# Microprocessors & Microcontrollers
## : Arm Cortex M0+
## (Using RP2040)

ESM_12

**Arithmetic Condition Flags**

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# Focus

- Arithmetic Conditional Flags
  - NZCV Flags
- About the Overflow Flag
- Unsigned and Signed Integers

# Arithmetic Condition Codes

# Arithmetic Conditional Flags

- All the processors have the following conditional flags to indicate the result of Integer Arithmetic operations in the ALU (Arithmetic Logic Unit)
  - Sign Flag (**N**)
  - Zero Flag (**Z**)
  - Carry Flag (**C**)
  - Overflow Flag (**V**)
- In the following sections let us understand the significance of each of them

# Definitions of Arithmetic Condition Codes

- **Sign Flag (N): Negative**
  - The last ALU operation which changed the flags produced a negative result (the **Most Significant Bit** of the 32-bit result was a **one**)
- **Zero Flag (Z)**
  - The last ALU operation which changed the flags produced a zero result (every bit of the 32-bit result was zero)
- **Carry Flag (C)**
  - The last ALU operation which changed the flags generated a carry-out, either as a result of an arithmetic operation in the ALU or from the shifter
- **oVerflow Flag (V)**
  - The last arithmetic ALU operation which changed the flags generated a result which cannot be represented within the range of signed values

# Interpretation of NZCV Flags

The numbers added in the previous quiz were:

**1101**

**1011**

| | Binary Values | Unsigned Value | Signed Value | Flags for Unsigned ZC | Flags for Signed NZV |
|---|---|---|---|---|---|
| | 1101 | 13 | -3 | | |
| + | 1011 | 11 | -5 | | |
| Result | 1000 | 8 | -8 | 01 | 100 |

Wrong Correct

**Note**: The Overflow (**V**) flag is set to indicate whether the **signed result** after the operation can be fit into the available bits or not. Here **V** is cleared because **-8** can be accommodated within four bits.

# Quiz 2

**Choose the correct option:**

1. Consider a **four bit ALU** which does four bit arithmetic. When the following four bit numbers are added what is the status of **NZCV** flags after the addition is performed?

   **1101**
   **+ 1011**

a) NZCV = 0111
b) NZCV = 1000
c) NZCV = 1001
d) NZCV = 1010

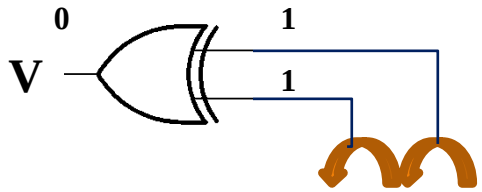
**Correct option: d**

**Note**: Relevant flags needs to be interpreted after the above addition based on whether a signed or unsigned result was needed. Let us spend some time on this.

# About the Overflow Flag

# How is Overflow (V) Flag Set?

**Note**: Overflow (**V**) is got by **XOR**ing the carry coming out of the bits **prior to Most Significant Bits** and the carry from the **Most Significant Bits**.




| | | | | | |
|---|---|---|---|---|---|
| **Carry Flag:** | **1** | **1** | **1** | **0** | **1** |
| | | **1** | **0** | **1** | **1** |
| **Result of addition:** | | **1** | **0** | **0** | **0** |

# One more Example

Let us take another example:

**0111**

**+ 0011**

| | Binary Values | Unsigned Value | Signed Value | Flags for Unsigned ZC | Flags for Signed NZV |
|---|---|---|---|---|---|
| | 0111 | 7 | 7 | | |
| + | 0011 | 3 | 3 | | |
| **Result** | 1010 | **10** | **-6** | **00** | **101** |

**Correct** **Wrong**

**Notes**:

1. The **V** (overflow flag) convey whether a **signed** arithmetic has given out a result which is **incorrect**.
2. If numbers are interpreted as **unsigned**, the **overflow flag is irrelevant**.
3. But if the numbers added are interpreted as **signed**, if **V** is set, it means, either two large positive numbers were added and the result became negative or two large negative numbers were added and the result became positive.

# Unsigned and Signed Integers

# Unsigned and Signed Integers

- In C, an integer variable can be defined either as s**igned** or **unsigned**
- When these variables are declared, compiler allocates memory space either in **data** or **stack** area depending on whether they are **global/static/local** variables
- When any arithmetic operation needs to be performed on these variables, they are brought into registers from memory
- The processor does not have any knowledge on whether a signed or unsigned integer is moved into a register
- When an arithmetic operation is performed they affect all the condition flags **NZCV**
- Later proper instructions are to be used by the compiler to check either **C** flag or **V** flag to interpret the result based on whether the variables are declared as **signed** or **unsigned**.

# Find the solution

1. Assume i and j are 32 bit data. Find (i<<5 && j>>3) given
int i = 0x12f and int j = 0xf

2. Assume i is a 32 bit data. Find i<<2 for
signed int i = -1

# Summary

- Arithmetic Conditional Flags
  - NZCV Flags
- About the Overflow Flag
- Unsigned and Signed Integers