CMPE011 Fall 2002

Pipelined CPU

- Pipeline principles
- Pipelined datapath
- Pipelined control

Textbook: 6.1 to 6.3
Single-cycle restaurant
Multicycle restaurant
Pipelined restaurant
Pipelined datapath

What is a “pipeline”?

- just like in the multicycle datapath, there are *stages*
- in a pipelined architecture, however, all stages operate concurrently
- a new instruction begins execution at every *clock* cycle
Our multicycle datapath
Pipelined datapath
Pipeline characteristics

number of stages: five in the classical pipeline
  (IF, ID, EX, MEM, WB — just like in the multicycle CPU)

$T_{ck}$ limitation: now the constraint is the longest worst-case path among all
the stages

resources: to perform some operations concurrently, we need to duplicate
some resources (like in the single-cycle implementation)
Single-cycle vs. pipeline execution
Pipeline performance

**speedup:** ideal speedup = # of pipeline stages

(only if the stages are perfectly balanced)

**CPI:** ?

**throughput:** we approach the ideal speedup only when considering the execution of many instructions

**latency time:** the execution time of a single instruction
MIPS instruction set architecture and pipelining

- all instructions are the same length
- few instruction formats (and very similar)
- memory accesses only in load/store instructions
**Pipelined datapath**

A walk through the pipeline

With the following piece of code:

\[
\begin{align*}
\text{lw} & \quad \$1 \ 20(\$1) \\
\text{sub} & \quad \$11, \ $2, \ $3
\end{align*}
\]
A walk through the pipeline: clock cycle 1

lw $10, 20($1)
A walk through the pipeline: clock cycle 2
A walk through the pipeline: clock cycle 3
A walk through the pipeline: clock cycle 4

```
lw $10, 20($1)
sub $11, $2, $3
```
A walk through the pipeline: clock cycle 5

\[ \text{lw } $10, 20($1) \]

\[ \text{sub } $11, $2, $3 \]
A walk through the pipeline: clock cycle 6

\[ \text{sub} \$11, \$2, \$3 \]
Pipelined control

- pipelining the datapath leaves the meaning of control lines unchanged
- control signals are pipelined too (grouped by stage)
- the control unit is combinatorial again
Pipelined control: complete schematic
Recommended exercises

Ex. 6.5, 6.7, 6.9, 6.10