Virtual Machines and Timesharing

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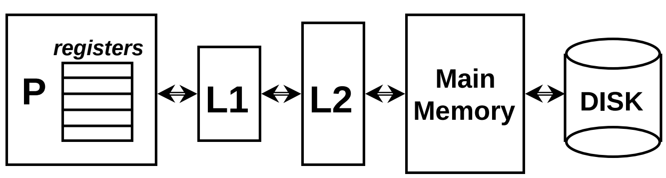
Recap: Memory Hierarchy



Virtual Memory: Main memory just a cache for disk

Have a large <u>virtual</u> address space of 2^{32} bytes.
Advantages are:

- **Removes programming burden of having a small, limited amount of main memory**
- **Efficient sharing of Main memory among multiple programs which can be isolated**

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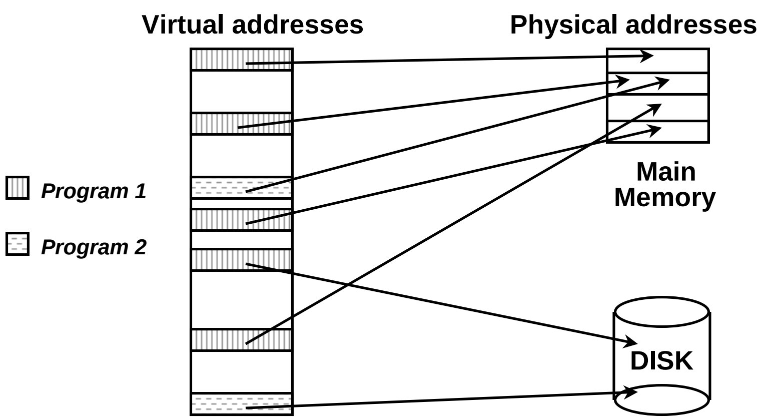
Virtual Memory



across time
Physical addresses can be shared by two virtual addresses.

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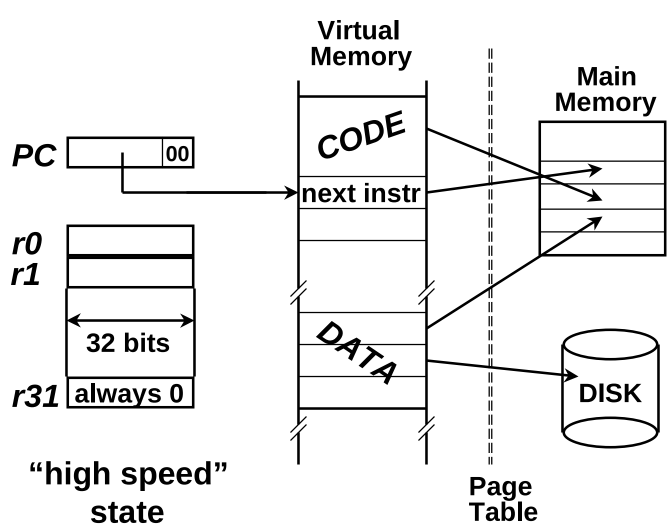
State of a Program



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Virtual Memory Implementation

Wish to read a location.

Steps are:

- **Present a virtual address to Main Memory.**
- **Determine if corresponding page is in Main Memory by accessing TLB/Page Table.**
- **If page is in Main Memory, access Main Memory again to obtain contents of location in page.**
- **If page is not in Main Memory, interrupt program and call a <u>Page Fault Handler</u> to bring in the page from disk.**
- **Repeat read; this time page is in Main Memory.**

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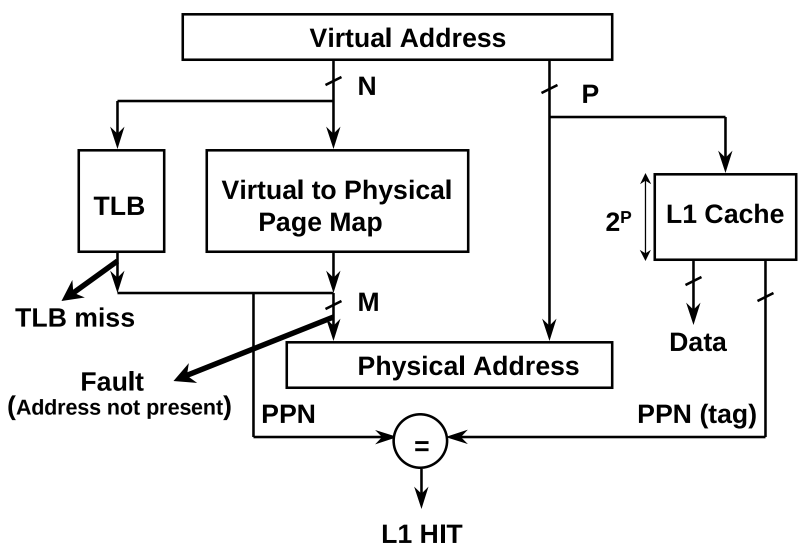
Virtual Memory and Cache Integration



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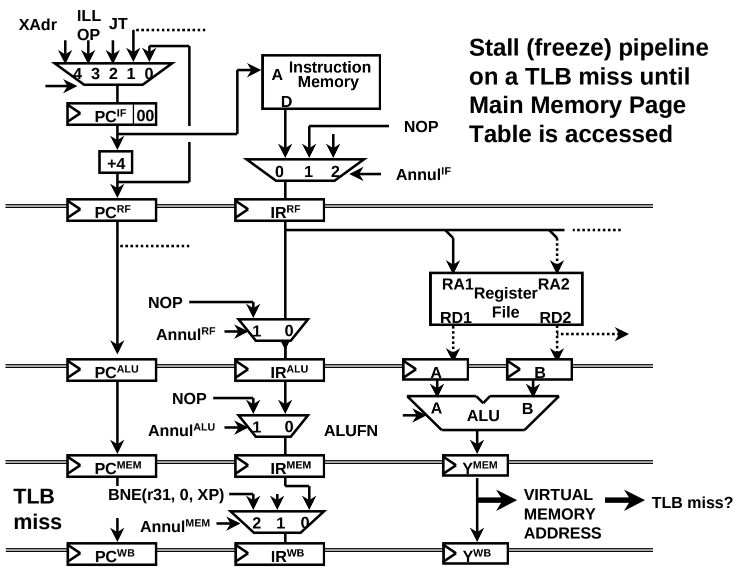
Pipelined β TLB Miss



Stall (freeze) pipeline on a TLB miss until Main Memory Page Table is accessed

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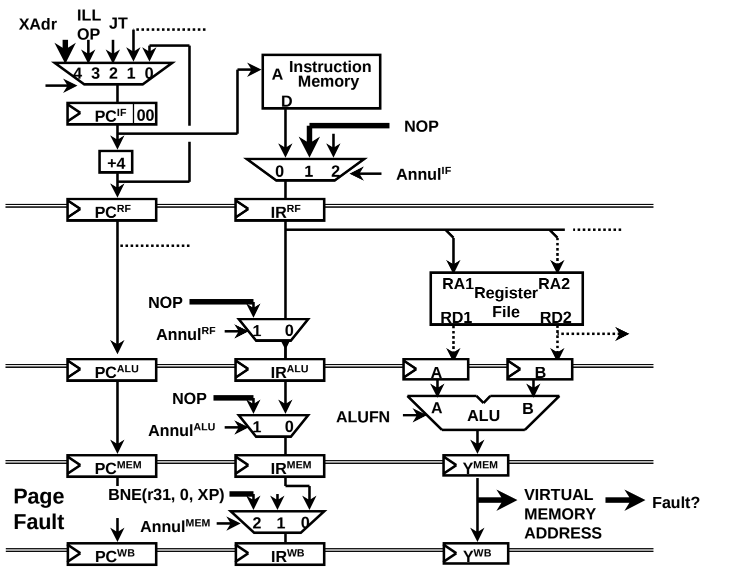
Pipelined β Page Faults



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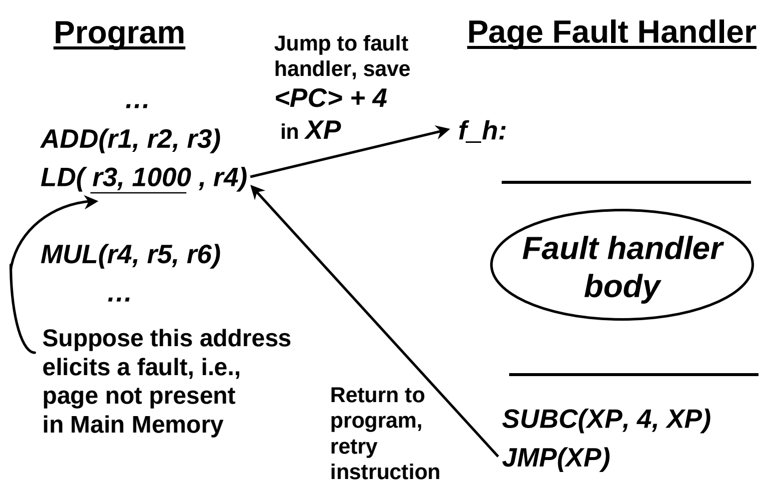
Page Fault Handler



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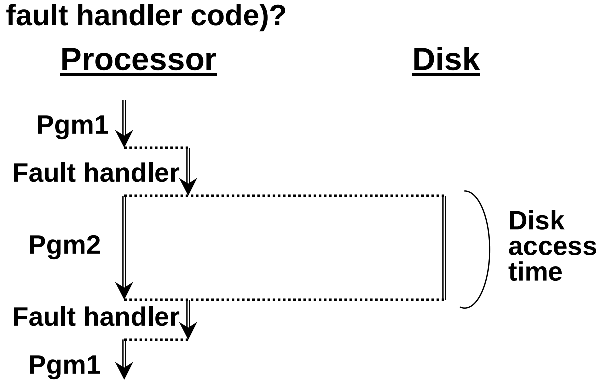
Waiting for Disk Access

Suppose page is on disk (page fault occurs)

- **Long access time of 100,000 processor cycles**
- **Should processor wait (i.e., stall processor in fault handler code)?**



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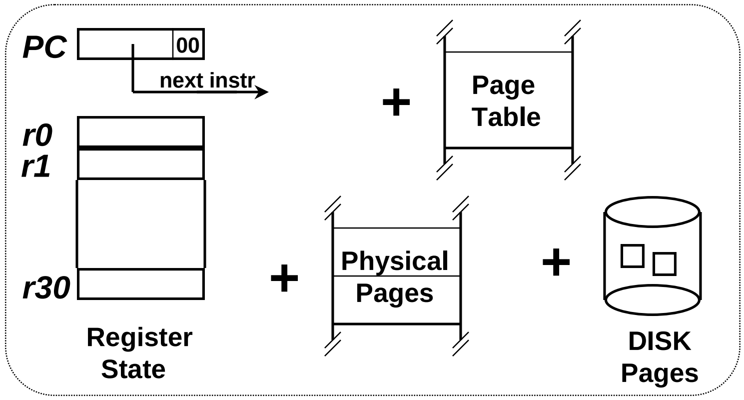
A Process



Many of these can coexist in memory.
ONE can be executing.

Assign each process a unique number (PID)

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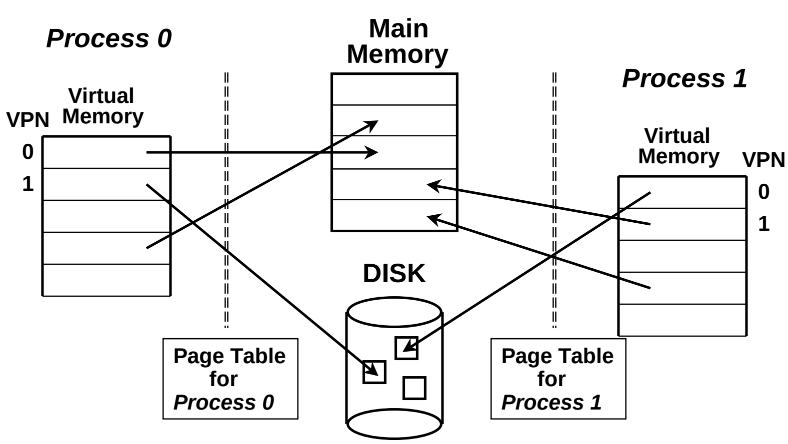
Process Isolation and Protection



Virtual addresses of each process begin from 0
Protection implies at each instant page tables are <u>disjoint</u>

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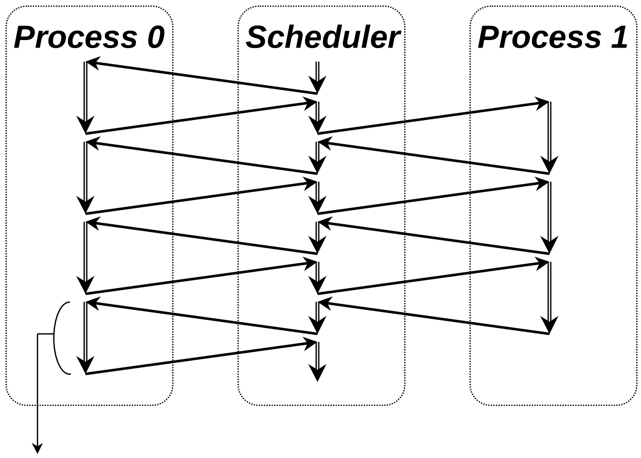
Process Scheduling



This period is called the <u>time quantum</u>

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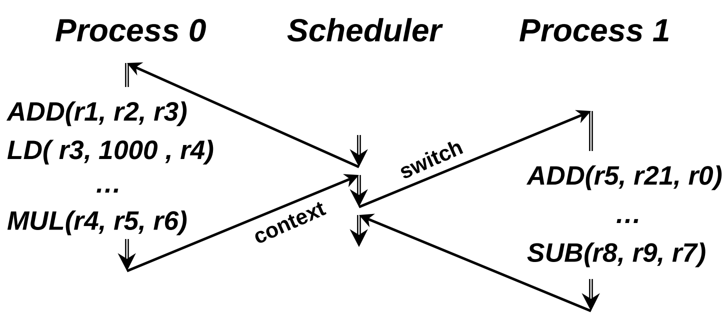
Context Switch



- **Processor state corresponding to the execution of *Process 0* is saved in memory**
- **Processor state associated with the execution of *Process 1* is installed in its place**

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Virtual Machines

- Give each process its own virtual machine
- An Operating System supports the process abstraction by managing physical resources
  - Maintaining disjoint page tables
  - Reloading page table and TLB
  - Allocating and reclaiming physical pages

  and scheduling processes
  - Choice of time quantum
  - Priorities of different processes
  - Interrupts

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