Motivation for Multi-processing Systems

- Performance can be improved in different ways
  - Higher clock rates
  - Power consumption varies as the square of clock rate
  - Superscalar operation with multiple execute units
  - Requires more complex control units
    - To schedule instructions
    - To avoid dependencies
  - Uses many more transistors
  - Consumes more power and dissipates more heat
  - The degree of improvement reaches a limit

Motivation for Multi-processing Systems

- Multiple less sophisticated processors can be used
  - Provide similar performance at a lower cost
  - Allows slower clock rates
  - Consumes less power
  - Generates less heat
- Coprocessors provide a form of multiprocessing
  - Asymmetric in nature
    - MIPS examples:
      - CP1 for floating point
      - CP0 for managing exceptions
- Vector & array coprocessors may be used

Multi-processor Systems

- Multi-processing Systems
  - Contain more than one processor
  - The processors are identical in an SMP (symmetric multi-processor)
  - Also known as homogeneous

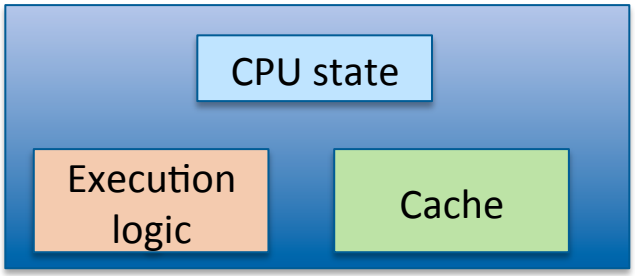
- Each processor plugs into a different socket
  - These are board level multiprocessors
  - A bus connects the processors
  - Provides additional performance on a single computer system
  - To benefit, software must take advantage of the additional processors
  - Inclusion of more processors in an SMP is a choice

Multi-core Systems

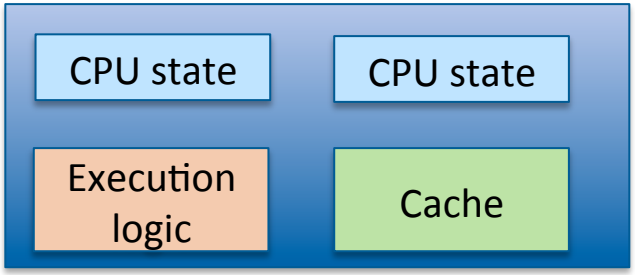
- "Core" logic is replicated on the same chip
  - Multiple cores are presented to the OS
  - Cores share data through on-chip logic or shared caches
  - Homogenous systems use identical cores
  - Heterogeneous systems mix cores having different:
    - ISA
    - Chip area
    - Performance
    - Power dissipation
  - These are chip level multiprocessors
    - Each core has a separate set of registers
    - The number of cores is predetermined
  - Issues relating to shared memory must be handled

Multi-core Systems

- Multi-core concepts & designs developed over time



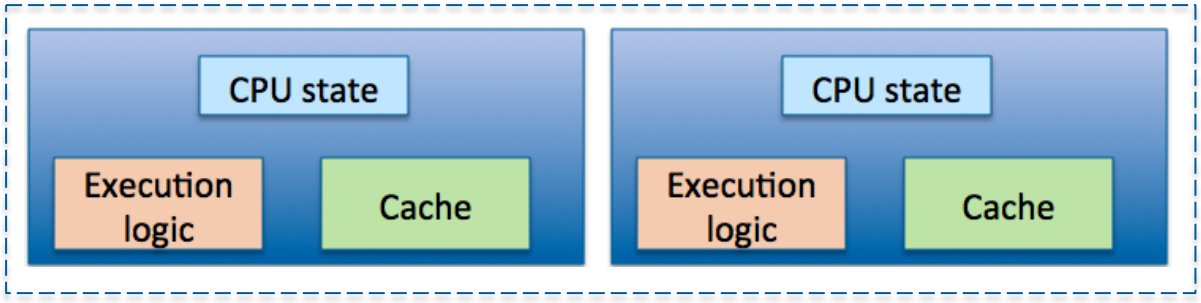
Basic single-core processor



Single-core processor with hyperthreading

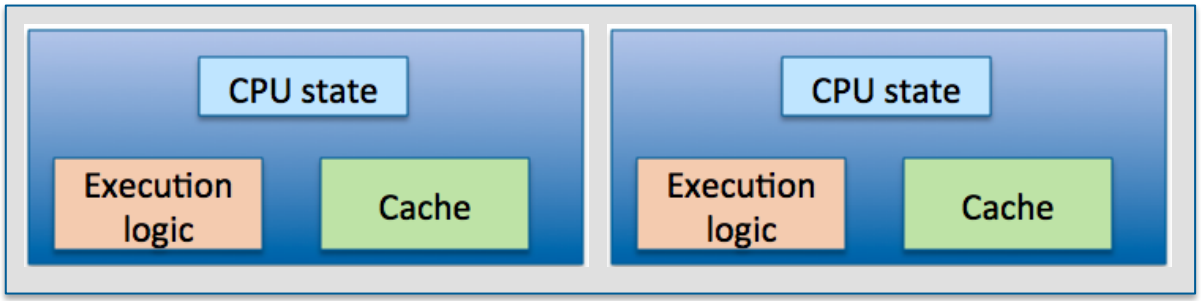
Hyperthreading also known as simultaneous multithreading uses additional hardware registers to allow one physical processor to act as two virtual processors

Multi-core Systems



Two or more separate processors

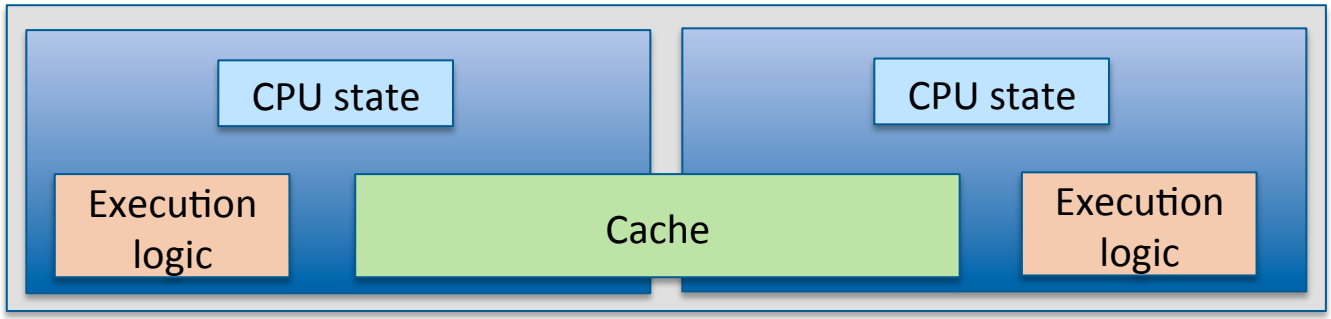
The processors share memory and the same environment (motherboard)
The dashed lines mean they are in the same system but not on the same chip



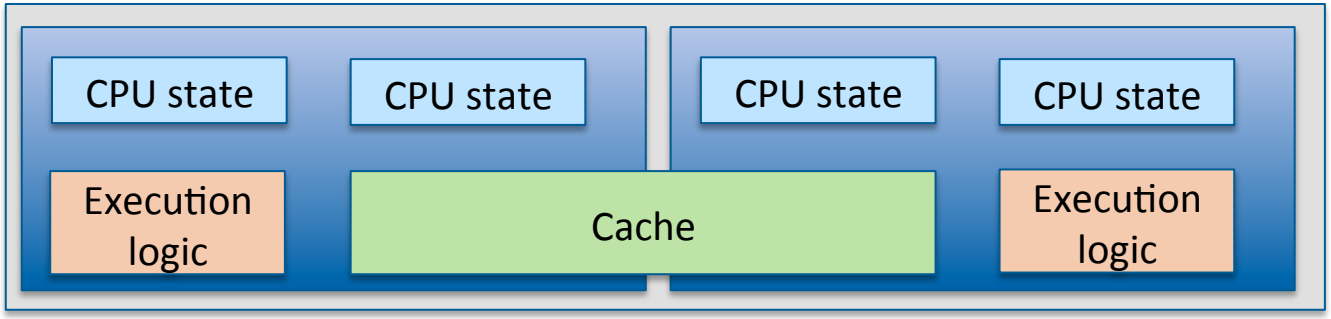
Multiple cores

Multi-core processor with two or more cores housed in the same package.

Multi-core Systems



Cores share a common cache

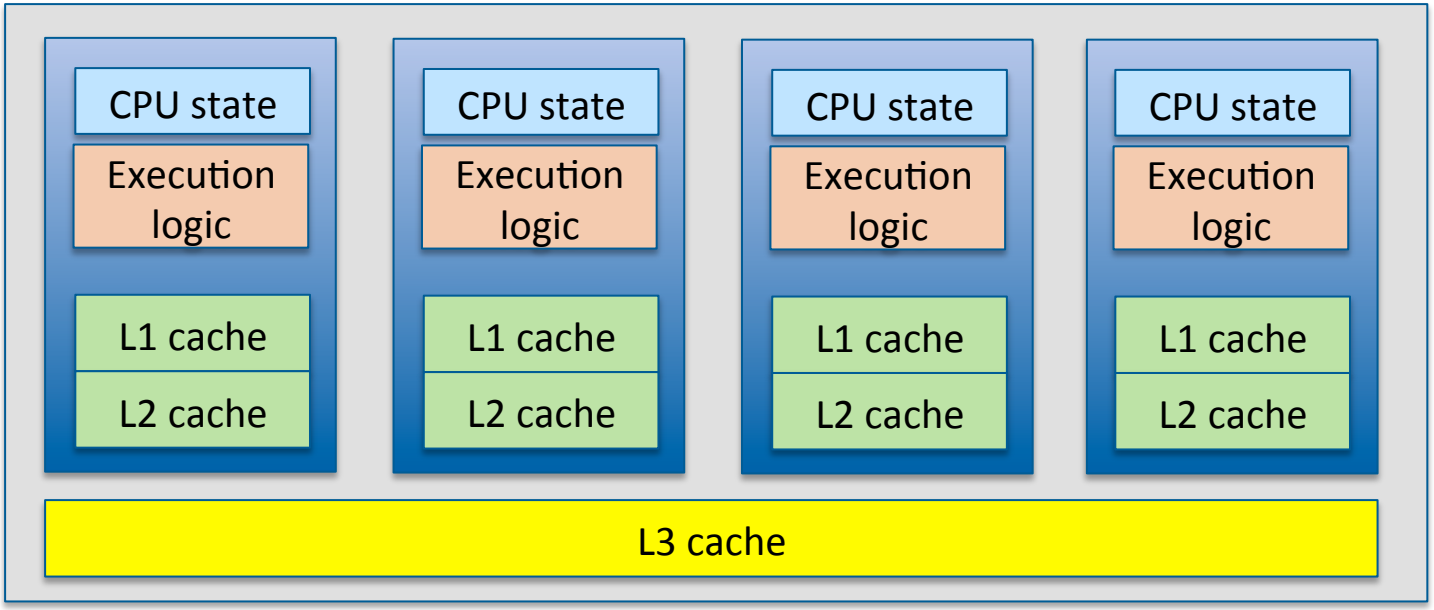


Dual-core processor with hyperthreaded cores

Sharing the cache increases the degree of coupling between the processor cores

Multi-core Systems

Quad-core system



Each processor has a private L1 and L2 cache
All processors share a much larger L3 cache