COMP 3221

Microprocessors and Embedded Systems

Lecture 8: C/Assembler Data Processing

http://www.cse.unsw.edu.au/~cs3221

August, 2003

Saeid Nooshabadi

Saeid@unsw.edu.au

Overview

- C operators, operands
- Variables in Assembly: Registers
- Comments in Assembly
- Data Processing Instructions
- Addition and Subtraction in Assembly

Review C Operators/Operands (#1/2)

- Operators: `+`, `-`, `*`, `/`, `%` (mod);
  - `7/4==1`, `7%4==3`
- Operands:
  - Variables: `lower`, `upper`, `fahr`, `celsius`
  - Constants: `0`, `1000`, `-17`, `15.4`
- Assignment Statement:

  Variable = expression

  - Examples:

```
celsius = 5*(fahr-32)/9;
a = b+c+d-e;
```


C Operators/Operands (#2/2)

- In C (and most High Level Languages) variables declared first and given a type
  - Example:

```
int fahr, celsius;
char a, b, c, d, e;
```

- Each variable can ONLY represent a value of the type it was declared as (cannot mix and match `int` and `char` variables).

Assembly Design: Key Concepts

- Keep it simple!
  - Limit what can be a variable and what can't
  - Limit types of operations that can be done to absolute minimum
    - if an operation can be decomposed into a simpler operation, don't include it.
    - For example `7%4 operation is complex. We break it into simpler operations in Assembly`

Assembly Variables: Registers (#1/4)

- Unlike HLL, assembly cannot use variables
  - Why not? Keep Hardware Simple
- Assembly Operands are registers
  - limited number of special locations built directly into the hardware
  - operations can only be performed on these!
- Benefit: Since registers are directly in hardware, they are very fast

Assembly Variables: Registers (#2/4)

- Drawback: Since registers are in hardware, there are a predetermined number of them
  - Solution: ARM code must be very carefully put together to efficiently use registers
- 16 registers in ARM
  - Why 16? Smaller is faster
- Each ARM register is 32 bits wide
  - Groups of 32 bits called a word in ARM

Assembly Variables: Registers (#3/4)

- Registers are numbered from 0 to 15
- Each register can be referred to by number or name
- Number references:

  `r0, r1, r2, … r15`
- `r15 = pc` has special significant:
- `r15` is program counter pointing to instructions being fetched from memory

Assembly Variables: Registers (#4/4)

- By convention, each register also has a name to make it easier to code
- For now:

  `r0 – r3 ➔ a1 – a4`

  (correspond to C functions arguments. Used for scratch pad too!)

  `r4 – r10 ➔ v1 – v7`

  (correspond to function variables)
- In general, use names to make your code more readable

Comments in Assembly

- Another way to make your code more readable: comments!
- Hash (;) is used for ARMS comments
  - anything from (;) mark to end of line is a comment and will be ignored
  - GNU ARM assembler accepts (@) instead of (;) as well
- Note: Different from C.
  - C comments have format /* comment */ , so they can span many lines
  - GNU ARM assembler accepts /* comments*/ as well.

Assembly Instructions

- In assembly language, each statement (called an Instruction), executes exactly one of a short list of simple commands
- Unlike in C (and most other High Level Languages), each line of assembly code contains at most 1 instruction

Data processing Instructions

- Largest category of ARM instructions, all sharing the same instruction format.
- Contains:
  - Arithmetic operations
  - Comparisons (no results saved - just set condition code flags NZCV)
  - Logical operations
  - Data movement between registers
- This is a load / store architecture
  - These instruction only work on registers, *NOT* memory.
- They each perform a specific operation on operands.

  4 field Format: 1 2, 3, 4

  where:

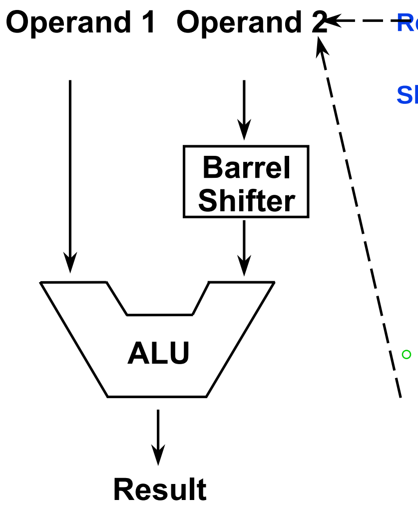
  1) operation by name

  2) operand getting result (“destination”)

  3) 1st operand for operation (“source1”)

  4) second operand: register or shifted register or immediate (numerical constant)

Using the Barrel Shifter: The Second Operand



Register, optionally with shift operation applied.

Shift value can be either be:

- 5 bit unsigned integer
```
add a1, v1, v3, lsl #8
;a1 ← v1 +(v3 << 8 bits)
```
- Specified in bottom byte of another register.
```
add a1, v1, v3, lsl v4
;a1 ← v1 +(v3 << v4 bits)
```

° Immediate value.
- 8 bit number
- Can be rotated right through an even number of positions.
- Assembler will calculate rotate for you from constant.

```
add a1, v1, #10
;a1 ← v1 + 10
```


Addition and Subtraction (#1/3)

° **Addition in Assembly**
- **Example:** `add v1,v2,v3` (in ARM)
  Equivalent to: `a = b + c` (in C)

  where registers `v1,v2,v3` are associated with variables `a, b, c`

° **Subtraction in Assembly**
- **Example:** `sub v4,v5,v6` (in ARM)
  Equivalent to: `d = e - f` (in C)

  where registers `v4,v5,v6` are associated with variables `d, e, f`

Addition and Subtraction (#2/3)

° **How do we do this?**
- `f = (g + h) - (i + j);`

° **Use intermediate register**

```
add v1,v2,v3   ; f = g + h
add a1,v4,v5   ; a1 = i + j
 ; need to save i+j, but can't use  f, so use a1
sub v1,v1,a1   ; f=(g+h)-(i+j)
```


Addition and Subtraction (#3/3)

° **How do the following C statement?**
`a = b + c + d - e;`

° **Break into multiple instructions**

```
add v1, v2, v3 ; a = b + c
add v1, v1, v4 ; a = a + d
sub v1, v1, v5 ; a = a - e
```

° **Notice: A single line of C may break up into several lines of ARM instructions.**

° **Notice: Everything after the (;) mark on each line is ignored (comments)**

Addition/Subtraction with Immediates (#1/2)

° Immediates are numerical constants.

° They appear often in code, so there are special instructions for them.

° Add Immediate:

`add v1,v2,#10` (in ARM)

`f = g + 10` (in C)

where registers `v1,v2` are associated with variables `f, g`

° Syntax similar to `add` instruction with register, except that last argument is a number instead of a register. This number should be preceded by (#) symbol

Addition/Subtraction with Immediates (#2/2)

° Similarly

`add v1,v2,#-10`

`f = g - 10` (in C)

where registers `v1,v2` are associated with variables `f, g`

° OR

`sub v1,v2,#10`

`f = g - 10` (in C)

where registers `v1,v2` are associated with variables `f, g`

Data Movement Instruction

° Addition with zero is conveniently used to move content of one register to another register, so:

`add v1,v2,#0` (in ARM)

`f = g` (in C)

where registers `v1,v2` are associated with variables `f, g`

° This is so often used in code that ARM has an specific instruction for it:

```
mov v1, v2
```

° Another useful instruction often used to provide delay in a loop is

```
mov v1, v1    ;this also called nop (No Operation)
```

- This does nothing useful

Reverse Subtraction Instruction

° Normal Subtraction:

- Example: `sub v4,v5,v6` (in ARM); v4 ← v5 – v6

  Equivalent to: `d = e - f` (in C)

where registers `v4,v5,v6` are associated with variables `d, e, f`

° Reverse Subtraction:

- Example: `rsb v4,v5,v6` (in ARM) ; v4 ← v6 – v5

  Equivalent to: `d = - (e) + f` (in C)

where registers `v4,v5,v6` are associated with variables `d, e, f`

° `rsb` is useful in many situations

COMP3221 Reading Materials (Week #3)

- Week #3: Steve Furber: ARM System On-Chip; 2nd Ed, Addison-Wesley, 2000, ISBN: 0-201-67519-6. We use chapters 3 and 5
- ARM Architecture Reference Manual –On CD ROM

"And in Conclusion…"

- New Instructions:
  - `add`
  - `sub`
  - `mov`
- New Registers:
  - C Function Variables: `v1` – `v7`
  - Scratch Variables: `a1` – `a4`