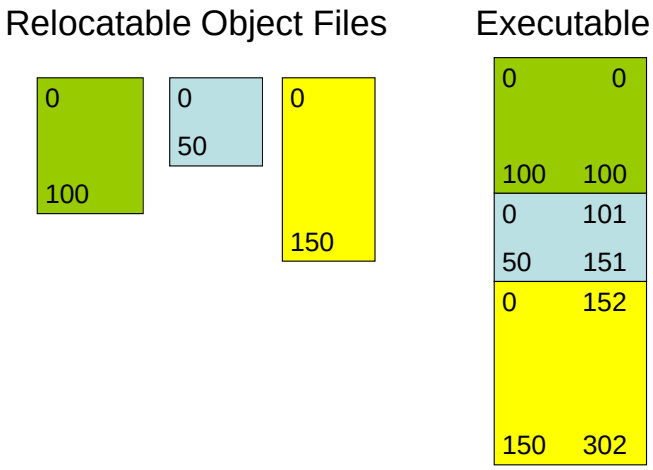
Memory Access Modes

COMP375 Computer Architecture and Organization

Steps in Address Mapping

- Programmer selects a variable name.
- Compiler allocates space and selects a relative address.
- Linker combines object files and updates references to relative address to be program addresses.
- Operating system allocates memory for the program and copies it into RAM.

Relocatable Address Adjustment



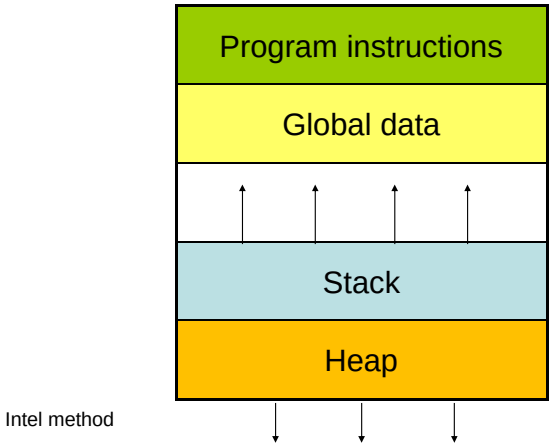
Adjusting Addresses

- When the linker combines object files to create an executable, it goes through the program and adjusts every address.
- When a program is executed, it is loaded into memory. The hardware adjusts each program relative address to a hardware address.

Program Memory Types

- Global variables
  - Data segment
- Local variables and parameters
  - Stack
- Dynamic variables
  - Heap
- Constants
  - Data segment or instruction segment
- Instructions
  - Instruction segment

Program Memory Organization



Effective Address

- The effective address (or logical address or virtual address) is the program relative address.
- The hardware maps the effective address to the physical address.
- Different programs in different physical addresses may have the same effective address.
- Effective addresses can be the result of address calculations.

Where is the data?

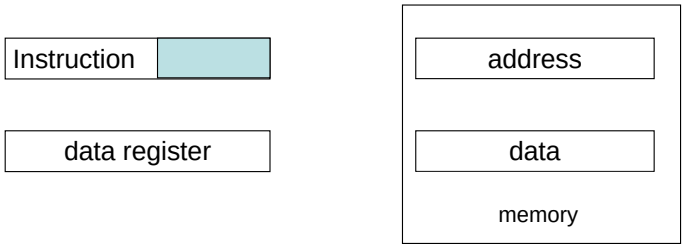
- The operands for an instruction can be in RAM, a register or in the instruction.
- The instruction specifies where the operand is located.
- There are several ways the operand's address can be specified.
- Different addressing modes have been created for different program situations.

Addressing modes

- immediate
- register
- memory direct
- register indirect
- register indirect with offset
- memory indirect
- register + offset memory indirect
- displacement

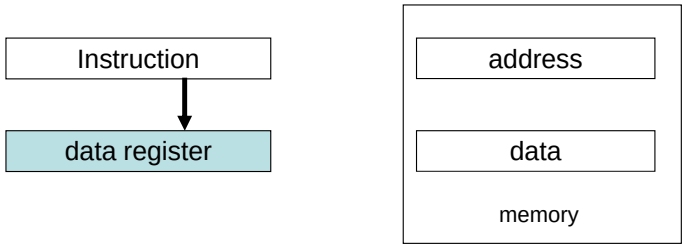
Immediate

- The data is part of the instruction.
- Immediate data items are read-only.
- There is usually a size limit.



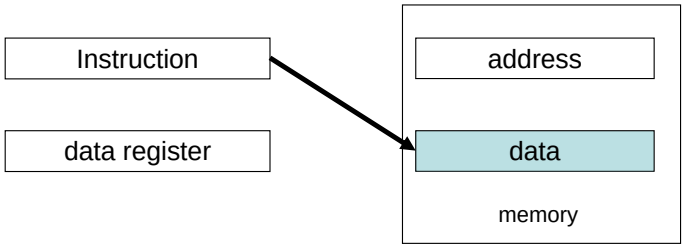
Register

- The data is in a CPU register.
- The instruction *might* indicate which register



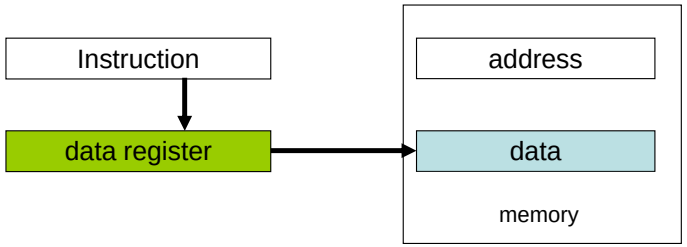
Memory Direct

- The data is in memory.
- The instruction contains the address of the memory location.



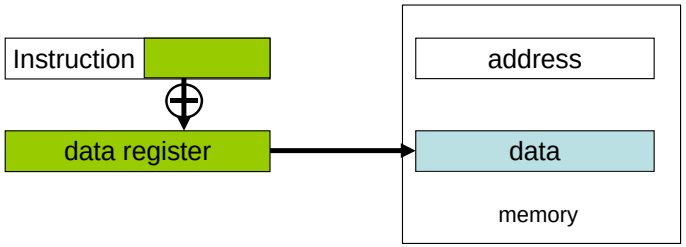
Register Indirect

- The address of the data is in a CPU register.
- Useful if the address is calculated.



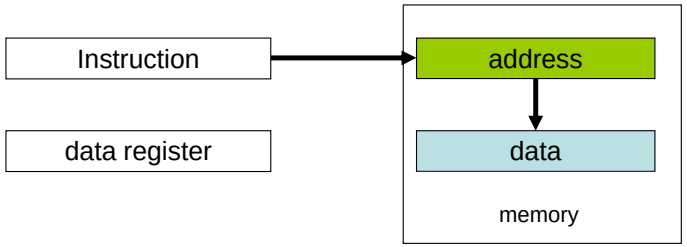
Register Indirect with Offset

- The address of the data is the sum of the instruction offset field and a register value.
- Useful when addressing an array.



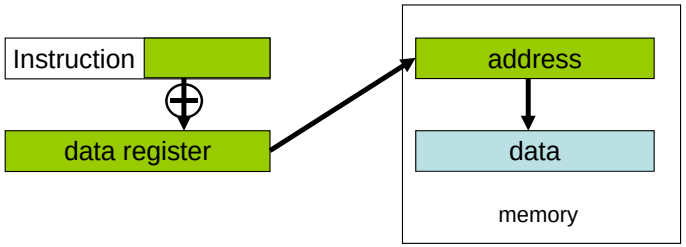
Memory Indirect

- A memory location contains the address of the data.
- Useful for pointers.



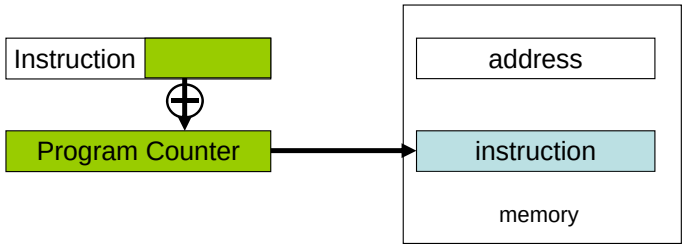
Register Offset & Memory Indirect

- The sum of the instruction offset field and a register value gives the location of the address in memory.
- Useful when addressing ref parameters.



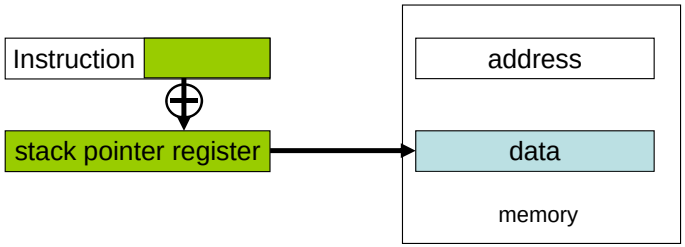
Displacement

- The address of the data is the sum of the instruction offset field and the program counter.
- Used for short jumps



Stack Addressing

- The same as Register Indirect with Offset using the stack pointer register
- Useful when addressing local variables or parameters.



Function Calls

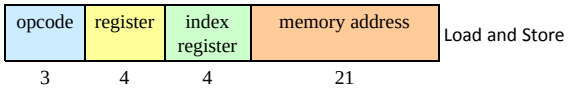
- To call a function or method, the program counter is pushed on the stack and then the program counter is loaded with the address of the function.
- This puts the address of the instruction after the function call on the stack.
- To return the return address is popped from the stack and loaded into the program counter.

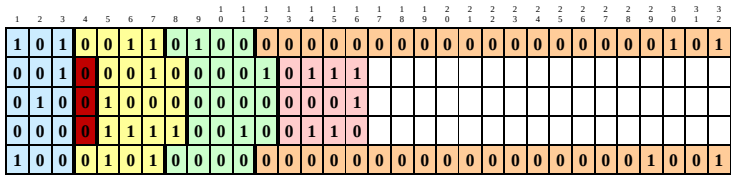
What are the Instructions?

Opcodes

Add	Subtract	Multiply	Divide	Load	Store	JumpEql	Jump
0	1	2	3	4	5	6	7

Instruction Formats





Notes on the Example Architecture

- This is an example of a “Load/Store” architecture. Only the load and store instructions access memory.
- Why is there a one bit unused field in the arithmetic instructions?
- Why is the opcode always the left most bits?
- The format of the jump instructions was not shown. What might be a good format?

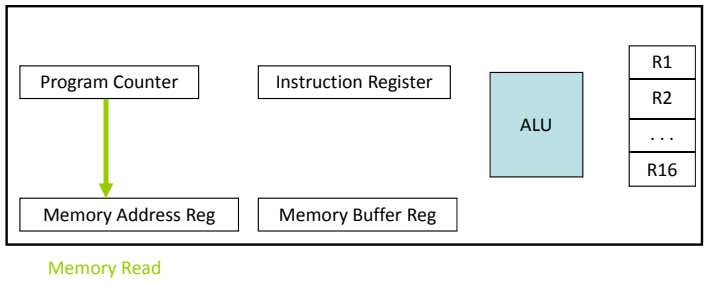
Instruction Cycle

- Fetch the instruction from the memory address in the Program Counter register
- Increment the Program Counter
- Decode the type of instruction
- Fetch the operands
- Execute the instruction
- Store the results

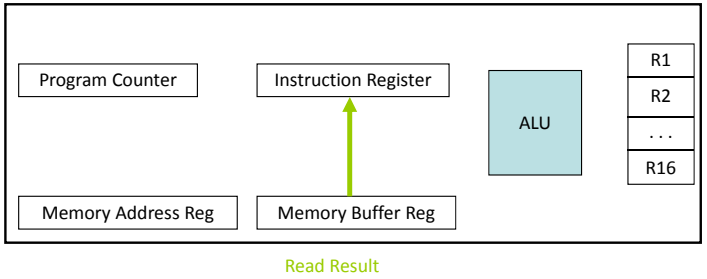
Basic Processor Components

- **Program Counter** – contains the address of the next instruction to execute.
- **Arithmetic Logic Unit** – logic to perform arithmetic and logical functions
- **User registers** – hold data
- **Memory Address Register** – contains the address to be copied to or from RAM
- **Memory Buffer Register** – contains data copied to or from RAM.

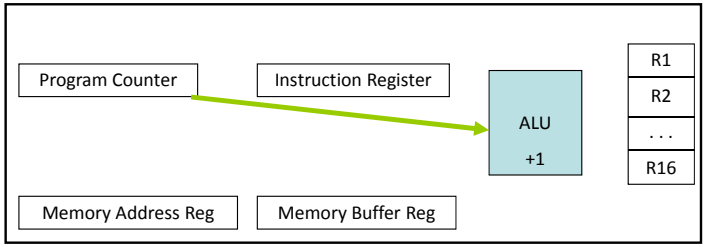
Instruction Fetch



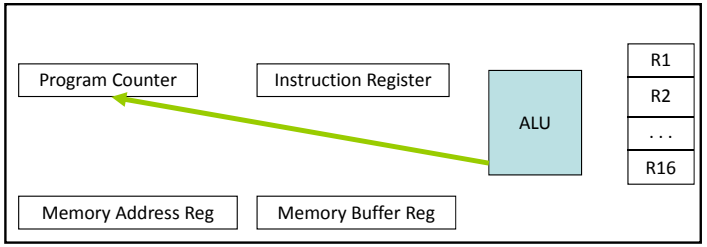
Instruction Fetch



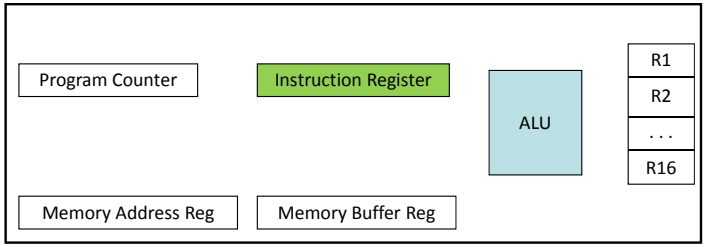
Increment Program Counter



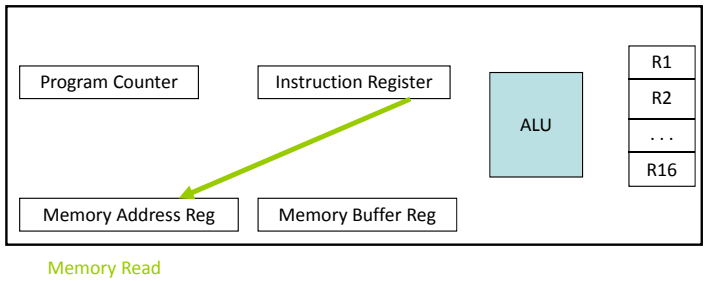
Increment Program Counter



Decode Instruction

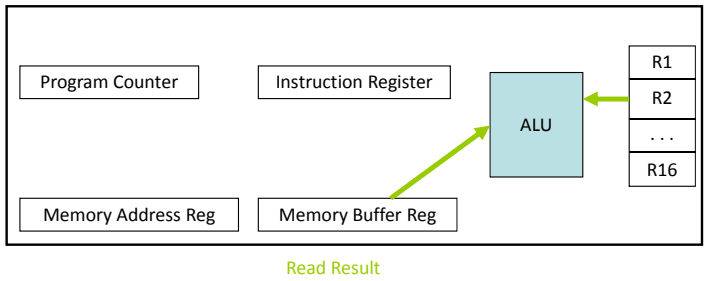


Operand Fetch



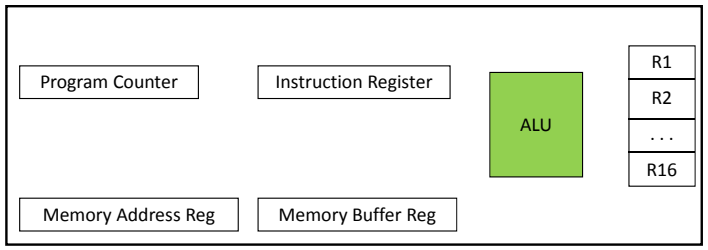
Memory Read

Operand Fetch

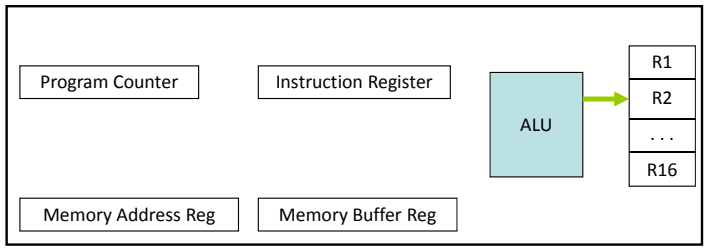


Read Result

Execution



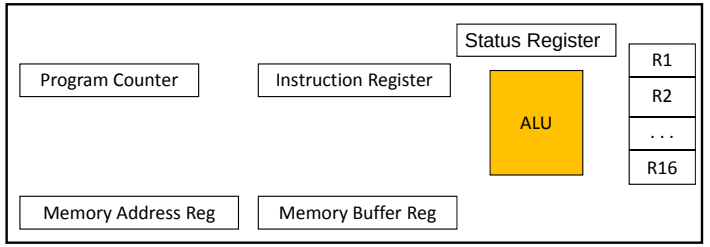
Result Store



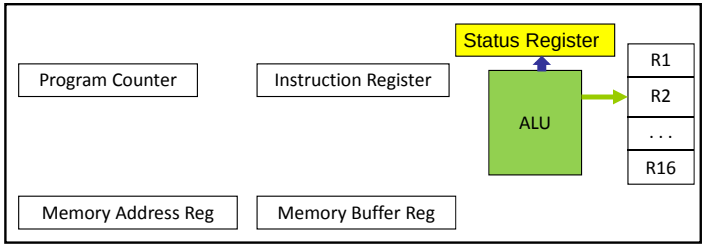
Jump Instruction

- Consider an arithmetic instruction followed by a jump instruction.
- The arithmetic instruction sets bits in the status register

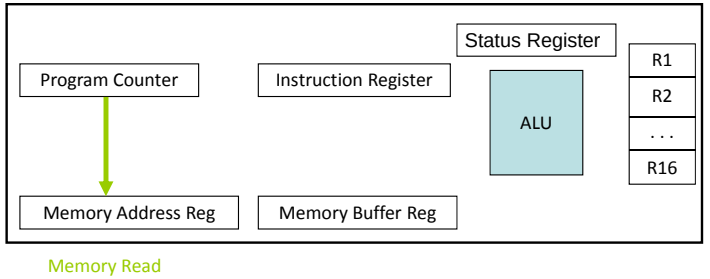
Execution Stage of Instruction 1



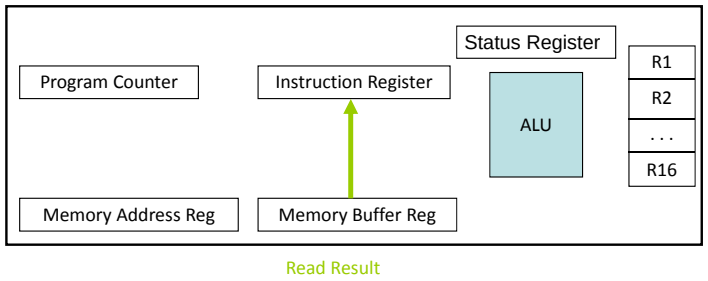
Result Save Stage of Instruction 1



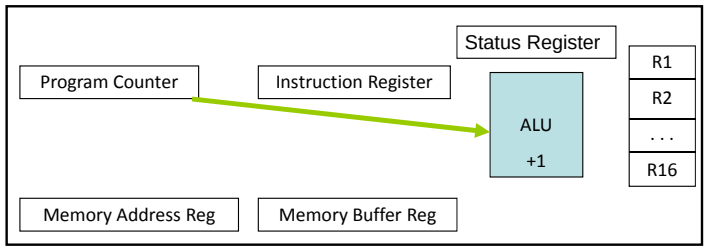
Instruction 2 Fetch



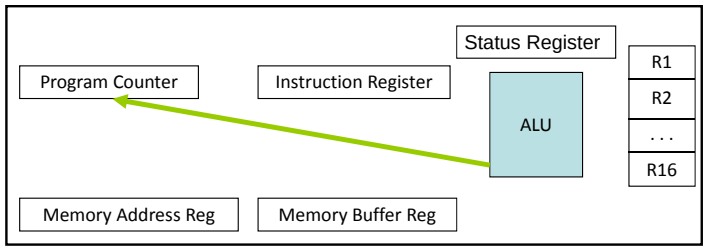
Instruction 2 Fetch



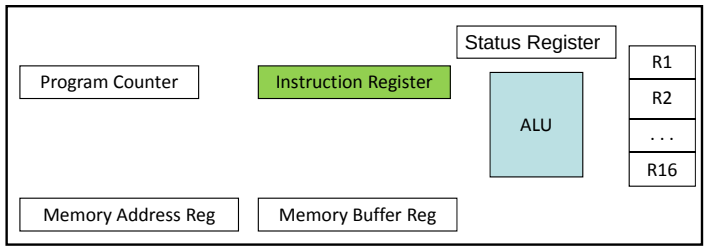
Increment Program Counter



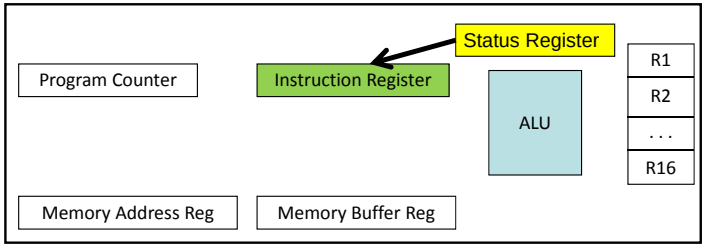
Increment Program Counter



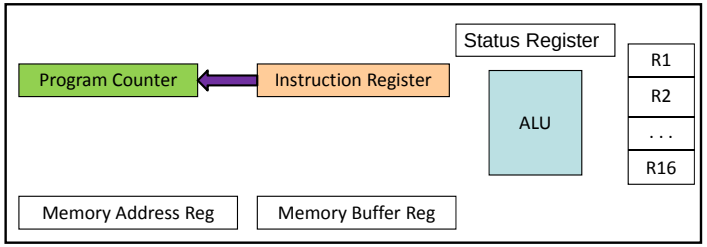
Decode Instruction



Execution of Instruction 2



Saving Result of Instruction 2



Goals for Instruction Set

- The purpose of the machine language is to run the applications.
- Compilers should be able to translate high level languages into machine language.
- Run ***fast***

RISC vs. CISC

- Complex Instruction Set Computers
  - many instructions
  - some instructions can perform complex operations.
  - each instruction may take several cycles
- Reduced Instruction Set Computers
  - fewer instructions
  - many RISC machines run 1 instruction / cycle

CISC Theory

- The machine language should be designed to be as close as possible to the application requirements.
- Machine instructions should support high level language constructs.

RISC Theory

- Many complex instructions are rarely executed. Most programs use only a small set of instructions.
- The few important instructions should run as fast as possible.
- If you have to do something complex, use several fast simple instructions.
- Registers are much faster than RAM.

PDP-8 Instruction Set

- The PDP-8 was a popular mini computer made by DEC in the 1970's.
- The 12 bit fixed length instructions had a 3 bit op code, an address field and two addressing mode bits.
- There were 7 instructions with the normal format.
- One op code was for zero operand instructions. The remaining bits of the instruction specified what to do.