Computer Organization and Architecture

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DEUEEE

YAŞAR UNIVERSITY, 2005
based on
Chapter 1-2 of
Computer Organization and Architecture
William Stallings

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Content

Week	CONTENT
1	Introduction to Computer Organization and Architecture, Comparison, Structure and Function, Why Organization, Computer Basics
2	History of Computers, Computer Evolution, Design and Performance Considerations
3	Computer Structure, Components, Functions, Bus Interconnection
4	Memory, Input-Output Units, Operating System
5	Instruction Methodology, Instuction Cycle, Instruction types
6	First Midterm Exam, Exam Discussion
7	Central Processing Unit-1: Computer Arithmetic, Instruction Sets,
8	Central Processing Unit-2: Addressing Modes and Formats, CPU Structure
9	Control Unit,
10	Input-Output Organization
11	Memories and Memory Organization
12	Software and Operating System Organization
13	Computer Architectures, Von-Neumann Architecture, RISC Computers, Parallel Processing
14	Second Midterm Exam, Exam Discussion

References

- Computer Organization and Architecture
  William Stallings, 2003, VI edition
- Computer System Architecture
  M. Morris Mano, 1993, III edition
- Computer Organization
  V.C. Hamacher, Z.G.Vranesic,S. G. Zaky, 1996, IV edition

Grading

- 30% Midterm I
- 40% Midterm II
- 20% HW+Presentation
- 10% Attendance

Architecture & Organization 1

- Architecture is those attributes visible to the programmer
  - Instruction set, number of bits used for data representation, I/O mechanisms, addressing techniques.
  - e.g. Is there a multiply instruction?
- Organization is how features are implemented
  - Control signals, interfaces, memory technology.
  - e.g. Is there a hardware multiply unit or is it done by repeated addition?

Architecture & Organization 2

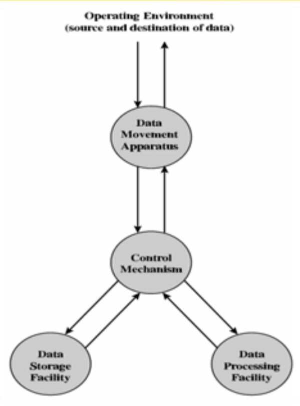
- All Intel x86 family share the same basic architecture
- The IBM System/370 family share the same basic architecture since 1970
- This gives code compatibility
  - At least backwards
- Organization differs between different versions

Structure & Function

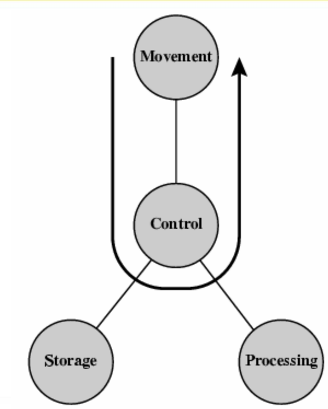
- A hierarchical system is a set of interrelated subsystems, each of the latter, in turn, hierarchical in structure until we reach some lowest level of elementary subsystem.
- Structure is the way in which components relate to each other
- Function is the operation of individual components as part of the structure

Function

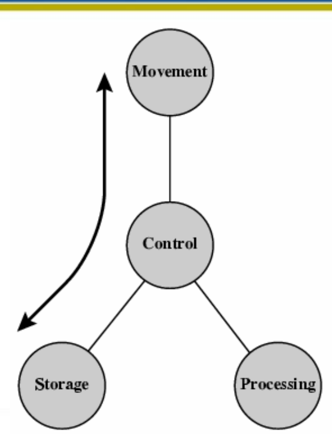
- All computer functions are:
  - Data processing
  - Data storage
  - Data movement
  - Control



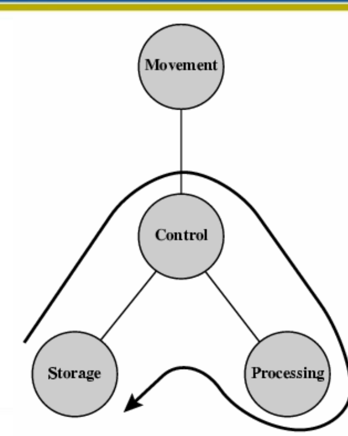
Operations (1) Data movement



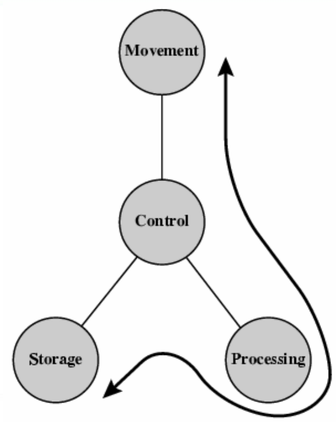
Operations (2) Storage



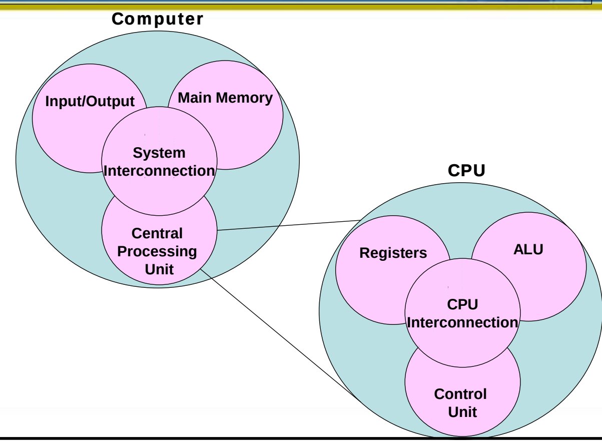
Operation (3) Processing from/to storage



Operation (4)
Processing from storage to I/O



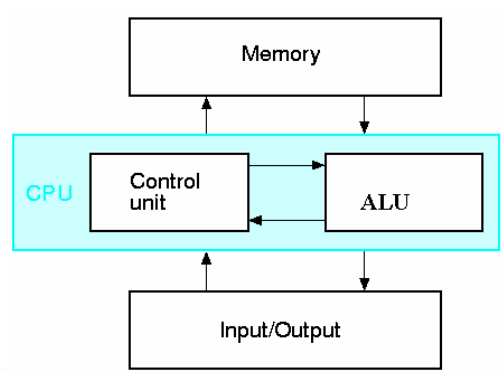
Structure - Top Level



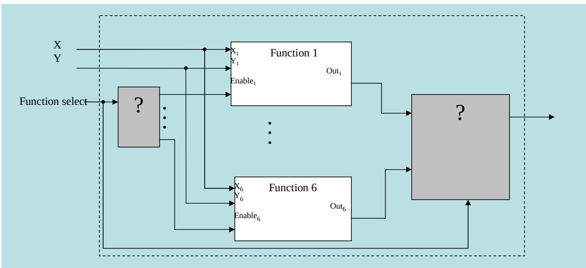
Computer Organization

- Synonymous with “architecture” in many uses and textbooks
- We will use it to mean the underlying implementation of the architecture
- Transparent to the programmer
- An architecture can have a number of organizational implementations
  - – Control signals
  - – Technologies
  - – Device implementations

Computer



Basic Computer



A basic computer making several operations like addition, multiplification

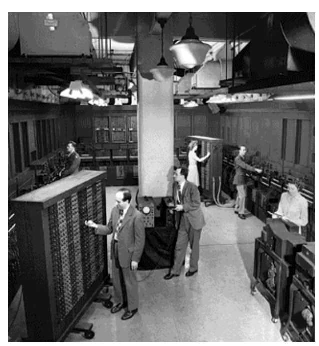
- Requires Command decoding
- Requires data
- Requires data and output seperation / combination
- Requires function implementtaion

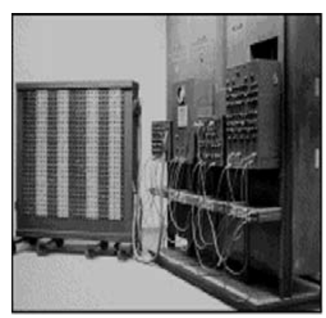
Chapter 2
Computer Evolution and Performance

ENIAC - background

- Electronic Numerical Integrator And Computer
- Eckert and Mauchly
- Constructed in University of Pennsylvania
- Trajectory tables for weapons
- Started 1943
- Finished 1946
  - Too late for war effort
- Used until 1955

ENIAC 1946





It was U shaped, 25m long, 2.5m high and 1m wide

ENIAC - details

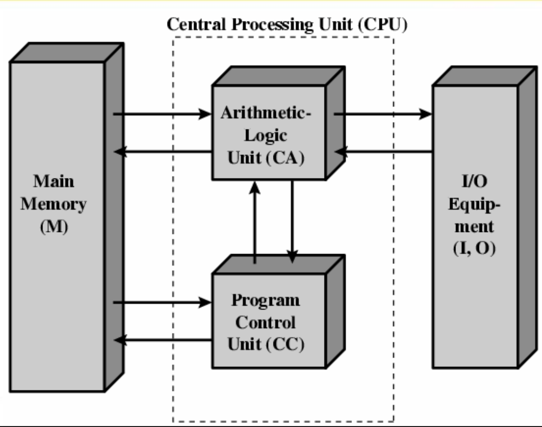
- Decimal (not binary)
- 20 accumulators of 10 digits
- Programming was done by plugging cables and setting switches. Data was entered by punched cards.
- Programming for typical calculations took from half a hour to a day.
- 18,000 vacuum tubes (reliability problem)
- 30 tons
- 140 kW power consumption (enough to light a small town)
- 5,000 additions per second

John Von Neumann

- Von Neumann (mathematician) was a consultant to both ENIAC and EDVAC (Electronic discrete variable computer) projects
- Proposal of Neumann EDVAC:

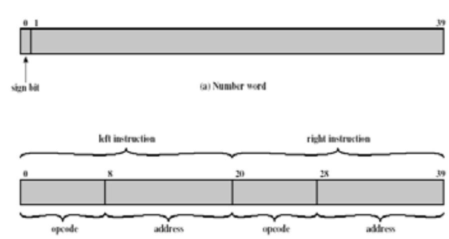
Basic elements of the stored-program computer
  - **A memory** containing both data and instructions
  - **A calculating unit** capable of performing both arithmetic and logical operations on the data
  - **A control unit**, which could interpret an instruction retrieved from the memory and select alternative courses of action based on the results of previous operations
- Princeton Institute for Advanced Studies
  - IAS (prototype of all subsequent general-purpose computers)
- Started in 1946, Completed in 1952

Structure of von Neumann machine



IAS - details

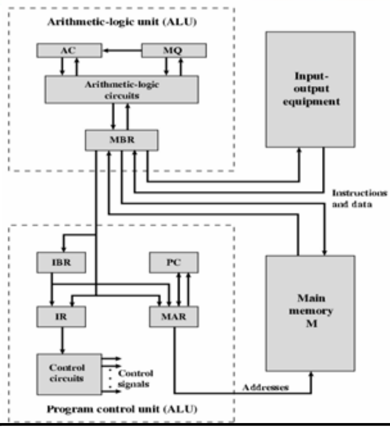
- 1000 x 40 bit words
  - Binary number
  - 2 x 20 bit instructions



Structure of IAS

Set of registers (storage in CPU) :

- Memory Buffer Register
- Memory Address Register
- Instruction Register
- Instruction Buffer Register
- Program Counter
- Accumulator
- Multiplier Quotient



IAS Instruction Set

- IAS have 21 instructions which can be grouped as
  - Data transfer
  - Unconditional branch
  - Conditional branch (sign condition)
  - Arithmetic
  - Address modify

Commercial Computers

- 1947 - Eckert-Mauchly Computer Corporation
- UNIVAC I (Universal Automatic Computer)
- Became part of Sperry-Rand Corporation
- Late 1950s - UNIVAC II
  - Faster
  - More memory

IBM

- Major manufacturer of punched-card processing equipment
- 1953 - the 701
  - IBM's first stored program computer
  - Scientific calculations
- 1955 - the 702
  - Business applications
- Lead to 700/7000 series

Transistors

- Replaced vacuum tubes
- Smaller
- Cheaper
- Less heat dissipation
- Solid State device
- Made from Silicon (Sand)
- William Shockley, Walter Brattain, and John Bardeen succeeded in creating the *first point-contact germanium transistor* in1947
- Bipolar junction transistor (Shockley) - 1950
- Field effect transistor (MOS FET) - 1962

Transistor Based Computers

- Second generation machines
- NCR & RCA produced small transistor machines
- DEC - 1957
  - Produced PDP-1
- IBM 7000
  - IBM 700/7000 series (1952-1964)

Model Number	First Delivery	CPU Tech-nology	Memory Tech-nology	Cycle Time (µs)	Memory Size (K)	Number of Opcodes	Number of Index Registers	Hardwired Floating-Point	I/O Overlap (Channels)	Instruction Fetch Overlap	Speed (relative to 701)
701	1952	Vacuum tubes	Electrostatic tubes	30	2–4	24	0	no	no	no	1
704	1955	Vacuum tubes	Core	12	4–32	80	3	yes	no	no	2.5
709	1958	Vacuum tubes	Core	12	32	140	3	yes	yes	no	4
7090	1960	Transistor	Core	2.18	32	169	3	yes	yes	no	25
7094 I	1962	Transistor	Core	2	32	185	7	yes (double precision)	yes	yes	30
7094 II	1964	Transistor	Core	1.4	32	185	7	yes (double precision)	yes	yes	50

IBM 7094

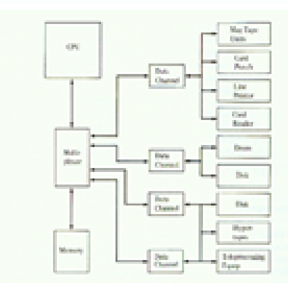
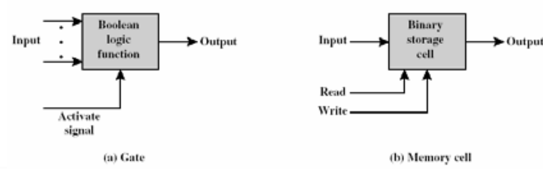


FIGURE 2.5. An IBM 7094 configuration.

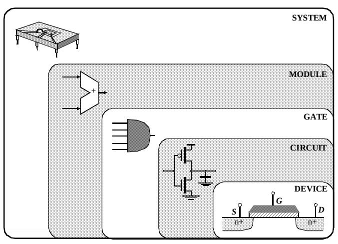
Microelectronics

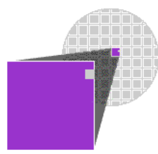
- Basic operations in a computer
  - data storage
  - data processing
  - data movement
  - control
- These operations can be performed by using gates and memory cells.



Microelectronics

- Literally - "small electronics"
- The gates and memory cells can be manufactured on a semiconductor (1958)
- e.g. silicon wafer





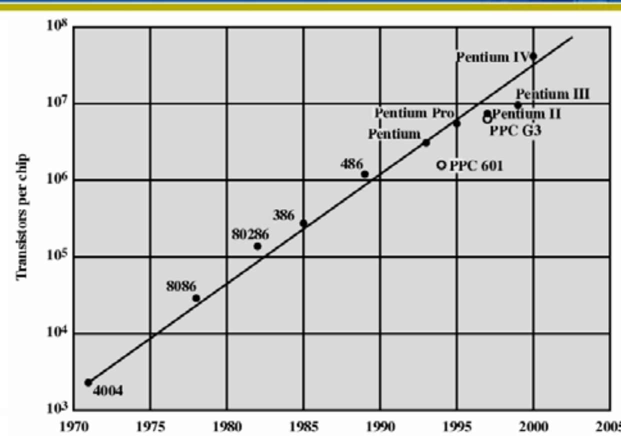
Generations of Computer

- Vacuum tube - 1946-1957
- Transistor - 1958-1964
- Small scale integration - 1965 on
  - Up to 100 devices on a chip
- Medium scale integration - to 1971
  - 100-3,000 devices on a chip
- Large scale integration - 1971-1977
  - 3,000 - 100,000 devices on a chip
- Very large scale integration - 1978 to date
  - 100,000 - 100,000,000 devices on a chip
- Ultra large scale integration
  - Over 100,000,000 devices on a chip

Moore's Law

- Increased density of components on chip
- Gordon Moore - cofounder of Intel
- Number of transistors on a chip will double every year
- Since 1970's development has slowed a little
  - Number of transistors doubles every 18 months
- Cost of a chip has remained almost unchanged
- Higher packing density means shorter electrical paths, giving higher performance
- Smaller size gives increased flexibility
- Reduced power and cooling requirements
- Fewer interconnections increases reliability

Growth in CPU Transistor Count



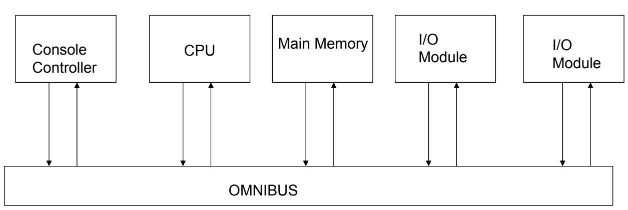
IBM 360 series

- 1964
- Replaced (& not compatible with) 7000 series
- First planned “family” of computers
  - Similar or identical instruction sets
  - Similar or identical O/S
  - Increasing speed
  - Increasing number of I/O ports (i.e. more terminals)
  - Increased memory size
  - Increased cost
- Multiplexing

DEC PDP-8

- 1964
- First minicomputer
- Did not need air conditioned room
- Small enough to sit on a lab bench
- $16,000
  - $100k+ for IBM 360
- Embedded applications & OEM
- BUS STRUCTURE

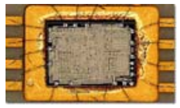
DEC - PDP-8 Bus Structure



Semiconductor Memory

- 1970
- Fairchild
- Size of a single core
  - i.e. 1 bit of magnetic core storage
- Holds 256 bits
- Non-destructive read
- Much faster than core
- Capacity approximately doubles each year

Intel



- 1971 - 4004
  - First microprocessor
  - All CPU components on a single chip
  - 4 bit
- Followed in 1972 by 8008
  - 8 bit
  - Both designed for specific applications
- 1974 - 8080
  - Intel's first general purpose microprocessor
  - Faster, richer instruction set, large addressing capability

Intel Microprocessors

1970s Processors

	4004	8008	8080	8086	8088
Introduced	11/15/71	4/1/72	4/1/74	6/8/78	6/1/79
Clock Speeds	108KHz	200KHz	2MHz	5MHz, 8MHz, 10MHz	5MHz, 8MHz
Bus Width	4 bits	8 bits	8 bits	16 bits	8 bits
Number of Transistors	2,300 (10 microns)	3,500 (10 microns)	4.500 (6 microns)	29,000 (3 microns)	29,000 (3 microns)
Addressable Memory	640 bytes	16 KBytes	64 KBytes	1 MB	1 MB
Virtual Memory	--	--	--	--	--
Brief Description	First microcomputer chip, Arithmetic manipulation	Data/character manipulation	10X the performance of the 8008	10X the performance of the 8080	Identical to 8086 except for its 8-bit external bus

Intel Microprocessors

1980s Processors

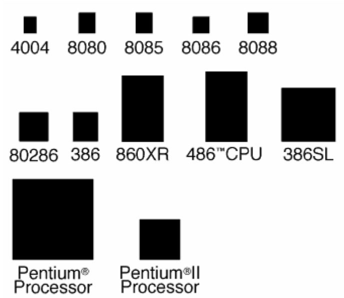
	80286	Intel386TM DX Microprocessor	Intel386TM SX Microprocessor	Intel486TM DX CPU Microprocessor
Introduced	2/1/82	10/17/85	6/16/88	4/10/89
Clock Speeds	6MHz, 8MHz, 10MHz, 12.5MHz	16MHz, 20MHz, 25MHz, 33MHz	16MHz, 20MHz, 25MHz, 33MHz	25MHz, 33MHz, 50MHz
Bus Width	16 bits	32 bits	16 bits	32 bits
Number of Transistors	134,000 (1.5 microns)	275,000 (1 micron)	275,000 (1 micron)	1.2 million (1 micron) (.8 micron with 50MHz)
Addressable Memory	16 megabytes	4 gigabytes	16 megabytes	4 gigabytes
Virtual Memory	1 gigabyte	64 terabytes	64 terabytes	64 terabytes
Brief Description	3-6X the performance of the 8086	First X86 chip to handle 32-bit data sets	16-bit address bus enabled low-cost 32-bit processing	Level 1 cache on chip

Intel Microprocessors

1990s Processors

	Intel486TM SX Microprocessor	Pentium® Processor	Pentium® Pro Processor	Pentium® II Processor
Introduced	4/22/91	3/22/93	11/01/95	5/07/97
Clock Speeds	16MHz, 20MHz, 25MHz, 33MHz	60MHz,66MHz	150MHz, 166MHz, 180MHz, 200MHz	200MHz, 233MHz, 266MHz, 300MHz
Bus Width	32 bits	64 bits	64 bits	64 bits
Number of Transistors	1.185 million (1 micron)	3.1 million (.8 micron)	5.5 million (0.35 micron)	7.5 million (0.35 micron)
Addressable Memory	4 gigabytes	4 gigabytes	64 gigabytes	64 gigabytes
Virtual Memory	64 terabytes	64 terabytes	64 terabytes	64 terabytes
Brief Description	Identical in design to Intel486™ DX but without math coprocessor	Superscalar architecture brought 5X the performance of the 33-MHz Intel486™ DX processor	Dynamic execution architecture drives high-performing processor	Dual independent bus, dynamic execution, Intel MMX™ technology

Approximate Size Relationship



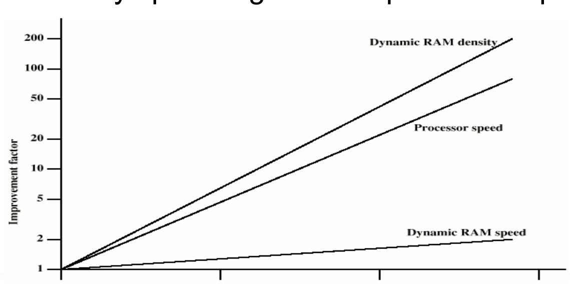
Source:
http://www.intel.com/intel/intelis/museum/online/hist_micro/hof/tspecs.htm

Speeding it up

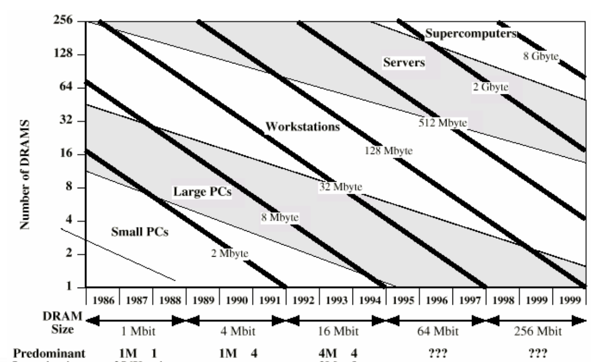
- Pipelining
- On board cache
- Branch prediction
- Data flow analysis
- Speculative execution

Performance Mismatch

- Processor speed increased
- Memory capacity increased
- Memory speed lags behind processor speed



Trends in DRAM use



Solutions

- Increase number of bits retrieved at one time
  - Make DRAM “wider” rather than “deeper”
- Change DRAM interface
  - Cache
- Reduce frequency of memory access
  - More complex cache and cache on chip
- Increase interconnection bandwidth
  - High speed buses
  - Hierarchy of buses

Pentium Evolution (1)

- **8080**
  - **first general purpose microprocessor**
  - **8 bit data path**
  - **Used in first personal computer – Altair**
- **8086**
  - **much more powerful**
  - **16 bit**
  - **instruction cache, prefetch few instructions**
  - **8088 (8 bit external bus) used in first IBM PC**
- **80286**
  - **16 Mbyte memory addressable**
  - **up from 1Mb**
- **80386**
  - **32 bit**
  - **Support for multitasking**

Pentium Evolution (2)

- 80486
  - sophisticated powerful cache and instruction pipelining
  - built in maths co-processor
- Pentium
  - Superscalar
  - Multiple instructions executed in parallel
- Pentium Pro
  - Increased superscalar organization
  - Aggressive register renaming
  - branch prediction
  - data flow analysis
  - speculative execution

Pentium Evolution (3)

- Pentium II
  - MMX technology
  - graphics, video & audio processing
- Pentium III
  - Additional floating point instructions for 3D graphics
- Pentium 4
  - Note Arabic rather than Roman numerals
  - Further floating point and multimedia enhancements
- Itanium
  - 64 bit

Internet Resources

- http://www.intel.com/
  - Search for the Intel Museum
- http://www.ibm.com
- http://www.dec.com
- Charles Babbage Institute
- PowerPC
- Intel Developer Home