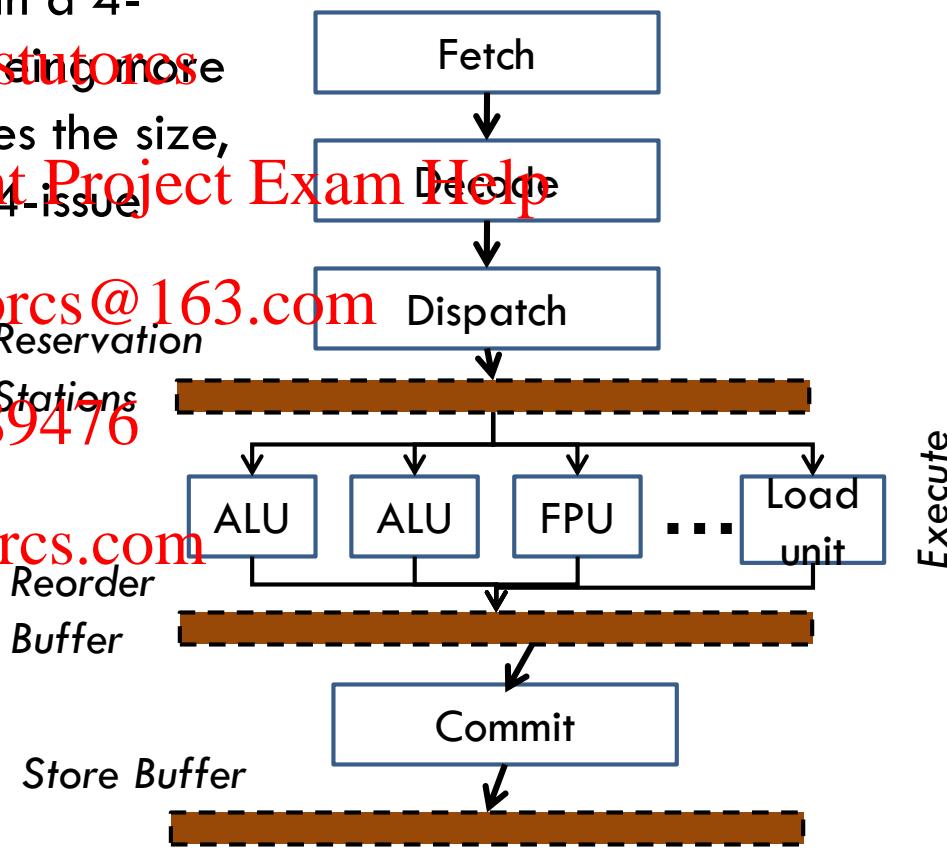
- Issuing many instructions in one cycle only ever happens for short bursts.



- Moreover, the dispatch latency of a 16-issue processor is more than 50% larger than a 4-issue design (chip area), with 6-issue being more than twice as large, 7-issue over 3 times the size, 8-issue more than 4 times larger than 4-issue (for only 2 times the width), and so on.

WeChat: cstutors
Assignment Project Exam Help
Email: tutorcs@163.com
QQ: 749389476

- Exploiting instruction level parallelism is expensive



Superscalar and Out of Order is not enough (3)

程序代写代做 CS编程辅导

32



Very important features that improve the performance of CPUs are:

- Simultaneous multi threading (SMT) or Hyper Threading in Intel processors
- Single Instruction Multiple Data (SIMD) - vectorization

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Simultaneous multi-threading (SMT) as a solution to improve CPU's performance (1)

33

- SMT is the process of a CPU which maps its physical cores into virtual cores
- Normally 2 threads are executed on one physical CPU core
- If additional independent instructions aren't available within the program being executed, there is another potential source of independent instructions – other running programs, or other threads within the same program



WeChat: cstutorcs

- Assignment Project Exam Help
- Simultaneous multi-threading (SMT) is a processor design technique which exploits exactly this type of thread-level parallelism
- Fill the empty bubbles in the pipelines with useful instructions, but this time rather than using instructions from further down in the same code, the instructions come from multiple threads running at the same time, all on the one processor core
- So, an SMT processor appears to the rest of the system as if it were multiple independent processors, just like a true multi-processor system

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Simultaneous multi-threading (SMT) as a solution to improve CPU's performance(2)

34

- From a hardware point of view, implementing SMT requires duplicating all of the parts of the processor
 - These parts only constitute a fraction of the overall processor's hardware
 - The really large and complex parts, such as the decoders and dispatch logic, the functional units, and the caches, are all shared between the threads
- On top of this, the fact that the threads in an SMT design are all sharing just one processor core and just one set of caches, has major performance downsides compared to a true multi-processor (or multi-core)
- SMT performance can actually be worse than single-thread performance
- Speedups from SMT on the Pentium 4 ranged from around -10% to +30% depending on the application(s)



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Single Instruction Multiple Data (SIMD) – Vectorization

程序代写代做 CS 编程辅导

35

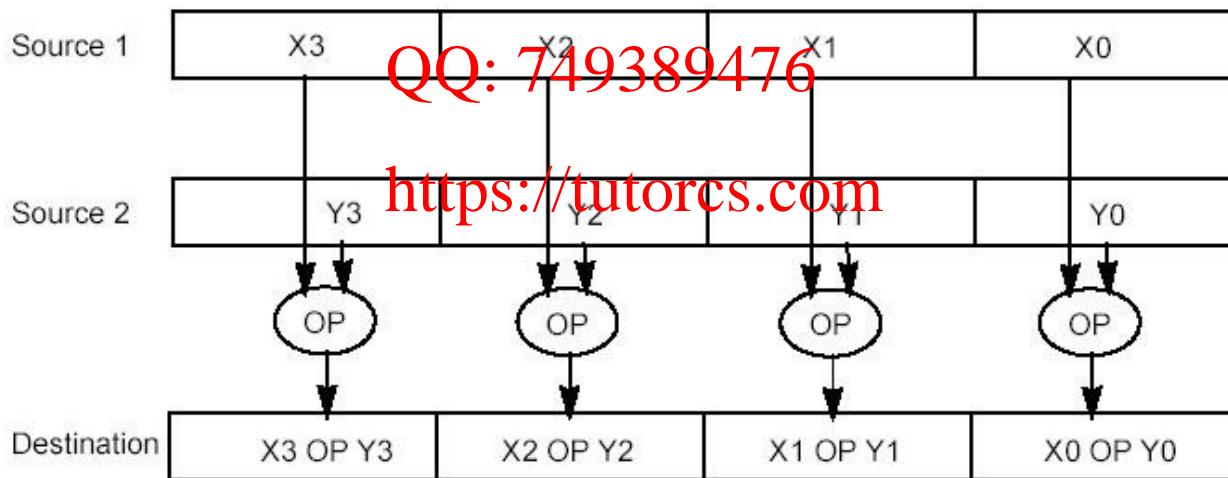
- In addition to instruction-level parallelism, there is yet another source of parallelism – data parallelism.
- Rather than looking for ways to make multiple groups of instructions in parallel, the idea is to look for ways to make one instruction apply to a group of data values in parallel.
- This is sometimes called SIMD parallelism (single instruction multiple data). More often, it's called vector processing.



WeChat: cstutorcs

Assignment Project Exam Help

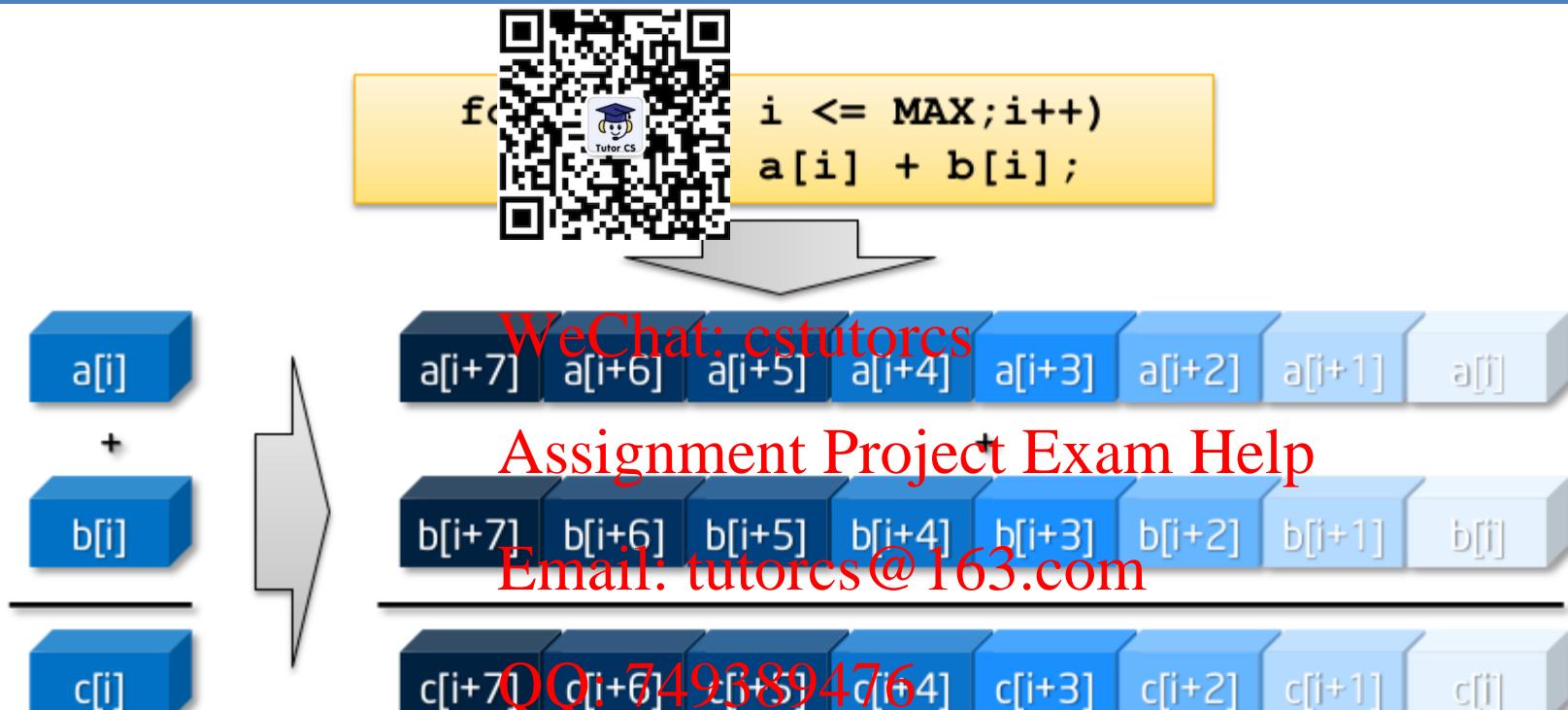
Email: tutorcs@163.com



Single Instruction Multiple Data (SIMD) –

Vectorization(2) 程序代码改CS编程辅导

36



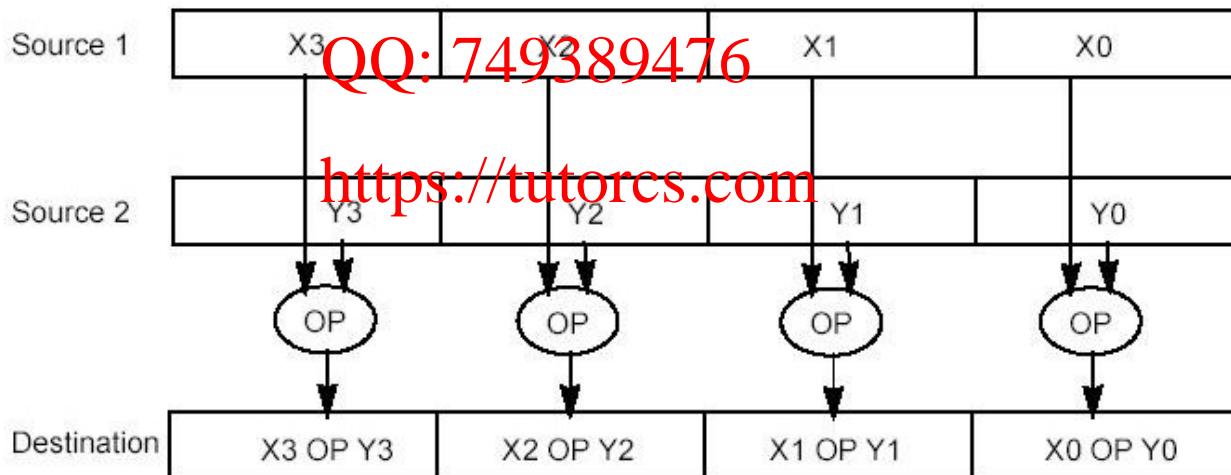
<https://tutorcs.com>

Single Instruction Multiple Data (SIMD) – Vectorization (3)

程序代写代做 CS编程辅导

37

- There is specific hardware (Intel) supporting a variety of vector instructions as well as wide registers
 - General Purpose Microprocessors
 - Laptops, desktops, servers
 - From 64-bit up to 512-bit vector instructions – all kind of instructions are supported, e.g., load/store, add/multiply, if-conditions
 - Microprocessors for embedded systems or Microcontrollers
 - From 32-bit up to 128-bit vector instructions
 - limited instruction set for Microcontrollers, but not for microprocessors



Single Instruction Multiple Data (SIMD) – Vectorization

程序代写代做 CS 编程辅导 (4)

38

- Modern compilers use vectorization – the compiler does this for us
- For applications where a lot of data parallelism is available and easy to extract, SIMD vector instructions can produce amazing speedups
- Unfortunately, it's quite difficult for a compiler to automatically make use of vector instructions
 - hand written code is more efficient
 - The key problem is that the way programmers write programs tends to serialize everything, which makes it difficult for a compiler to prove two given operations are independent and can be done in parallel.
- Rewriting just a small amount of code in key places has a widespread effect across many applications
- Almost every CPU has now added SIMD vector extensions



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com
QQ: 749589476

<https://tutorcs.com>

Current trend

程序代写代做 CS编程辅导

39

More cores . More threads . Wider vectors



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

	Intel® Xeon® processor 64-bit	Intel® Xeon® processor 5100 series	Intel® Xeon® processor 5500 series	Intel® Xeon® processor 5600 series	Intel® Xeon® processor code-named "Dally Bridge" EP	Intel® Xeon® processor code-named "Merrimack" EP	Future Xeon		Intel® Xeon Phi™ coprocessor Knights Corner	Intel® Xeon Phi™ processor & coprocessor Knights Landing ¹
Core(s)	1	2	4	6	8	12	18	>18	61	70+
Threads	2	2	8	12	16	24	36	>36	244	280+
SIMD Width	128	128	128	128	256	256	256	512	512	512

Hardware Trends

From single core processors to heterogeneous systems on a chip 程序代写代做 CS 编程辅导

40

Driven by
frequency scaling
Constrained by
power consumption

Single-Core

1975-2005

Multicore
since 2005



WeChat: cstutorcs

Heterogeneous systems
today

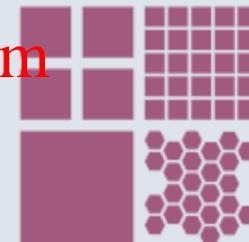
Driven by
high performance per Watt ratio
Constrained by
programming complexity

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



GPU

CPU

DSP

FPGA

H. Esmaeilzadeh et al., "Dark silicon and the end of multicore scaling", International Symposium on Computer Architecture (ISCA). ACM, 2011.
M. Zahran, "Heterogeneous Computing Here to Stay". ACM Queue, Nov/Dev 2016.

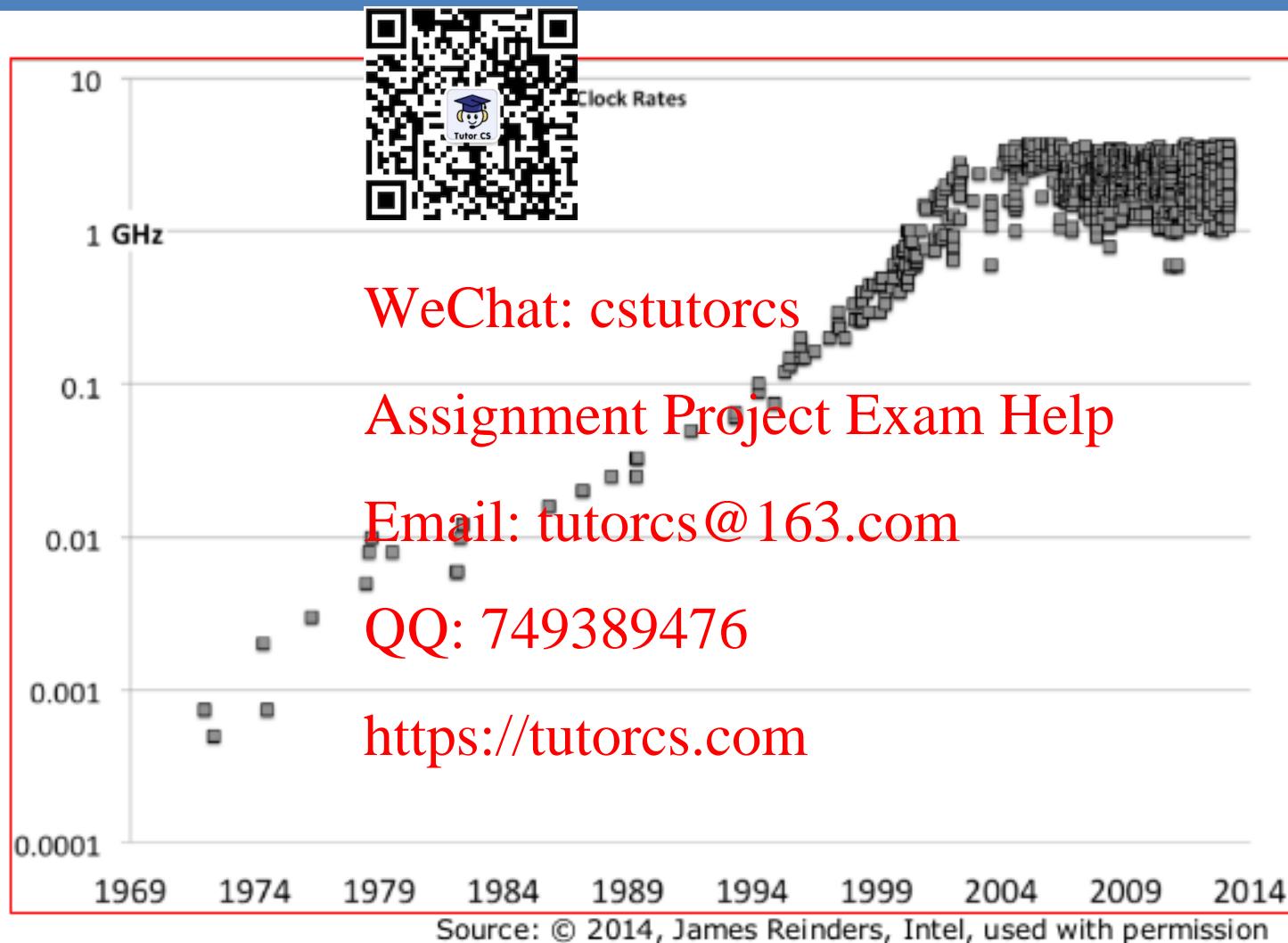
Unrestricted © Siemens AG 2017

Taken from https://embb.io/downloads/MTAPI_EMBB.pdf

The CPU frequency has ceased to grow

程序代写代做 CS编程辅导

41



Moore's Law Is STILL Going Strong

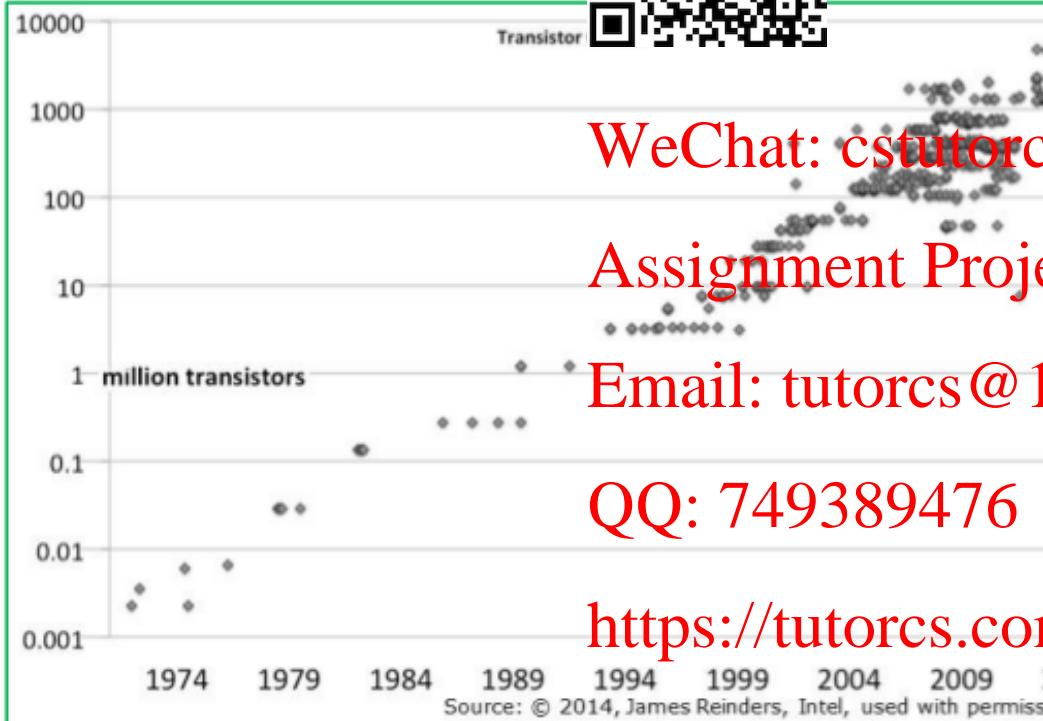
程序代写代做CS编程辅导

Hardware performance potential *continues to grow*

"We think we can continue to follow Moore's Law for at least another 10 years."



Intel Senior Fellow Mark Bohr, 2015



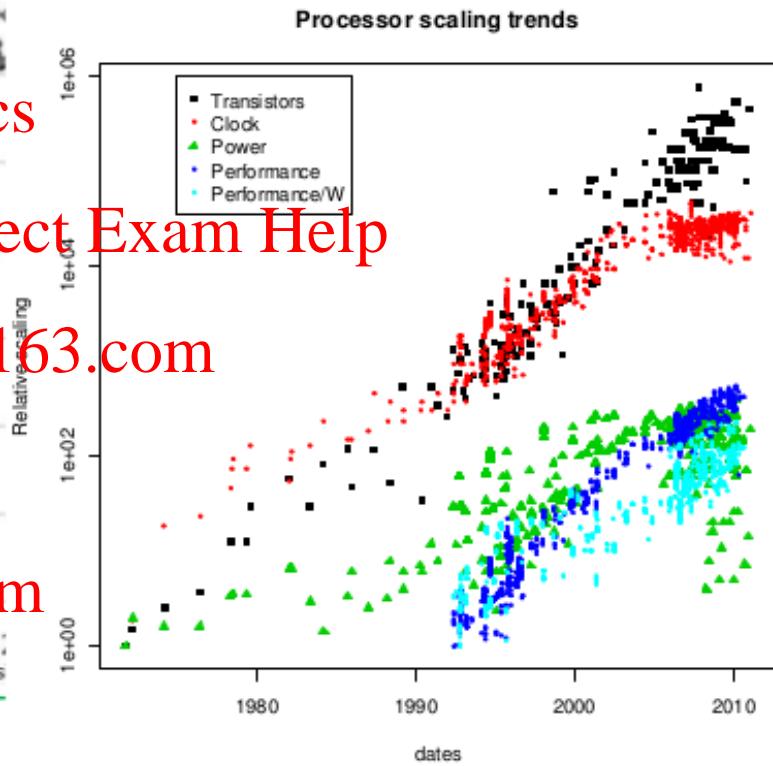
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>



Hardware Evolution

程序代写代做 CS编程辅导

43

- Scalar Processors
- Pipelined Processors
- Superscalar and VLIW Processors
- Out of order Processors
- Vectorization
- Multicore Processors
- Heterogeneous systems



WeChat: cstutorcs

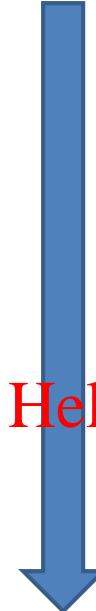
Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Time



Heterogeneous computing (1)

程序代写代做 CS编程辅导

44

Single core Era ->



Era -> Heterogeneous Systems Era

- **Heterogeneous computing refers to systems that use more than one kind of processors or cores**

WeChat: cstutorcs

- These systems gain performance or energy efficiency not just by adding the same type of processors, but by adding dissimilar (co-)processors, usually incorporating specialized processing capabilities to handle particular tasks

- Systems with General Purpose Processors (GPPs), GPUs, DSPs, ASIPs etc.

<https://tutorcs.com>

- **Heterogeneous systems offer the opportunity to significantly increase system performance and reduce system power consumption**

Heterogeneous computing (2)

程序代写代做 CS编程辅导

45

- Software issues:

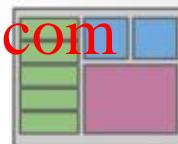
- Offloading
- Programmability – third party code (C code), GPU code (CUDA), FPGA code (VHDL)
- Portability - What happens if your code runs on a machine with an FPGA instead of a GPU



WeChat: estutorcs

Assignment Project Exam Help
Comparisons between
Homogeneous and Heterogeneous Computing

Email: tutorcs@163.com



QQ: 749389476

Symmetric, Same cores (Usually CPUs)	Assymmetric, Different cores (CPUs, GPUs, DSPs and accelerators)
operation is guaranteed to be same at each core	operation cannot be supposed to be same at each core
easy to off load tasks	more complicated to off load tasks
good compatibility	less compatibility specialized for specific tasks

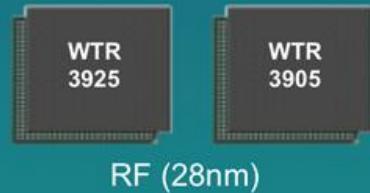
<https://tutorcs.com>

Heterogeneous computing (3) – A mobile phone

程序代写代做CS编程辅导

46

The Complete Snapdragon Platform



Think-Pair-Share Exercise

程序代写代做 CS编程辅导

- What is in your opinion the most appropriate computer architecture for a smart phone



- a. 1 microcontroller
- b. 1 normal speed GPP, e.g., Pentium II
- c. 1 quad-core Intel i7
- d. A heterogeneous computer architecture with 1 normal speed GPP, 1 DSP, 1 GPU and a few Microcontrollers

WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Conclusions

程序代写代做 CS 编程辅导

48

- Modern Computer Systems → Parallel Heterogeneous Computer Architectures
- General purpose processor → specific purpose processors + co-processors
- Heterogeneous systems offer the opportunity to significantly
 - increase performance
 - reduce power consumption
 - reduce cost
- Issues:
 - Programmability
 - Portability
 - Design good Compilers – optimize the code



WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

References and Further Reading

程序代写代做 CS 编程辅导

49

- [1] Nohl, A, Schirrmeister, F & Application specific processor design:
Architectures, design methods and tools" Computer-Aided Design (ICCAD), 2010
IEEE/ACM International Conference, Nov. 2010.



- [2] Tom Spyrou Challenges in the Static Timing Analysis of FPGA's, ALTERA, TAU 2015
3/2015

WeChat: cstutorcs

- [3] Modern Microprocessors A 90-Minute Guide!. Lighterra,

<http://www.lighterra.com/papers/modernmicroprocessors/>

Assignment Project Exam Help

- [4] Introduction to GPU computing, available at

http://www.int.washington.edu/PROGAMS/10-11/week3/clark_01.pdf

- [5] Yousef Qasim, P Radyumna Janga, Sharath Kumar, Hani Alesaimi, APPLICATION
SPECIFIC PROCESSORS, ECE/CS 570 PROJECT FINAL REPORT, available at

http://web.engr.oregonstate.edu/~qassimy/index_files/Final_ECE570.asp_2012_Project_Report.pdf

QQ: 749389476

<https://tutorcs.com>

- [6] William Stallings, Computer Organization & Architecture. Designing for Performance,
Seventh Edition

- [7] Andrew S. Tanenbaum, Todd Austin, Structured Computer Organization. Sixth Edition,
PEARSON

程序代写代做 CS编程辅导



Thank you
WeChat: cstutorcs

Assignment Project Exam Help

Email: tutorcs@163.com

QQ: 749389476

<https://tutorcs.com>

Date

04/11/2019

School of Computing
(University of Plymouth)