

Recitation 3 – Introduction to ARM Assembly Language

Overview

This recitation introduces **ARM Assembly Language**, focusing on:

- ARM assembly syntax and structure
- Register usage and load/store architecture
- Writing simple functions in ARM Assembly
- Looping and conditional execution
- Recursion and stack management

ARM Assembly is a **low-level programming language** that maps closely (often 1-to-1) with machine code instructions executed directly by the CPU. Unlike high-level languages such as C/C++, assembly gives you explicit control over registers, memory, and execution flow.

ARM Assembly Basics

General Syntax

```
Label: Opcode Destination, Operand1, Operand2 // Comment
```

Components:

- **Label** (optional): Marks a memory location (used for loops/branches)
- **Opcode**: Instruction to execute (e.g., ADD, MOV, SUB)
- **Destination**: Register where the result is stored
- **Operands**: Source registers or immediate values
- **Comment**: Starts with // or @

Example

```
add r0, r0, r1 // r0 = r0 + r1
```

Core Concepts

Registers (Workspace)

ARM processors perform arithmetic **only on registers**, not directly on memory.

Register	Purpose
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Register	Purpose
R0–R12	General-purpose registers
R13 (SP)	Stack Pointer
R14 (LR)	Link Register (stores return address)
R15 (PC)	Program Counter (next instruction address)

Load/Store Architecture

ARM uses a **load/store architecture**:

- **LDR** – Load from memory → register
- **STR** – Store from register → memory

Example restriction:

Invalid:

```
add [memory_address], #1
```

Correct approach:

```
ldr r0, [address]
add r0, r0, #1
str r0, [address]
```

Assembler Directives

These guide the assembler (not executed by CPU):

- **.global symbol** – Makes function visible to linker
- **.text** – Start of code section

Reference:

- ARM Assembly Directives (GNU AS): <https://sourceware.org/binutils/docs/as/ARM-Directives.html>

Conditional Execution (Suffixes)

ARM allows conditional execution via suffixes:

Instruction	Meaning
B	Branch always

Instruction	Meaning
BNE	Branch if Not Equal
BEQ	Branch if Equal
ADDNE	Add if Not Equal

Implemented Functions

1. Add Two Numbers

Description

Simple function that:

- Takes two arguments
- Performs addition
- Returns result in `r0`

Calling Convention

- `r0` → first number
- `r1` → second number
- Return value → `r0`

Implementation

```
.global add_asm

// Function: add_asm
// R0 = a, R1 = b
// Returns: R0 = a + b
add_asm:
    add r0, r0, r1
    bx lr
```

2. Sum Elements of an Array (Basic Loop)

Description

Iterates through an array of bytes and accumulates their sum.

Parameters

- `r0` → pointer to array

- `r1` → number of elements

Implementation

```
// Function: summation1
// r0: pointer to array
// r1: number of elements (n)

summation1:
    mov r4, #0          // accumulator = 0

add_loop1:
    ldrb r2, [r0], #1  // load byte, increment pointer
    add r4, r4, r2      // add to accumulator
    subs r1, r1, #1     // decrement counter
    bne add_loop1       // loop if not zero

    mov r0, r4          // return result
    bx lr
```

3. Sum Elements (Optimized Variation)

Description

Uses **conditional execution (IT blocks)** to reduce branching and improve efficiency.

Implementation

```
summation2:
    mov r4, #0
    add r1, r1, #1

add_loop2:
    subs r1, r1, #1
    ldrb r2, [r0], #1

    IT NE
    addne r4, r4, r2

    bne add_loop2

    mov r0, r4
    bx lr
```

Optimization Idea

- Uses conditional execution (`ADDNE`)

- Reduces unnecessary branch instructions
 - Can improve pipeline efficiency on some ARM architectures
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4. Factorial Function (Recursive)

Description

Demonstrates:

- Recursion
- Stack usage (**push** / **pop**)
- Preserving registers
- Proper handling of the Link Register (**lr**)

Parameter

- **r0** → integer **n**

Implementation

```
// Function: factorial
// r0: integer n

factorial:
    cmp r0, #1
    ble base_case

    push {r1, lr}
    mov r1, r0
    sub r0, r0, #1
    bl factorial

    mul r0, r0, r1
    pop {r1, lr}
    bx lr

base_case:
    mov r0, #1
    bx lr
```

Key Concepts Demonstrated

- **bl** stores return address in **lr**
 - **push {r1, lr}** preserves state across recursive calls
 - Stack ensures correctness during nested recursion
 - Base case prevents infinite recursion
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Key Takeaways

- ARM Assembly gives precise control over CPU operations.
- Arithmetic operations must use registers.
- Memory access requires explicit load/store instructions.
- Conditional execution can optimize performance.
- Stack management is essential for recursion.
- Understanding calling conventions is critical for interoperability with C/C++.