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AND OPERATOR

Boolean Instructions in Assembly Language

Boolean instructions let us perform logical operations on bits or bytes. They’re super handy for manipulating data, making decisions, and steering the flow of a program.

**✨** AND

The **AND** instruction compares two operands bit by bit.

* If *both* bits are 1, the result is 1.
* Otherwise, the result is 0. 👉 The outcome is stored in the destination operand.

**✨** OR

The **OR** instruction also works bit by bit.

* If *either* bit is 1, the result is 1.
* If both are 0, the result is 0. 👉 The result goes into the destination operand.

**✨** XOR (Exclusive OR)

The **XOR** instruction checks two operands bit by bit.

* If *only one* of the bits is 1, the result is 1.
* If both are the same (both 0 or both 1), the result is 0. 👉 The result is stored in the destination operand.

**✨** NOT

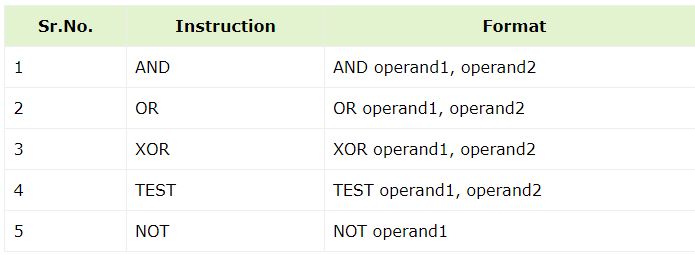
The **NOT** instruction flips every bit in a single operand.

* 1 becomes 0
* 0 becomes 1 👉 The inverted result is stored in the destination operand.

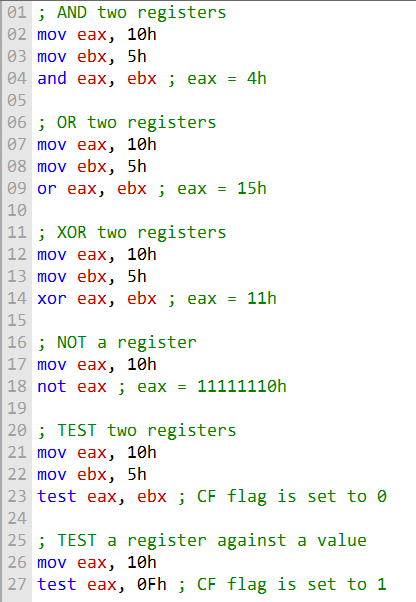
**✨** TEST

The **TEST** instruction performs a bit-by-bit **AND** operation on two operands— but here’s the twist: it doesn’t save the result!

Instead, it updates the CPU flags based on the outcome. 👉 This makes it perfect for checking values in registers or memory before making a decision.



Here are some examples of how to use the Boolean instructions in assembly language:



CPU Flags

Flags are little indicators inside the CPU that light up based on the result of an operation. They help the processor make decisions and control program flow.

**✨** Zero Flag (ZF)

* **Set when**: The result of an operation is 0.
* **Use case**: Perfect for checking equality or non-equality.
* **Example**: Skip instructions if the result is zero.

**✨** Carry Flag (CF)

* **Set when**: An operation produces a carry out of the highest bit.
* **Use case**: Common in addition and subtraction.
* **Example**: Signals overflow in addition if set.

**✨** Sign Flag (SF)

* **Set when**: The most significant bit (MSB) of the result is 1.
* **Use case**: Tells whether the result is positive or negative.
* **Example**: Set if the result is negative.

**✨** Overflow Flag (OF)

* **Set when**: The result goes outside the signed number range.
* **Use case**: Detects arithmetic errors.
* **Example**: Adding two positive numbers gives a negative result.

**✨** Parity Flag (PF)

* **Set when**: The destination operand has an even number of 1 bits.
* **Use case**: Helpful for error checking.
* **Example**: Can signal data corruption if not set when reading from memory.

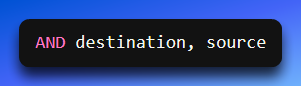
AND Instruction

The **AND** instruction compares two operands bit by bit and stores the result in the destination operand.

**Operation**: Each pair of matching bits is checked.

* If both bits are 1, the result is 1.
* Otherwise, the result is 0.

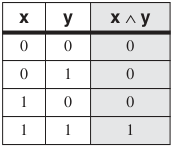




**Operand Sizes:** The operands can be 8, 16, 32, or 64 bits, and they must be the same size.

If both bits equal 1, the result bit is 1; otherwise, it is 0.

Example: x AND y, where x and y are bits.



**Bit Masking:** Think of the **AND** instruction as a 'filter.' If you need to reset a hardware device by turning off specific bits (like bits 0 and 3) while leaving everything else exactly as it is, you can use a mask to 'wipe' those spots clean.



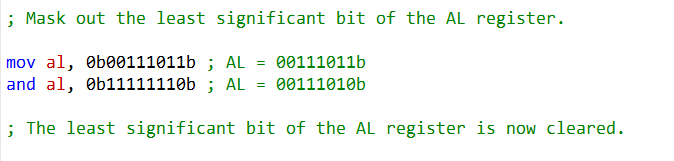
**🌟** AND Instruction & Flags

* The **AND instruction** always clears the **Overflow** and **Carry** flags.
* It updates the **Sign**, **Zero**, and **Parity** flags depending on the result stored in the destination operand.

**🎭** Masking with AND

The AND instruction isn’t just about logic—it’s also a handy tool for **masking**. Masking means you can clear specific bits in an operand while leaving the rest untouched.

* To clear a bit, you AND the operand with a mask that has a **0** in the position you want to wipe out.
* Example: To clear the **least significant bit (LSB)** of the **AL register**, use this mask: **0b11111110**



You can use the **same masking technique** to clear *any* bit in an operand, no matter its position.

To mask out bit **n**, simply AND the operand with a mask that has a **0** in that bit position.

**🛠** Why Masking Matters

Masking is a powerful tool in assembly language programming. It lets you:

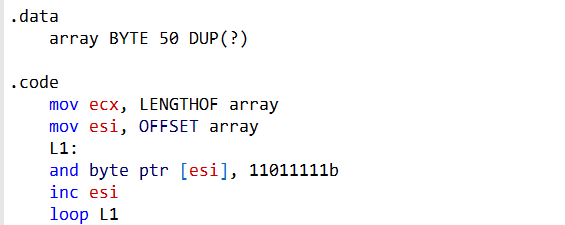
* 🔍 **Isolate** a specific bit (or group of bits).
* 🧹 **Clear or set** chosen bits without touching the rest.
* ✅ **Check** whether certain bits are set or cleared.
* 🤝 Perform logical **AND operations** across multiple operands.

**✨** Example: Lowercase → Uppercase

Here’s a neat trick: you can convert a character from **lowercase to uppercase** by clearing **bit 5** of the character.

* Bit 5 is the one that decides whether a character is lowercase or uppercase.
* By masking it out, you flip the character into its uppercase form.

**🧩** Code Breakdown



**🔠** How the Code Works (Step by Step)

1. **Load the character** into a register.
2. **AND it** with a mask that clears bit 5.
3. The result is the **uppercase version** of the original character.

**🗂** Sections of the Program

* .data **section** → Declares an array of 50 bytes. Each byte can hold a single character.
* .code **section** → Contains the actual instructions that perform the conversion to uppercase.

**⚙️** Key Instructions Explained

* mov ecx, LENGTHOF array → Loads the length of the array into register ecx. This tells the program how many characters to process.
* mov esi, OFFSET array → Loads the address of the first element in the array into register esi. This sets up a pointer to the start of the data.
* L1: **label** → Marks the beginning of a loop. The loop will run once for each character in the array.
* and byte ptr [esi], 11011111b → Performs an AND operation on the byte at the address stored in esi with the mask 11011111b. This clears **bit 5**, which flips the character from lowercase to uppercase.
* inc esi → Increments esi by 1, moving the pointer to the next character in the array.
* loop L1 → Jumps back to the start of the loop until all characters have been processed.

**🎉** End Result

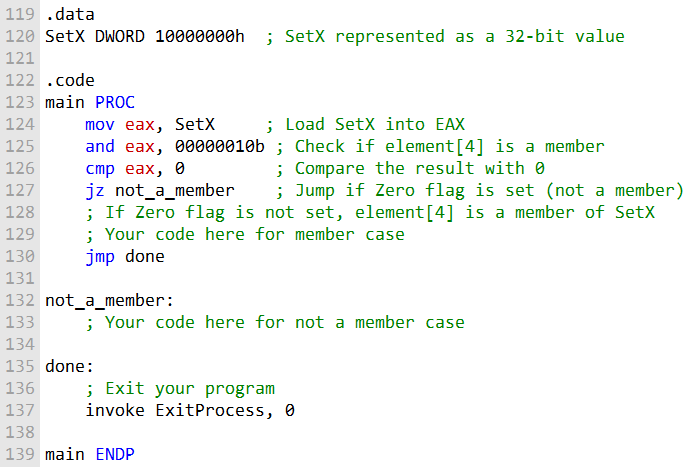
After the loop finishes, every character in the array has been converted to **uppercase**. The program efficiently walks through the array, one character at a time, applying the bit-clearing trick to achieve the transformation.

BIT-MAPPED SETS

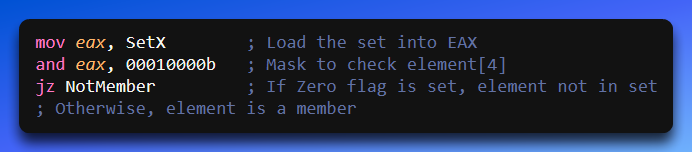
* **Representation**: A set is represented as a **bit vector**. Each bit corresponds to an element in the universal set.
* **Efficiency**: Instead of complex data structures, you manipulate sets directly with bitwise instructions.
* **Applications**: Common in **systems programming**, hardware control, and memory management where speed and compactness matter.

**🔍** Checking Set Membership

To see if an element is in a set, AND the set with a mask that isolates the bit for that element.



OR



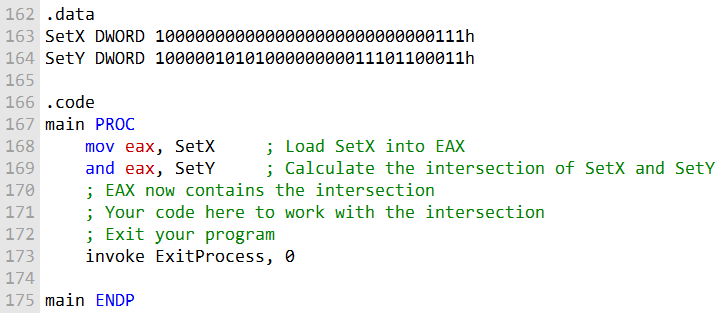
**🔄** Set Complement

Flip all bits with the NOT instruction to get the complement.



**🤝** Set Intersection

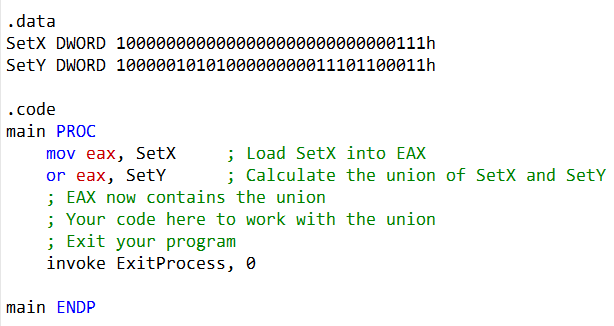
Use AND to find elements common to both sets.



**🌐** Set Union

Use OR to combine elements from both sets.

Example of SetX and SetY:



**🎉** Why This Matters

Bit-mapped sets let you:

* Quickly check membership with a single instruction.
* Perform **set operations** (union, intersection, complement) at machine speed.
* Save memory by representing sets compactly as bit vectors.

OR OPERATION

The **OR instruction** performs a **bitwise OR** between each pair of matching bits in two operands.

The result is stored in the **destination operand**.



**Combinations above:** Same as the AND instruction.

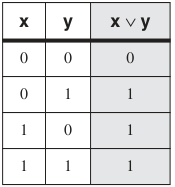
**📏** Operand Sizes

* Operands can be **8, 16, 32, or 64 bits**.
* Both operands must be the **same size**.

✨ Truth Table:

For each matching bit in the two operands:

Example: x OR y, where x and y are bits.



👉 The output bit is **1** if *at least one* of the input bits is 1.

**🔧** Setting Bits with OR

Think of the **OR** instruction as a surgical strike for your data. It’s the go-to move in embedded programming when you need to flip a specific "switch" in a register without disturbing any of the other settings.

To turn on bit 2 in the AL register while leaving the rest of the configuration untouched, you’d use:



or



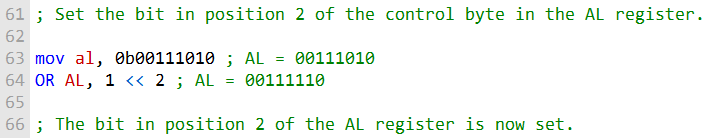
The OR instruction performs a bitwise OR operation on its two operands.

The **<< operator** shifts the number on its left by the number of bits specified by the number on its right.

In this case, the number 1 is shifted left by 2 bits, which results in the number 4.

The OR instruction then ORs the AL register with the number 4, which sets the bit in position 2 of the AL register.

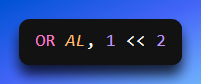
Here is an example of how to use the code above:



You can use the **OR instruction** to set any bit in an operand, no matter its position.

* To set bit **n**, OR the operand with the value 1 shifted left by **n** positions.
* This creates a **bitmask** where only the target bit is 1, and all others are 0.

**✨** Example: Setting Bit 2 in AL



**Step-by-Step Breakdown:**

Start with 00000001 (binary for 1).

Shift it left by 2 → 00000100.

This creates a mask with **bit 2** set to 1.

Perform OR AL, 00000100b.

* The OR operation sets **bit 2** in AL to 1.
* All other bits remain unchanged.

**Result:** After executing this instruction:

* **Bit 2** in the AL register is guaranteed to be 1.
* Every other bit in AL stays exactly as it was before.

Flags and the OR Instruction

* The **OR instruction** always **clears** the **Carry** and **Overflow** flags.
* It **updates** the **Sign**, **Zero**, and **Parity** flags based on the result stored in the destination operand.

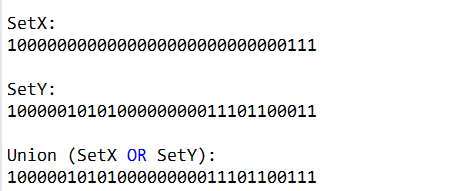
Why It Matters

Bitwise instructions like **OR** are essential in assembly programming because they let you:

* 🔧 Perform precise **bit manipulation**.
* 🎯 Control or check **flags** for conditional logic.
* ⚡ Work efficiently with low-level data structures.

Typical Uses

* Setting specific bits without disturbing others.
* Combining values (like set union in bit-mapped sets).
* Flag setting/clearing in system-level code.



It's clear that the OR operation combines the two sets by preserving any bits that are set in either SetX or SetY.

In binary representation:

* SetX has bits set at positions 0, 1, and 31.
* SetY has bits set at positions 0, 5, 9, 14, 18, 23, 26, 30, and 31.

When you perform a bitwise OR between SetX and SetY, the resulting union has bits set at all the positions where at least one of SetX or SetY had a bit set. In this case, the union contains bits set at positions 0, 1, 5, 9, 14, 18, 23, 26, 30, and 31.

This operation can be visualized as a union operation in set theory, where you're combining the elements of two sets while eliminating duplicates.

XOR OPERATION / INSTRUCTION

**✨** XOR (Exclusive OR) Instruction

* The **XOR instruction** performs a **boolean exclusive-OR** operation between corresponding bits in two operands.
* The result is stored in the **destination operand**.

**📏** XOR Rules

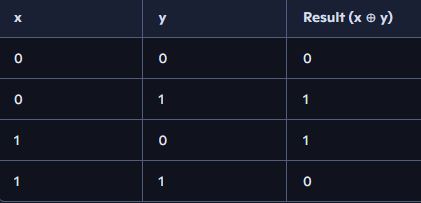
* If both bits are the **same** (both 0 or both 1), the result is 0.
* If the bits are **different** (0 and 1), the result is 1.
* A bit XORed with 0 → **retains its value**.
* A bit XORed with 1 → **toggles (complements)** its value.

**🔄** Reversibility

XOR is **reversible**:

* Applying XOR twice with the same operand restores the **original value**.
* This property makes XOR useful in tasks like **encryption/decryption** and **bit manipulation tricks**.

**🧮** Truth Table for XOR (x ⊕ y)



The XOR instruction performs a bitwise exclusive OR operation on its two operands.



Flags and the XOR Instruction

* The **XOR instruction** always **clears** the **Overflow** and **Carry** flags.
* It **updates** the **Sign**, **Zero**, and **Parity** flags based on the result stored in the destination operand.

**🔍** Parity Checking

* **Parity** is a way to check whether a binary number has an **even** or **odd** count of 1 bits.
  + Even number of 1s → **even parity**.
  + Odd number of 1s → **odd parity**.
* In **x86 processors**, the **Parity Flag (PF)** is set if the **lowest byte (8 bits)** of the result has **even parity**.
* If the lowest byte has **odd parity**, the PF is **cleared**.

**✨** Example: Checking Parity Without Changing a Value

Here’s how you can check parity in assembly without altering the actual byte:



**🧩** Breakdown

* mov al, byteValue → Loads the byte into the AL register.
* test al, al → Performs an AND of AL with itself. This doesn’t change AL, but it updates the flags (including PF).
* jpo OddParity → Jumps if the Parity Flag is **not set** (odd parity).
* If the jump doesn’t occur, it means the byte has **even parity**.



The XOR instruction can be used to toggle (invert) bits, check the parity of a number, and perform other bitwise operations. Here are some examples of how to use the XOR instruction:



To calculate parity for 32-bit values, you can XOR all the bytes together, like this:



NOT OPERATION

The **NOT instruction** is used to invert or toggle all the bits in an operand. This operation is also known as taking the one's complement of the operand. Here's how it works:

**NOT reg:** This form of the NOT instruction operates on a register. It inverts all the bits in the specified register.



**NOT mem:** This form of the NOT instruction operates on a memory location. It inverts all the bits in the value stored at that memory location.



In both examples, the NOT instruction flips all the bits. In the first example, it's applied to the AL register, and in the second example, it's applied to a byte stored in memory via the EBX register.

Flags: The NOT instruction does not affect any of the CPU flags. It simply performs the bitwise inversion without changing the status flags like Zero Flag, Sign Flag, etc.

TEST OPERATION

The **TEST instruction** is a handy tool for performing **bitwise logical checks** without changing the actual contents of the destination operand.

**🧪** What TEST Does

* Performs a **bitwise AND** between two operands.
* Updates the **Sign (S)**, **Zero (Z)**, and **Parity (P)** flags based on the result.
* Unlike the **AND instruction**, it does **not modify** the destination operand.

👉 This makes TEST perfect for **checking whether specific bits are set** while leaving the original data untouched.

**📊** Operand Combinations

The TEST instruction supports the same operand combinations as the AND instruction:

* Register ↔ Register
* Register ↔ Memory
* Register ↔ Immediate (constant)
* Memory ↔ Immediate

**✨** Why It’s Useful

* Efficient way to **check bit status**.
* Commonly used in **conditional branching** (e.g., jump if zero, jump if sign).
* Preserves the original data while still giving you flag information to act on.

Example: Testing Multiple Bits:

In the example you provided, the goal is to determine whether bit 0 or bit 3 is set in the AL register. The following instruction accomplishes this:



Think of the **TEST** instruction as a "silent inspector." It performs a bitwise AND between two values to see what’s happening under the hood, but it doesn't actually change anything in your registers. It’s the perfect way to "peek" at a status bit before deciding what your code should do next.

If you want to find out if either **bit 0** or **bit 3** is active in the AL register, you’d use a mask like this:

Reading the Flags (The "Secret Sauce")

Since TEST doesn't save the result, you have to look at the **CPU flags** to see what happened. The most important one here is the **Zero Flag (ZF)**:

* **If ZF = 1 (Zero):** Neither bit was set. The result was a total blank.
* **If ZF = 0 (Not Zero):** Success! At least one of those bits (0 or 3) was a 1.

What happens to the other flags?

While the TEST instruction is busy checking your bits, it also does a little housekeeping on the status register:

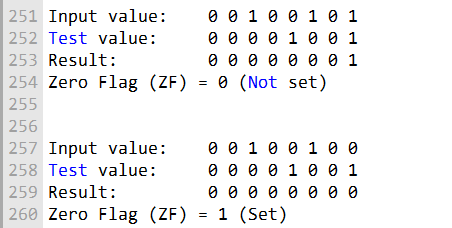
* **ZF, SF, and PF:** These are updated based on the result (just like a standard AND).
* **CF and OF:** These are always cleared (set to 0) because bitwise logic doesn't involve carries or overflows.

The TEST instruction is your go-to for **conditional branching**.

You use it to check a status, and then immediately follow it with a jump instruction (like JZ for "Jump if Zero" or JNZ for "Jump if Not Zero") to steer your program's logic.

Example of using a bit mask with the TEST instruction

(The value 00001001 in this example is called a bit mask.)



The Big Correction: Equality vs. Bits

The text you have says TEST checks if two values are **equal**. That’s not quite right.

* **CMP (Compare):** Subtracts values to see if they are equal.
* **TEST:** Performs an **AND** to see if specific bits are "on."

If you TEST AL, 09h, you aren't checking if AL is 9. You are checking if **Bit 0** or **Bit 3** (the bits that make up 9) have any life in them.

How the Flags Actually Work

Think of the **Zero Flag (ZF)** as a "Nothing Found" flag.

* **ZF = 1 (True/Set):** The result was zero. This means **none** of the bits you were looking for were turned on. It’s like searching a room and finding nothing.
* **ZF = 0 (False/Clear):** The result was *not* zero. This means **at least one** of the bits you were testing is active.

The "Always" Flags

No matter what bits you are checking, the CPU always does a quick bit of house-cleaning:

* **Carry (CF) & Overflow (OF):** These are **always forced to 0**. Why? Because bitwise logic doesn't "carry over" or "overflow" like addition does.
* **Sign (SF) & Parity (PF):** These just report on the result. If the top bit of the result is 1, SF turns on. If the number of 1s is even, PF turns on.

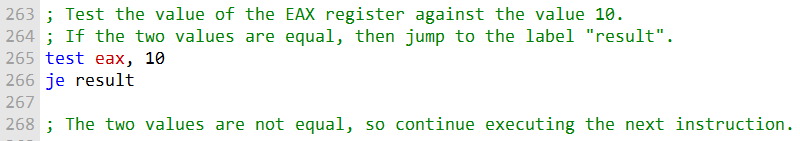
Using it for Branching

In your example, the TEST is usually followed by a jump:

* **JZ (Jump if Zero):** Take this path if the bits we checked were **all zeros**.
* **JNZ (Jump if Not Zero):** Take this path if **at least one** of those bits was a 1.

**Wait, a quick tip:** If you actually wanted to see if AL is exactly equal to 9, you should use CMP AL, 9. Using TEST for equality only works in very specific, rare cases!

Here is a simple example of how to use the test operation in assembly language:



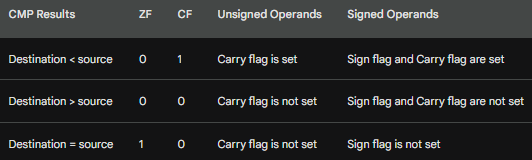
CMP INSTRUCTION

The **CMP instruction** is used to compare two operands (integers, character codes, etc.) by performing an **implied subtraction**: DESTINATION – SOURCE.

* **No operands are modified**.
* Only the **CPU flags** are updated based on the result.
* This makes CMP essential for **conditional branching** and building logic structures similar to if statements in high-level languages.

The **CMP instruction** performs an implied subtraction of the source operand from the destination operand. However, the actual subtraction is not performed. Instead, the status flags are set according to the result of the subtraction.

Here's a breakdown of how the CMP instruction affects flags based on the comparison results:

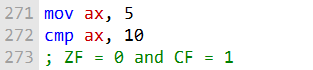


Unsigned Operands. When comparing two unsigned operands:

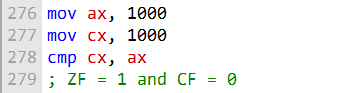
If the destination is less than the source, the Zero Flag (ZF) is set to 0, and the Carry Flag (CF) is set to 1. If the destination is greater than the source, ZF is set to 0, and CF is set to 0. If the destination equals the source, ZF is set to 1, and CF is set to 0.

Signed Operands. When comparing two signed operands:

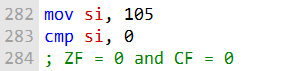
If the destination is less than the source, the Sign Flag (SF) is not equal to the Overflow Flag (OF). If the destination is greater than the source, SF is equal to OF. If the destination equals the source, the Zero Flag (ZF) is set to 1.



In this example, when AX (with a value of 5) is compared to 10, the CMP instruction sets the Zero Flag (ZF) to 0 because 5 is not equal to 10. The Carry Flag (CF) is set to 1 because subtracting 10 from 5 would require a borrow. Example 2:



Here, when AX and CX both contain 1000, the CMP instruction sets the Zero Flag (ZF) to 1 because subtracting one 1000 from the other results in zero. The Carry Flag (CF) is set to 0 because no borrow is required. Example 3:



In this case, when SI (with a value of 105) is compared to 0, the CMP instruction sets both the Zero Flag (ZF) and the Carry Flag (CF) to 0 because subtracting 0 from 105 generates a positive, nonzero value.

CMP, when used in conjunction with conditional jump instructions, allows you to create conditional logic structures, akin to high-level programming languages' IF statements, in assembly language. It's a powerful tool for controlling the flow of your programs based on comparisons between values in registers or memory locations.

SETTING AND CLEARING FLAGS

Setting the Zero Flag

To set the Zero flag, you can use the TEST or AND instruction. In the code:



This instruction tests the value in the al register against 0. If the result is zero, the Zero flag is set.

Clearing the Zero Flag

To clear the Zero flag, you can use the OR instruction with 1:



This instruction logically ORs the al register with 1, ensuring that the Zero flag is cleared.

Setting the Sign Flag

To set the Sign flag, you can use the OR instruction with the highest bit of an operand (bit 7 in the al register) set to 1:



This operation sets the highest bit of al to 1, which sets the Sign flag.

Clearing the Sign Flag

To clear the Sign flag, you can use the AND instruction with the highest bit (bit 7) set to 0:



This operation clears the highest bit of al, ensuring that the Sign flag is cleared.

Setting the Carry Flag

To set the Carry flag, you can use the STC (Set Carry) instruction:



This instruction sets the Carry flag, indicating a carry condition.

Clearing the Carry Flag

To clear the Carry flag, you can use the CLC (Clear Carry) instruction:



This instruction clears the Carry flag, indicating no carry condition.

Setting the Overflow Flag

To set the Overflow flag, you can add two positive values that produce a negative sum. This condition naturally sets the Overflow flag.

Clearing the Overflow Flag

To clear the Overflow flag, you can use the OR instruction with an operand of 0:



This operation performs a logical OR with 0, ensuring that the Overflow flag is cleared.

Our code also mentions the relationship between flags (SF, OF, ZF) and the results of comparisons and arithmetic operations.

It's crucial to understand these flag behaviors in ASM.

BOOLEANS AND 64-BIT MODE

In 64-bit mode, instructions work similarly to how they do in 32-bit mode, but with some differences due to the larger register size.

**Operand Size:** When you operate on 64-bit registers or memory operands with a source operand that's smaller than 32 bits, all bits in the destination operand are affected eg.



Here, the and operation affects all 64 bits of RAX.

When you use a **32-bit constant or register** as the source operand, only the **lower 32 bits** of the destination operand are modified.



Only the **lower 32 bits of RAX** are affected. The upper 32 bits are cleared to zero.

**🗂** Memory Operands

* The same rules apply when the **destination operand is in memory**.
* If you perform a 32-bit operation on a memory location, only the 32-bit portion is modified.

**⚠️** Special Handling

In **64-bit mode**, 32-bit operands behave differently compared to other operand sizes:

* **8-bit and 16-bit operations** → Only affect the specified portion, leaving the rest unchanged.
* **32-bit operations** → Affect the lower 32 bits and **zero out the upper 32 bits** of the 64-bit register.
* **64-bit operations** → Affect the entire register.

**🎯** Why This Matters

* Misunderstanding these distinctions can lead to **unexpected results** in 64-bit assembly programming.
* Always be mindful of operand size when working with registers or memory in 64-bit mode.

**Question: How can you clear the high 8 bits of AX without changing the low 8 bits using a single 16-bit operand instruction?**

Answer: You can clear the high 8 bits of AX by using the AND instruction with the 16-bit mask 00FFh. The instruction would look like and ax, 00FFh.



**Question: How can you set the high 8 bits of AX without changing the low 8 bits using a single 16-bit operand instruction?**

Answer: You can set the high 8 bits of AX by using the OR instruction with a 16-bit value.



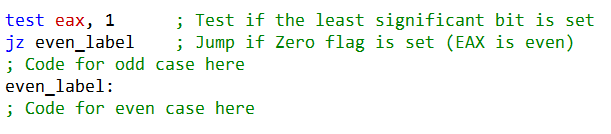
**Question: What instruction can you use to reverse all the bits in EAX with a single instruction?**

Answer: To reverse all the bits in EAX, you can use the XOR instruction with a mask where all bits are set to FFFFFFFFh. The instruction would be xor eax, FFFFFFFFh.



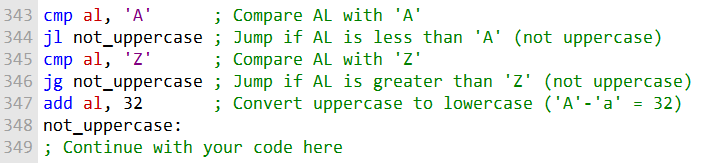
**Question: How can you set the Zero flag if the 32-bit value in EAX is even and clear the Zero flag if EAX is odd?**

Answer: You can set the Zero flag if the 32-bit value in EAX is even and clear the Zero flag if EAX is odd using the TEST instruction and conditional jumps. Here's an example:



**Question: How can you convert an uppercase character in AL to lowercase using a single instruction, but without modifying AL if it's already lowercase?**

Answer: To convert an uppercase character in AL to lowercase without modifying it if it's already lowercase, you can use conditional instructions like this:



This code first checks if AL is between 'A' and 'Z' (inclusive) using CMP and conditional jumps (JL and JG). If it's within that range, it adds 32 to AL, converting the uppercase letter to lowercase.

CONDITIONAL JUMPS

x86 does not have explicit high-level logic structures in its instruction set, but you can implement them using a combination of comparisons and jumps. Two steps are involved in executing a conditional statement:

An operation such as CMP, AND, or SUB modifies the CPU status flags. A conditional jump instruction tests the flags and causes a branch to a new address.

The following example compares EAX to zero. The **JZ (Jump if zero) instruction** jumps to label L1 if the Zero flag was set by the CMP instruction:



*Here's a breakdown:*

**cmp eax, 0:** This instruction compares the value in the EAX register to zero. After this instruction, the Zero Flag (ZF) will be set if EAX is equal to zero.

**jz L1:** This is a conditional jump instruction. It checks the Zero Flag (ZF). If ZF is set (meaning the comparison result was zero), it jumps to the label L1.

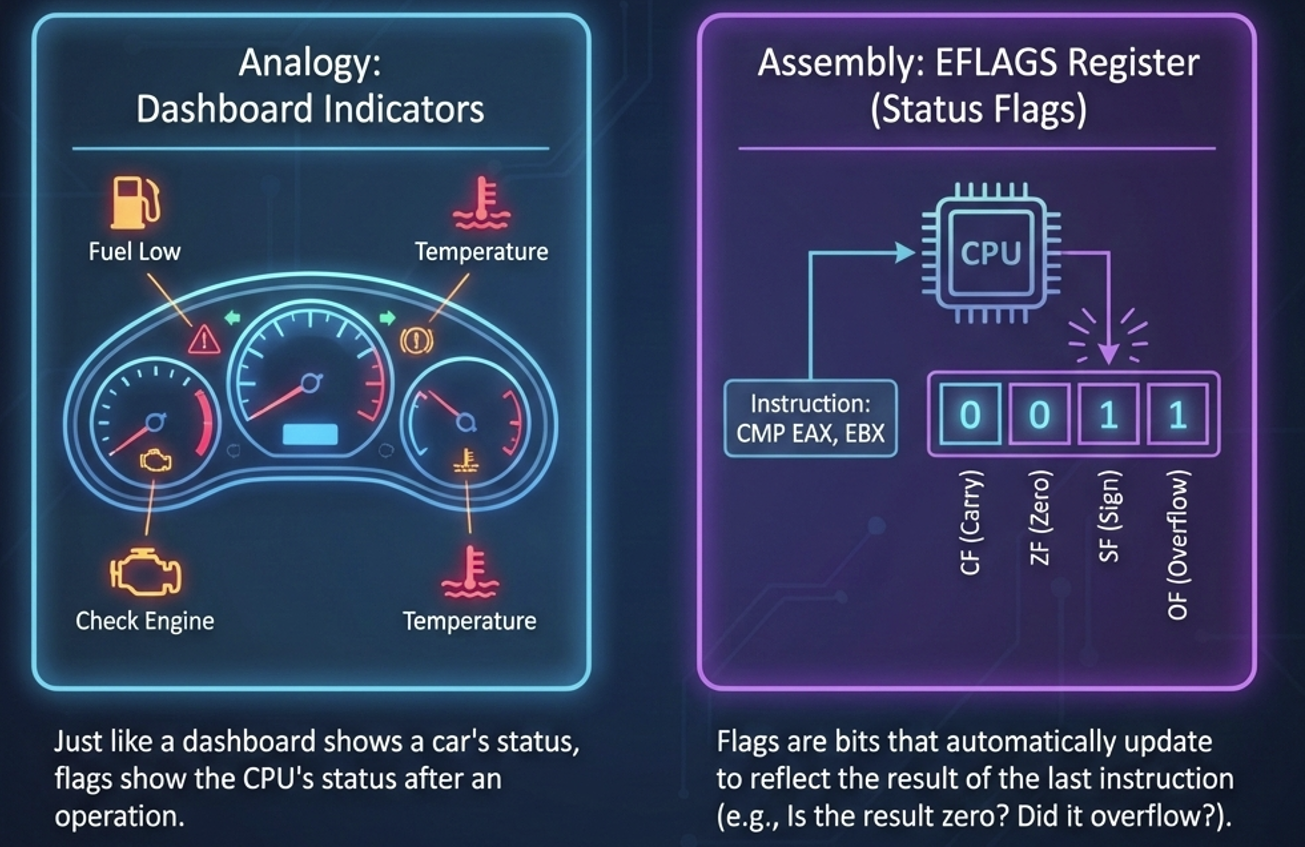
So, in simple terms, this code checks if the value in the EAX register is zero. If it is, it jumps to L1. If not, it continues executing the code below the jz instruction.



* **and dl, 10110000b**: This line performs a *bitwise AND* between the value stored in the DL register and the binary value 10110000.
* The result affects the Zero Flag (ZF). If the outcome of the AND operation is zero, the ZF is cleared. If the result is anything other than zero, the ZF gets set.
* **jnz L2**: This is a *conditional jump* instruction, just like the one we saw earlier.
* It checks the Zero Flag (ZF), and if ZF is not set (meaning the result of the AND operation wasn't zero), it jumps to the label L2.
* If ZF *is* set (meaning the AND result was zero), it won’t jump and will continue with the next instructions.

So, if the bitwise AND result isn’t zero, the program jumps to L2. If the result is zero, it keeps going to the next part of the code.

These jumps help guide the flow of the program, much like if-else statements in higher-level languages!



Let’s dive into conditional jumps in assembly

Conditional jump instructions are super useful because they let you change the flow of your program based on certain flags set by previous instructions, like comparisons or arithmetic operations.

These flags are like indicators that tell the program how things are going. Some common jump instructions:

I. JE (Jump if Equal):

This instruction will jump to a specific label only if the Zero flag (ZF) is set. The Zero flag gets set when two values are equal, so this is the instruction you’d use when you want to take action if the comparison shows equality.

For example, if you compare two values and they turn out to be equal, JE will trigger a jump to a label you’ve set in the code, otherwise, it keeps going.



II. JC (Jump if Carry):

Jumps to a destination label if the Carry flag is set, indicating that a carry occurred in an arithmetic operation.

III. JNC (Jump if Not Carry):

Jumps to a destination label if the Carry flag is clear, indicating no carry occurred in an arithmetic operation.

IV. JZ (Jump if Zero):

Jumps to a destination label when the Zero flag is set, indicating that a value is zero.

V. JNZ (Jump if Not Zero):

Jumps to a destination label when the Zero flag is clear, indicating that a value is not zero.

In your example, you're using the CMP instruction to compare the value in the EAX register to 5. If EAX equals 5, the Zero flag is set by the CMP instruction, and the JE instruction jumps to the label L1. If EAX is not equal to 5, the Zero flag is cleared, and the JE instruction does not jump.

Jumps Based on Specific Flag Values

Conditional jumps in this group rely on the states of specific CPU flags to determine whether to take the jump. Here are some common conditional jumps based on specific flag values:

JE (Jump if Equal):

Jumps when the Zero flag (ZF) is set, indicating that the compared values are equal.

JNE (Jump if Not Equal):

Jumps when the Zero flag (ZF) is clear, indicating that the compared values are not equal.

JZ (Jump if Zero):

Similar to JE, jumps when the Zero flag (ZF) is set.

JNZ (Jump if Not Zero):

Similar to JNE, jumps when the Zero flag (ZF) is clear.

JC (Jump if Carry):

Jumps when the Carry flag (CF) is set, indicating a carry occurred.

JNC (Jump if Not Carry):

Jumps when the Carry flag (CF) is clear, indicating no carry occurred.

JO (Jump if Overflow):

Jumps when the Overflow flag (OF) is set, indicating signed overflow.

JNO (Jump if No Overflow):

Jumps when the Overflow flag (OF) is clear, indicating no signed overflow.

JS (Jump if Sign):

Jumps when the Sign flag (SF) is set, indicating a negative result.

JNS (Jump if Not Sign):

Jumps when the Sign flag (SF) is clear, indicating a non-negative result.

Jumps Based on Equality Between Operands or the Value of (E)CX

These jumps are used for comparing values for equality. The value of (E)CX can also be used for comparisons. Examples include:

JE (Jump if Equal):

Jumps if two values are equal.

JNE (Jump if Not Equal):

Jumps if two values are not equal.

JCXZ (Jump if CX is Zero):

Jumps if the (E)CX register is zero.

Jumps Based on Comparisons of Unsigned Operands

These jumps are used for comparing unsigned integers. They consider values without their sign. Examples include:

JA (Jump if Above):

Jumps if the result is strictly greater (unsigned) than another value.

JAE (Jump if Above or Equal):

Jumps if the result is greater than or equal (unsigned) to another value.

JB (Jump if Below):

Jumps if the result is strictly less (unsigned) than another value.

JBE (Jump if Below or Equal):

Jumps if the result is less than or equal (unsigned) to another value.

Jumps Based on Comparisons of Signed Operands

Similar to the previous group, but used for comparing signed integers, considering their sign. Examples include:

JG (Jump if Greater):

Jumps if the result is strictly greater (signed) than another value.

JGE (Jump if Greater or Equal):

Jumps if the result is greater than or equal (signed) to another value.

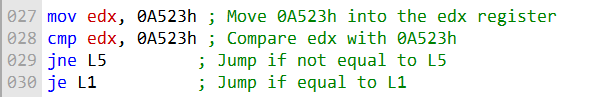
JL (Jump if Less):

Jumps if the result is strictly less (signed) than another value.

JLE (Jump if Less or Equal):

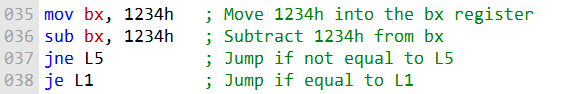
Jumps if the result is less than or equal (signed) to another value.

Example 1



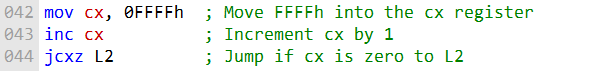
In this example, cmp compares the value in edx with 0A523h. Since they are equal, the jne instruction is not taken, but the je instruction is taken, leading to a jump to L1.

Example 2



In this example, sub subtracts 1234h from bx, resulting in zero. Therefore, the jne instruction is not taken, but the je instruction is taken, leading to a jump to L1.

Example 3:



Here, jcxz checks if the cx register is zero after the inc instruction. Since inc increments cx by 1, it becomes zero. Hence, the jcxz instruction is taken, leading to a jump to L2.

Example 4:



In this case, xor is used to set ecx to zero. Then, jecxz checks if ecx is zero.

Since it is zero, the jecxz instruction is taken, leading to a jump to L2.

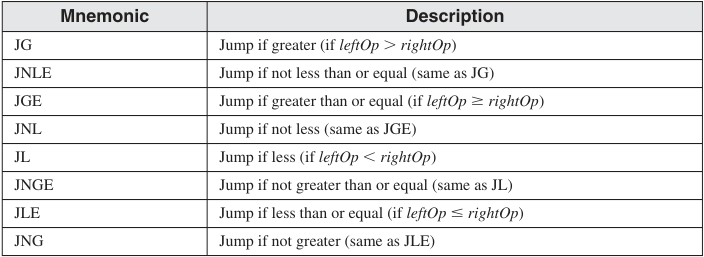
These examples demonstrate how conditional jump instructions like je, jne, jcxz, and jecxz work in assembly language to control program flow based on the result of comparisons and the state of registers.

Unsigned Comparisons (Table Below)



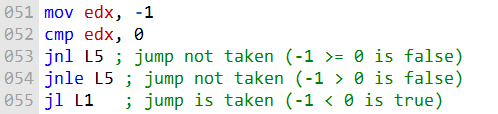
These comparisons are used when you are dealing with unsigned values, which means that they don't have a sign (positive or negative).

Signed Comparisons (Table Below)



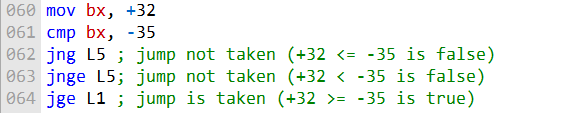
These comparisons are used when you are dealing with signed values, which have both positive and negative numbers.

Example 1:



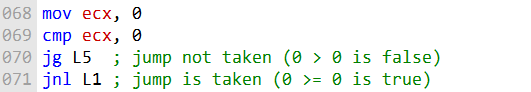
In this example, you have a signed comparison. jl jumps because -1 is indeed less than 0.

Example 2:



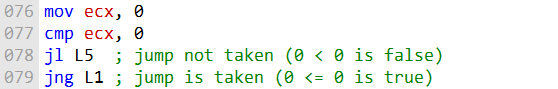
Again, this is a signed comparison. jge jumps because +32 is indeed greater than or equal to -35.

Example 3:



This is a signed comparison. jnl jumps because 0 is greater than or equal to 0.

Example 4:



Here, jng jumps because 0 is indeed less than or equal to 0.

Conditional Jump Applications in Assembly

Conditional jump instructions are the backbone of **decision-making** in assembly programming. They allow the program to **branch** to different labels depending on the state of **status flags** set by previous instructions. **🔀**

**🚩** Status Bits and Flags

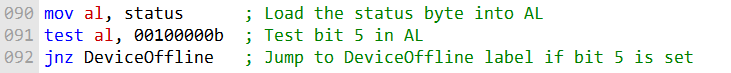
* **Zero Flag (ZF)** → Set when the result of an operation is zero.
* **Sign Flag (SF)** → Reflects the sign of the result (negative = 1, positive = 0).
* **Carry Flag (CF)** → Indicates a carry/borrow in arithmetic operations.
* **Overflow Flag (OF)** → Indicates signed arithmetic overflow.
* **Parity Flag (PF)** → Shows whether the lowest byte has even parity.

These flags are updated by instructions like CMP, TEST, AND, OR, and arithmetic operations.

**🧩** Common Conditional Jumps

* **JZ / JE (Jump if Zero / Equal)** → Branch if ZF = 1.
* **JNZ / JNE (Jump if Not Zero / Not Equal)** → Branch if ZF = 0.
* **JS (Jump if Sign)** → Branch if SF = 1.
* **JNS (Jump if Not Sign)** → Branch if SF = 0.
* **JC (Jump if Carry)** → Branch if CF = 1.
* **JNC (Jump if Not Carry)** → Branch if CF = 0.

In:



**🔧** Step-by-Step Breakdown

1. mov al, status
   * Loads the **status byte** into the **AL register**.
   * AL is an 8-bit register, perfect for handling single-byte values.
2. test al, 00100000b
   * Performs a **bitwise AND** between AL and the mask 00100000b.
   * This mask isolates **bit 5** (counting from the least significant bit = bit 0).
   * The result is **not stored**—only the **flags** are updated.
   * If bit 5 in AL is set → result ≠ 0 → **ZF = 0**.
   * If bit 5 in AL is clear → result = 0 → **ZF = 1**.
3. jnz DeviceOffline
   * **JNZ (Jump if Not Zero)** checks the **Zero Flag (ZF)**.
   * If **ZF = 0** (bit 5 was set), execution jumps to the label **DeviceOffline**.
   * If **ZF = 1** (bit 5 was clear), execution continues with the next instruction.

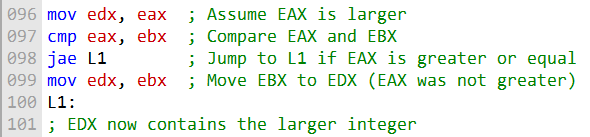
**🎯** Why This Matters

* This technique lets you **check specific bits** in a register without altering the register’s value.
* Conditional jumps (JZ, JNZ, JE, JG, JL, etc.) allow you to build **branching logic** in assembly, similar to if-else statements in higher-level languages.
* In this example, the program decides whether to branch to **DeviceOffline** based on the state of **bit 5** in the status byte.

2. Larger of Two Integers:

Here, the code snippet compares two unsigned integers (EAX and EBX) and moves the larger value to EDX.

It uses conditional jumps to make the comparison and assignment. This is a basic example of conditional branching based on integer comparisons.



**🔧** Instruction Details

1. mov edx, eax
   * Default assumption: EAX contains the larger integer.
   * Copies EAX into EDX.
2. cmp eax, ebx
   * Compares EAX and EBX by performing an implied subtraction (EAX - EBX).
   * Sets flags (Zero Flag, Carry Flag, Sign Flag, Overflow Flag) based on the result.
   * Neither EAX nor EBX is modified.
3. jae L1 **(Jump if Above or Equal)**
   * Checks the **Carry Flag (CF)**.
   * If **CF = 0**, it means EAX ≥ EBX (unsigned comparison).
   * Execution jumps to label **L1**.
4. mov edx, ebx
   * Executed only if **EAX < EBX** (CF = 1).
   * Updates EDX with EBX, ensuring EDX holds the larger integer.
5. L1:
   * Label where execution continues after the conditional jump.
   * At this point, **EDX contains the larger of the two integers**.

**🚩** Important Notes

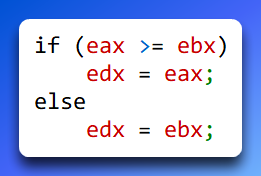
**Unsigned comparison**: jae is used for unsigned integers.

**Signed comparison**: For signed integers, you’d use:

* jge → Jump if Greater or Equal (signed).
* jl → Jump if Less (signed).

**🎯** Why This Matters

This snippet demonstrates how **conditional branching** in assembly allows you to implement logic similar to high-level constructs like:

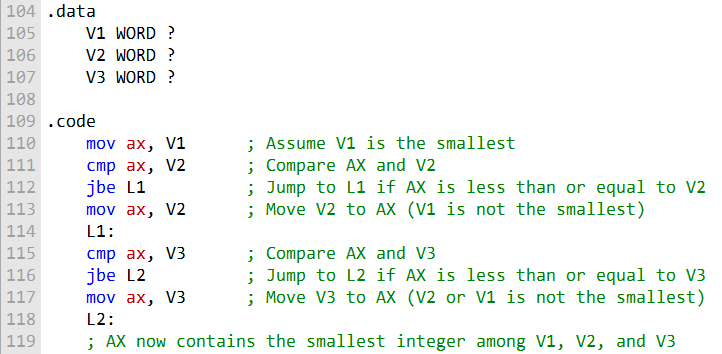


Efficiently, at the machine level, you’re selecting the larger of two integers and storing it in **EDX**.

3. Smallest of Three Integers

This section shows how to find the smallest of three unsigned 16-bit integers (V1, V2, and V3) and assigns the result to AX.

It uses a series of conditional jumps to compare and select the smallest value.

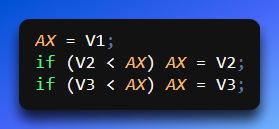


**🔧** Step-by-Step Explanation

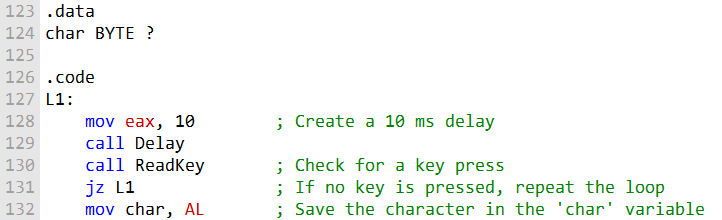
1. mov ax, V1
   * Start by assuming **V1** is the smallest.
   * Load V1 into the AX register.
2. cmp ax, V2
   * Compare AX (currently V1) with V2.
   * Flags are set based on the subtraction AX - V2.
3. jbe L1 **(Jump if Below or Equal)**
   * If AX ≤ V2 → keep AX unchanged (V1 is still the smallest).
   * If AX > V2 → jump not taken, so mov ax, V2 executes, updating AX with V2.
4. cmp ax, V3
   * Compare the current smallest (AX, either V1 or V2) with V3.
5. jbe L2
   * If AX ≤ V3 → keep AX unchanged.
   * If AX > V3 → jump not taken, so mov ax, V3 executes, updating AX with V3.
6. **Result**
   * After these comparisons, **AX contains the smallest of V1, V2, and V3**.

**🎯** Why This Works

* The code uses **conditional branching** (jbe) to decide whether to update AX.
* Each comparison narrows down the smallest value step by step.
* This is equivalent to the high-level logic:



4. Loop until Key Pressed



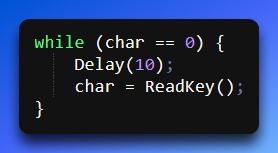
**🔧** Step-by-Step Breakdown

1. mov eax, 10
   * Loads the value 10 into the **EAX register**.
   * This sets up the delay duration (10 milliseconds).
2. call Delay
   * Calls the **Delay subroutine** from the Irvine32 library.
   * Introduces a short pause to prevent the loop from consuming CPU resources too aggressively.
3. call ReadKey
   * Calls the **ReadKey subroutine**.
   * If a key is pressed → AL contains its **ASCII code**.
   * If no key is pressed → AL = 0.
4. jz L1 **(Jump if Zero)**
   * Checks the **Zero Flag (ZF)**.
   * If AL = 0 (no key pressed), ZF = 1 → jump back to **L1** and repeat the loop.
   * If AL ≠ 0 (key pressed), ZF = 0 → continue execution.
5. mov char, al
   * Stores the ASCII code of the pressed key into the variable **char**.
   * This captures the user’s input for later use in the program.

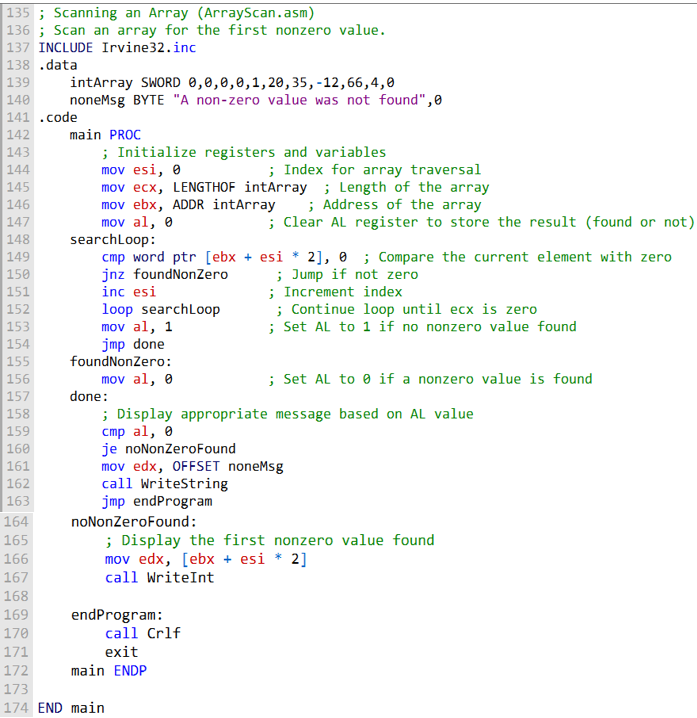
**🎯** Why This Matters

* This loop is a **practical way to wait for user input** in assembly.
* It avoids busy-waiting by inserting a small delay, making the program more efficient.
* The technique is useful for interactive programs, menus, or controlled input handling.

This is essentially the assembly equivalent of:



The provided code is a simple example of how to search for the first nonzero value in an array of 16-bit integers.



* **Data Section**:
  + intArray → holds 16-bit integers to be checked.
  + noneMsg → message displayed if no nonzero value is found.
* **Registers Used**:
  + **ESI** → index pointer for traversing the array.
  + **ECX** → loop counter (length of the array).
  + **EBX** → base address of intArray.
  + **AL** → status indicator (0 = nonzero found, 1 = none found).

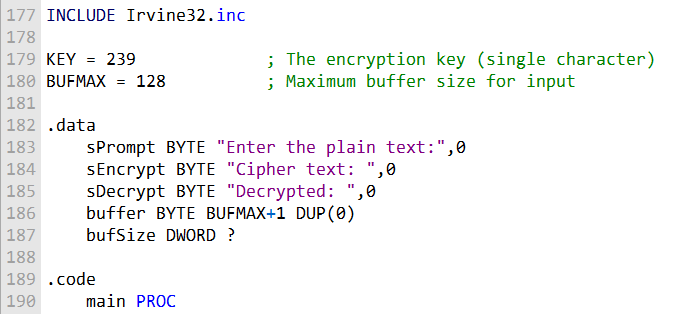
**🔧** Step-by-Step Execution

1. **Initialization**
   * Load the base address of intArray into **EBX**.
   * Set **ECX** to the length of the array.
   * Clear **AL** (set to 0) → assume a nonzero will be found.
   * Reset **ESI** to 0 → start at the first element.
2. **Loop (**searchLoop**)**
   * Use cmp to compare the current element with 0.
   * If element ≠ 0 → jnz foundNonZero (jump to label).
   * Otherwise → increment **ESI**, decrement **ECX**, and continue until ECX = 0.
3. **No Nonzero Found**
   * If the loop finishes without finding a nonzero, set **AL = 1**.
   * This indicates that all elements were zero.
4. **Output**
   * If **AL = 0** → display the nonzero value found.
   * If **AL = 1** → display noneMsg (“non-zero value not found”).
5. **Program End**
   * Call Crlf to print a newline.
   * Exit the program.

Encryption Program Overview

This assembly program demonstrates a simple symmetric encryption technique using the XOR operation. The program follows these steps:

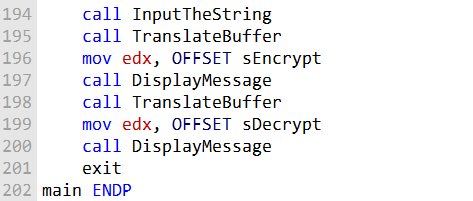
* **User Input:** The user enters a plain text message.
* **Encryption:** The program encrypts the plain text by XORing each character with a single character key and displays the cipher text.
* **Decryption:** It then decrypts the cipher text using the same key and displays the original plain text.



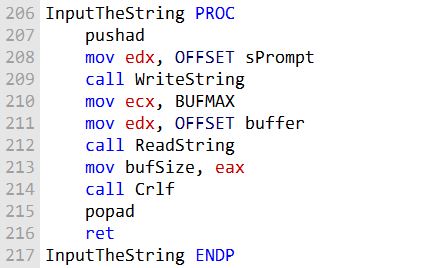
The program starts by including the Irvine32 library for input and output functions.

KEY is defined as the encryption key, set to 239.

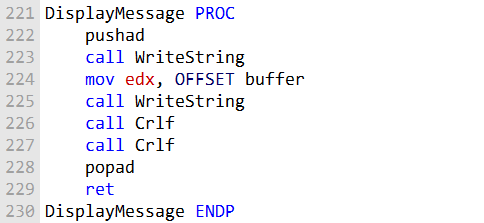
BUFMAX defines the maximum buffer size for input.



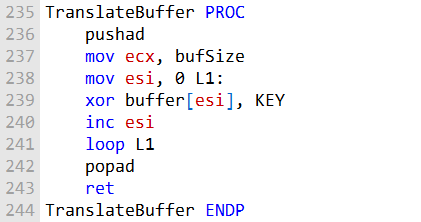
The main procedure calls InputTheString to get user input, TranslateBuffer for encryption, and DisplayMessage to show the cipher text. It repeats this process for decryption.



InputTheString procedure prompts the user for input, reads it into the buffer, and stores its length in bufSize.



DisplayMessage procedure displays a given message (in EDX) followed by the contents of the buffer and two line breaks.



TranslateBuffer procedure translates the string in the buffer by XORing each byte with the encryption key (KEY).

Final Note

The program uses a single-character key (which is not secure in real-world scenarios).

The exercises suggest using a multi-character encryption key for stronger security.

This program is a basic example to understand the concept of XOR-based encryption in assembly language.

In practice, encryption algorithms like AES or RSA are used for secure data protection.

**Which jump instructions follow unsigned integer comparisons?**

Jump instructions following unsigned integer comparisons typically include JA (Jump if Above), JAE (Jump if Above or Equal), JB (Jump if Below), and JBE (Jump if Below or Equal).

**Which jump instructions follow signed integer comparisons?**

Jump instructions following signed integer comparisons usually include JG (Jump if Greater), JGE (Jump if Greater or Equal), JL (Jump if Less), and JLE (Jump if Less or Equal).

**Which conditional jump instruction is equivalent to JNAE?**

JNAE stands for "Jump if Not Above or Equal," and its equivalent for signed comparisons is JB which stands for "Jump if Below."

**Which conditional jump instruction is equivalent to the JNA instruction?**

The JNA instruction stands for "Jump if Not Above," and its equivalent for signed comparisons is JL, which stands for "Jump if Less."

**Which conditional jump instruction is equivalent to the JNGE instruction?**

JNGE stands for "Jump if Not Greater or Equal," and its equivalent for signed comparisons is JG, which stands for "Jump if Greater."

**(Yes/No): Will the following code jump to the label named Target?**



Yes, the code will jump to the label named "Target" if the value in the ax register (8109h) is greater than the immediate value 26h. This is because jg stands for "Jump if Greater."

CONDITIONAL LOOPS

**🔄** LOOPZ / LOOPE Instructions in Assembly

**LOOPZ (Loop if Zero)** and **LOOPE (Loop if Equal)** are **conditional loop instructions**.

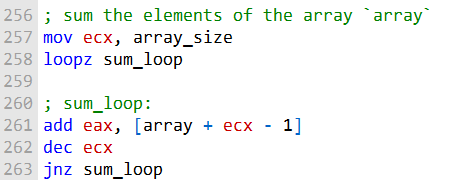
They are used to repeat a block of code while two conditions are true:

* The **loop counter register** (ECX in 32-bit mode, RCX in 64-bit mode) is greater than 0.
* The **Zero Flag (ZF)** is set (meaning the result of the last comparison or operation was zero/equal).

**⚙️** How They Work

1. **Decrement ECX/RCX** → Each iteration reduces the loop counter by 1.
2. **Check ECX/RCX** → If it reaches 0, the loop ends.
3. **Check ZF** → If ZF = 1 (last result was zero/equal), the loop continues.
4. **Jump or Exit** → If both conditions are met, execution jumps to the destination label. Otherwise, the loop exits.

For example, the following code snippet will sum the elements of an array using the LOOPZ instruction:



* **ECX register**: This is the loop counter. At the start, it’s set to the size of the array (how many items are in it).
* **EAX register**: This is the accumulator, where results (like sums) are stored.

How LOOPZ works:

1. ECX is decreased by 1 each time the loop runs.
2. The element at array + ECX - 1 is added into EAX.
3. The loop continues **only if**:
   * ECX is still greater than 0, **and**
   * The **Zero Flag (ZF)** is set.
4. If either condition fails, the loop stops and moves on to the next instruction.



* LOOPZ doesn’t change other status flags, only checks the Zero Flag.
* **LOOPE** is the same as LOOPZ (they share the same behavior and opcode).
* These instructions are useful when you want to repeat code a certain number of times **while a condition is true**.

Common uses:

* Running loops with conditions.
* Searching for a value in an array.
* Reversing a string.
* Creating nested loops (loops inside loops).

LOOPNZ (Loop if Not Zero) and LOOPNE (Loop if Not Equal) Instructions

The **LOOPNZ (Loop if Not Zero)** and **LOOPNE (Loop if Not Equal)** instructions are used to create loops that repeat a block of code while a certain condition is met.

These instructions are quite similar and often interchangeable, as they share the same opcode and perform similar tasks.

The LOOPNZ instruction continues looping while two conditions are met: The **unsigned value** of the **ECX register** is **greater than zero** after being decremented. The **Zero Flag (ZF) is clear.** The syntax for LOOPNZ is:



Here's how it works:

* Decrement ECX by 1.
* If ECX > 0 and ZF = 0 (i.e., the Zero Flag is clear), jump to the specified destination label.
* If ECX becomes zero or ZF is set, the loop terminates, and control passes to the next instruction.

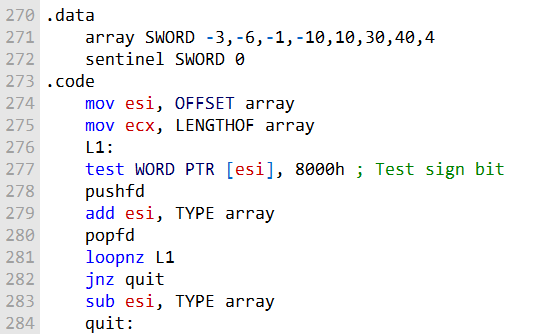
The **LOOPNE instruction** is equivalent to LOOPNZ in terms of functionality and shares the same opcode.

It also performs the following tasks:

* Decrement ECX by 1.
* If ECX > 0 and ZF = 0 (i.e., the Zero Flag is clear), jump to the specified destination label.
* If ECX becomes zero or ZF is set, the loop terminates, and control passes to the next instruction.

In essence, both LOOPNZ and LOOPNE create loops that continue while a counter (usually stored in ECX) is not zero and the Zero Flag is not set. They are often used for iterating through arrays or data structures until a specific condition is met.

Here's an example code excerpt that uses LOOPNZ to scan an array until a non-negative number is found:



* **mov esi, OFFSET array** → ESI points to the start of the array.
* **mov ecx, LENGTHOF array** → ECX is set to the number of elements in the array (loop counter).
* **L1:** → Label marking the start of the loop.
* **test WORD PTR [esi], 8000h** → Checks the sign bit of the current element (8000h = sign bit mask).
* **pushfd** → Saves the processor flags (important because the next instruction changes them).
* **add esi, TYPE array** → Moves ESI to the next element in the array.
* **popfd** → Restores the saved flags.
* **loopnz L1** → Decreases ECX by 1. If ECX > 0 **and** Zero Flag = 0, loop continues at L1. Otherwise, loop stops.
* **jnz quit** → If no nonnegative value is found, jump to quit.
* **sub esi, TYPE array** → If a nonnegative value is found, ESI is adjusted back to point at that element.

Summary:

The code scans through the array, checking each element’s sign bit.

* If it finds a nonnegative value → ESI points to that element.
* If none are found → ESI points to the sentinel value (0) after the array.

True/False Clarifications

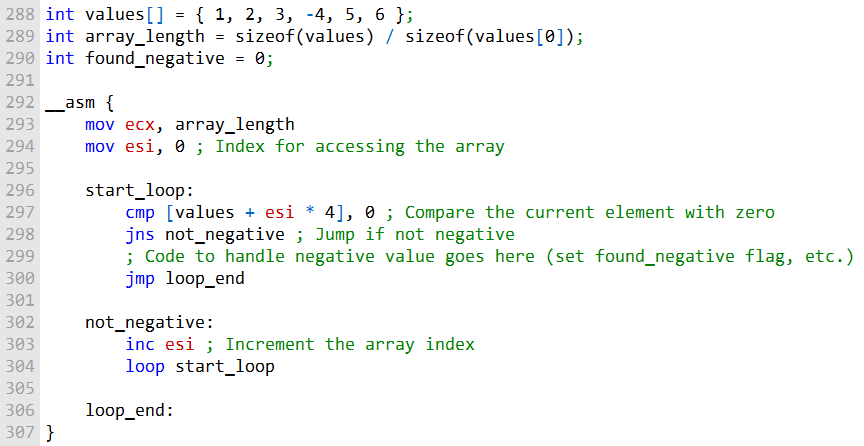
1. **LOOPE jumps when Zero Flag is clear.** ❌ False. LOOPE (Loop If Equal) jumps when **Zero Flag is set** and ECX > 0.
2. **LOOPNZ in 32-bit mode jumps when ECX > 0 and Zero Flag is clear.** ✅ True. LOOPNZ (Loop If Not Zero) continues only if ECX > 0 and ZF = 0.
3. **LOOPZ destination must be within ±128 or ±127 bytes.** ✅ True. LOOPZ uses a short jump, limited to -128 to +127 bytes.

Modification Task

To make the **LOOPNZ example** scan for the **first negative value** instead of nonnegative:

* Change the test condition so it looks for the sign bit being set (negative).
* Adjust the array initializers so they start with positive values, ensuring the loop actually scans before hitting a negative.

To modify the LOOPNZ example to scan for the first negative value in the array, you can change the array initialization to start with positive values. Here's an example in C:



Removing the Sentinel in LOOPNZ

* **Sentinel value** → A special marker (like 0 after the array) used to signal the end of data.
* In the LOOPNZ example, the sentinel ensures the loop stops if no positive value is found.
* **If you remove the sentinel:**
  + The loop has no clear stopping point.
  + It could keep running forever → **infinite loop risk**.
* To prevent this, you need another way to stop the loop, such as:
  + Using a counter (limit the number of iterations).
  + Adding a condition that checks when the array ends.

**Key takeaway:** Without a sentinel or another stopping mechanism, the loop cannot safely terminate when the desired value isn’t found.

Here’s an example of how you might modify the LOOPNZ code to remove the sentinel value and handle the case where a positive value might not be found.

In this modified code, we use a counter to limit the number of iterations:



The "Infinite Loop" Safety Net

We’ve added an iterations counter that ticks up every time the loop runs.

Think of it as a **tripwire**: if that counter hits the array\_length, it means we’ve checked every single spot and come up empty-handed.

Instead of spinning our wheels forever looking for a positive value that isn't there, the code realizes the search is over and hops out of the loop.

It’s a simple way to keep the program from freezing up when the data doesn't give us what we want.

Why this works:

* **The Guardrail:** By comparing iterations to array\_length, you ensure the loop has a hard "expiration date."
* **The Exit Strategy:** Without this, a list of negative numbers would keep the loop running indefinitely.

CONDITIONAL STRUCTURES

Think of **conditional structures** as the "forks in the road" for your code. If you’ve spent any time in C++, you’re already used to these—they’re just the decisions your program makes based on what’s happening at that moment.

How it looks in High-Level (C++)

In a language like C++, an IF statement is pretty intuitive. You give it a question (a boolean expression), and it follows one of two paths:

* **True:** It runs the first block of code.
* **False:** It either skips ahead or runs the else block if you’ve provided one.

How it looks under the hood (Assembly)

When you translate that "human" logic down to **Assembly**, the CPU doesn't see a neat block of code; it sees a two-step process:

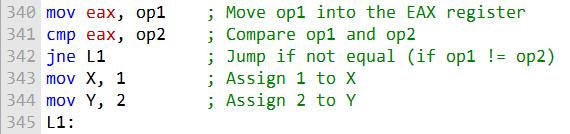
1. **The Comparison:** First, you have to actually test the values. Using an instruction like CMP (Compare) is like the CPU taking a quick measurement and marking down the result in its "status flags."
2. **The Jump:** Based on those flags, you tell the code where to go next. Instead of a structural block, you use **Conditional Jumps** (like JNE for "Jump if Not Equal"). It’s like saying, *"If these two aren't the same, hop over this next section of code and keep going."*

The Real-World Swap

In your C++ example, you’re checking if op1 == op2. If they match, the code sets X=1 and Y=2.

In Assembly, you’d essentially do the opposite: you'd check if they are *not* equal, and if so, "jump" past the part where X and Y get updated.

Walking Through the Assembly Logic



Think of these lines as a quick conversation between the code and the CPU:

* **mov eax, op1**: We’re grabbing the value of op1 and putting it into the EAX register (the CPU’s "workspace") so we can do something with it.
* **cmp eax, op2**: Now we compare that value against op2. The CPU doesn’t "know" if they’re equal yet; it just notes the difference in its status flags.
* **jne L1**: This is the decision point. It says, *"If they aren't equal, skip the next part and jump straight to the spot marked L1."*
* **The "Fall Through"**: If they **are** equal, the code just keeps rolling right into mov X, 1 and mov Y, 2. This is called "falling through"—it’s efficient because the CPU doesn't have to do any extra work to jump to a new location.

Label vs. Procedure: What’s the difference?

You asked a great question: **Why not call L1 a procedure?** While it feels like a small distinction, in the world of programming, they are actually two very different tools.

I. Labels: The "Bookmark"

In Assembly, a **label** (like L1) is just a bookmark.

It’s a name given to a specific memory address.

When you "jump" to a label, you’re basically telling the CPU,

*"Stop reading here and start reading over there."*

There is no expectation that the code will ever "come back" to where it started.

II. Procedures: The "Round Trip"

A **procedure** (or function) is more like a formal errand.

1. You **Call** it.
2. It goes off, does its job.
3. It **Returns** specifically to the spot where you left off.

In high-level languages like C++, we use procedures to keep things organized and reusable.

In Assembly, we use labels because we are manually directing the CPU's "eyes" across the page.

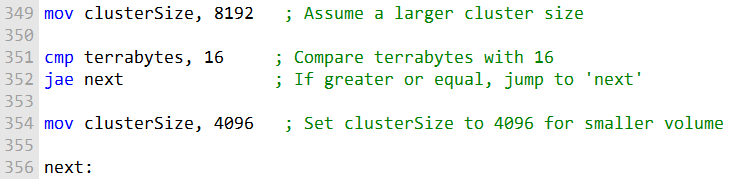
Using a label for a simple jump is like glancing down the page; using a procedure is like opening a different book entirely and then coming back to your original page.

We want to implement these conditional structures in real life:

Example 2: Setting Cluster Size Based on Volume Capacity

Setting the NTFS Cluster Size

Think of this code as a quick "if-then" check for a disk drive. Since NTFS cluster sizes change depending on how much storage you have, the code needs to make a decision based on that 16-terabyte threshold.



How the Logic Flows

Instead of checking "if-this-else-that," the code uses a **"set and override"** strategy, which is often faster in Assembly:

1. **The Default Setting (mov clusterSize, 8192):** The code starts by assuming the disk is massive (16TB or more) and sets the cluster size to 8192 by default.
2. **The Comparison (cmp terrabytes, 16):** It then checks the actual size of the volume against the 16TB limit.
3. **The "Check-and-Skip" (jae next):** This is the crucial part. If the disk **is** actually 16TB or larger (Jump if Above or Equal), it says, *"Cool, our default was right,"* and skips straight to the end.
4. **The Correction (mov clusterSize, 4096):** If the disk is smaller than 16TB, the "jump" doesn't happen. The code "falls through" to this line and overwrites the cluster size to 4096.

Why do it this way?

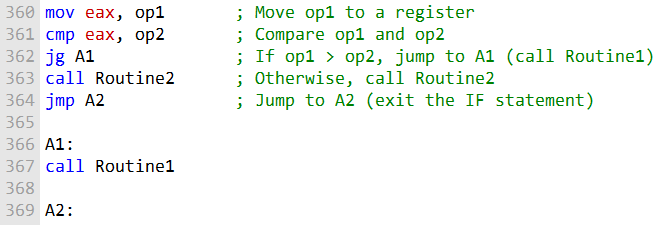
In high-level languages, we love if/else blocks because they are easy to read.

In Assembly, we often prefer this "default and override" method because it uses fewer labels and keeps the instructions moving in a straight line as much as possible, which the CPU appreciates for speed.

Example 3: Conditional Routine Calls

Deciding Which Routine to Run

Think of this like a traffic controller directing a car to one of two different paths based on a quick check. Instead of just setting a variable, the code is deciding which **sub-program** (routine) to execute.



The Play-by-Play

1. **The Setup (mov eax, op1 & cmp eax, op2):** As usual, we load our first value into the CPU's workspace and compare it to the second.
2. **The High Road (jg A1):** If op1 is truly greater than op2 (Jump if Greater), the CPU takes the exit to the A1 label. Over at A1, it finds the command to call Routine1.
3. **The Low Road (call Routine2):** If op1 is *not* greater, the jump never happens. The CPU just keeps moving down the page and hits call Routine2 instead.
4. **The Clean Exit (jmp A2):** This is the "secret sauce." If we ran Routine2, we don't want to accidentally "crash" into Routine1 right after. So, we use an **unconditional jump** (jmp A2) to hop over the other path and reach the finish line.

Key Takeaway: The "Jump Over"

In high-level languages like Python or C++, the compiler automatically handles the "exit" for you.

Once an if block finishes, it skips the else block automatically.

In Assembly, you are the architect! You have to manually tell the code to jmp over the alternative path so it doesn't execute both by mistake.

Labels as "Traffic Signs"

In this context, A1 and A2 aren't doing any math; they are just signs pointing the CPU in the right direction to ensure it only visits the routine it’s supposed to.

WHITEBOX TESTING

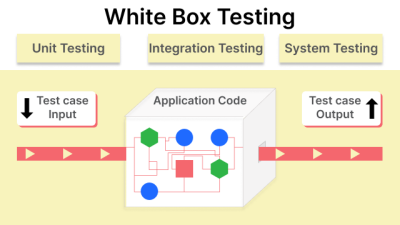
**White box testing**—also called *clear box, glass box, transparent box,* or *structural testing*—is a software testing method where you look **inside the code itself**.

Instead of only checking what goes in and what comes out, you examine the internal structure, logic, and design of the application to make sure everything works correctly.

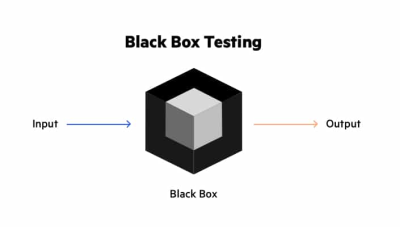
It helps verify:

* Input–output flow
* Code quality and design
* Usability and security

White box testing is one half of the overall testing strategy.



The other half is **black box testing**, which focuses on how the software behaves from the user’s point of view.



At its core, white box testing means **testing the internal logic and execution paths** of a program by directly examining the source code.

How white box testing works

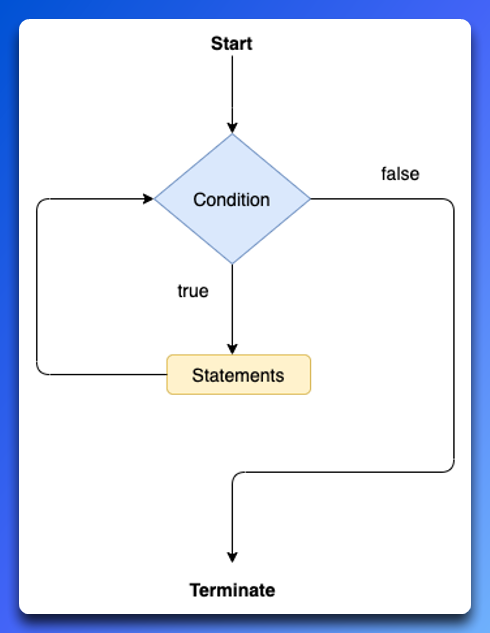
In white box testing, testers **have full access to the source code**.

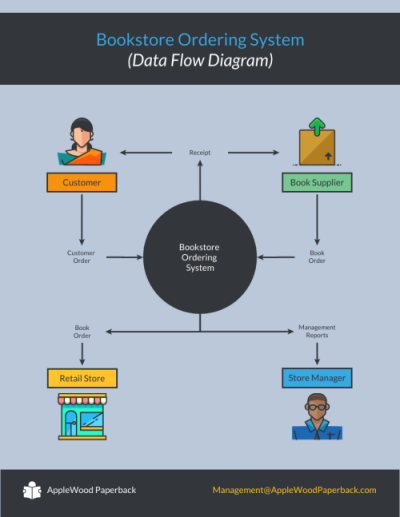
They use this knowledge to design test cases that validate whether the software behaves correctly *at the code level*, not just at the surface.

What white box testing checks

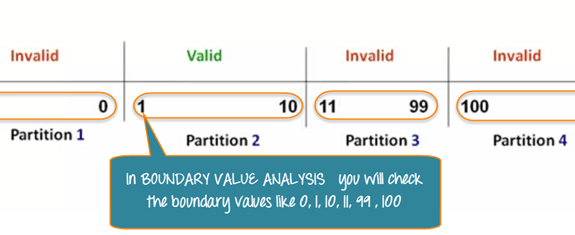
White box testing is commonly used to examine:

I. Control Flow  
Ensures all possible execution paths in the program are tested. This is done using techniques like control flow analysis and path testing.



II. Data Flow  
Verifies that data moves correctly through the program. Techniques such as data flow analysis and taint analysis help confirm that variables are used and updated properly. 

III. Boundary Values  
Checks how the program behaves at the edges of valid input and output ranges. This is done using equivalence partitioning and boundary value analysis.

[](https://www.guru99.com/images/3-2016/032316_0620_Equivalence6.png)

IV. Error Handling  
Confirms the program responds correctly to errors by deliberately triggering different failure scenarios.



What are you *really* looking for?

When you do white box testing, you’re not just checking if a button works—you’re digging into the logic behind it:

* **Execution paths:** Are there parts of the code that can never be reached?
* **Security gaps:** Is there a hidden way to bypass authentication?
* **Efficiency:** Is the code taking a long, inefficient route when a shorter one exists?

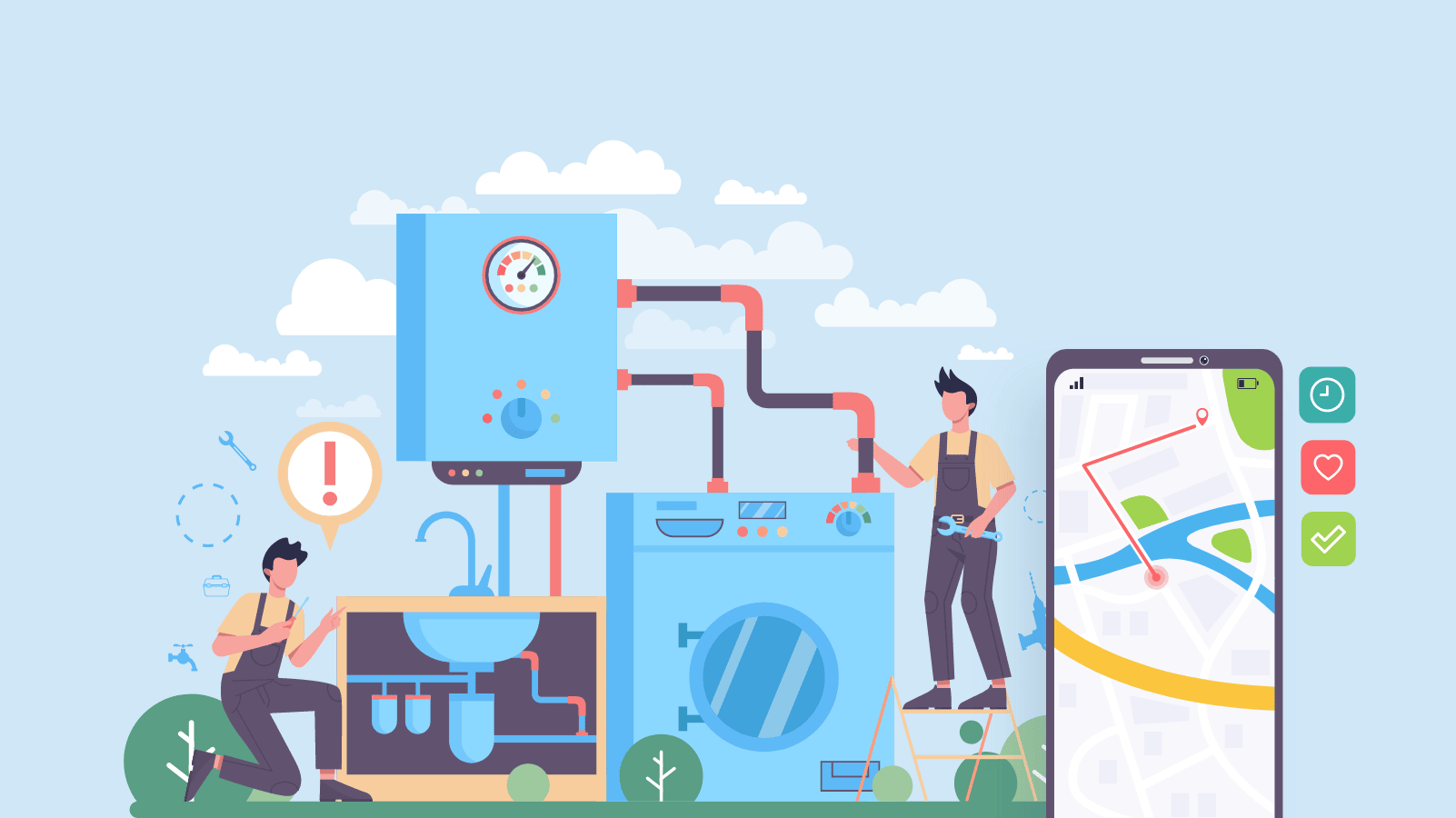
The “box” perspective

White box testing focuses on the **internal structure** of the software. Black box testing focuses on what the **user sees and experiences**.

Think of it like plumbing:

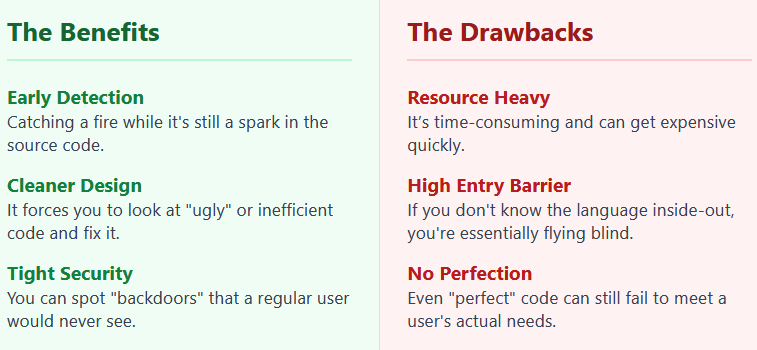
* White box testing checks whether the pipes are connected properly and not leaking.
* Black box testing checks whether the water pressure feels right when you turn on the faucet.

You need both for a complete picture.



The Pros and Cons

Like any specialized tool, White Box testing has its trade-offs:



White box testing in assembly language

White box testing becomes especially clear in **assembly programming**:

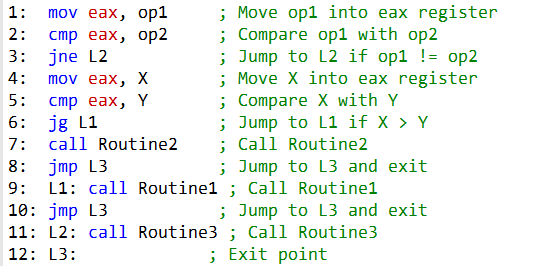
* You test the *inside workings* of the program, not just the final output.
* Execution paths are traced **step by step**.
* By changing variable values (for example, running one test where op1 > op2 and another where op1 < op2), you force the program to take different IF–ELSE branches.
* This lets you observe:
  + When the CPU **jumps** (takes a branch)
  + When it **falls through** (continues without jumping)

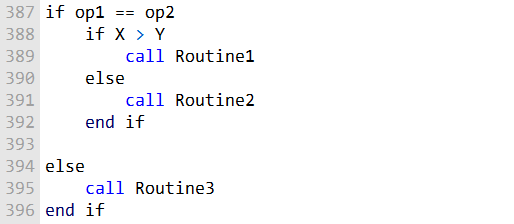
You’re not guessing that the code works—you’re watching the CPU make decisions in real time and proving that each path behaves correctly.

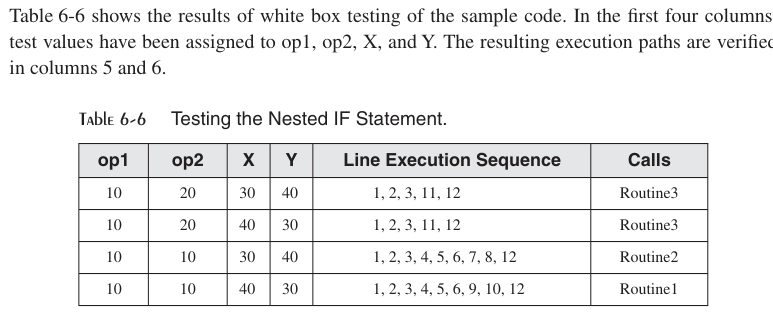
Key takeaway

White box testing lets you see *how* the program thinks, not just *what* it does. By examining execution paths, data flow, boundaries, and error handling, you can confidently prove that the internal logic of the software is solid and reliable.

Let's break down the code and the testing results:







The **first four columns** list the test values assigned to **op1, op2, X, and Y**.  
The **fifth column** shows which **execution path** the program takes based on those values.  
The **sixth column** shows the **output produced** as a result of that path.

Let’s walk through the test cases to see what’s happening:

Test Case 1  
Here, op1 = 10 and op2 = 10, while X = 20 and Y = 30.  
Since op1 is equal to op2, the program follows the **first branch** of the IF statement, which calls **Routine1**.  
The exact output of Routine1 isn’t specified, but it likely returns a value indicating that the condition op1 == op2 is true.

Test Case 2  
In this case, op1 = 10 and op2 = 10 again, but now X = 30 and Y = 20.  
Once more, op1 == op2, so the program enters the **first IF branch**.  
This time, the additional condition X > Y is also true, so the program takes the **first branch of the nested IF statement**, resulting in **Routine1** being called again.

Test Case 3  
Here, op1 = 10 and op2 = 20, with X = 30 and Y = 20.  
Since op1 is **not equal** to op2, the program follows the **second branch** of the main IF statement.  
The condition X > Y is false, so the program takes the **second branch of the nested IF**, which leads to **Routine2** being called.

Test Case 4  
In the final case, op1 = 10, op2 = 20, X = 20, and Y = 30.  
Again, op1 is not equal to op2, so the program enters the **second branch** of the main IF statement.  
The condition X > Y is false, so execution falls through to the **ELSE clause** of the nested IF statement, resulting in **Routine3** being called.

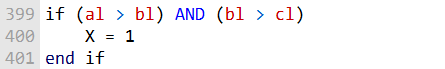
SHORT CIRCUIT EVALUATION(AND)

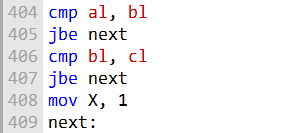
**Short-circuit evaluation** is a smart optimization used by compilers and interpreters when evaluating Boolean expressions.

For an **AND** operation, the second condition is checked **only if the first one is true**.

If the first condition is false, the entire expression is already false, so there’s no reason to evaluate the second one. This saves time and avoids unnecessary work.

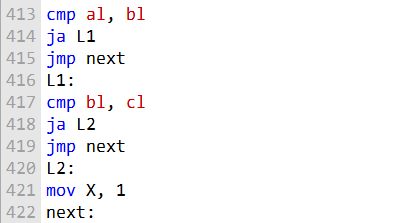
The following assembly language code demonstrates how short-circuit evaluation is implemented for the **AND** operator:





* This code first compares the values of the registers al and bl.
* If al is less than or equal to bl, then the second operand of the AND expression is not evaluated, and the program jumps to the next label.
* Otherwise, the program compares the values of the registers bl and cl.
* If bl is less than or equal to cl, then the program jumps to the next label.
* Otherwise, the program stores the value 1 in the register X and jumps to the next label.
* The next label is used to exit the code, regardless of whether the AND expression evaluated to true or false.

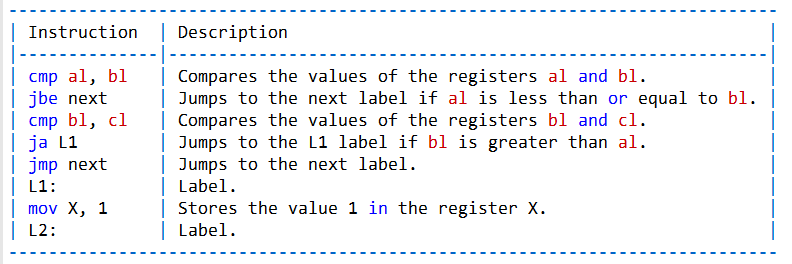
The following assembly language code implements short-circuit evaluation for the AND operator without using a jbe instruction:



This code is functionally equivalent to the previous example, but it uses a ja instruction instead of a jbe instruction.

The ja instruction jumps to the specified label if the first operand is greater than the second operand.

The following table shows the difference between the two code examples:



The first code example is more efficient because it uses a jbe instruction instead of a ja instruction.

The jbe instruction can be implemented as a single machine instruction, while the ja instruction may require multiple machine instructions.

In practice, the compiler will typically generate the most efficient code possible, regardless of whether the programmer uses a jbe instruction or a ja instruction.

However, it is important for programmers to understand how short-circuit evaluation is implemented in assembly language so that they can write efficient code.

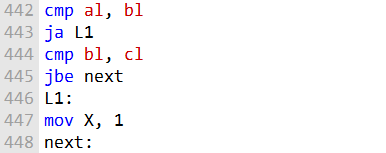
SHORT CIRCUIT EVALUATION(OR)

With **short-circuit evaluation**, the second operand of an **OR** expression is evaluated **only if the first operand is false**.

If the first operand is true, the overall expression is already true, so the second condition doesn’t need to be checked. This improves efficiency by avoiding unnecessary evaluations.

The following assembly language code demonstrates how short-circuit evaluation is implemented for the **OR** operator:





This code begins by comparing the values in registers **AL** and **BL**.

If **AL is greater than BL**, the OR expression is already true, so the second operand does **not** need to be evaluated.

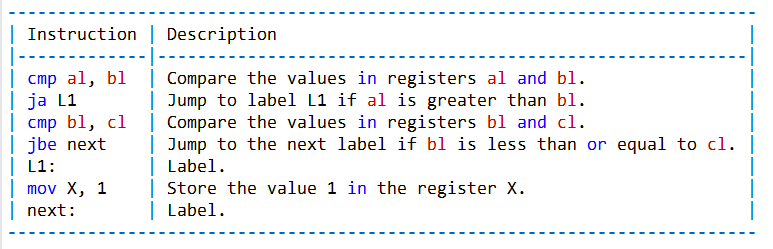
In this case, the program immediately jumps to the **L1** label.

If that condition is not met, the program then compares the values in **BL** and **CL**. If **BL is less than or equal to CL**, the program jumps to the next label.

Otherwise, the program stores the value **1** in register **X** and then jumps to the next label.

The final label serves as a clean exit point for the code, regardless of whether the OR expression ultimately evaluates to true or false.

The following table highlights the differences between the two code examples:



The **first code example** is more efficient because it uses the **ja** instruction instead of **jbe**.

The ja instruction can be executed as a **single machine instruction**, while jbe may require multiple instructions, making it slightly less efficient.

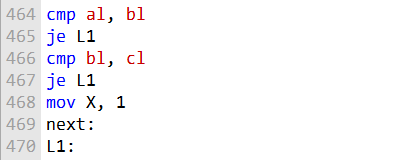
In real-world scenarios, modern compilers usually generate the **most efficient code automatically**, regardless of whether the programmer explicitly uses ja or jbe.

That said, it’s still important for programmers to understand **how short-circuit evaluation works at the assembly level**.

This knowledge helps when writing or analyzing performance-critical code and makes it easier to reason about execution flow.

As you pointed out, there are **multiple valid ways** to implement a compound expression containing **OR** operators in assembly language.

For example, the following code is functionally equivalent to the previous example:



This code starts by comparing the values in registers **AL** and **BL**. If **AL is equal to BL**, the program immediately jumps to the **L1** label. If not, it then compares the values in **BL** and **CL**.

If **BL is equal to CL**, the program again jumps to **L1**. If neither condition is true, the program stores the value **1** in register **X** and then jumps to the next label.

The **L1 label** represents the point where the overall OR expression evaluates to **true**.

The final label serves as a common exit point, allowing the program to finish cleanly regardless of whether the expression evaluates to true or false.

In the end, there’s no single “best” way to implement a compound OR expression in assembly language.

The right approach depends on the specific requirements of the program, such as performance, readability, and maintainability.

WHILE LOOPS

A **WHILE loop** in assembly works much like a WHILE loop in a high-level language. The loop begins by **checking a condition**.

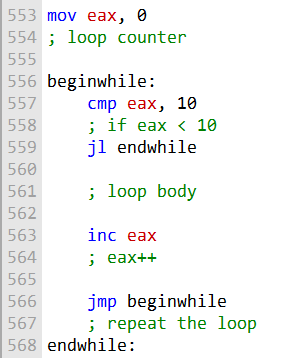
If the condition is true, the loop body runs. After the loop body finishes, the condition is checked again.

As long as the condition remains true, the loop keeps repeating. Once the condition becomes false, the loop ends.

To implement a WHILE loop in assembly language, you generally follow these steps:

1. Initialize a register or variable that will be used in the loop condition.
2. Check the loop condition.
3. If the condition is false, jump to the end of the loop.
4. Execute the loop body.
5. Update the loop condition.
6. Jump back to the condition check.

The following assembly code demonstrates a simple WHILE loop:



This loop will print the numbers from 0 to 9 to the console.

Reverse the loop condition

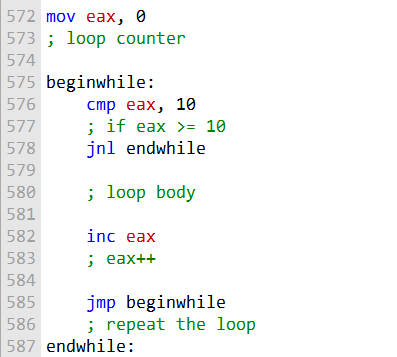
As mentioned earlier, it’s often more convenient in assembly language to **reverse the loop condition**.

This means the loop continues running **while the condition is false**, rather than true. Doing this can simplify the control flow and reduce the number of jumps needed.

To reverse the loop condition, you can use the **jnl** instruction instead of **jl**.

The jnl instruction causes a jump when the value is **not less than zero**, which effectively flips the original condition.

For example, the following assembly code is functionally equivalent to the previous version, but it uses a **reversed loop condition**:



Copy and restore the loop variable

If you plan to **use the loop variable inside the loop body**, you need to be careful in assembly language. The safest approach is to **copy the loop variable to a register before the loop starts** and then **restore it at the end of the loop**.

Why is this necessary? Assembly is largely **stack-based**:

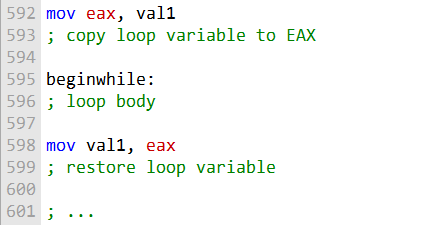
* Variables are stored on the stack.
* When a function is called, parameters are **pushed onto the stack**.
* When the function returns, parameters are **popped off the stack**.

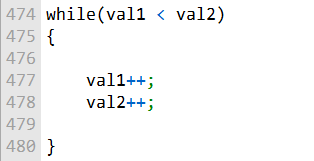
If the loop variable is used in the loop body and that body calls a function, the variable will be **pushed and popped** as part of the function call. This can unintentionally **modify the loop variable**, leading to incorrect behavior.

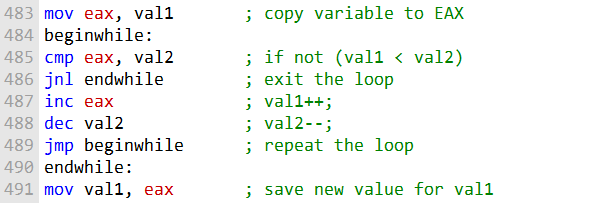
To prevent this:

1. Copy the loop variable to a register before entering the loop.
2. Use the register inside the loop body.
3. Restore the original loop variable value from the register after the loop finishes.

The following assembly code demonstrates how to safely **copy and restore a loop variable**:







This assembly code implements a **C++ style while (val1 < val2) loop**. Here’s how it works:

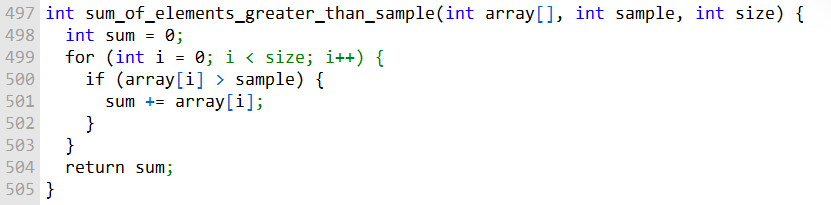
1. **Copy the loop variable to a register:**  
   The value of val1 is first copied into the **EAX register**. This is because the loop operates on the register directly, not the variable itself. EAX acts as a **proxy** for val1 throughout the loop.
2. **Check the loop condition:**  
   The program compares the value in **EAX** with val2. If **EAX is not less than val2**, the loop condition is false, and the program jumps to the **end of the loop**. Otherwise, the loop body executes.
3. **Execute the loop body:**
   * **Increment EAX by 1**, which corresponds to val1++ in C++.
   * **Decrement val2 by 1**, which corresponds to val2-- in C++.
4. **Repeat the loop:**  
   After executing the loop body, the program jumps back to the beginning of the loop to check the condition again. This continues until the loop condition is no longer true.
5. **End of the loop:**  
   When the loop finishes, the updated value in **EAX** is copied back into val1 to save the final result.



* **EAX is a stand-in for val1**, so all operations inside the loop use the register, not the variable itself.
* The jump instruction is used to exit the loop when the condition is false. Since val1 and val2 are signed integers, this ensures the loop behaves correctly for all values.
* Labels mark the **start and end** of the loop, clearly defining the loop boundaries.

The C code ABOVE you provided is a good example of using a **nested IF statement inside a WHILE loop**. Here’s what it does:

1. **Set up the array and variables:**
   * An integer array array is defined with ten elements.
   * A variable sample is set to 50.
   * The size of the array is calculated by dividing sizeof(array) by sizeof(sample) and stored in ArraySize.
   * An **index variable** is initialized to 0 to keep track of the current position in the array.
   * A **sum variable** is initialized to 0 to accumulate the total of elements greater than sample.
2. **Iterate through the array:**  
   A **WHILE loop** runs as long as index is less than ArraySize.
3. **Check each element:**  
   Inside the loop, an **IF statement** checks whether the current array element is greater than sample.
   * If it is, the element’s value is added to sum.
   * If not, nothing happens and the loop continues.
4. **Move to the next element:**  
   The index is incremented at the end of each loop iteration to move to the next array element.
5. **Output the result:**  
   After the loop finishes, the program prints the **sum of all elements greater than sample**.

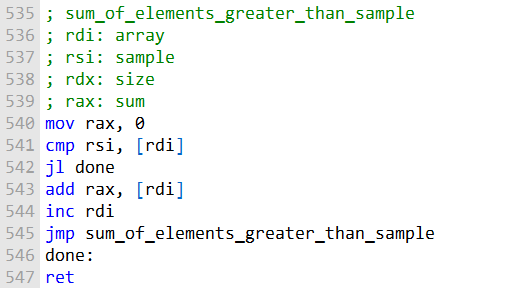


1. **Initialize variables:**  
   Set up sum, sample, ArraySize, and index to their starting values.
2. **Enter the WHILE loop:**  
   The loop will continue as long as index < ArraySize.
3. **Check the loop condition:**  
   Compare index with ArraySize.
   * If index is less, proceed to check the current array element.
   * If not, exit the loop.
4. **Compare array element to sample:**  
   Check if array[index] > sample.
   * If true, add array[index] to sum.
   * If false, do nothing.
5. **Increment index:**  
   Move to the next element by increasing index by 1.
6. **Repeat:**  
   Go back to step 3 and continue until the loop condition is no longer true.
7. **Exit the loop:**  
   Once the loop finishes, sum contains the total of all array elements greater than sample.

The **assembly code version** mirrors this logic:

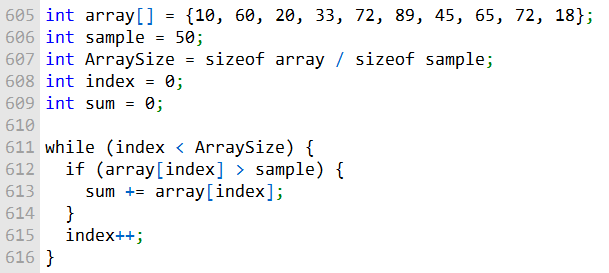
* Registers store the values of sum, sample, ArraySize, index, and the array elements.
* Labels mark key parts of the loop (start, body, and exit).
* Instructions like cmp, jl/jnl, inc, and add implement the conditional checks and updates step by step.

Here is a brief explanation of the assembly code am talking about:



This code is more efficient because it avoids the overhead of branching.

IF STATEMENTS IN ASSEMBLY



This code calculates the sum of all array elements greater than the value in sample.

The following assembly language code is equivalent to the C++ code above:



This assembly code works as follows:

1. **Initialize the sum:**  
   The **EAX register** is set to 0. It will hold the sum of all array elements greater than the value in **EDX** (which stores sample).
2. **Start the loop:**  
   The **ESI register** is compared to **ECX** (which stores the array size). If **ESI < ECX**, the program jumps to the **L1 label**, meaning the loop continues to iterate over the array elements.
3. **Check the array element:**  
   At **L1**, the program checks the value of array[ESI \* 4] (scaling by 4 because each element is 4 bytes) against **EDX**.
   * If the array element is greater than EDX, it jumps to **L3**.
   * At **L3**, the value of the array element is added to **EAX**.
4. **Increment and repeat:**  
   The **ESI register** is incremented to move to the next array element. The loop jumps back to **L1**.
5. **End of the loop:**  
   Once all elements have been checked, the loop jumps to **L5**, marking the end. The final sum in **EAX** is then stored in the sum variable.

Possible Improvements

The assembly code could be made more efficient:

1. **Replace cmp with test at L1:**
   * test is faster because it doesn’t affect the condition flags as much as cmp.
2. **Replace jmp with loop at L1:**
   * The loop instruction automatically decrements a counter and jumps, avoiding pushing a return address onto the stack.
3. **Replace cmp with sub at L2:**
   * sub can perform the comparison more efficiently without setting extra flags.
4. **Replace jmp with jbe at L2:**
   * jbe (jump if below or equal) is faster than a generic jump and avoids pushing a return address onto the stack.

In short, this code loops through the array, selectively adds elements greater than a given sample, and there are several small tweaks in assembly instructions that can make it faster and more efficient.

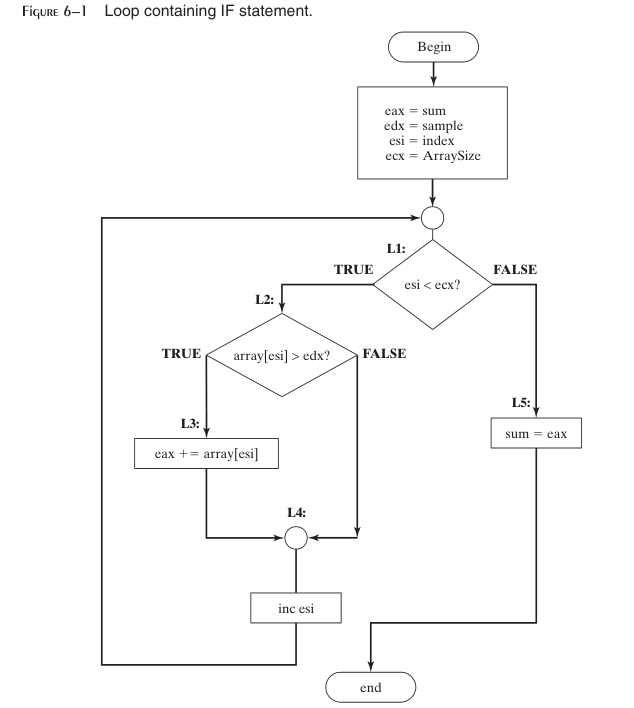


TABLE DRIVEN SELECTION

**Table-driven selection** is a technique where you use a **lookup table** instead of writing a long series of IF or CASE statements.

This approach is especially useful when you have **many possible values** to check—it saves time and makes the code cleaner.

How it works

I. Create a table:

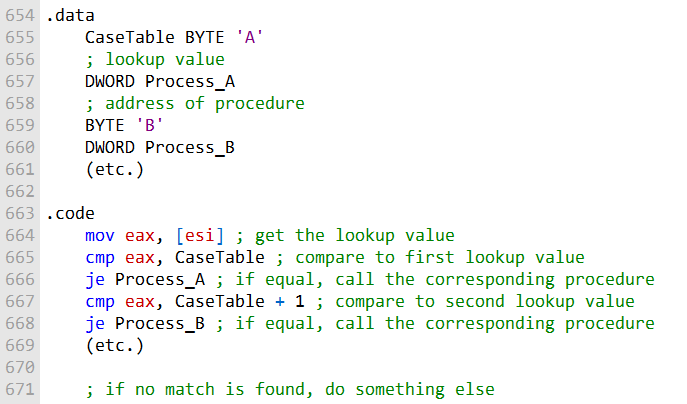
* The table stores the possible values you want to check.
* It also stores the **addresses of the corresponding procedures** or actions for each value.

II. Search the table:

* Write a loop to go through the table.
* When you find a matching value, call the procedure associated with it.

This method turns a complex multiway selection into a simple **lookup and jump**, which is often faster and easier to maintain.

The following is an example of a **simple table-driven selection in assembly language**:



In this example, the program uses a **loop to go through the table of lookup values**:

1. For each entry in the table, it **compares the lookup value to the value in the EAX register**.
2. If a match is found, the program **calls the procedure** associated with that value.
3. If no match is found, the loop ends, and the program can **perform some default action** or continue with other code.

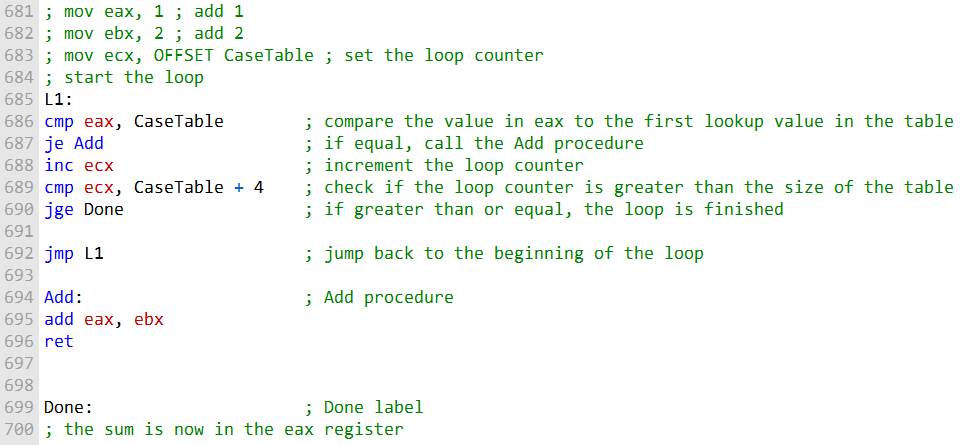
The table-driven selection example you mentioned is for a **simple calculator**. It has a table that contains:

* **Lookup values** (like numbers representing operations)
* **Addresses of the procedures** that implement each operation

This approach makes it easy to **handle multiple operations efficiently**, without writing a long chain of IF or CASE statements.



The table also contains the addresses of the corresponding procedures for each operation. The following is an example of how to use the table-driven selection example to perform addition:



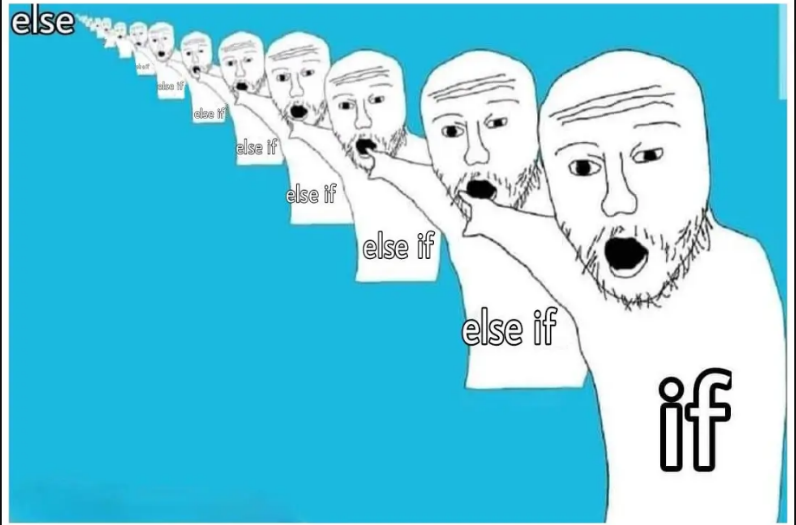
This assembly code works by **comparing the value in the EAX register to each lookup value in the table**:

1. It starts with the first value in the table.
2. If the value in EAX matches the lookup value, the corresponding procedure—like **Add**—is called.
3. If it doesn’t match, the **loop counter is incremented**, and the loop moves to the next table entry.
4. This process continues until the loop has checked all entries in the table.
5. Once the loop ends, the result—like the **sum of two numbers**—is stored in the EAX register.

Advantages of table-driven selection

Table-driven selection can be better than nested IF statements or long multiway conditions:

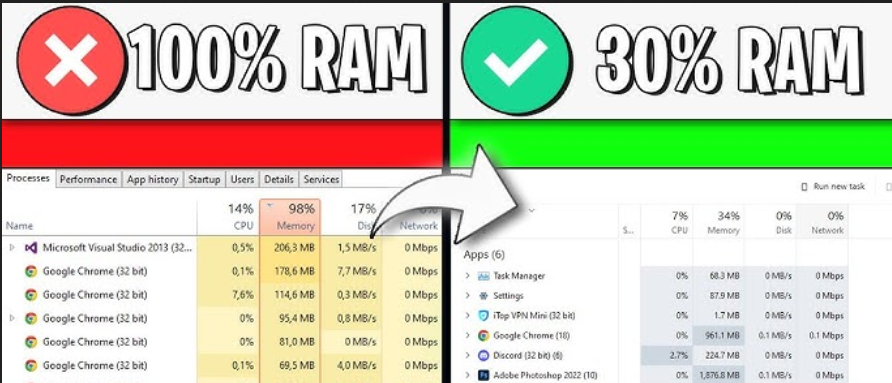
* **Efficiency:** Avoids writing long chains of nested IF statements.
* **Clarity:** Makes code easier to read and maintain.
* **Flexibility:** Easy to extend with new lookup values and procedures without rewriting the loop.



Disadvantages of table-driven selection

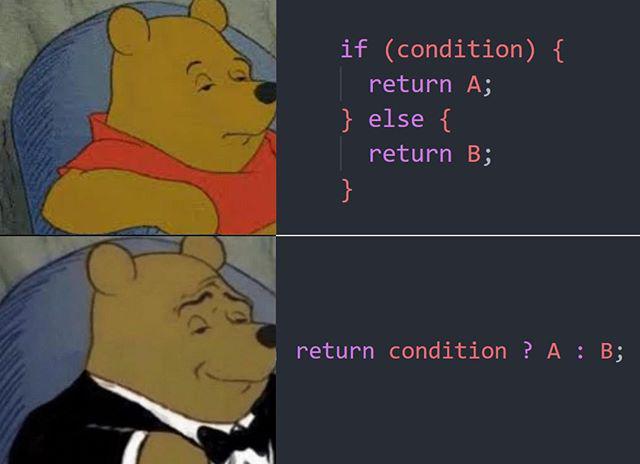
There are some trade-offs to consider:

* **Memory usage:** Requires extra memory to store the table.
* **Speed:** Searching through the table can be slower than using direct conditional jumps.

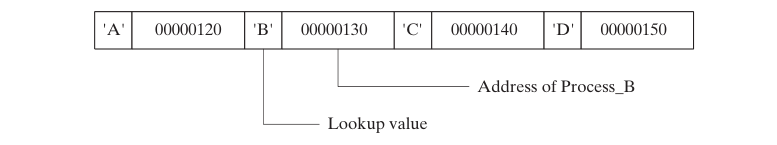


Summary:  
Table-driven selection is very useful for **handling multiple cases efficiently**, especially when you have a **large number of values to compare**.

However, it’s important to balance **clarity, memory, and speed** when deciding whether to use this approach.

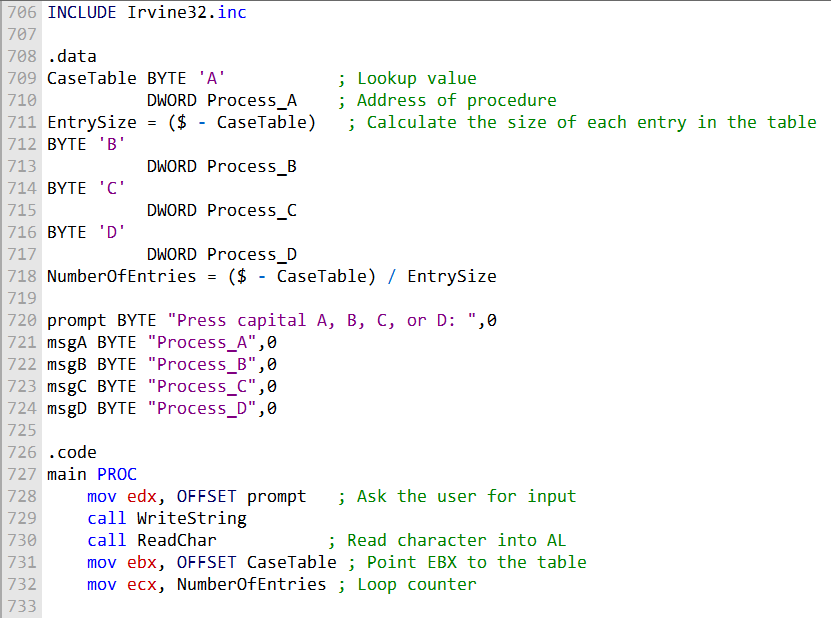
Unrelated image.

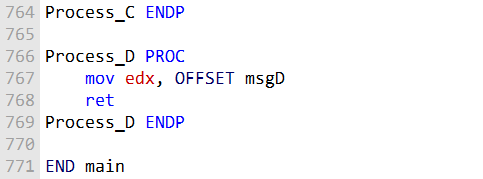
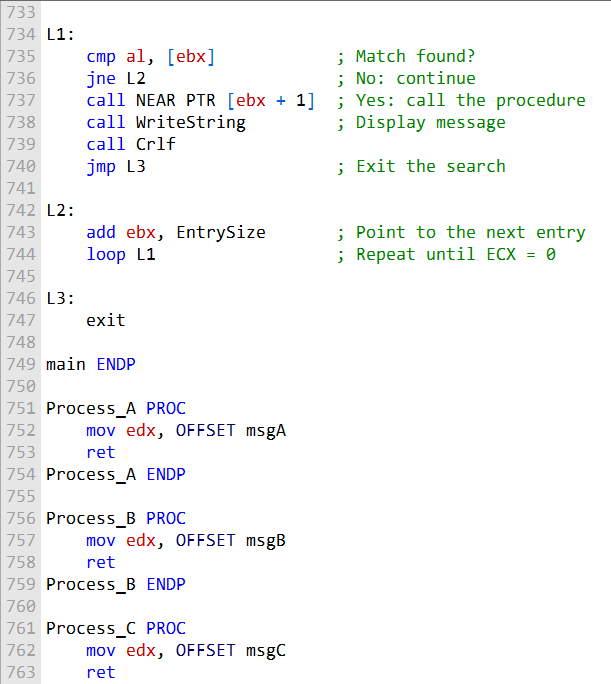
Example 1:



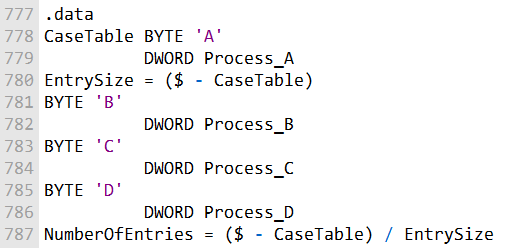
Program that uses a lookup table and procedures for character-based processing.

* This program takes user input,
* Compares it to entries in the lookup table and then…
* Calls the corresponding procedure to display a message.





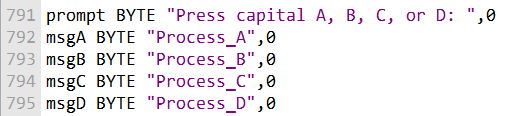
In this part of the program, we **define the data for table-driven selection**:



1. **CaseTable:**
   * This table contains **lookup values**—characters 'A', 'B', 'C', and 'D'.
   * Each character is paired with the **address of the procedure** that should be called when that character is selected: Process\_A, Process\_B, Process\_C, and Process\_D.
2. **EntrySize:**
   * Calculated as the difference between the **current memory position ($)** and the start of CaseTable.
   * This gives the **size of each entry** in the table (i.e., one character + one procedure address).
3. **NumberOfEntries:**
   * Calculated by dividing the **total size of CaseTable** by EntrySize.
   * This tells the program **how many entries** are in the table so it knows how many to loop through when searching.

In short, this sets up the **lookup table** and the information needed to **iterate through it efficiently**.

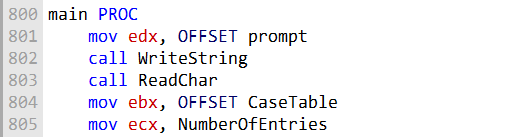
I. Section: .data (continued)



In this continuation of the .data section, we define message strings to be displayed later:

**prompt** is a message prompting the user to input a character. msgA, msgB, msgC, and msgD are messages associated with procedures Process\_A to Process\_D.

II. Section: .code - main PROC

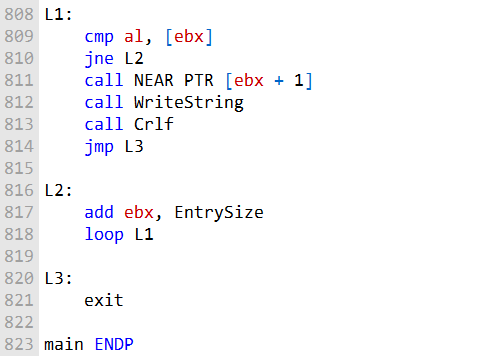


In the **main procedure**, the program does the following:

1. **Display the prompt:**
   * The program loads the **address of the prompt message** so it knows what text to show the user.
   * It then calls a procedure to **print that prompt** to the screen.
2. **Read user input:**
   * The program calls a procedure to **read a single character** typed by the user.
   * That character is stored in a register for later use.
3. **Set up the table-driven selection:**
   * The program loads the **address of the lookup table** (CaseTable) so it can find the correct procedure for the input.
   * It also loads the **number of entries in the table**, which tells the program how many entries it needs to check when searching for a match.

Essentially, these steps **prompt the user, capture their input, and prepare the program to look up and execute the appropriate action** from the table.

III. In this part of the main procedure:



In the **table-driven selection loop**, the program works like this:

1. **Start of the loop:**
   * A label marks the beginning of the loop, so the program knows where to jump back for the next table entry.
2. **Compare the input to the table entry:**
   * The program checks if the **user’s input character** matches the character in the **current table entry**.
3. **If there’s no match:**
   * The program skips to the next table entry and continues searching.
4. **If there is a match:**
   * The program **calls the procedure** stored in the table for that character.
   * It then **displays the corresponding message**.
   * Adds a **line break** for readability.
   * After handling the match, it **jumps out of the loop** to avoid checking the remaining entries.
5. **Loop termination:**
   * The loop continues until either a **match is found** or **all table entries have been checked**.

In short, this loop **searches the table for a match and executes the corresponding procedure**, making multiway selection efficient and easy to manage.

IV. Section: .code - Process\_A, Process\_B, Process\_C, Process\_D



These sections define the **procedures** (Process\_A to Process\_D). Each procedure simply:

* Sets the **EDX register** to point to the corresponding **message string**.
* Returns control back to the main program.

The program then reaches the **end of the main procedure**, completing its execution.

Summary of how the program works:

1. A **lookup table** is defined, pairing characters (A, B, C, D) with their corresponding procedures.
2. **Message strings** are stored for each procedure.
3. The **main procedure**:
   * Reads a character from the user.
   * Searches the table for a matching entry.
   * Calls the corresponding procedure to **display the appropriate message**.

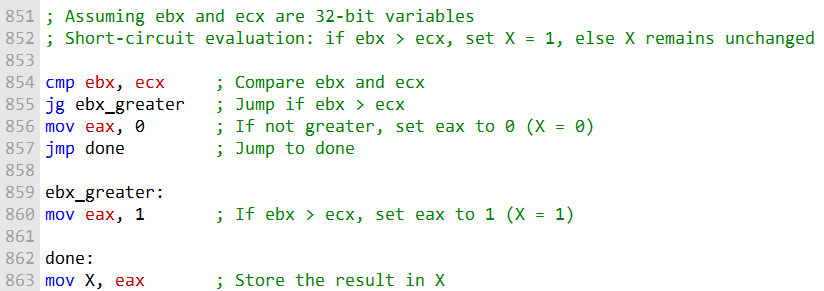
The **table-driven approach** makes the program:

* **Easy to extend**: Adding new characters or messages is straightforward.
* **Easy to modify**: You can change the behavior for a specific input without rewriting the whole selection logic.

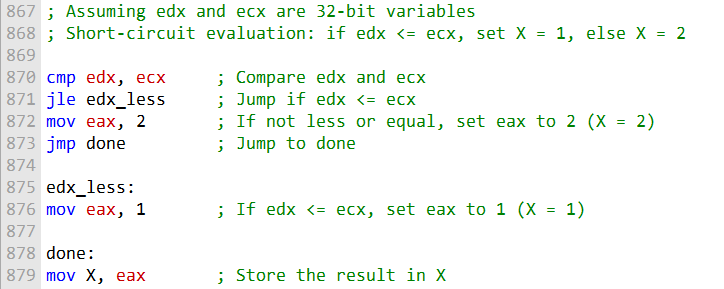
In short, this is a clean and efficient way to handle **multiway selection** in assembly language.

QUESTIONS

Implementing the pseudocode in assembly language:



Implementing the pseudocode with short-circuit evaluation:



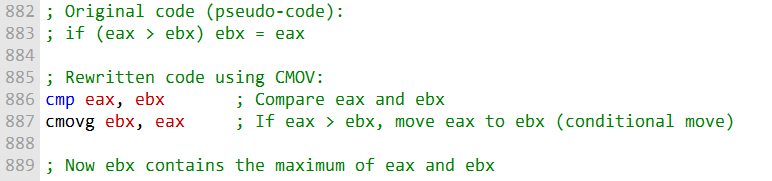
In the program above, it’s **better to let the assembler calculate NumberOfEntries** rather than hardcoding a constant.

* If you were to assign a fixed value, like NumberOfEntries = 4, you would need to **manually update it** whenever the table changes.
* By letting the assembler calculate it automatically, NumberOfEntries always **matches the actual table size**, which makes your code **more flexible, maintainable, and less error-prone**.

**Optimizing the code with fewer instructions**

You can also **rewrite the table-driven selection loop** using **conditional move (CMOV) instructions** to reduce the number of jumps and instructions:

* A **CMOV instruction** moves a value only if a specified condition is true, eliminating the need for some conditional jumps.
* This can **simplify the loop** while keeping the program logic exactly the same.



This code achieves the same result as the original code but with fewer instructions by utilizing the conditional move instruction to conditionally update ebx based on the comparison result.

In short, **letting the assembler handle calculations and using CMOV** can make your assembly code **shorter, cleaner, and safer**, without changing how it works.

FINITE STATE MACHINES

An **FSM** is a computational model that can be used to simulate sequential logic, or, in other words, to represent and control execution flow.

It is a mathematical model of computation that can be used to model the behavior of a system that can be in a finite number of states. The system can change state based on the input it receives.

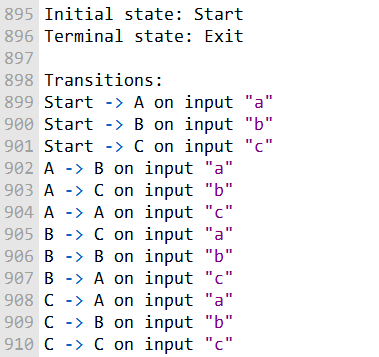
FSMs can be represented using a graph, where each node represents a state and each edge represents a transition from one state to another.

The edges are labeled with the input symbols that trigger the transitions. One node is designated as the initial state, and one or more nodes are designated as terminal states.

FSMs are used in a wide variety of applications, including:

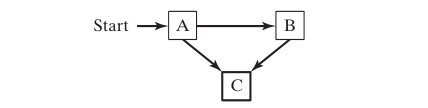
* Traffic lights
* Vending machines
* Telephone systems
* Computer software
* Robotics

Here is a simple example of an FSM:



* This FSM can be used to simulate the behavior of a traffic light.
* The FSM starts in the Start state.
* If the input is "a", the FSM transitions to the A state, which represents the green light.
* If the input is "b", the FSM transitions to the B state, which represents the yellow light.
* If the input is "c", the FSM transitions to the C state, which represents the red light.
* The FSM will continue to transition between states until it reaches the terminal state, the Exit state.
* This FSM will never reach the terminal state, because it is always possible to receive an input "a", "b", or "c".

FSMs can be used to model and control much more complex systems than a traffic light. For example, an FSM could be used to model and control the behavior of a vending machine, a telephone system, or a computer program.



This diagram shows a **finite state machine (FSM)** with the following structure:

* The **initial state** is **Start**.
* There are three main states: **A, B, and C**.
* Arrows indicate the **possible transitions** between states based on input.
* The **terminal state** is **Exit**, which ends the FSM.

**Behavior of the FSM in words:**

1. The FSM **begins at the Start state**.
2. From Start:
   * Input "a" → moves to state **A**.
   * Input "b" → moves to state **B**.
   * Input "c" → moves to state **C**.
3. From **A**:
   * Input "a" → moves to **B**.
   * Input "b" → moves to **C**.
   * Input "c" → stays in **A**.
4. From **B**:
   * Input "a" → moves to **C**.
   * Input "b" → stays in **B**.
   * Input "c" → moves to **A**.
5. From **C**:
   * Input "a" → moves to **A**.
   * Input "b" → moves to **B**.
   * Input "c" → stays in **C**.

The FSM continues **transitioning between states** based on the inputs until it eventually reaches the **Exit state**, which stops the process.

Validating an Input String Programs

**Rules for a valid string:**

1. Must **start with "x"**.
2. Must **end with "z"**.
3. Between "x" and "z", you can have **zero or more letters** from a to y.

**States:**

* **A (Start state)** → Beginning point.
* **B (Middle state)** → After reading "x", stays here while reading letters a–y.
* **C (Terminal state)** → Reached when "z" is read. This means the string is valid.

**Transitions:**

* From **A → B** when the first character is "x".
* From **B → B** when the next character is any letter in {a…y}.
* From **B → C** when the next character is "z".
* If the FSM reaches **C**, the string is valid.
* If the string ends before reaching **C**, it’s invalid.

**Example of a valid string:**

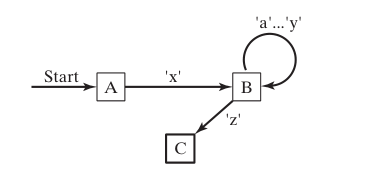
* "xyz"
  + Start in A → read "x" → move to B.
  + Read "y" → stay in B.
  + Read "z" → move to C.
  + FSM ends in C → **Valid**.

**Example of an invalid string:**

* "xab"
  + Start in A → read "x" → move to B.
  + Read "a" → stay in B.
  + Read "b" → stay in B.
  + End of string, never reached C → **Invalid**.

**Key takeaway:** The FSM acts like a **checker machine**:

* It only accepts strings that begin with "x", end with "z", and have only letters a–y in between.
* If the string doesn’t meet these rules, it’s rejected.



* If the input ends while the program is still in **state A or B**, it’s an **error**.
  + Only **state C** is a terminal (accepting) state.
  + This means the string must **end with "z"** to be valid.

**Examples of valid strings:**

* xaabcdefgz
* xz
* xyyqqrrstuvz

👉 All of these start with "x", end with "z", and have only letters a–y in between.

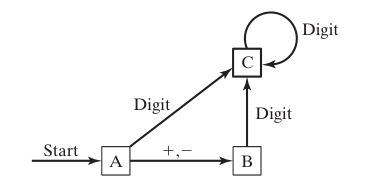
**Example of an invalid string:**

* xab
  + Starts with "x" but does **not** end with "z".
  + Therefore, it’s invalid.

**Validating Integers in Programs**

* Just like strings, programs often need to **validate integers** (numbers) before using them.
* Validation ensures the input is **correct and safe** to process.
* Common checks include:
  + Making sure the input is actually a number (not letters or symbols).
  + Checking if the number is within a valid range (e.g., between 0 and 100).
  + Ensuring the number is positive or negative depending on the program’s rules.
* If the integer fails validation, the program should **reject it or raise an error** instead of continuing with bad data.
* FSMs are great for validating **patterns in strings**.
* For numbers, validation is more about **rules and ranges** (is it numeric, is it within limits, etc.).

Validating Integers in Programs



The FSM diagram in Figure 6-5 shows how to validate a signed integer. The FSM starts in the Start state.

If the next character in the input stream is a plus sign (+) or a minus sign (-), the FSM transitions to the Sign state.

If the next character in the input stream is a digit, the FSM transitions to the Digits state.

If the FSM is in the Sign state and the next character in the input stream is a digit, the FSM remains in the Sign state.

This is because the sign can be followed by any number of digits.

If the FSM is in the Digits state and the next character in the input stream is a digit, the FSM remains in the Digits state.

This is because the sequence of digits can be any length.

If the FSM is in the Digits state and the next character in the input stream is not a digit, the FSM transitions to the End state.

This is because the sequence of digits must end with a non-digit character.

The End state is a terminal state. This means that the input string is valid if the FSM reaches the End state.

***Here is an example of a valid input string:***



-123456 The FSM will start in the Start state. It will then read the first character, which is a minus sign (-).

This will transition the FSM to the Sign state. The FSM will then read the second character, which is the digit 1.

This will cause the FSM to remain in the Sign state. The FSM will then read the third character, which is the digit 2.

This will cause the FSM to remain in the Sign state. The FSM will then read the fourth character, which is the digit 3.

This will cause the FSM to remain in the Sign state. The FSM will then read the fifth character, which is the digit 4.

This will cause the FSM to remain in the Sign state. The FSM will then read the sixth character, which is the digit 5.

This will cause the FSM to remain in the Sign state. The FSM will then read the seventh character, which is the digit 6.

This will cause the FSM to transition to the Digits state. The FSM will then read the eighth character, which is not a digit.

This will cause the FSM to transition to the End state. Since the FSM has reached the End state, it means that the input string is valid.

***Here is another example of an invalid input string:***



-123456.78 The FSM will start in the Start state. It will then read the first character, which is a minus sign (-).

This will transition the FSM to the Sign state.

The FSM will then read the second character, which is the digit 1. This will cause the FSM to remain in the Sign state.

The FSM will then read the third character, which is the digit 2. This will cause the FSM to remain in the Sign state.

The FSM will then read the fourth character, which is the digit 3. This will cause the FSM to remain in the Sign state.

The FSM will then read the fifth character, which is the digit 4. This will cause the FSM to remain in the Sign state.

The FSM will then read the sixth character, which is the digit 5. This will cause the FSM to remain in the Sign state.

The FSM will then read the seventh character, which is the digit 6. This will cause the FSM to transition to the Digits state.

The FSM will then read the eighth character, which is a period (.). This is not a digit, so the FSM will transition to the End state.

However, the End state is not a terminal state. This means that the input string is invalid.

FSMs are a powerful tool for validating input strings and other types of data. They are used in a wide variety of applications, including programming language compilers, text editors, and network protocols.

***===================================***

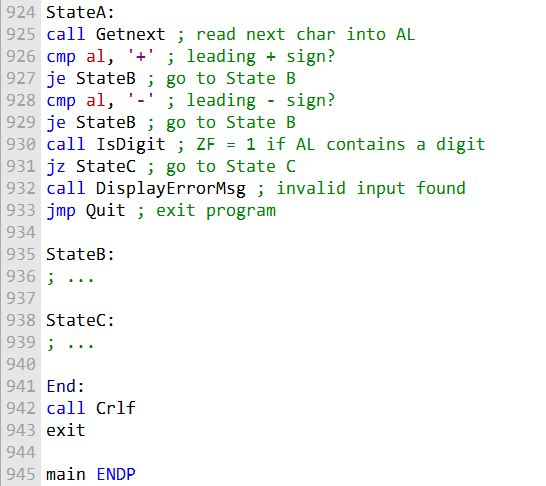
***Validating Integers in Programs***

***===================================***

FSM for parsing a signed integer:

* This FSM diagram shows how to validate a signed integer. The FSM starts in the Start state. If the next character in the input stream is a plus sign (+) or a minus sign (-), the FSM transitions to the Sign state. If the next character in the input stream is a digit, the FSM transitions to the Digits state.
* If the FSM is in the Sign state and the next character in the input stream is a digit, the FSM remains in the Sign state. This is because the sign can be followed by any number of digits.
* If the FSM is in the Digits state and the next character in the input stream is a digit, the FSM remains in the Digits state. This is because the sequence of digits can be any length.
* If the FSM is in the Digits state and the next character in the input stream is not a digit, the FSM transitions to the End state. This is because the sequence of digits must end with a non-digit character.
* The End state is a terminal state. This means that the input string is valid if the FSM reaches the End state.

The following assembly language code implements the FSM diagram above:



This code works as follows:

* The label StateA marks the start of the FSM.
* The call to the Getnext procedure reads the next character from the console input into the AL register.
* The code checks for a leading plus (+) or minus (-) sign.
* If a leading sign is found, the code jumps to the label StateB.
* If a leading sign is not found, the code calls the IsDigit procedure to check if the character in AL is a digit. If the character is a digit, the code jumps to the label StateC.
* If the character in AL is not a digit or a leading sign, the code calls the DisplayErrorMsg procedure to display an error message on the console and then jumps to the label Quit.
* The label StateB marks the state where the FSM is after reading a leading sign.
* The code in StateB will check for the other possible transitions away from this state and take the appropriate action. The label StateC marks the state where the FSM is after reading a digit.
* The code in StateC will check for the other possible transitions away from this state and take the appropriate action. The label End marks the terminal state of the FSM.
* The code in End will perform any necessary cleanup and then exit the program. The main procedure simply calls the StateA procedure to start the FSM.
* This is just a basic example of how to implement a FSM in assembly language. More complex FSMs can be implemented using the same basic principles.

------------------------------------------------

; Finite State Machine (Finite.asm)  
INCLUDE Irvine32.**inc**  
  
ENTER\_KEY = 13  
  
.data  
InvalidInputMsg: db "Invalid input", 13, 10, 0  
  
.code  
main:  
 ; Clear screen  
 **call** Clrscr  
  
 ; Start state  
StateA:  
 ; Read next character into AL  
 **call** Getnext  
  
 ; Check for leading + or - sign  
 **cmp** al, '+'  
 **je** StateB  
 **cmp** al, '-'  
 **je** StateB  
  
 ; Check if AL contains a digit  
 **call** IsDigit  
 **jz** StateC  
  
 ; Invalid input  
 **call** DisplayErrorMsg  
 **jmp** Quit  
  
StateB:  
 ; Read next character into AL  
 **call** Getnext  
  
 ; Check if AL contains a digit  
 **call** IsDigit  
 **jz** StateC  
  
 ; Invalid input  
 **call** DisplayErrorMsg  
 **jmp** Quit  
  
StateC:  
 ; Read next character into AL  
 **call** Getnext  
  
 ; Check if AL contains a digit  
 **call** IsDigit  
 **jz** StateC  
  
 ; Check if Enter key pressed  
 **cmp** al, ENTER\_KEY  
 **je** Quit  
  
 ; Invalid input  
 **call** DisplayErrorMsg  
 **jmp** Quit  
  
Quit:  
 ; Call Crlf to print a newline  
 **call** Crlf  
 exit  
  
; Getnext procedure  
; Reads a character from standard input  
; Receives: nothing  
; Returns: AL contains the character  
Getnext:  
 ; Input from keyboard  
 **call** ReadChar  
  
 ; Echo on screen  
 **call** WriteChar  
  
 **ret**  
  
; DisplayErrorMsg procedure  
; Displays an error message indicating that  
; the input stream contains illegal input  
; Receives: nothing  
; Returns: nothing  
DisplayErrorMsg:  
 ; Push EDX onto the stack  
 **push** edx  
  
 ; Move the offset of the error message to EDX  
 **mov** edx, OFFSET InvalidInputMsg  
  
 ; Call WriteString to print the error message  
 **call** WriteString  
  
 ; Pop EDX from the stack  
 **pop** edx  
  
 **ret**

**main procedure:**

The main procedure is the entry point for the program. It starts by clearing the screen and then entering the StateA state.

**StateA state:**

The StateA state is the start state for the FSM. It reads the next character from the input stream and checks for a leading + or - sign. If a leading sign is found, the FSM transitions to the StateB state. If a leading sign is not found, the FSM checks if the character is a digit. If the character is a digit, the FSM transitions to the StateC state. Otherwise, the FSM calls the DisplayErrorMsg procedure to display an error message and then jumps to the Quit label to exit the program.

**StateB state:**

The StateB state is the state where the FSM is after reading a leading + or - sign. It reads the next character from the input stream and checks if it is a digit. If the character is a digit, the FSM transitions to the StateC state. Otherwise, the FSM calls the DisplayErrorMsg procedure to display an error message and then jumps to the Quit label to exit the program.

**StateC state:**

The StateC state is the state where the FSM is after reading a digit. It reads the next character from the input stream and checks if it is a digit. If the character is a digit, the FSM remains in the StateC state. Otherwise, the FSM checks if the Enter key was pressed. If the Enter key was pressed, the FSM transitions to the Quit label to exit the program. Otherwise, the FSM calls the DisplayErrorMsg procedure to display an error message and then jumps to the Quit label to exit the program.

**Quit label:**

The Quit label is the exit point for the program. The main procedure jumps to the Quit label to exit the program when the Enter key is pressed or when an invalid character is encountered.

**Getnext procedure:**

The Getnext procedure reads a character from standard input and echoes it to the screen. It returns the character in the AL register.

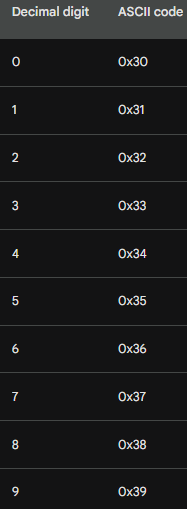
**DisplayErrorMsg procedure:**

The DisplayErrorMsg procedure displays an error message indicating that the input stream contains illegal input. It receives nothing and returns nothing. This is a basic example of how to implement a FSM in assembly language.

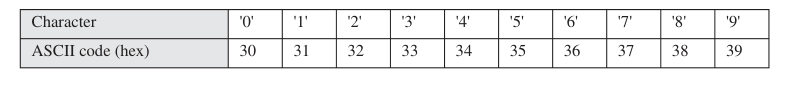
-------------------------------------------------

* The IsDigit procedure determines whether the character in the AL register is a valid decimal digit. It returns the setting of the Zero flag, which is 1 if the character is a valid decimal digit and 0 otherwise.
* The IsDigit procedure works by first comparing the character in AL to the ASCII code for the digit 0. If the character is less than 0, then it is not a valid decimal digit and the Zero flag is cleared.
* Next, the IsDigit procedure compares the character in AL to the ASCII code for the digit 9. If the character is greater than 9, then it is not a valid decimal digit and the Zero flag is cleared.
* Finally, the IsDigit procedure sets the Zero flag.

The following table shows the hexadecimal ASCII codes for decimal digits:



As you can see, the ASCII codes for decimal digits are **contiguous.** This means that we only need to check for the starting and ending range values.



The IsDigit procedure uses the CMP instruction to compare the character in the AL register to the ASCII codes for the digits 0 and 9. If the character is less than 0 or greater than 9, then the JB or JA instruction will jump to the label ID1, respectively.

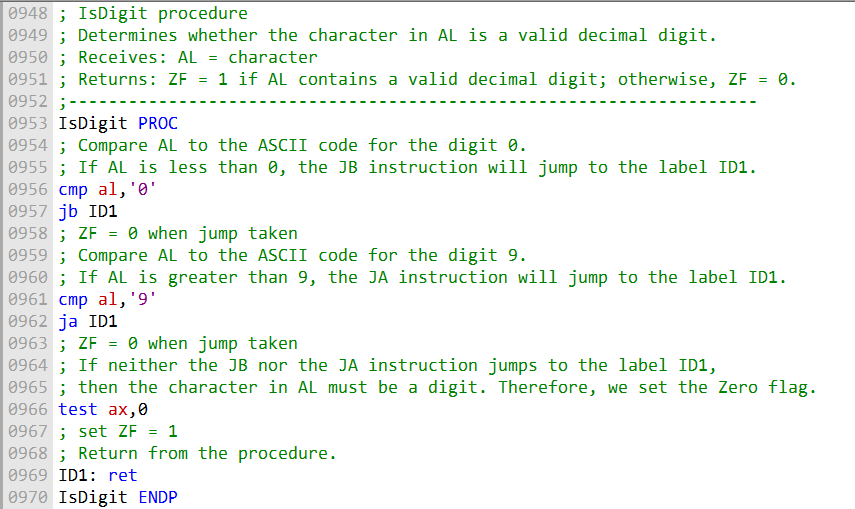
The JB instruction jumps to a label when the Carry flag (CF) is set and the Zero flag (ZF) is clear. The JA instruction jumps to a label when the Carry flag (CF) is clear and the Zero flag (ZF) is clear.

If neither the JB nor the JA instruction jumps to the label ID1, then the TEST instruction is executed. The TEST instruction sets the Zero flag if the result of the AND operation is zero.

Since the JB and JA instructions jump to the label ID1 if the Zero flag is clear, the TEST instruction will only be executed if the character in the AL register is a digit.

Therefore, the IsDigit procedure returns the setting of the Zero flag, which is 1 if the character in the AL register is a digit and 0 otherwise.

Here is a more detailed explanation of the code:



This is a very efficient way to implement the IsDigit procedure, because it takes advantage of the hardware characteristics of the CPU.

CONDITIONAL CONTROL FLOW DIRECTIVES

**Conditional control flow directives** in MASM are used to control the flow of execution of a program depending on the result of a condition. These directives are used to implement conditional statements such as if, else, and elseif.

The following are the most common conditional control flow directives in MASM:



Here are some additional things to keep in mind:

Conditions can be complex, but they must evaluate to a single Boolean value (true or false).

If the condition in the .IF directive is true, the assembler will assemble all of the statements between the .IF and .ELSEIF (or .ENDIF) directives.

If the condition in the .IF directive is false, the assembler will skip all of the statements between the .IF and .ELSEIF (or .ENDIF) directives.

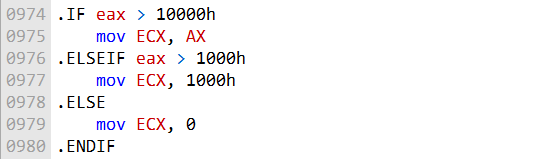
If the .ELSEIF directive is present, the assembler will evaluate the condition in the .ELSEIF directive.

If the condition is true, the assembler will assemble all of the statements between the .ELSEIF and .ELSE (or .ENDIF) directives.

If the .ELSEIF directive is present and the condition is false, the assembler will skip all of the statements between the .ELSEIF and .ELSE (or .ENDIF) directives.

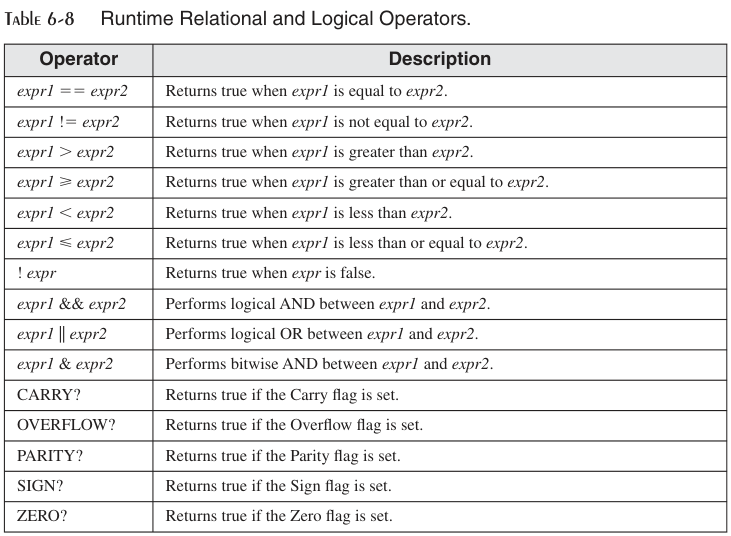
.ELSE directive is optional. If it is present, the assembler will assemble all of the statements between the .ELSE and .ENDIF directives if all of the previous conditions were false.

The .ENDIF directive is required. It tells the assembler the end of the conditional statement. Here is an example of a more complex conditional statement using the .IF, .ELSEIF, and .ELSE directives:



This code will move the contents of the AX register to the ECX register if the value of AX is greater than 10000h. Otherwise, if the value of AX is greater than 1000h, the code will move the value 1000h to the ECX register. Otherwise, the code will move the value 0 to the ECX register.

-------------------------------------------



The table you sent shows the relational and logical operators in MASM. These operators are used to compare two values and return a Boolean value (true or false). The Boolean value can then be used to control the flow of execution of a program using conditional control flow directives such as .IF, .ELSE, and .ELSEIF.

The following is a detailed explanation of each of the operators in the table:

**== (equal to):** Returns true if the two values are equal.

**!= (not equal to):** Returns true if the two values are not equal.

**> (greater than):** Returns true if the first value is greater than the second value.

**>= (greater than or equal to):** Returns true if the first value is greater than or equal to the second value.

**< (less than):** Returns true if the first value is less than the second value.

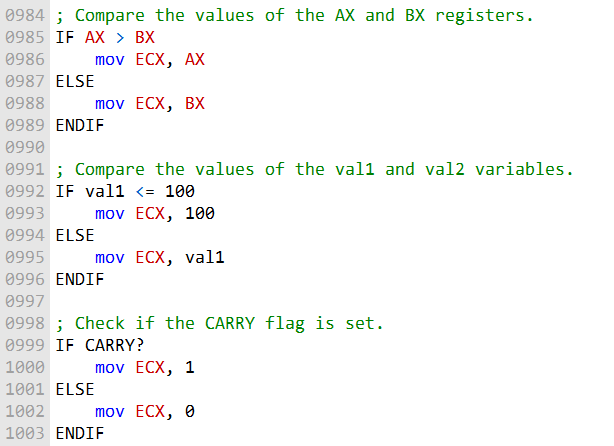
**<= (less than or equal to):** Returns true if the first value is less than or equal to the second value.

**&& (logical AND):** Returns true if both operands are true.

**|| (logical OR):** Returns true if either operand is true.

**! (logical NOT):** Returns true if the operand is false.

The following are some examples of how to use the relational and logical operators in MASM:



Here is a simpler explanation of the notes you provided:

Before using MASM conditional directives, be sure you thoroughly understand how to implement conditional branching instructions in pure assembly language.

This means that you should understand how to use the following assembly language instructions to implement conditional branching:

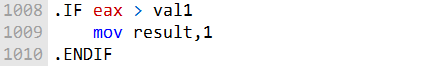
* • **• CMP (compare)**
* **JBE (jump if below or equal)**
* **JA (jump if above)**
* **JE (jump if equal)**
* **JNE (jump if not equal)**

Once you understand how to implement conditional branching in pure assembly language, you can use MASM conditional directives to make your code more concise and readable.

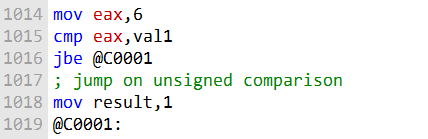
In addition, when a program containing decision directives is assembled, inspect the listing file to make sure the code generated by MASM is what you intended.

MASM conditional directives are translated into assembly language instructions by the assembler. It is a good idea to inspect the listing file to make sure that the assembler generated the code that you expected. This can help you to identify any errors in your code.

Generating ASM Code: When you use a MASM conditional directive such as .IF, the assembler generates assembly language instructions to implement the conditional branching. For example, the following .IF directive:



would be expanded by the assembler into the following assembly language instructions:



The label name @C0001 is created by the assembler to ensure that all labels within the same procedure are unique.

Controlling Whether or Not MASM-Generated Code Appears in the Source Listing File

You can control whether or not MASM-generated code appears in the source listing file by setting the Enable Assembly Generated Code Listing property in the Visual Studio Project Properties dialog box.

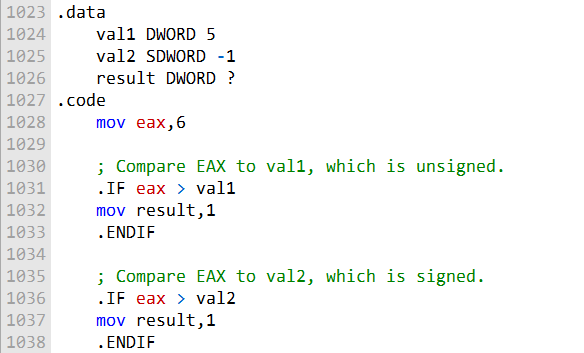
**To do this, follow these steps:** Open the Visual Studio Project Properties dialog box. Select Microsoft Macro Assembler. Select Listing File. Set the Enable Assembly Generated Code Listing property to Yes. Once you have set this property, the MASM-generated code will be included in the source listing file. This can be helpful for debugging purposes.

SIGNED AND UNSIGNED IN ASSEMBLY CODE

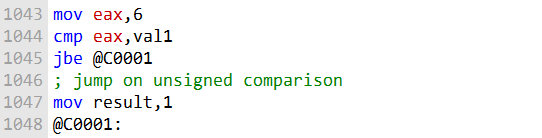
When you use the .IF directive to compare values, you must be aware of whether the values are signed or unsigned.

If the values are signed, the assembler will generate a signed conditional jump instruction. If the values are unsigned, the assembler will generate an unsigned conditional jump instruction.

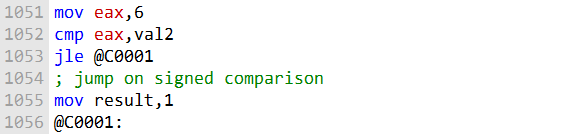
Example:



The assembler will generate the following code for the first .IF directive:



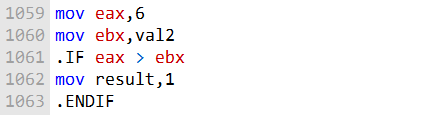
The assembler will generate the following code for the second .IF directive:



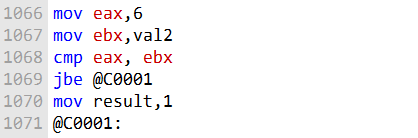
COMPARING REGISTERS

If you compare two registers using the .IF directive, the assembler cannot determine whether the values are signed or unsigned. Therefore, the assembler will default to an unsigned comparison.

Example:



The assembler will generate the following code:



**Conclusion:** It is important to be aware of whether the values you are comparing are signed or unsigned when using the .IF directive. This will help you to ensure that the assembler generates the correct conditional jump instruction.

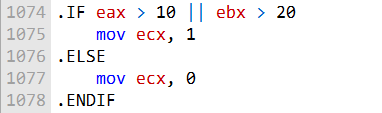
COMPOUND EXPRESSIONS

**Compound Boolean expressions** allow you to combine two or more Boolean expressions using the logical OR and AND operators.

The **logical OR operator (||)** returns true if either of the Boolean expressions is true. The logical AND operator (&&) returns true if both of the Boolean expressions are true. Using Compound Expressions with the .IF Directive

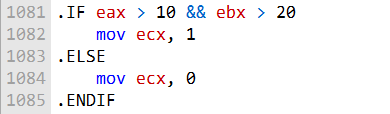
You can use compound expressions with the .IF directive to control the flow of execution of your program.

For example, the following .IF directive uses the logical OR operator to compare the values of the eax and ebx registers:



This code will move the value 1 to the ecx register if the value of eax is greater than 10 or the value of ebx is greater than 20. Otherwise, the code will move the value 0 to the ecx register.

The following .IF directive uses the logical AND operator to compare the values of the eax and ebx registers:



This code will move the value 1 to the ecx register only if the value of eax is greater than 10 and the value of ebx is greater than 20. Otherwise, the code will move the value 0 to the ecx register.

Compound Boolean expressions can be used to create more complex conditional statements using the .IF directive. This can be helpful for controlling the flow of execution of your program in response to different conditions.

***==========================***

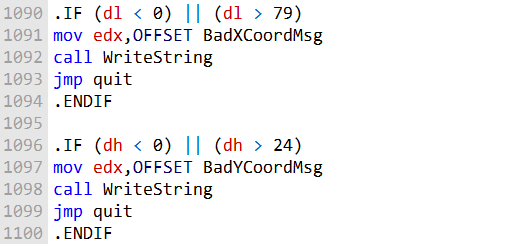
***SetCursorPosition Example***

***==========================***

The SetCursorPosition procedure sets the cursor position to the specified coordinates. It receives two input parameters: DL (X-coordinate) and DH (Y-coordinate).

The procedure first checks if the X-coordinate and Y-coordinate are within the valid ranges. If either coordinate is out of range, the procedure displays an error message and exits.

The following code shows the range checking code in the SetCursorPosition procedure



The .IF directive is used to check if the X-coordinate or Y-coordinate is out of range. The logical OR operator (||) is used to combine the two conditions.

If either condition is true, the procedure displays an error message and exits.

If the X-coordinate and Y-coordinate are within the valid ranges, the procedure calls the Gotoxy procedure to set the cursor position.

The following code shows the code that sets the cursor position:



The Gotoxy procedure is a built-in MASM procedure that sets the cursor position to the specified coordinates.

The SetCursorPosition procedure is an example of how to use the .IF directive to range check input parameters. This can be helpful for preventing errors in your program.

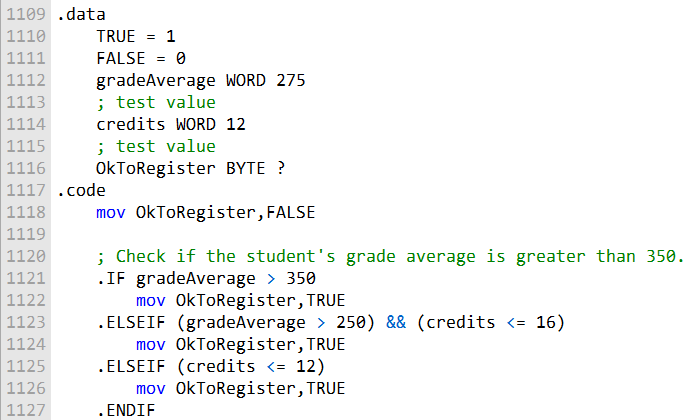
***==============================***

***College Registration Example***

***===============================***

The college registration example you provided uses the .IF, .ELSEIF, and .ENDIF directives to implement a multiway branch structure. The structure checks the student's grade average and number of credits to determine whether or not the student can register.

The following is a simpler explanation of the code:



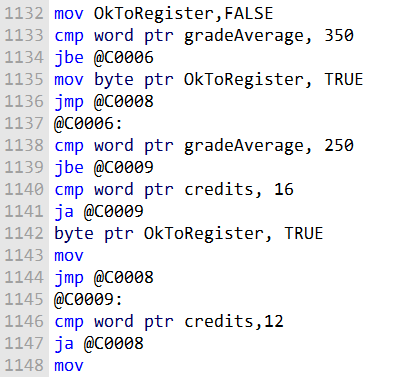
The .IF directive is used to check the first condition: whether the student's grade average is greater than 350. If the condition is true, the mov instruction sets the OkToRegister variable to TRUE.

The .ELSEIF directive is used to check the second condition: whether the student's grade average is greater than 250 and the number of credits the student wants to take is less than or equal to 16. If both conditions are true, the mov instruction sets the OkToRegister variable to TRUE.

The .ELSEIF directive is used to check the third condition: whether the number of credits the student wants to take is less than or equal to 12. If the condition is true, the mov instruction sets the OkToRegister variable to TRUE.

If none of the conditions are true, the OkToRegister variable will remain set to FALSE.

The following is a breakdown of the generated code that you sent:



* The first line of code moves the value FALSE to the OkToRegister variable.
* The next two lines of code compare the student's grade average to 350. If the grade average is greater than 350, the program jumps to the label @C0008. Otherwise, the program continues to the next line of code.
* The next three lines of code compare the student's grade average to 250 and the number of credits the student wants to take to 16. If both conditions are true, the program jumps to the label @C0008. Otherwise, the program continues to the next line of code.
* The next two lines of code compare the number of credits the student wants to take to 12. If the number of credits is less than or equal to 12, the program jumps to the label @C0008. Otherwise, the program continues to the next line of code.
* The label @C0008 is a jump target. If the program jumps to this label, the OkToRegister variable will be set to TRUE.
* The program exits at the end of the code.

CREATING LOOPS WITH .REPEAT AND .WHILE

Here is a more complete explanation of the .REPEAT and .WHILE directives:

***==============================***

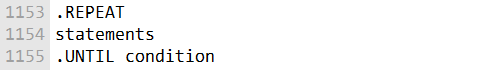
***.Repeat directive***

***===============================***

The .REPEAT directive creates a loop that executes the statements in the loop body once before testing the condition following the .UNTIL directive.

If the condition is false, the loop body is executed again. The loop continues to execute until the condition becomes true.

Syntax:





This code will display the values 1 through 10 to the console.

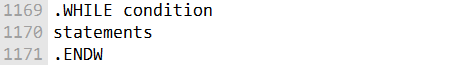
***==============================***

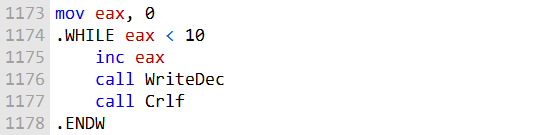
***.While directive***

***===============================***

The .WHILE directive creates a loop that tests the condition before executing the loop body. If the condition is false, the loop body is skipped. The loop continues to execute until the condition becomes false.

Syntax:





This code will also display the values 1 through 10 to the console.

***Differences Between .REPEAT and .WHILE***

The main difference between the .REPEAT and .WHILE directives is that the .REPEAT directive executes the loop body at least once, even if the condition is false. The .WHILE directive, on the other hand, will skip the loop body if the condition is false.

***Which Directive to Use?***

In general, you should use the .WHILE directive for loops where you need to test the condition before executing the loop body. This is because the .WHILE directive is more efficient than the .REPEAT directive, as it avoids executing the loop body if the condition is false.

However, there are some cases where you may want to use the .REPEAT directive. For example, you may want to use the .REPEAT directive if you need to initialize a variable before executing the loop body.

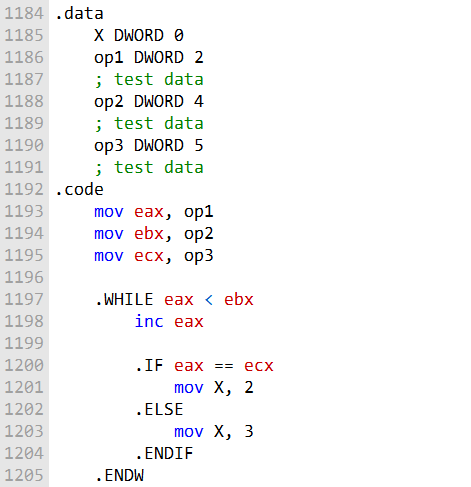
***Conclusion***

The .REPEAT and .WHILE directives are two powerful tools for creating loops in MASM. By understanding the differences between the two directives, you can choose the right directive for your needs.

---------------------------------------------

The notes you provided are unclear and incomplete because they do not provide a complete explanation of how to implement the pseudocode using the .WHILE and .IF directives.

Here is a more complete explanation:



This code will loop from the value of op1 to the value of op2, incrementing op1 on each iteration. Within the loop, the code uses the .IF directive to check if op1 is equal to op3.

If it is, the code moves the value 2 to X. Otherwise, the code moves the value 3 to X.

The .WHILE directive will continue to loop until op1 is greater than or equal to op2.

***Here is a breakdown of the code:***

The code you provided is a loop that executes the following steps:

1. **Moves the values of the variables op1, op2, and op3 to the registers eax, ebx, and ecx, respectively.**
2. **Starts a .WHILE loop that will continue to execute until eax is greater than or equal to ebx.**
3. **Increments the eax register by 1.**
4. **Uses the .IF directive to check if eax is equal to ecx.**

* • **• If eax is equal to ecx, the code moves the value 2 to the variable X.**
* **Otherwise, the code moves the value 3 to the variable X.**
* **Ends the .WHILE loop.**

This loop will essentially iterate from the value of op1 to the value of op2, incrementing op1 on each iteration. Within the loop, the code checks if op1 is equal to op3. If it is, the code moves the value 2 to X. Otherwise, the code moves the value 3 to X.

Here is a simpler explanation:

* • **• Input: Three variables: op1, op2, and op3.**
* **Output: The variable X.**
* **Algorithm:1. Initialize X to 0.**

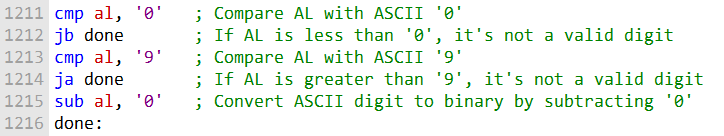
Iterate from op1 to op2, incrementing op1 on each iteration.▪ If op1 is equal to op3, set X to 2. Otherwise, set X to 3.

***===========***

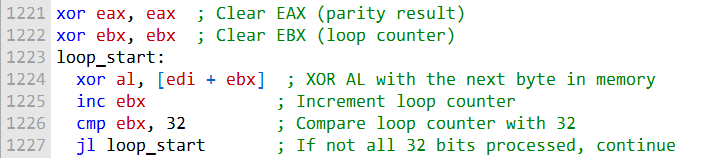
***Questions***

***===========***

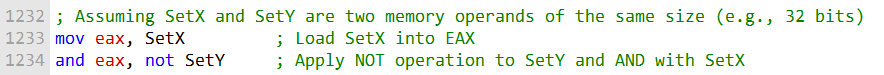
Convert an ASCII digit in AL to its corresponding binary value:



Calculate the parity of a 32-bit memory operand:



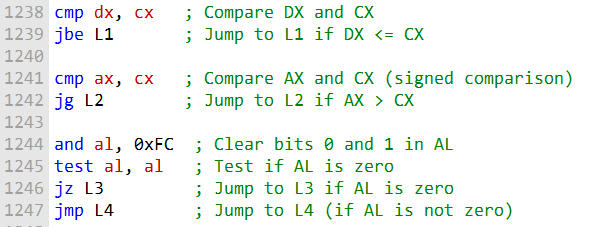
Generate a bit string in EAX representing members in SetX not in SetY:



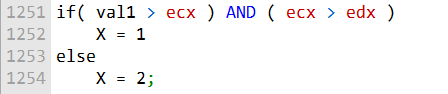
Jump to label L1 when DX <= CX:

Jump to label L2 when AX > CX (signed comparison):

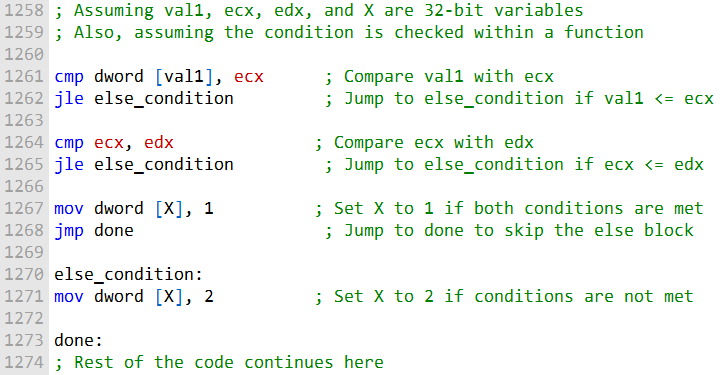
Clear bits 0 and 1 in AL and jump based on the destination operand:



Let's start with implementing the pseudocode for the first exercise using short-circuit evaluation in assembly language. The pseudocode is as follows:



Here's the corresponding assembly code:



In this code, we first compare val1 with ecx. If val1 is less than or equal to ecx, we jump to the else\_condition label, effectively skipping the X = 1 assignment.

Then, we compare ecx with edx. If ecx is less than or equal to edx, we also jump to the else\_condition label.

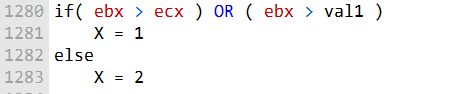
If both conditions are met (val1 > ecx and ecx > edx), we set X to 1. Otherwise, if either condition is not met, we set X to 2.

The jmp done statement ensures that we skip the else\_condition block when both conditions are met.

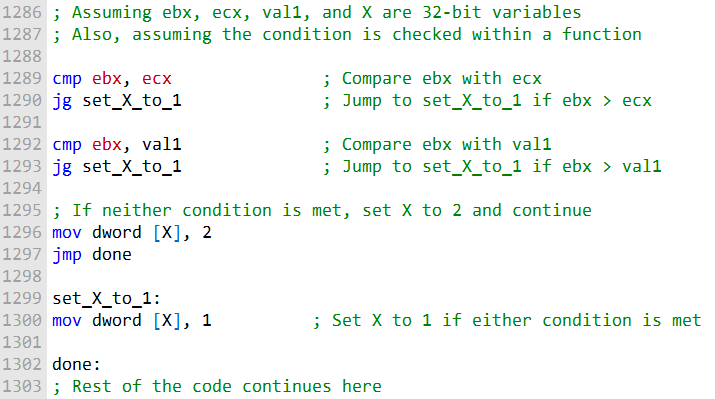
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***Exercise 8:***

Implement the following pseudocode using short-circuit evaluation:



Here's the corresponding assembly code:



In this code, we first compare ebx with ecx. If ebx is greater than ecx, we jump to the set\_X\_to\_1 label, effectively setting X to 1.

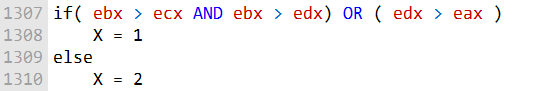
Next, we compare ebx with val1. If ebx is greater than val1, we again jump to set\_X\_to\_1, ensuring that X is set to 1 if either condition is met.

If neither condition is met, we set X to 2 and continue with the code.

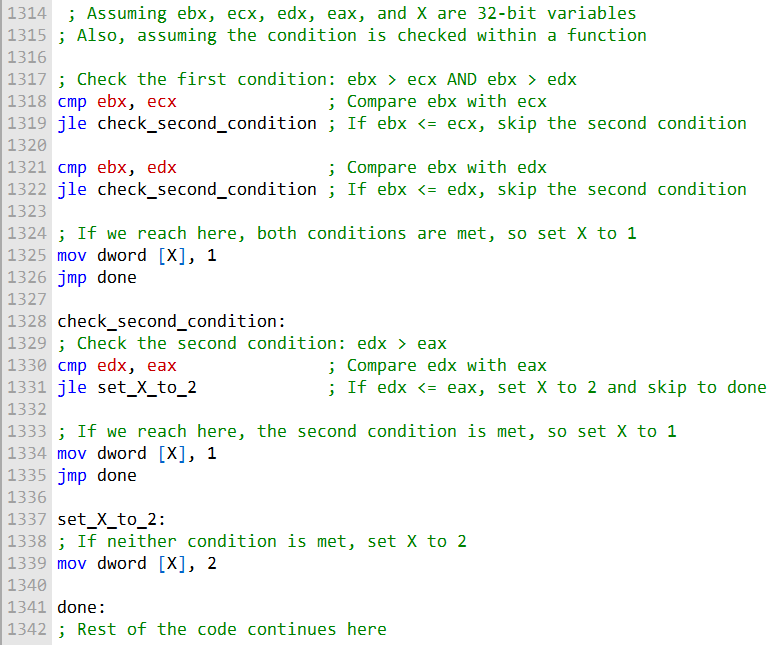
-----------------------------------------------------

***Exercise 9:***

Implement the following pseudocode using short-circuit evaluation:



Here's the corresponding assembly code:



In this code, we first check the first condition: ebx > ecx AND ebx > edx. If either of these subconditions is not met, we skip to check\_second\_condition.

If both subconditions are met, we set X to 1 and jump to done.

In check\_second\_condition, we check the second condition: edx > eax. If this condition is met, we set X to 1 and jump to done. If the second condition is not met, we set X to 2.

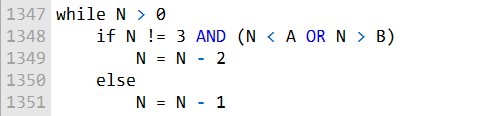
This code implements the pseudocode with short-circuit evaluation as requested.

Now, we have one more exercise remaining:

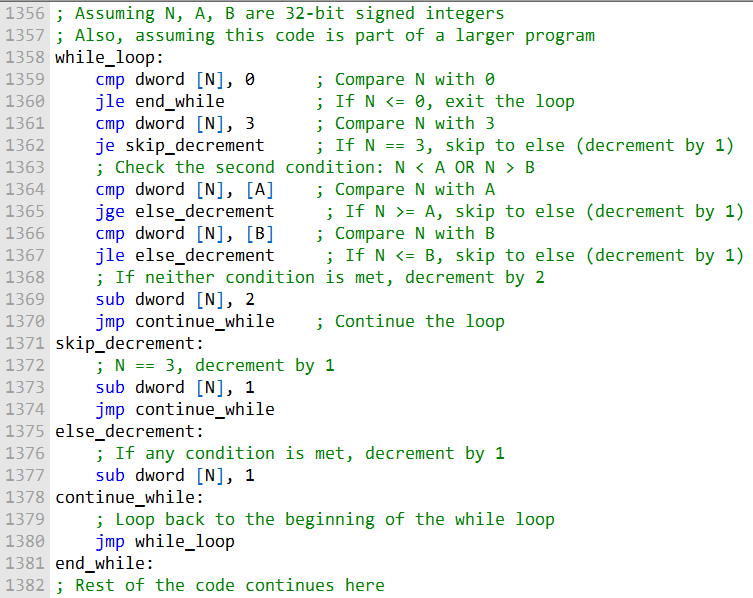
-----------------------------------------------------

***Exercise 10:***

Implement the following pseudocode using short-circuit evaluation:



Here's the corresponding assembly code:



In this code, we use a while loop to repeatedly check the conditions and decrement N accordingly. The loop continues as long as N is greater than 0.

If N is equal to 3, we decrement it by 1 (skip to the else part). If N is not equal to 3 and either N is greater than A or N is less than B, we decrement N by 2.

Otherwise, we decrement N by 1. The loop continues until N becomes less than or equal to 0.

------------------------------------

In the provided assembly code, continue\_while, end\_while, and else\_decrement are not procedures or labels that you explicitly call; they are labels used for control flow within the while loop. Let me clarify their roles:

**continue\_while:** This is a label used to mark the point in the code where the loop should continue if none of the conditions for decrementing N are met. It is not a procedure or function that you explicitly call; instead, it's a reference point for the code to jump back to the beginning of the while loop.

**end\_while:** This is also a label used to mark the end of the while loop. When the condition N <= 0 is met, the code jumps to this label to exit the loop and continue with the rest of the program.

**else\_decrement:** This label is used to mark the point in the code where N is decremented by 1 when the condition N != 3 AND (N < A OR N > B) is not met. It's used to skip the decrement by 2 and directly decrement by 1.

These labels are simply reference points in the code to control the flow of execution within the while loop. You don't explicitly call them as procedures or functions. Instead, the program flow jumps to these labels based on conditional branches (jmp) to implement the logic of the while loop.

I hope this helps!

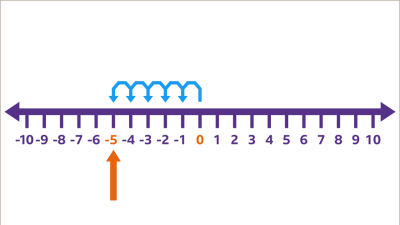
FINAL QUESTIONS FOR THIS TOPIC ON CONDITIONAL PROCESSING

I can explain the suggestions provided for testing your code:

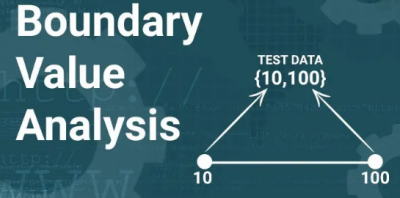
**Using a Debugger:** Debugging your code using a debugger is a crucial step in ensuring its correctness. Debuggers allow you to step through your code line by line, inspect variables, and identify issues. You can use debugging tools provided by your development environment (e.g., Visual Studio Debugger).



**Testing with Negative Values:** If your code deals with signed data, it's essential to include negative values in your test cases to cover all possible scenarios.



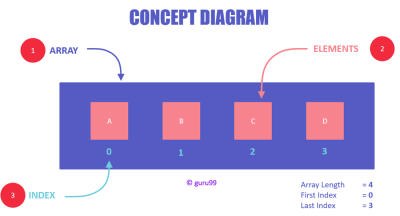
**Testing at Boundaries:** When a range of input values is specified, test your code with values that fall before, on, and after these boundaries. This helps verify how your code handles edge cases.



**Multiple Test Cases:** Create multiple test cases with different inputs and conditions. This ensures that your code is robust and can handle a variety of scenarios.



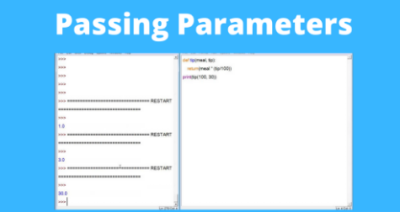
**Using a Debugger for Array Operations:** When working with arrays, especially when modifying them, a debugger's Memory window can be very useful. It allows you to inspect the array's contents in hexadecimal or decimal representation.



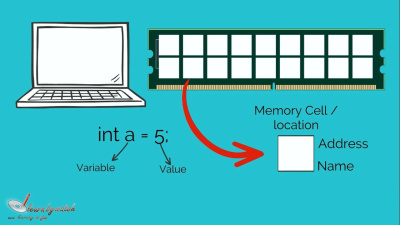
**Checking Register Preservation:** If you have a procedure that modifies registers, consider calling it twice in a row. This helps verify that the procedure correctly preserves register values between calls.



**Parameter Passing for Multiple Arrays:** When passing multiple arrays to a procedure, it's a good practice not to refer to arrays by name inside the procedure. Instead, set registers like ESI or EDI to the offsets of the arrays before calling the procedure. Use indirect addressing ([esi] or [edi]) inside the procedure to access array elements.



**Local Variables in Procedures:** If you need to create variables for use only within a procedure, you can declare them using the .data directive before the variable and the .code directive afterward. Initialize these variables within the procedure to ensure they start with the correct values when the procedure is called multiple times.



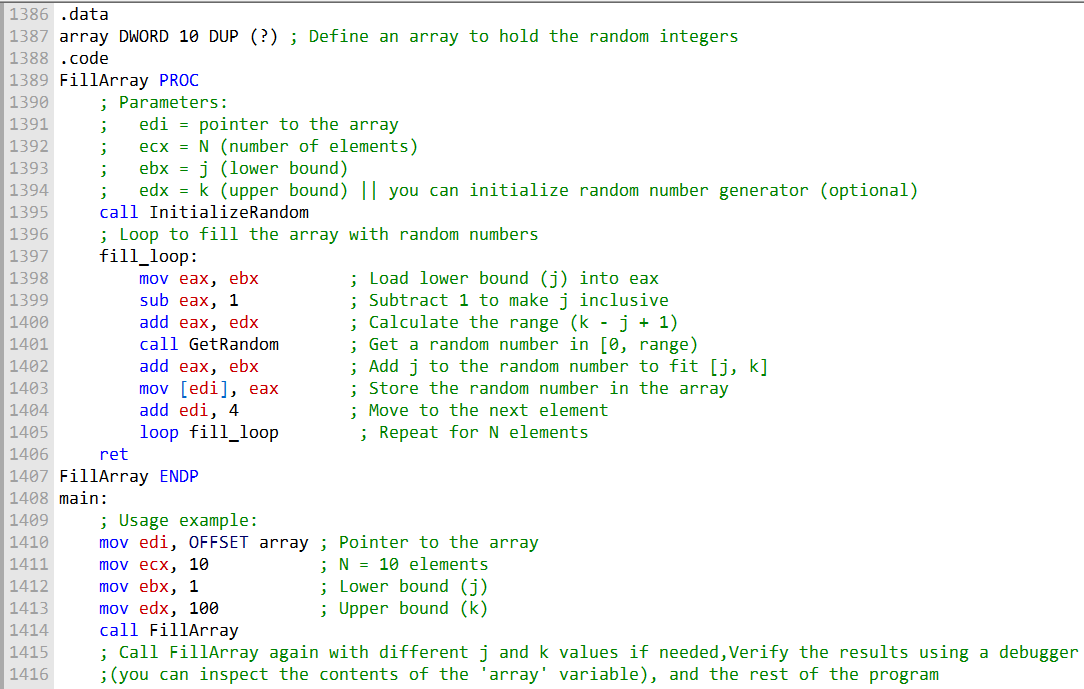
***=============================***

***Exercise 1: Filling an Array***

***=============================***

This exercise requires you to create a procedure that fills an array of doublewords with N random integers within the range [j, k]. You need to pass a pointer to the array, the value of N, and the values of j and k as parameters to the procedure. Additionally, you should preserve all register values between calls to the procedure.

Here's a sample assembly code for this exercise:



This code defines a procedure called FillArray, which fills an array with random integers within the specified range. The main program demonstrates how to use this procedure with different values of j and k.

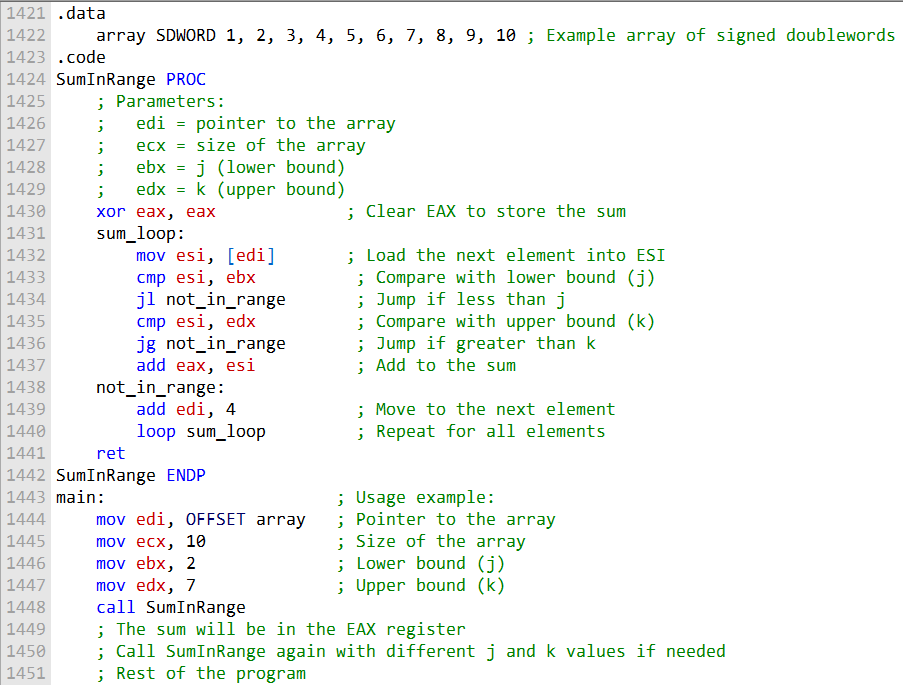
***=============================***

***Exercise 1: Summing an Array***

***=============================***

This exercise requires you to create a procedure that returns the sum of all array elements within the range [j, k]. You'll pass a pointer to the array, the size of the array, and the values of j and k as parameters to the procedure. The sum should be returned in the EAX register, and all other register values should be preserved between calls.

Here's a sample assembly code for this exercise:



This code defines a procedure called SumInRange, which calculates the sum of array elements within the specified range [j, k]. The main program demonstrates how to use this procedure with different values of j and k.

***=================================***

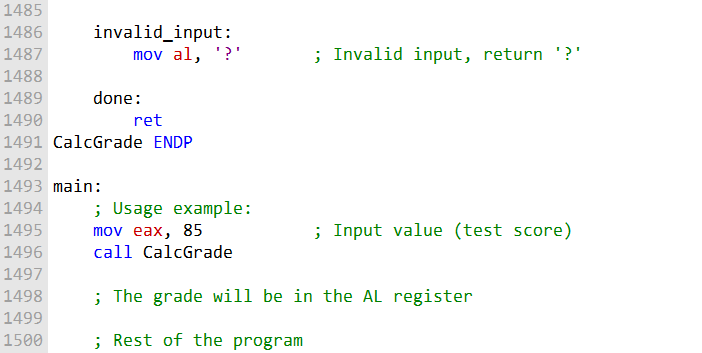
***Exercise 1: TestScore Evaluation***

***=================================***

This exercise requires you to create a procedure named CalcGrade that receives an integer value between 0 and 100 and returns a single capital letter grade in the AL register. The grade returned should be based on specified ranges.

Here's a sample assembly code for this exercise:





This code defines a procedure called CalcGrade, which returns a grade based on the specified ranges. The main program demonstrates how to use this procedure by passing a test score (integer value) and receiving the corresponding grade in the AL register.

==================================

Now it's time for you to do your own practice:

***Exercise 4: Test Score Evaluation***

Create a program that generates 10 random integers between 50 and 100 (inclusive). For each integer generated, pass it to the CalcGrade procedure, which will return a corresponding letter grade based on specified ranges. Display the integer and its corresponding letter grade. You can use the RandomRange procedure from the Irvine32 library to generate random integers.

***Exercise 5: Boolean Calculator (1)***

Create a program that acts as a simple boolean calculator for 32-bit integers. It displays a menu with options to perform logical operations (AND, OR, NOT, XOR) and allows the user to choose an operation. Implement this menu using Table-Driven Selection. When the user selects an operation, call a procedure to display the operation name. Implement this menu-driven program.

***Exercise 6: Boolean Calculator (2)***

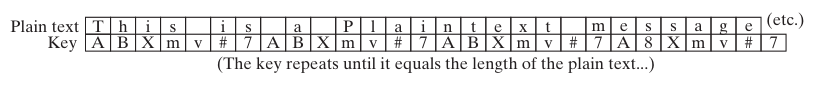
Continuing from Exercise 5, implement procedures for each of the logical operations (AND, OR, NOT, XOR). Prompt the user for inputs (hexadecimal integers) as required by the chosen operation, perform the operation, and display the result in hexadecimal.

***Exercise 7: Probabilities and Colors***

Write a program that randomly selects one of three colors (white, blue, green) with specific probabilities (30%, 10%, 60%). Use a loop to display 20 lines of text, each with a randomly chosen color based on the given probabilities. You can generate a random integer between 0 and 9 and use it to select colors accordingly.

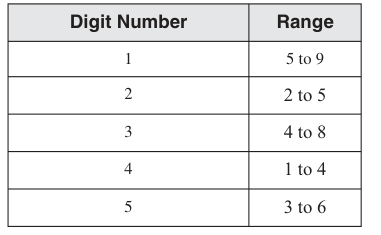
***Exercise 8: Message Encryption***

Revise an encryption program to encrypt and decrypt a message using an encryption key consisting of multiple characters. Implement encryption and decryption by XOR-ing each character of the key against a corresponding byte in the message. Repeat the key as necessary until all plaintext bytes are translated.



***Exercise 9: Validating a PIN***

Create a procedure called Validate\_PIN that checks the validity of a 5-digit PIN based on specified digit ranges. The procedure receives a pointer to an array containing the PIN and validates each digit. If any digit is outside its valid range, return the digit's position (1 to 5) in the EAX register; otherwise, return 0. Write a test program that calls Validate\_PIN with valid and invalid PINs and verifies the return values.



***Exercise 10: Parity Checking***

Implement a procedure that checks the parity (even or odd) of bytes in an array. The procedure returns True (1) in EAX if the bytes have even parity and False (0) if they have odd parity. Write a test program that calls the procedure with arrays having even and odd parity and verifies the return values.