

Exceptions/Interrupts

Definition:

- an “unexpected” event in the normal flow of execution
- interrupts, traps, faults, aborts, exceptions
 - **exceptions** caused by instruction execution **within the processor**
 - **interrupts** caused by some event **external to the processor**

Some examples:

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Precise Interrupts

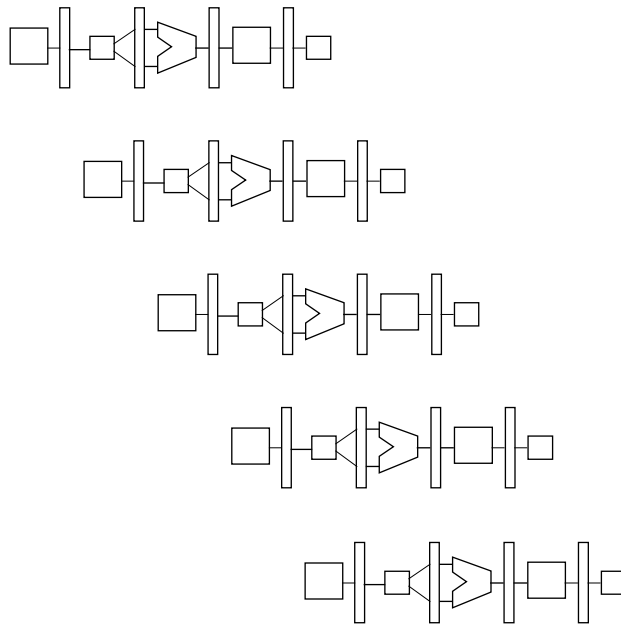
Precise interrupts preserve the model that instructions execute in program-generated order

If an interrupt occurs, the processor can recover from it

What happens on a precise interrupt

- **identify the instruction that caused the interrupt**
 - pipelines execute several instructions at once:
how determine which one caused the exception?
- **let the instructions before faulting instruction finish**
- disable writes for faulting & subsequent instructions
- force trap instruction into pipeline
- trap routine
 - save the state of the executing program
 - correct the cause of the interrupt
 - restore program state
- **restart faulting & subsequent instructions**

A 5-Stage Pipeline



How Pipelines Complicate Interrupts

It's fairly simple to maintain precise interrupt in the R3000 integer pipeline

- one instruction fetched and executed each cycle
- instructions executed in fetch order

Simultaneous interrupts

- a solution: handle them in program order
- still precise

Interrupts out of order wrt sequential instruction execution

- subsequent instruction causes an interrupt before a previous instruction
- interrupts still must be handled in program order for precise interrupts
- interrupt handled before the write stage
 - a solution: interrupt recorded in a per-instruction bit vector which flows with it down the pipeline
 - interrupts for *this* instruction handled before it changes any state
 - restart all instructions in the pipeline
 - interrupts are precise: **why?**

How Pipelines Complicate Interrupts

Multicycle operations

- some types
 - floating point operations
 - integer multiply & divide
- can cause **imprecise interrupts** because operations don't necessarily complete in program-generated order
- example:

divf	FP exception
multf	not done
addf	completed

- cannot restart interrupting & subsequent instructions because some have completed
- completed instruction may have overwritten one its source operands