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CS251 - Computer Organization and Design

Introduction to ARM

Instructor: Zille Huma Kamal

University of Waterloo

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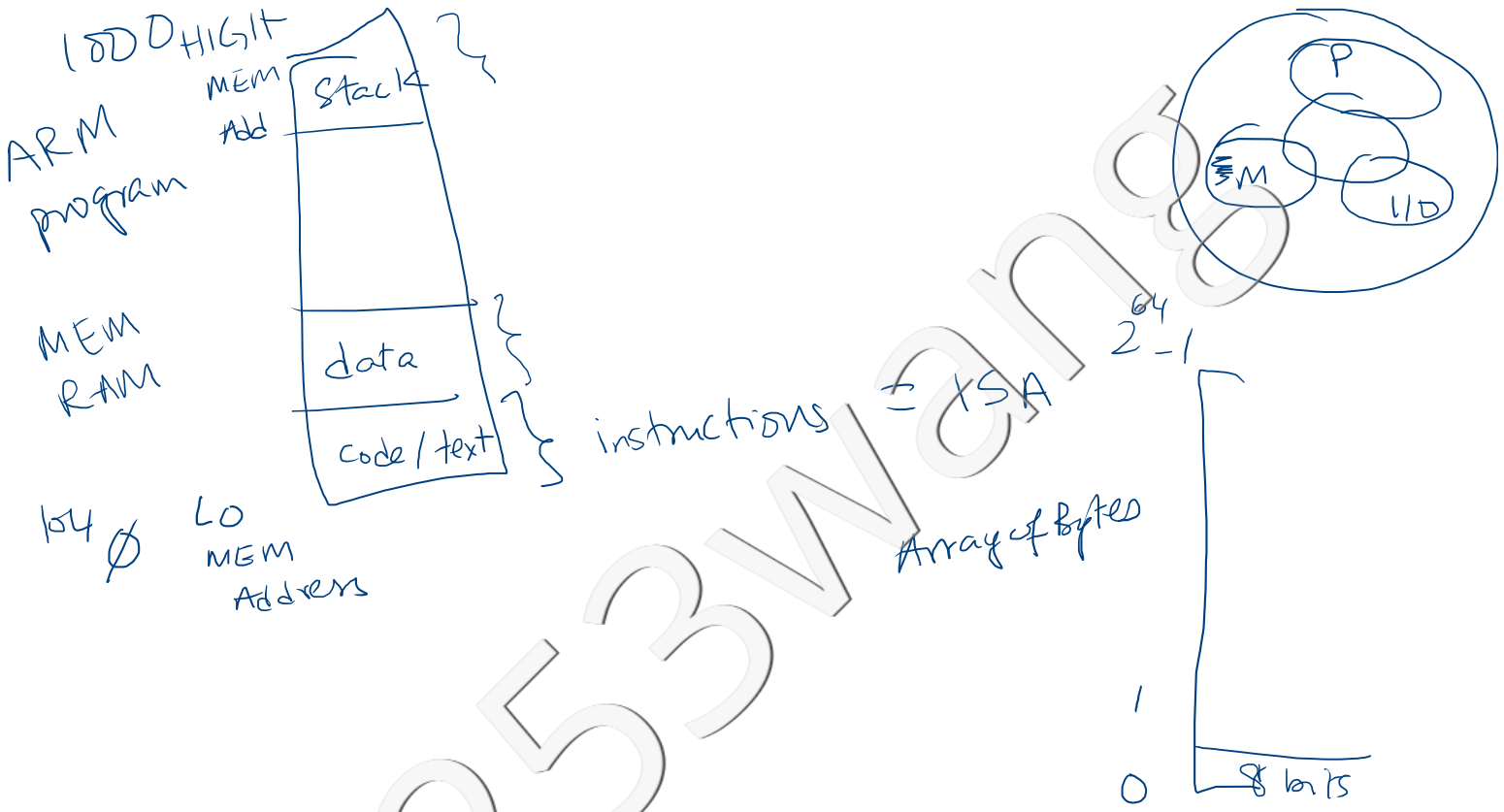
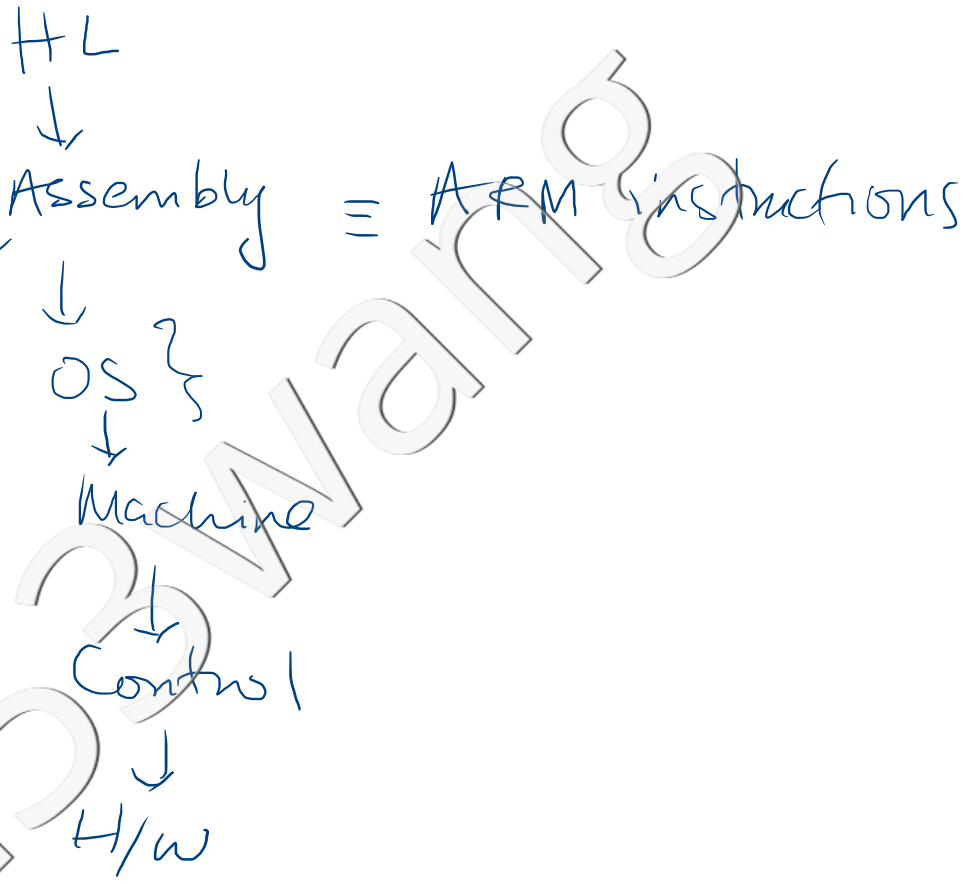
ARM/LEG Overview

- Computers execute assembly instructions
  In binary on computer, but text form for humans
- Only simple operations
  Addition, subtraction, goto, conditional goto
- Instructions operate on two types of data
  - Registers — high speed access
  - Memory (RAM) — slow to access
- This course uses ARM
  Our ARM instructions are a subset of LEGv8, which is a subset of the actual ARMv8 instructions

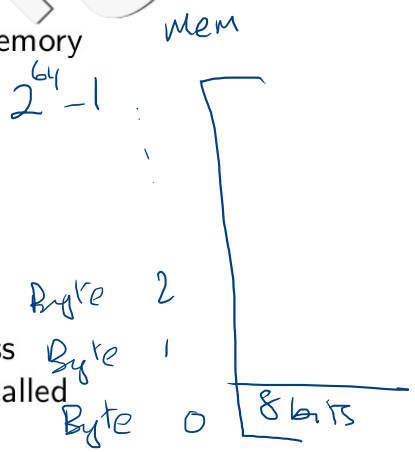
- **A main goal of this course is to design hardware to execute a subset of ARM instructions**


1000 HIGH
MEM
Add
Stack
ARM
program
MEM
RAM
data
code / text
instructions = ISA
0
LO
MEM
Address
P
SM
I/O
64
2 - 1
Array of Bytes
1
0
8 bits

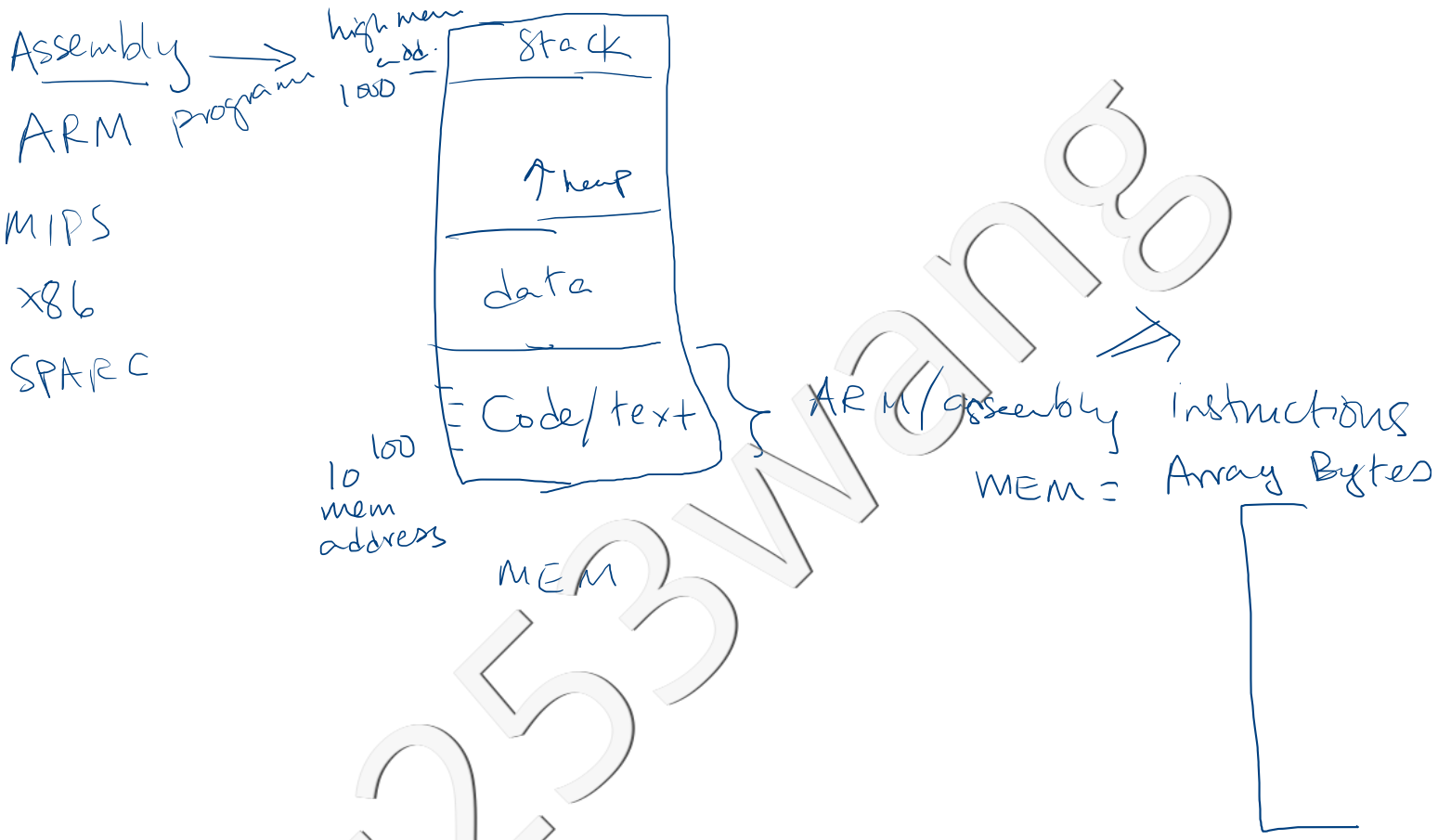


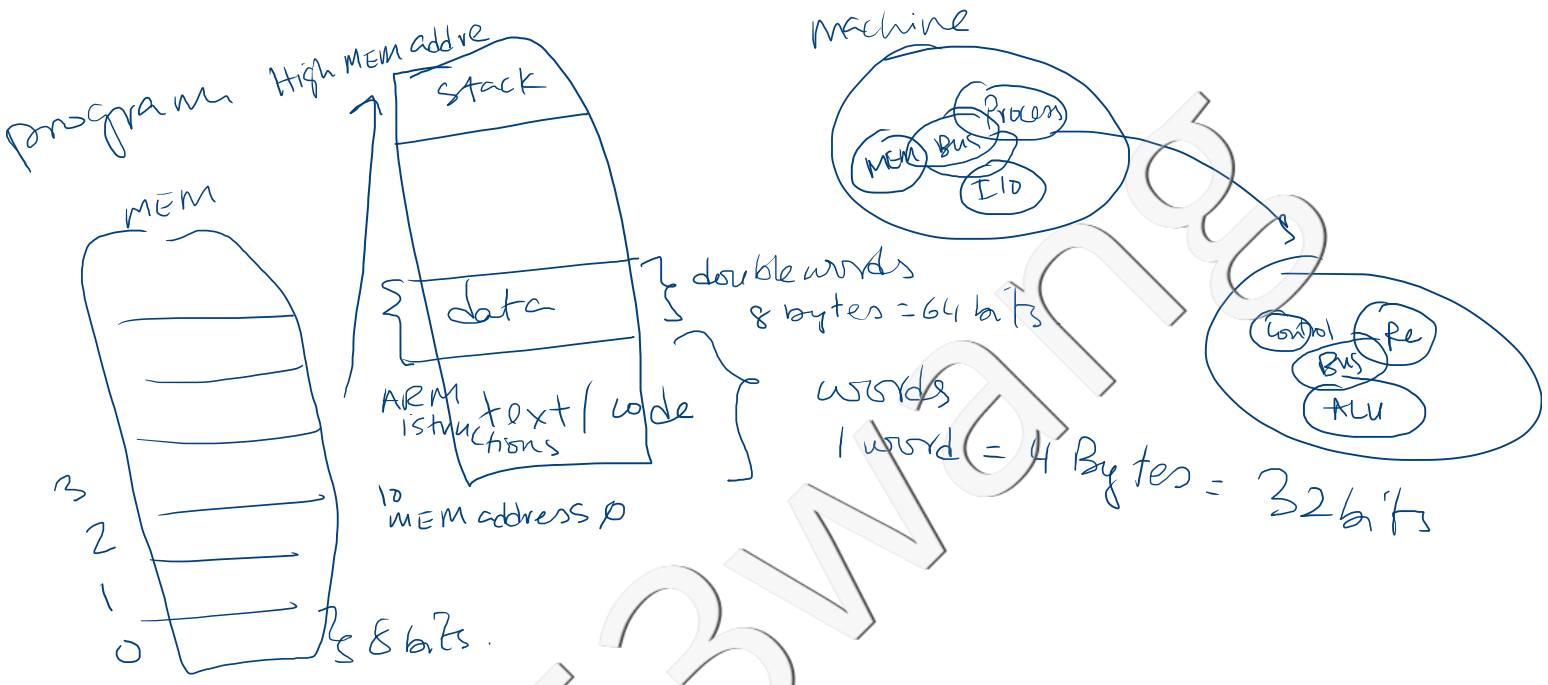
ARM Program - Instructions and Data

- An ARM program and the data for the program are stored in Random Access Memory[1] (RAM)
- Five general formats of ARM instructions
  - Format refers to how many and what type of operands
  - Operands refer to where the data is located
  - Only two sources for data in our ARM programs: Register or Memory
- 32 general purpose registers, used like a variable in an ARM instruction
  - Each register has 64 bits, eight bytes
  - Registers are identified as X0, X1,...,X31
  - X31 (XZR) always contains 0
- RAM Memory: consists of 2^{64} bytes
  - Memory accessed with byte number from 0 to $2^{64} - 1$ as address
  - Usually grouped in 4-byte blocks called *words* or 8-byte blocks called *double-words*.
  - Most memory accesses are to addresses that are multiples of 4 for instructions or multiple of 8 for data.



[1] Often in notes, examples, assignment questions or exam, we will use the term MEM to refer to off-chip RAM


Assembly
ARM
MIPS
x86
SPARC
program
high mem addr.
1000
Stack
heap
data
Code/text
100
10
mem address
MEM
ARM/assembly instructions
MEM = Array Bytes


program
High MEM addre
stack
data
ARM text/code
instructions
to MEM address 0
MEM
3
2
1
0
& bits.
double words
& bytes = 64 bits
words
1 word = 4 Bytes = 32 bits
machine
Proces
MEM
Bus
I/O
control
Re
Bus
ALU

ARM Program and Program Counter (PC) for Program in Memory

- Each program instruction is one word in length
- Instruction address is multiple of four
- Often write memory program as memory byte address followed by instruction:

Memory

Address	Instruction
100:	`ADD X1,X2,X3`
104:	`SUB X1,X3,X5`
108:	`ADDI X2,X12,#16`

- Often don't need address and use symbolic label of important instructions:

```
start:  ADD X1,X2,X3
        SUB X1,X3,X5
        ADDI X2,X12,#16
```

- Special register, *program counter* (PC), stores address of instruction currently executing

ARM Instructions

- R-Format:
  - 3 operands, each operand is in a general purpose register
  - Example: `ADD X1,X2,X3`
    Adds contents of X2 with the contents of X3; store result in X1
  - Example: `SUB X1,X2,X3`
    Subtracts contents of X3 from the contents of X2; store result in X1

Try this

Consider the following high-level code:

```
a = b + c - d;
```

Assume, variables `a`, `b`, `c`, and `d` are in registers X0, X1, X2 and X3, respectively.
Convert the high-level code into an ARM program using minimum ARM assembly instructions.