ECE 220 Computer Systems & Programming

Interrupts & Exceptions

ECE ILLINOIS

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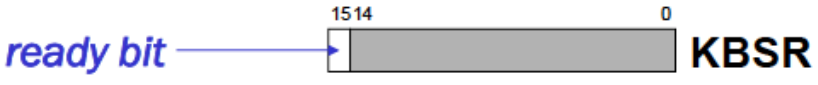
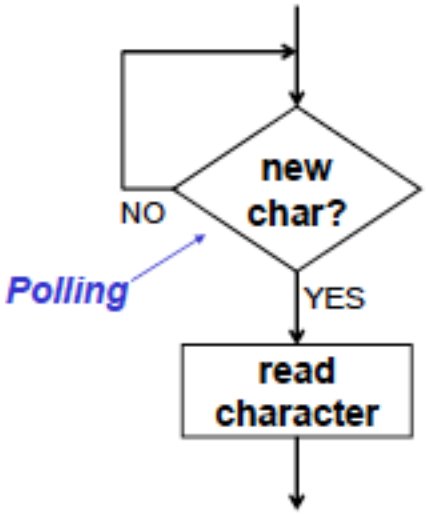
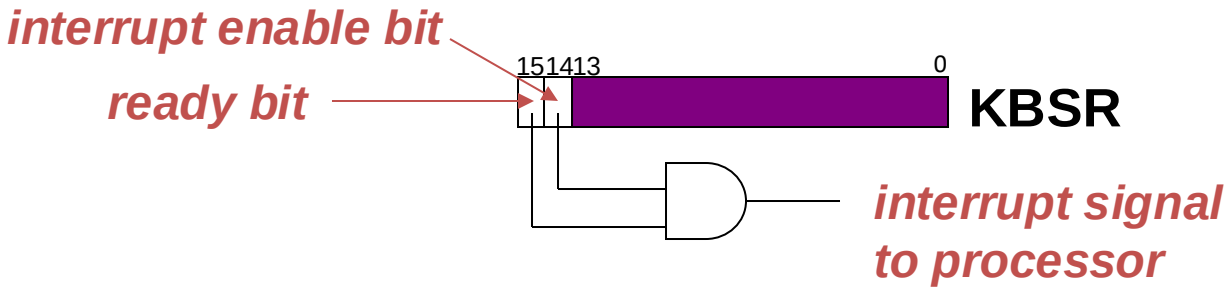
Polling vs. Interrupt-Driven I/O






```
POLL   LDI  R0, KBSR
       BRzp POLL
       LDI  R0, KBDR
       ...
KBSR .FILL xFE00
KBDR .FILL xFE02
```

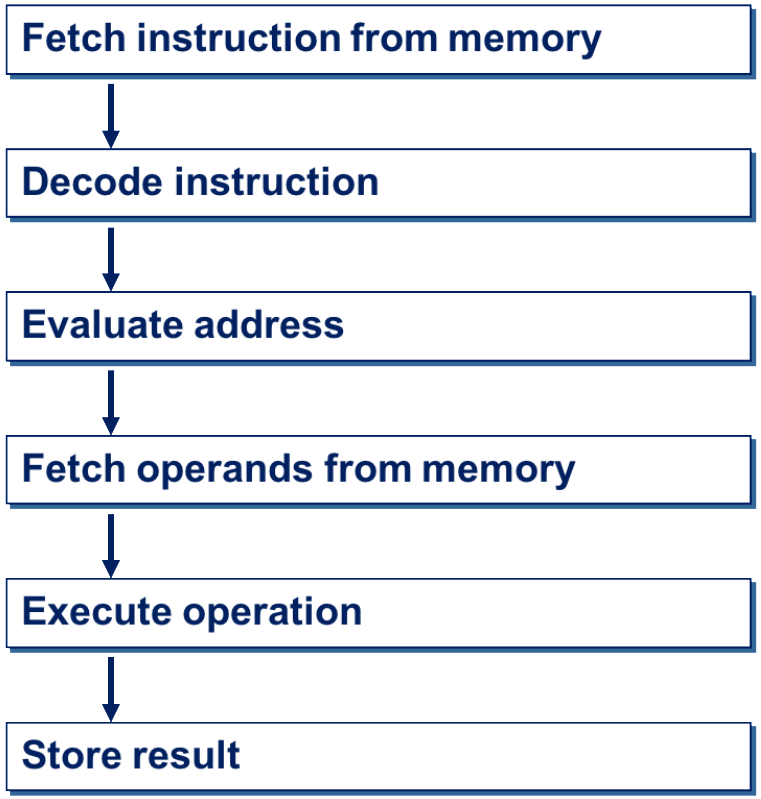


- Software sets "interrupt enable" bit in device register
- When Ready bit and IE bit are both set, interrupt is signaled

Interrupt-Driven I/O

An I/O device can:

1. **Force currently executing program to stop**
2. **Have the processor carry out the need of the I/O device**
3. **Resume the stopped program as if nothing had happened**



- **If INT is not asserted**
- **If INT is asserted**

Two Parts of Interrupt-Driven I/O

1. The mechanism to interrupt the processor
   - A way for the I/O device to _____ the CPU that an interesting event has occurred
   - A way for the CPU to _____ whether the interrupt signal is set and whether its priority is higher than the current program.

2. The process that manages the transfer of the I/O data
   - Initiate the interrupt (saving the state of the interrupted program & loading the state of the Interrupt Service Routine)
   - Service the interrupt
   - Return from interrupt

Processor State

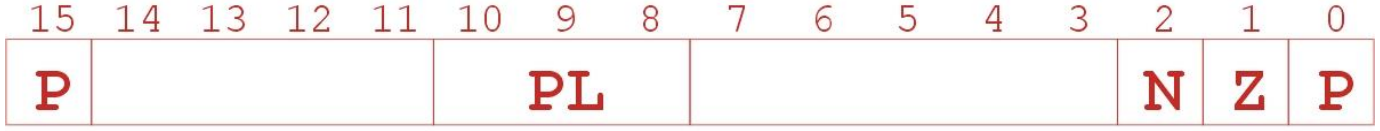
- Enough state info saved for interrupted program to resume later
- Enough state info loaded for the interrupt service routine to begin service

State of a Program (snapshot of the system):

-
-
- PSR (processor status register)

PSR[15] – privileged (supervisor - 0) or unprivileged (user - 1) mode

PSR[10:8] – priority level, PSR[2:0] – condition code



Where to save state information?

Supervisor Stack

A special region of memory used as the stack for interrupt service routines.

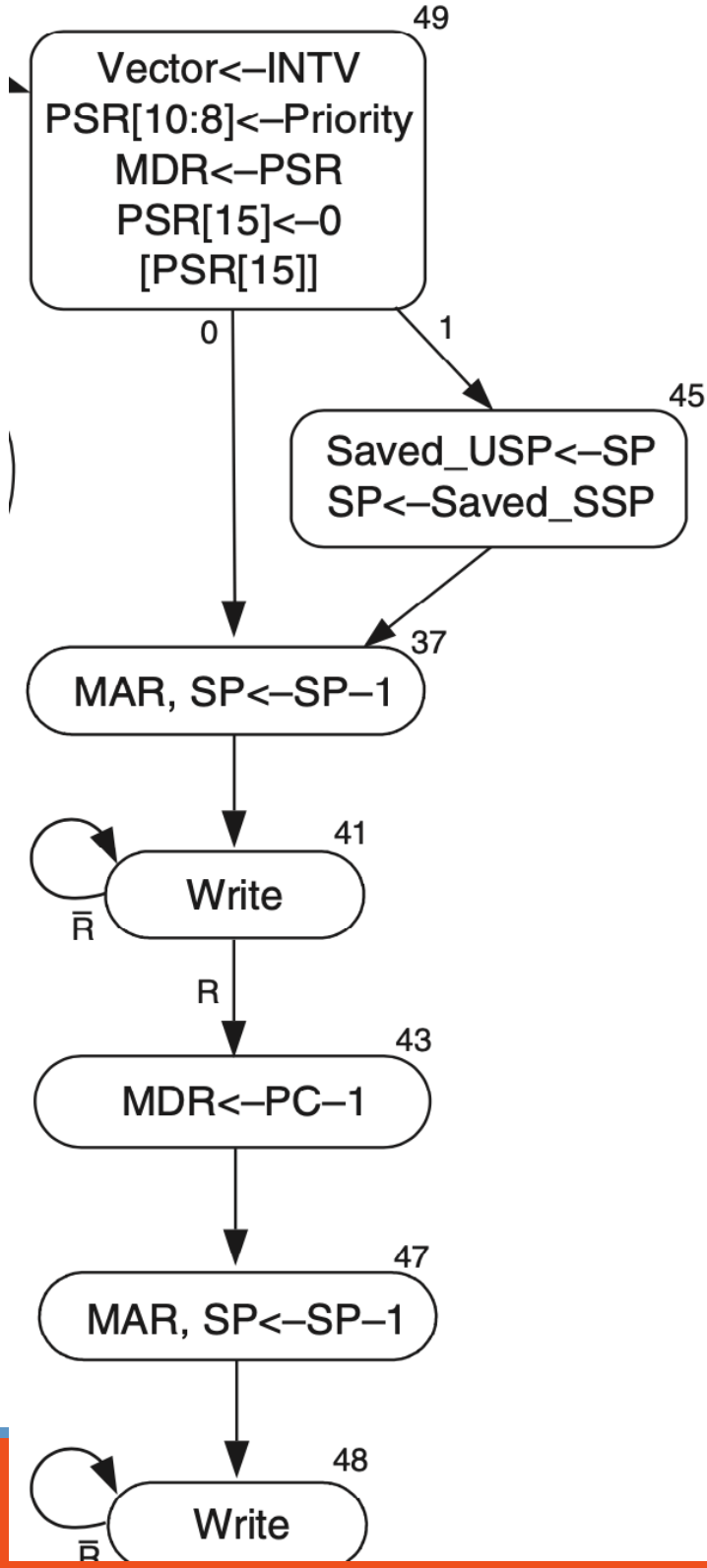
- Initial Supervisor Stack Pointer (SSP) stored in _____
- Storing User Stack Pointer (USP) in _____

Want to use R6 as _____, so that our PUSH/POP routines still work.

When switching from User mode to Supervisor mode (as result of interrupt), save R6 to _____.

Supervisor Stack Contents

- Save the SP when entering supervisor mode
- Push the PSR
- Push the PC



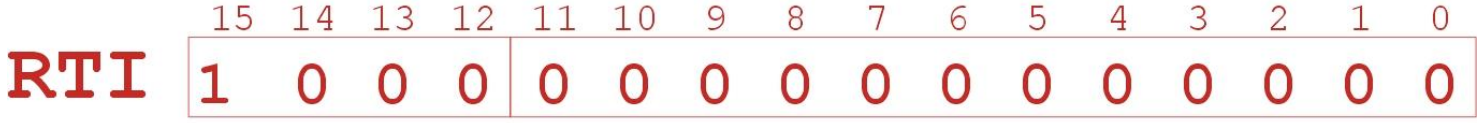
Invoking the Service Routine / Returning from Interrupt

Invoking:

I/O device transmits Interrupt Vector (INTV, 8-bit) along with interrupt signal and priority level.

Returning:

Special instruction (RTI) – restores state

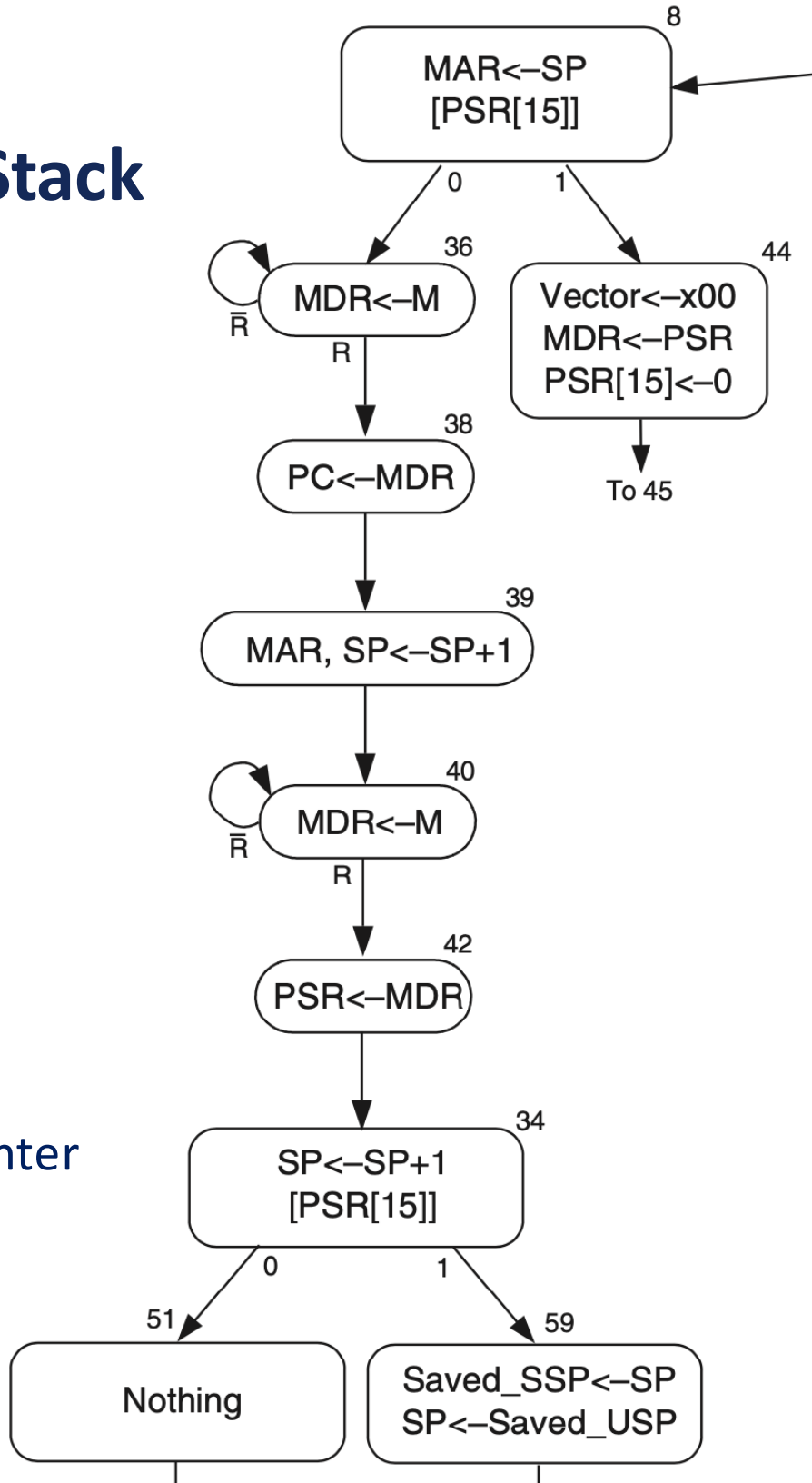


RTI is a privileged instruction.

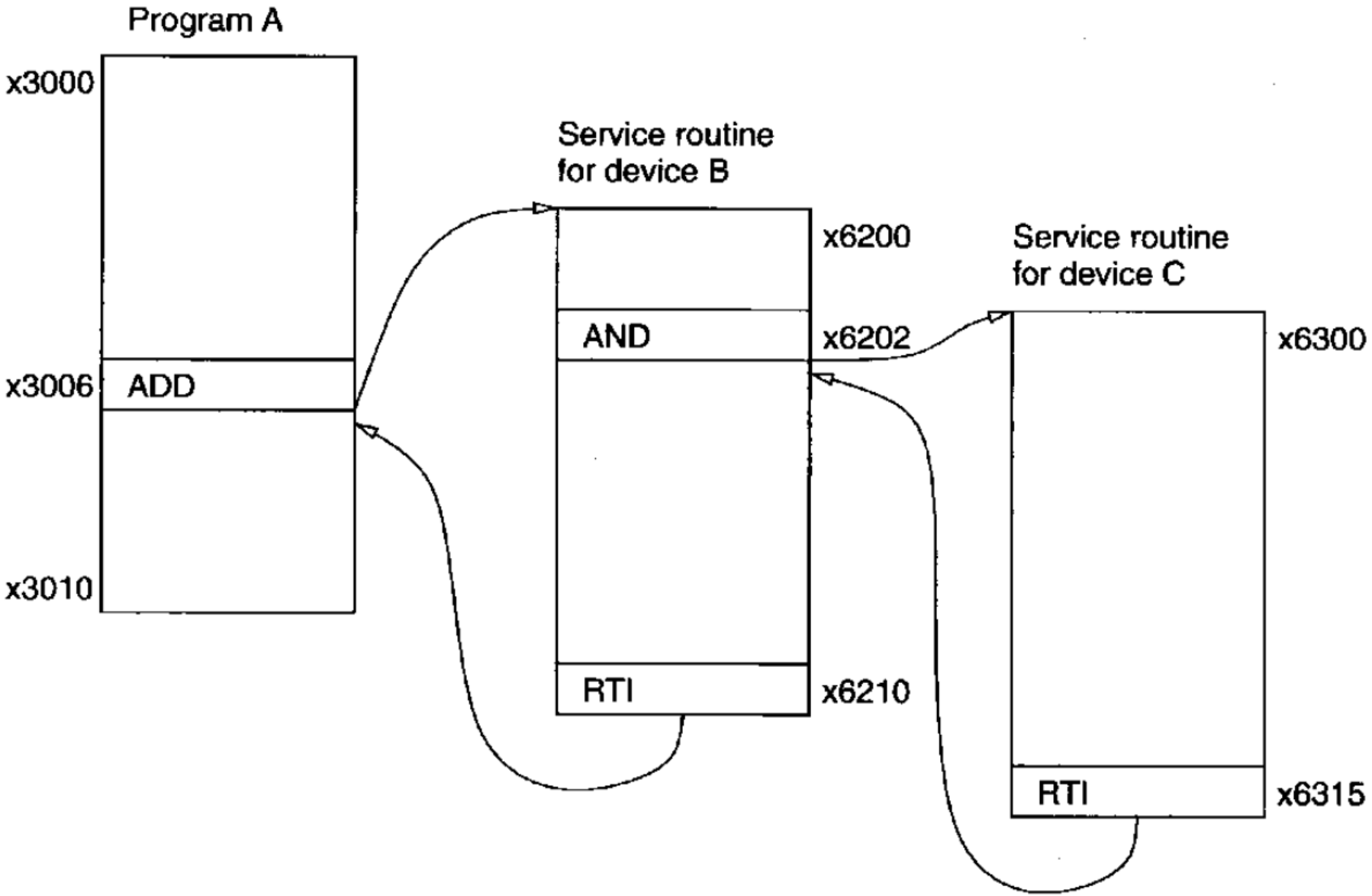
- **Can only be executed in Supervisor Mode.**
- **If executed in User Mode, causes an exception.**

RTI Pops Frame off Supervisor Stack

- Check for Supervisor mode
- Pop the PC
- Pop the PSR
- If returning to user mode, restore Stack Pointer



Nested Interrupt



Exceptions: Internal Interrupt

When something unexpected happens *inside* the processor, it may cause an exception.

Examples of Exception in LC-3:

- **Privileged operation (e.g., RTI in user mode)**
- **Executing an illegal opcode (Bits[15:12] = 1101)**

Handled just like an interrupt

- **Vector is determined internally by type of exception**
- **Priority is the same as running program**

Interrupt Vector Table

Exception Service Routines – x0100 to x017F

Interrupt Service Routines – x0180 to 01FF

LC-3 Memory Map