
# Interrupts

## Interrupts (Outside the course topics)
## Not required at the exam

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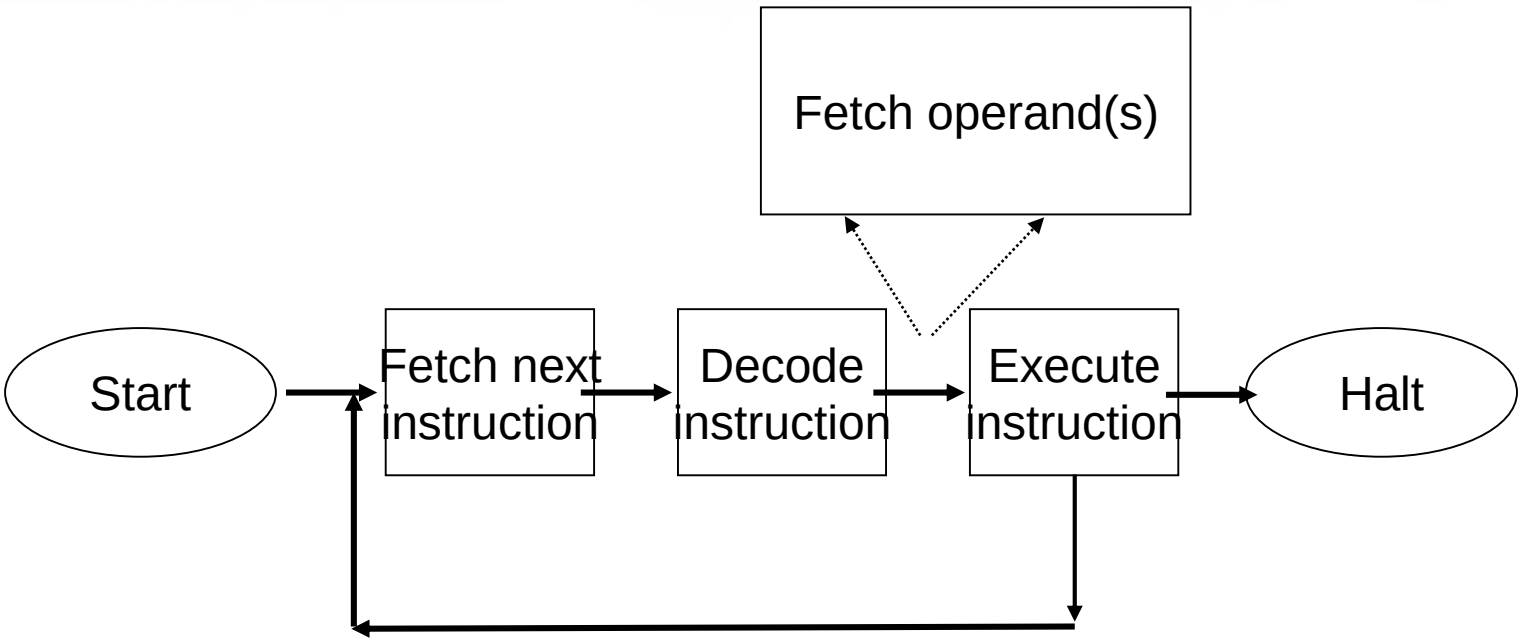
# Instruction cycle

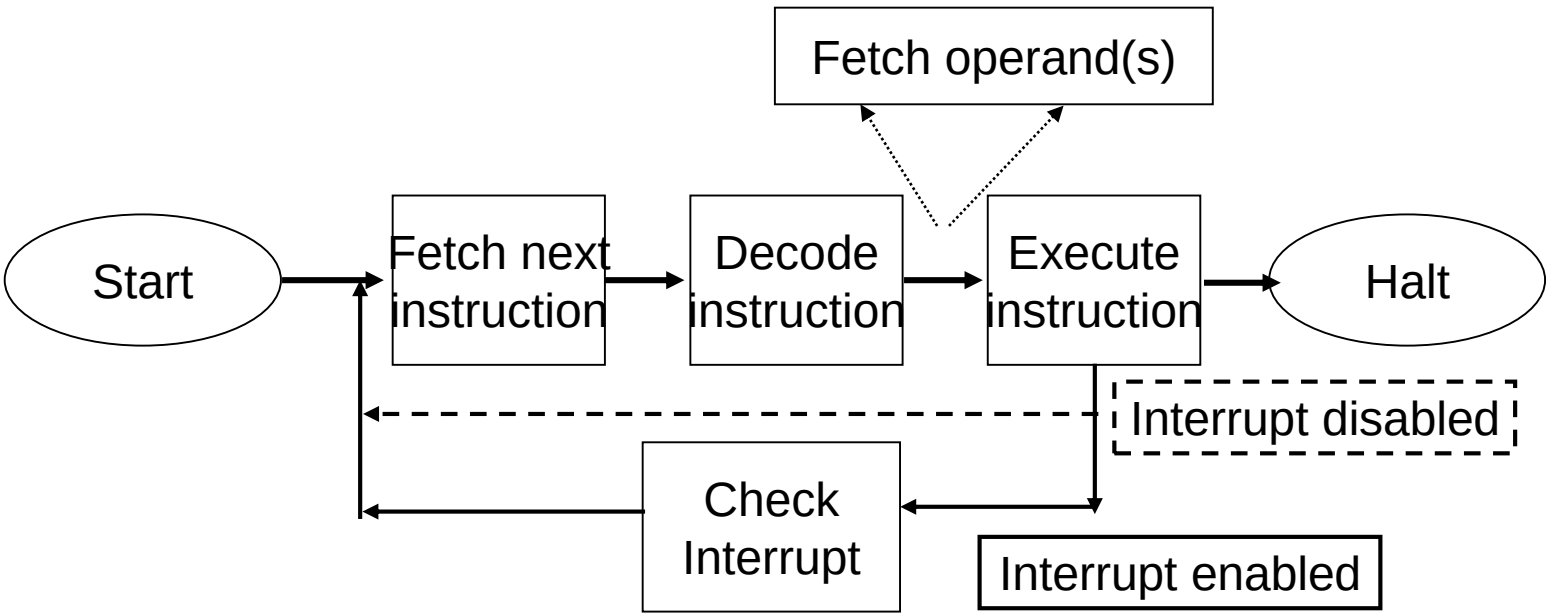


# Interrupts

- **Interrupt** is a signal to the CPU generated by hardware or by software indicating an event that needs immediate attention

- **Interrupts** are generated by timers and devices
  - are **asynchronous**, i.e., they are generated at unpredictable times, or during the execution of any program instruction

# Instruction cycle with interrupt



# Interrupts

- An interrupt signal makes the control flow of a CPU to be moved from the current executing code to an interrupt handler routine that executes another code before returning to the original code.
- It is implemented by
  - saving the current value of the program counter (PC) and status (PSW) registers into a stack, so that the interrupted code can **restart from the next instruction**
  - loading in the PC register the address of the routine corresponding to the specific interrupt

# Program Status Word

- The PSW contains
  - condition codes
  - interrupt enable/disable flags
  - kernel/user mode flag
  - ...

# Interrupt Vector

| | | |
|---|---|---|
| Interrupt Handler | 116 | int_h_10() |
| | ..... | |
| | 108 | |
| | 164 | iret |
| ..... ..... ..... | | ..... ..... ..... |
| main | 20000 | |
| | ..... | |
| 10 | 20064 | |
| | 20068 | |
| | ..... | |
| | 23000 | |
| ..... ..... ..... | | ..... ..... ..... |
| Stack | 52540 | main PSW |
| | 52544 | 20068 |
| | 52548 | |
| | ..... | |

| Memory | Address | Content |
|---|---|---|
| Interrupt vector | 6 | |
| | 10 | 116 |
| | 14 | PSW of int_h_10() |
| | 16 | |
| | ..... | ..... |

| | |
|---|---|
| PC | 20068 |
| SP | 52548 |
| PSW | main PSW |

# Issues

- An interrupt needs fast processing, that can be obtained splitting the task in two phases
  - Urgent or critical operations (e.g., get a keyboard code)
  - Operations that can be delayed (e.g., manage the code according to its meaning)
- Nested interrupt processing
- Processing of critical regions with disabled interrupts

# Enable/Disable Interrupt (Intel)

- Each interrupt is identified by a number between 0 e 255, which Intel calls **vector**
- The assembler instructions
  - disable interrupt **cli**
  - enable interrupt **sti**

  manage bit **IF** of the register **eflags**, which is tested in AND with masking

# Interrupt management

- Disable interrupts while an interrupt is being processed
  - Processor ignores any new interrupt request signals
  - Interrupts remain pending until the processor enables interrupts
  - After interrupt handler routine completes, the processor checks for additional interrupts
- Higher priority interrupts cause lower-priority interrupts to wait.
  - Causes a lower-priority interrupt handler to be interrupted

# Exceptions

- **Exception** differ from interrupts because they are **synchronous**
  - Program errors
  - System call ( `int` or `sysenter` instructions)
  - Page faults
  - Fault conditions

# Exceptions

- **Exception** are divided in 3 groups depending of the value of register **`eip`**, which is saved into the stack when the CPU raises an exception
  - Faults
    - The fault condition can be corrected and the process **can restart from the same instruction**
  - Traps
    - Used mainly for supporting debug
  - Abort
    - The error condition is such that it is impossible to decide which value **`eip`** should have

# Exceptions examples

- **Program Errors**:
  - divisions by zero
  - illegal instruction
  - memory parity error
  - . . .
- **Protection violations**
  - memory violation

# Exceptions examples

```
#include <stdio.h>
int i, j, *pk; // global variables initialized to 0
int main(){
  scanf("%d", &i);
  j=2;
  j = j / i;   // possible division by 0 exception
  printf("%d\n", j);
// Correct program
  pk = &i; // pk set to the address of variable i
  scanf("%d", pk);
  printf("i contains: %d %d\n", i, *pk);
// Program generates here a memory violation exception
pk = 0;
scanf("%d", pk);// tries to write where pk points to,
                // a memory location out of user domain
printf("i contains: %d %d\n", i, *pk);
return 0;
}
```

# Programmed exceptions

- A programmed exception occurs because a specific instruction is executed
  - `int` or `int3`
  - `into` (check for overflow)
  - `bound` (check on address bound)
- Programmed exceptions, or software interrupts, allow
  - implementing **system calls**
  - signal events to the debugger