INTRINSIC DATA TYPES

What does “intrinsic data types” mean?

Intrinsic data types are the **built-in data sizes** that the assembler understands.

They answer three simple questions:

1. **How big is the data?** (8 bits, 16 bits, 32 bits, etc.)
2. **Is it signed or unsigned?** (can it be negative?)
3. **Is it an integer or a real (floating-point) number?**

That’s it. No magic.

What the assembler actually cares about

Here’s the key idea:

The assembler mainly cares about **size.**

It needs to know:

- how many bytes to reserve
- how many bytes an instruction will read or write

The assembler **does NOT strongly enforce**:

- signed vs unsigned

That distinction is mostly **for humans.**

Signed vs Unsigned (Important but subtle)

- DWORD → 32-bit **unsigned**
- SDWORD → 32-bit **signed**

Both:

- are **32 bits**
- take up **4 bytes**
- look identical in memory

The only difference is **how *you* interpret the bits**

That’s why programmers often use SDWORD:

- not because the assembler demands it
- but because it makes intent clear

Why intrinsic data types matter

Intrinsic data types help you:

- choose the correct **operand size**
- avoid reading or writing the wrong number of bytes
- understand how values are stored in memory

If you get the size wrong, the CPU will still execute —
but your result may be **wrong or corrupted**.

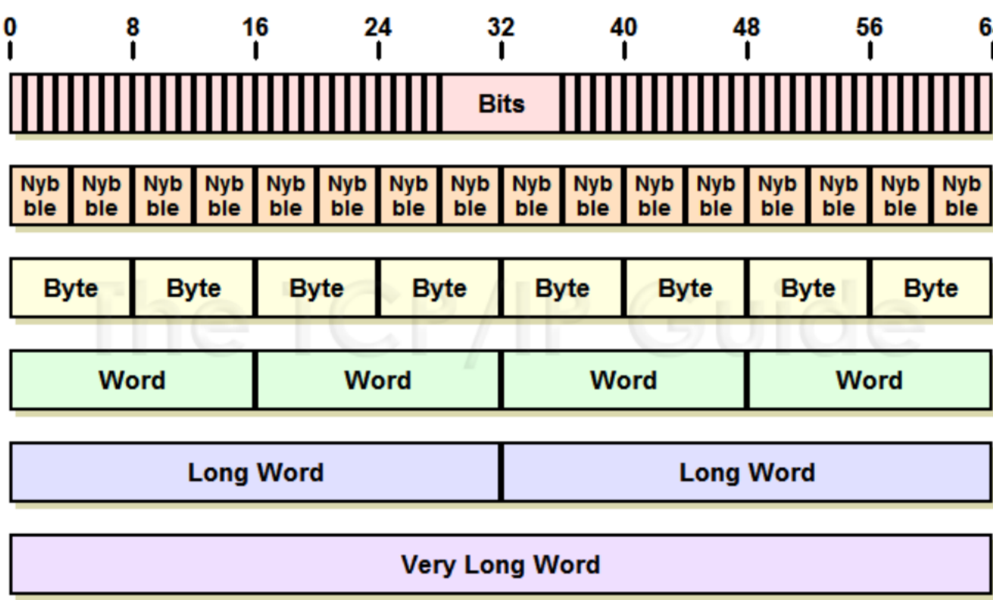


Figure 8: Binary Information Representations and Terms

This diagram shows the relative sizes of the most commonly-sized “collections” of binary information.

Key Takeaways

Intrinsic data types describe the **size**, **signed/unsigned nature**, and whether the value is an **integer or real number**.

The assembler cares about **operand size**, but does **not enforce signed vs unsigned**.

Programmers often use SDWORD to indicate signedness, but it is **not required**.

Intrinsic data types help explain how data is stored and used in assembly.

About overlapping types (Very important concept)

Some types overlap in functionality.

Example:

- DWORD → 32-bit unsigned
- SDWORD → 32-bit signed

Same size. Same memory.
Different **meaning**.

The assembler sees "32 bits".
The programmer sees "signed" or "unsigned".

So when I say "intrinsic data types"...

Yes — you mean **the ones in that image**.

These are the **basic building blocks** of all data in a computer.

Let's walk through them naturally.

Bit-Level Building Blocks (From smallest to bigger)

- **Bit**
  A single 0 or 1. The smallest possible unit of data.
- **Nibble (4 bits)**
  Half a byte. One hexadecimal digit fits here.
- **Byte (8 bits)**
  Stores:
  - ✓ a character
  - ✓ a small number
    This is the most common basic unit.
- **Word (16 bits)**
  Twice a byte. Used for larger numbers.
- **Double Word (32 bits)**
  Four bytes. Very common in 32-bit programs.
- **Quad Word (64 bits)**
  Eight bytes. Used for very large numbers.

Everything else is built from these.

Intrinsic Data Types in Assembly

Integer types

- **BYTE**
  8-bit **unsigned** integer
  Range: 0 to 255
- **SBYTE**
  8-bit **signed** integer
  Range: –128 to 127
- **WORD**
  16-bit **unsigned** integer
  Range: 0 to 65,535
- **SWORD**
  16-bit **signed** integer
  Range: –32,768 to 32,767

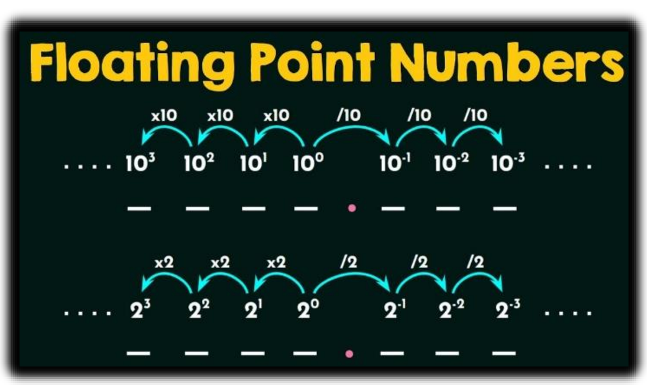
- **DWORD**
  32-bit **unsigned** integer
  Range: 0 to 4,294,967,295
- **SDWORD**
  32-bit **signed** integer
  Range: –2,147,483,648 to 2,147,483,647

Larger / special integer types

- **FWORD (48 bits)**
  Used mainly for **far pointers** (old protected-mode stuff)
- **QWORD (64 bits)**
  Very large integers
- **TBYTE (80 bits)**
  Rarely used
  Mostly related to the floating-point unit

Floating-point (real numbers)

- **REAL4**
  32-bit floating-point
  Common for basic decimal values
- **REAL8**
  64-bit floating-point
  Higher precision
- **REAL10**
  80-bit floating-point
  Very high precision, rarely used



Final idea

The assembler cares about **how many bytes**.
The programmer cares about **what those bytes mean**.

That's why intrinsic data types exist.

DATA DEFINITIONS (ASSEMBLY VARIABLES)

A **data definition** in assembly is how you create a variable.

It answers two questions:

1. **How much memory do I need?**
2. **What value should it start with?**

General syntax

```
[label] directive value
```

- **label** → the variable name (optional, but almost always used)
- **directive** → the data type / size
- **value** → the initial value

Example

```
count DWORD 12345
```

This means:

- create a variable named count
- reserve 4 bytes (32 bits)
- store the value 12345 in it

Equivalent C code:

```c
int count = 12345;
```

Same idea, different language.

More examples

```
message DB "Hello, world!"
age     BYTE 25
salary  SDWORD 100000
```

What's happening here:

- message
  - ✓ DB reserves **1 byte per character**
  - ✓ "Hello, world!" takes **13 bytes**
- age
  - ✓ BYTE reserves **1 byte**
  - ✓ stores the value 25
- salary
  - ✓ SDWORD reserves **4 bytes**
  - ✓ stores a signed integer value

Why the data type matters

The assembler **must know the size** of the variable:

- how many bytes to reserve
- how many bytes instructions should read or write

If you don't specify the type, the assembler has no idea what to do.

Assembly vs C (Same concept)

```
count DWORD 12345
int count = 12345;
```

Both:

- reserve memory
- assign an initial value
- give the memory a name

Assembly just makes the size explicit.

Short forms (Just aliases)

These are **short names**, not new types:

- BYTE → DB
- WORD → DW
- DWORD → DD
- QWORD → DQ
- TBYTE → DT

They all do the same job: **reserve memory**.

Legacy Data Directives (Still used in 2026?)

Yes — **absolutely still used.**

Directives like DB, DW, DD, DQ, and DT are:

- still supported
- still common
- still the standard way to define data in MASM

They are called "legacy" only because they've been around forever — not because they're obsolete.

The Core Data Directives (Explained Clearly)

1. DB — Declare Byte (8 bits)

Reserves **1 byte** per value.

```
x DB 10
letter DB 'A'
text DB "Hi", 0
```

Common uses:

- characters
- small numbers
- strings (byte-by-byte)

2. DW — Declare Word (16 bits)

Reserves **2 bytes**.

```
count DW 500
```

Used for:

- 16-bit values
- older or compact data

3. DD — Declare Doubleword (32 bits)

Reserves **4 bytes**.

```
total DD 12345
```

This is one of the **most common** directives in 32-bit programs.

4. DQ — Declare Quadword (64 bits)

Reserves **8 bytes**.

```
bigNumber DQ 1234567890123
```

Used for:

- large integers
- 64-bit values

5. DT — Declare Ten Bytes (80 bits)

Reserves **10 bytes**.

```
realValue DT 1.23
```

Used for:

- extended precision floating-point (FPU)
- rare, but valid

About strings and null terminators

```
message DB "Hello, world!"
message DB "Hello, world!", 0
```

Both are valid.

The second one:

- adds a **null terminator**
- is better when interacting with C-style functions

MASM does **not** automatically add 0 for you.

Big Idea to Remember

Data definition directives:

- reserve memory
- define size
- optionally initialize values

The assembler:

- assigns addresses
- tracks them in the symbol table
- replaces variable names with real memory locations

You write **names**.
The assembler handles **addresses**.

Data definitions are how assembly creates variables — by explicitly stating how many bytes to reserve and what value to store in them.

Defining Data Types (Part 1 – Beginner Explanation)

Big Picture: What This Section Is About

This section explains:

- How variables are **defined** in assembly
- How variables are **initialized**
- What happens if variables are **not initialized**
- How different **byte-sized data types** work

Main Rules for Data Definitions

1. At Least One Initializer Is Required

When you define a variable, the assembler expects **a value**.

Example:

```
sum DWORD 0
```

- DWORD → data type (4 bytes)
- 0 → initializer

Even zero counts as a valid initializer.

2. Multiple Initializers Use Commas

You can define **multiple values** at once by separating them with commas. Example:

```
nums BYTE 1, 2, 3, 4
```

This creates **four bytes** in memory.

3. Integer Initializers Must Match the Data Size

For integer data types, the value must **fit in the size** of the variable. Example:

```
count BYTE 255      ; valid (fits in 1 byte)
count BYTE 300      ; invalid (too large)
```

4. Leaving a Variable Uninitialized (?)

If you want to reserve memory **without giving it a value**, use ?.

Example:

```
value6 BYTE ?
```

This means:

- Memory is reserved
- The value is unknown (garbage) at program start

⚠️ **Important:** Uninitialized variables **must not be used** before assigning a value.

5. Everything Becomes Binary

No matter how you write an initializer:

- Decimal
- Hex
- Character literal

👉 The assembler converts it into **binary** before storing it in memory.

6. Worked Example: Adding Two Numbers

```
; AddTwo.asm
.386
.model flat, stdcall
.stack 4096

ExitProcess PROTO, dwExitCode:DWORD

.data
sum DWORD 0

.code
main PROC
    mov eax, 5
    add eax, 6
    mov sum, eax
    INVOKE ExitProcess, 0
main ENDP

END main
```

Defines a variable: **sum DWORD 0**

sum is a 4-byte integer initialized to 0; the program loads 5 into eax, adds 6 to it so eax becomes 11, and then stores the result: **mov sum, eax**

The program exits and final value is 11.

7. Debugging Tip

To observe the variable, set a breakpoint after mov sum, eax, step through the instructions, and watch sum in the debugger to see the memory value change in real time.

BYTE-SIZED DATA TYPES (Very Important)

BYTE / DB (Unsigned, 8 bits)

- Size: **1 byte (8 bits)**
- Range: **0 to 255**
- Used for: small numbers, characters, raw data

Examples:

```
age    BYTE 25
letter DB 'A'
flag   DB 1
```

```
value1 BYTE 0
value2 BYTE 255
```

SBYTE is a signed 8-bit data type that occupies 1 byte of memory, can store values from −128 to +127, and is commonly used for small numbers that may be negative (for example: temp SBYTE -10 or change SBYTE 5).

```
value3 SBYTE -128
value4 SBYTE 127
```

Signed vs Unsigned

- **Unsigned** → only positive values (and zero)
- **Signed** → positive **and** negative values

Uninitialized Variables (Important Warning)

```
value6 BYTE ?
```

Reserves 1 byte of memory but does not initialize it, so the value stored is random garbage just like

```c
char value6;
```

...in C language, which is why you must always initialize variables before using them.

Data Definition Directives

DIRECTIVE	MEANING	CAPACITY
DB	**Define Byte** (Legacy MASM style)	8-bit
BYTE	**Unsigned Byte** (Modern MASM style)	8-bit (0 to 255)
SBYTE	**Signed Byte**	8-bit (-128 to +127)

```
; These are functionally identical
value9 DB 'B' ; Allocated 1 byte
value9 BYTE 'B' ; Same allocation

; Range difference
val1 BYTE 255 ; Valid
val2 SBYTE -1 ; Valid (same bit pattern as 255)
```

> **Pro Tip:** Use SBYTE when the value represents a temperature, coordinate, or any number that can be negative. Use BYTE for raw data or characters.

Character Initialization Example

```
value9 DB 'B'
```

- 'B' is a character
- ASCII value of 'B' = **66**
- Stored as **one byte**

Signed Byte Example

```
value10 SBYTE -12
```

- Stores -12
- Uses signed representation
- Can hold negative values

Key Takeaways (Exam-Ready)

- Variables must have an initializer (or ?)
- ? means uninitialized (garbage value)
- BYTE / DB = unsigned 8-bit
- SBYTE = signed 8-bit
- Character literals are stored as ASCII values
- All data becomes binary in memory

💡 **Defining a variable means reserving memory and deciding how the bits should be interpreted.**

DATA DEFINITION PART 2: ARRAYS & SIZES

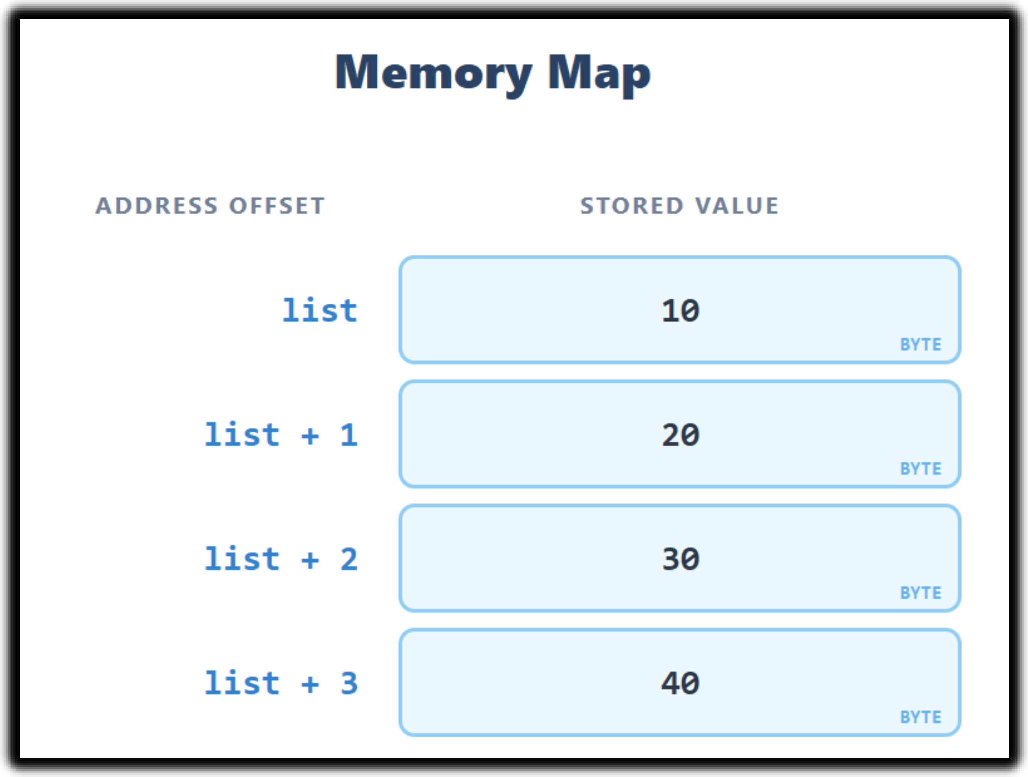
In high-level languages like C++ or Python, you create an array with brackets []. In Assembly, you just list values one after another.

Creating Arrays (The "Label" Trick)

When you define multiple values under one name, you are creating an array.

```
list BYTE 10, 20, 30, 40
```

You are creating **4 bytes in memory**:



- The **label list only points to the first value**, which is 10.
- The assembler doesn't automatically give names to the other values (20, 30, 40).
- To access them, you have to calculate their position relative to list.

For example:

- list → gives you 10
- list + 1 → gives you 20
- list + 2 → gives you 30
- list + 3 → gives you 40

So, the **label is like the "starting address" of your array**, and the other elements are reached by adding an offset in bytes.

The Memory Map:

If list starts at memory offset **0000**:

OFFSET (HEX)	VALUE (DEC)	DESCRIPTION
0000	10	This is where the label **list** points.
0001	20	This is **list + 1**.
0002	30	This is **list + 2**.
0003	40	This is **list + 3**.

Contiguous Memory

When you write:

```
list BYTE 10, 20, 30, 40
     BYTE 50, 60, 70, 80
     BYTE 81, 82, 83, 84
```

here's what's happening:

- The assembler **doesn't care about line breaks**.
- As long as you **don't give a new label**, it just keeps placing the numbers **right after the previous ones in memory**.
- So all 12 numbers are stored **one after another** in memory.

Memory layout looks like this:

Offset	Value
0	10
1	20
2	30
3	40
4	50
5	60
6	70
7	80
8	81
9	82
10	83
11	84

- The **label list points only to the first number (10 at offset 0)**.
- To access the others, you use **offsets**: list + 1 → 20, list + 4 → 50, etc.
- To the computer, this is **just one long strip of memory**, like a long row of boxes.

BYTE vs INTEGER Confusion 😨

Many beginners get confused because:

- In **C++/Java**, int is always **4 bytes (32 bits)**.
- In **Assembly**, numbers don't have a fixed size by default. They are stored in a **container (data type) you choose**.

Think of it like **boxes**:

Data Storage Capacities

BOX TYPE	SIZE	CAPACITY (RANGE)
BYTE	**1 Byte** 8 bits	U: 0 to 255 S: -128 to +127
DWORD	**4 Bytes** 32 bits	U: 0 to 4,294,967,295 S: -2,147,483,648 to +2,147,483,647

- **Number 10** fits easily in a BYTE (8-bit box).
- You **don't need a DWORD (4-byte box)** for such a small number.
- U is unsigned, S is signed.

Why use BYTE instead of DWORD?

1. **Memory efficiency**:
   - ✓ 1,000 small numbers (like ages 0–100) → 1,000 bytes with BYTE, but 4,000 bytes with DWORD.
   - ✓ Saving 75% of memory!
2. **Compatibility**:
   - ✓ Some old hardware or file formats expect data to be **in bytes**.

⚠ The Catch

- If you try to put a number bigger than 255 into a BYTE:
  - ✓ The assembler will **give an error**, or
  - ✓ It might **silently chop off the extra bits**, giving you the **wrong value**.

✅ In short:

- You can spread your data across multiple lines; the assembler just packs them in a row.
- BYTE is just a small container—use it when the number is small.
- Integers in assembly are **as big as you declare** (BYTE, WORD, DWORD, etc.), unlike high-level languages.

MIXING RADIXES (THE "SALAD BOWL")

Assembly doesn't care how you write the number.

You can mix Hex, Decimal, Binary, and Character literals in the same list.

They all get converted to binary in the end.

```
; All of these are valid in the same list
myList BYTE 10,       ; Decimal
            20h,      ; Hexadecimal
            'A',      ; Character (ASCII value 65)
            001010b   ; Binary
```

Big Idea to Remember

- **Labels point to the start:** list is just the address of the first item. To get the rest, you add to the address (Offset).
- **Contiguous Memory:** Data defined sequentially sits sequentially in RAM.
- **Size matters, not type:** You can store an "integer" in a BYTE as long as it fits (0-255). You don't always need a DWORD.

STRINGS

Strings Are Just Arrays of Bytes

In assembly, there is **no "string type"** like in high-level languages (C, Python, etc.).

- A **string is just a sequence of bytes**.
- Each **character** in the string is stored in **one byte**.
- The byte holds the **ASCII value** of the character.

Example:

```
greeting1 BYTE "Good afternoon", 0
```

MEMORY DUMP: 0x0000 - 0x000E LITTLE ENDIAN

ADDR	HEX	CHAR
0	47	G
1	6F	o
2	6F	o
3	64	d
4	20	(sp)
5	61	a
6	66	f
7	74	t
8	65	e
9	72	r
10	6E	n
11	6F	o
12	6F	o
13	6E	n
14	00	*NULL*

String Result: "Good afternoon"

✅ Notice that:

- Each **character takes 1 byte**.
- The **null terminator (0)** is also a **single byte** marking the end of the string.

Labels Are Just Starting Addresses

```
names1 DB "Learning Assembly then WinAPI", 0
names2 DB "Learning Reverse Engineering then C#", 0
names3 DB "Learning to be good as C programming", 0
```

- names1, names2, names3 are **labels**.
- A label is **just a pointer to the first byte** of the string in memory.
- The computer uses the label as a **starting reference**, but it doesn't know the length of the string unless you tell it.
- Everything after the first byte is **contiguous memory** (like we discussed with list BYTE 10,20...).

Why We Use BYTE

- We write BYTE because each **character fits in 1 byte**.
- Strings are really **arrays of bytes**, not a special datatype.

Think of it like this:

```
String "Hi" → H   i   0
Bytes         48  69  00
```

- Each character is **stored in one box** (byte).
- The **null byte** (0) is the **stop signal** for string functions, like printf in C or WinAPI string routines.

Multi-line Strings & Special Characters

You can split strings across multiple lines or add special characters:

```
greeting BYTE "Welcome to the program", 0Dh, 0Ah, \
       "Created by ChatGPT", 0
```

- 0Dh = **carriage return** (CR) → moves cursor to start of line
- 0Ah = **line feed** (LF) → moves cursor down a line
- \ → line continuation character (lets you break one string across multiple lines)

Memory layout is still **just a sequence of bytes**, now including CR/LF:

```
"W", "e", "l", "c", "o", ..., 0Dh, 0Ah, "C", "r", "e", ... , 0
```

Everything remains a **byte**.

Putting It All Together

1. Each string is a **contiguous sequence of bytes** in memory.
2. The **label points to the first byte**.
3. Each **character = 1 byte (ASCII code)**.
4. **Null terminator (0) = 1 byte** marks the end.
5. Multi-line strings or special characters like CR/LF are just **additional bytes** in the same array.

So even the biggest sentence like "Learning Reverse Engineering then C#" is just **a row of bytes**:

Byte 0	Byte 1	...	Byte n	Byte n+1
'L'	'e'	...	'#'	0

✅ Key Insight

Strings in assembly are **not magical objects**.

- They are **arrays of bytes**.
- The **label is the pointer**.
- The **assembler only cares about memory**.
- Null terminators allow functions to **know where the string ends**.

DUP Operator (Duplicate Made Easy)

The **DUP operator** in assembly is all about **making copies**—it lets you allocate multiple pieces of memory and optionally initialize them with the same value.

Think of it as a "memory copy machine" for variables, arrays, strings, or even structures.

How it works:

- **Count:** How many times you want to repeat something.
- **Value:** What you want to repeat (it can be a number, a string, or even an uninitialized placeholder).

The syntax looks like this:

```
<data type> <count> DUP(<value>)
```

- <data type> could be BYTE, WORD, DWORD, etc.
- <count> is how many times you want to repeat.
- <value> is what you want to fill each slot with. If you leave it as ?, the memory is just reserved but contains random "garbage" values until you set it.

Examples:

Allocate 20 bytes, all zero:

```
BYTE 20 DUP(0)
```

This creates a block of **20 bytes**, each containing 0.

Allocate 20 bytes, uninitialized:

```
BYTE 20 DUP(?)
```

Memory is reserved for 20 bytes, but the values are **undefined**. Think of it like an empty box—you can fill it later.

Create a repeated string:

```
BYTE 4 DUP("STACK")
```

This repeats the sequence "STACK" four times in memory, effectively making "STACKSTACKSTACKSTACK".

Allocate an array of 10 integers, initialized to zero:

```
DWORD 10 DUP(0)
```

Here, you get **10 integers**, each 4 bytes, all set to 0.

Allocate an array of structures:

```
STRUC MyStructure
    DWORD integer
    BYTE 4 string
ENDSTRUC

MyStructure 10 DUP(0)
```

This reserves space for **10 structures**, each containing a 4-byte integer and a 4-byte string.

Key idea:

Yes, **DUP literally means "duplicate"**. It's your way to **repeat a value or pattern** efficiently in memory without writing it out multiple times.

Whether you're filling arrays, initializing strings, or creating structures, **DUP saves time, space, and effort**.

Think of it like telling the assembler: *"Hey, make 10 of this, or 20 of that, all lined up in memory, and set them to this value—or leave them blank for now."*

WORD and SWORD

In assembly language, **WORD** and **SWORD** are used to work with **16-bit numbers**. Each 16-bit number takes **2 bytes** of memory.

WORD (Unsigned 16-bit Integer)

- **WORD** is for **unsigned numbers**, meaning only positive numbers from 0 to 65535.
- Each WORD reserves **2 bytes** in memory.

```
word1 WORD 65535   ; reserves 2 bytes and stores the largest unsigned 16-bit value
word3 WORD ?       ; reserves 2 bytes but leaves it uninitialized (random value)
```

SWORD (Signed 16-bit Integer)

- **SWORD** is for **signed numbers**, meaning it can store **negative and positive numbers** from -32768 to 32767.
- Each SWORD also takes **2 bytes** in memory.
- Example:

```
word2 SWORD -32768  ; reserves 2 bytes and stores the smallest signed 16-bit value
```

Key Idea:

Think of **WORD as a box that only holds positive numbers**, and **SWORD as a box that can hold negative numbers too**. Both boxes are **16 bits** (2 bytes) wide, so the memory size is the same, only the interpretation changes.

WORD Arrays

You can create **arrays of 16-bit numbers** in assembly, just like arrays in C, using either **explicit listing** or the **DUP operator**.

- **Memory layout:** Each 16-bit element occupies **2 bytes.** So if your array starts at memory offset 0000, the next element is at 0002, then 0004, and so on.
- **Example with explicit listing:**

```
myList WORD 1000, 2000, 3000  ; 3 elements, each 2 bytes
```

Example with DUP (uninitialized array):

```
myArrayList2 WORD 5 DUP(?)  ; reserves 5 elements, each 2 bytes, values undefined
```

Here, ? means the elements are **uninitialized.** They have random "garbage" values until your code sets them.

Visualizing Memory (Conceptual):

```
myArrayList2: | ? ? | ? ? | ? ? | ? ? | ? ? |
Offsets:        0000  0002  0004  0006  0008
```

Each element takes **2 bytes**, so to access the next element, you **increment the offset by 2**.

Summary:

- **WORD:** Unsigned 16-bit number (0 to 65535)
- **SWORD:** Signed 16-bit number (-32768 to 32767)
- Arrays: Use **listing or DUP** to store multiple words, remembering each takes 2 bytes in memory.

Offset	Value
0000:	1
0002:	2
0004:	3
0006:	4
0008:	5

DWORD and SDWORD

In assembly language, **DWORD** and **SDWORD** are used to work with **32-bit integers**. Each 32-bit number takes **4 bytes** of memory.

I. DWORD (Unsigned 32-bit Integer)

- **DWORD** is for **unsigned numbers**, meaning only positive numbers from 0 to 4,294,967,295.
- Each DWORD reserves **4 bytes** in memory.

```
val1 DWORD 12345678h    ; reserves 4 bytes and stores the unsigned number 0x12345678
val3 DWORD 20 DUP(?)    ; reserves 20 DWORDs (80 bytes), all uninitialized
```

Usage Tip: You can also use **DD** (Define Doubleword) as a legacy directive. It works the same as DWORD:

```
val1 DD 12345678h
```

II. SDWORD (Signed 32-bit Integer)

- **SDWORD** is for **signed numbers**, meaning it can store **negative and positive numbers** from -2,147,483,648 to 2,147,483,647.
- Each SDWORD also takes **4 bytes** in memory.

```
val2 SDWORD -12324352   ; reserves 4 bytes for a signed 32-bit integer
```

III. Arrays of 32-bit Numbers

You can create arrays of DWORDs or SDWORDs either by listing values explicitly or using the **DUP operator**:

Explicit initialization:

```
my32BitArray DWORD 10, 203, 482, 505  ; 4 elements, each 4 bytes
```

Uninitialized array using DUP:

```
myArrayList DWORD 5 DUP(?)   ; 5 DWORDs, each 4 bytes, values undefined
```

Memory layout concept:

- Each element occupies **4 bytes**, so if the first element is at offset 0000, the next is at 0004, then 0008, and so on.
- Arrays let you easily store multiple 32-bit numbers in **contiguous memory**.

IV. Extra Tip: DWORD for Offsets

You can also use **DWORD** to store the **32-bit memory offset of another variable**:

```
pval DWORD va13   ; pval now contains the offset (address) of va13
```

This is useful for pointers or referencing other variables in memory.

V. Summary:

- **DWORD:** Unsigned 32-bit integer, 4 bytes, 0 → 4,294,967,295
- **SDWORD:** Signed 32-bit integer, 4 bytes, -2,147,483,648 → 2,147,483,647
- Arrays: Use listing or **DUP** to store multiple DWORDs
- Legacy DD directive works the same as DWORD

QWORD (Quadword)

The **QWORD directive** in assembly language is used to allocate storage for **64-bit values**, meaning each QWORD takes **8 bytes** of memory.

Think of it as a really big box that can hold very large numbers.

1. Syntax and Usage

You can define QWORD values in two ways:

Standard directive:

```
quad1 QWORD 1234567812345678h  ; allocate 8 bytes and store the 64-bit value
```

Short form (DQ – Define Quadword):

```
quad2 DQ 1234567812345678h      ; same as above, just shorthand
```

Tip: The value must fit in 64 bits, otherwise the assembler will throw an error.

2. Memory Organization

Each QWORD takes **8 bytes**, so if you define multiple QWORDs in an array, memory offsets increase by 8 each time:

64-Bit Memory Offsets

QWORD Alignment (Step = 8 Bytes)

OFFSET (HEX)	STORED VALUE
0000	First QWORD
0008	Second QWORD
0010	Third QWORD
0018	Fourth QWORD

This is just like how **DWORD arrays** worked, but each element is double the size.

3. Arrays of QWORDs

Just like with BYTE or DWORD, you can use the **DUP operator** to define multiple QWORDs at once:

```
myArray QWORD 10 DUP(0)   ; allocate 10 QWORDs, each initialized to 0
```

Each element is **8 bytes**, so this reserves **80 bytes total** (10 × 8).

Using ? instead of 0 leaves them uninitialized:

```
myArray QWORD 10 DUP(?)   ; 10 QWORDs, uninitialized
```

4. QWORD and Registers

- In **32-bit mode**, your registers like **EAX** are 32 bits, so storing a 64-bit QWORD might need **two 32-bit registers** or special memory instructions.
- In **64-bit mode**, the **RAX** register can hold a full QWORD directly.

Example:

```
mov rax, quad1   ; 64-bit move in 64-bit mode
```

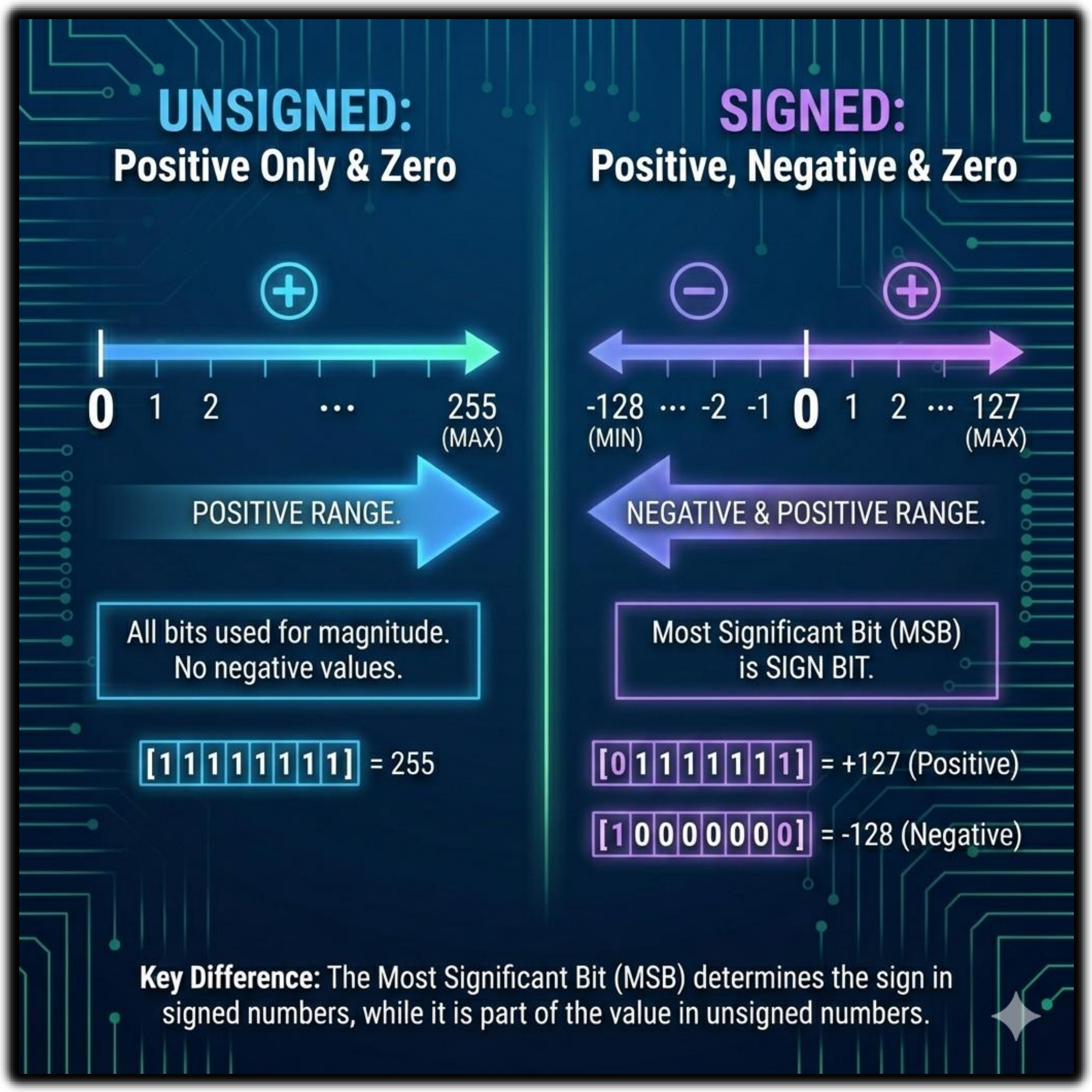
- This is important if you start working with large numbers, addresses, or high-precision calculations.

5. Summary Notes

- QWORD = 64 bits = 8 bytes
- QWORD can be initialized directly or with DUP
- Short form DQ is equivalent to QWORD
- Arrays increment in memory by 8 bytes per element
- 32-bit registers can't hold QWORDs directly; use 64-bit registers or split into two 32-bit halves

💡 **Memory efficiency tip:**
Use QWORD only when you need numbers bigger than 32 bits, otherwise DWORD is enough and takes half the memory.

Never forget this concept in Assembly:



Let’s continue….

PACKED BCD AND TBYTE

Packed BCD (Binary Coded Decimal) is a **special way to represent decimal numbers in binary**, designed for **efficiency and precision**, especially in financial or scientific applications.

1. What is Packed BCD?

Packed BCD stores decimal digits in **pairs**, with **two decimal digits per byte**.

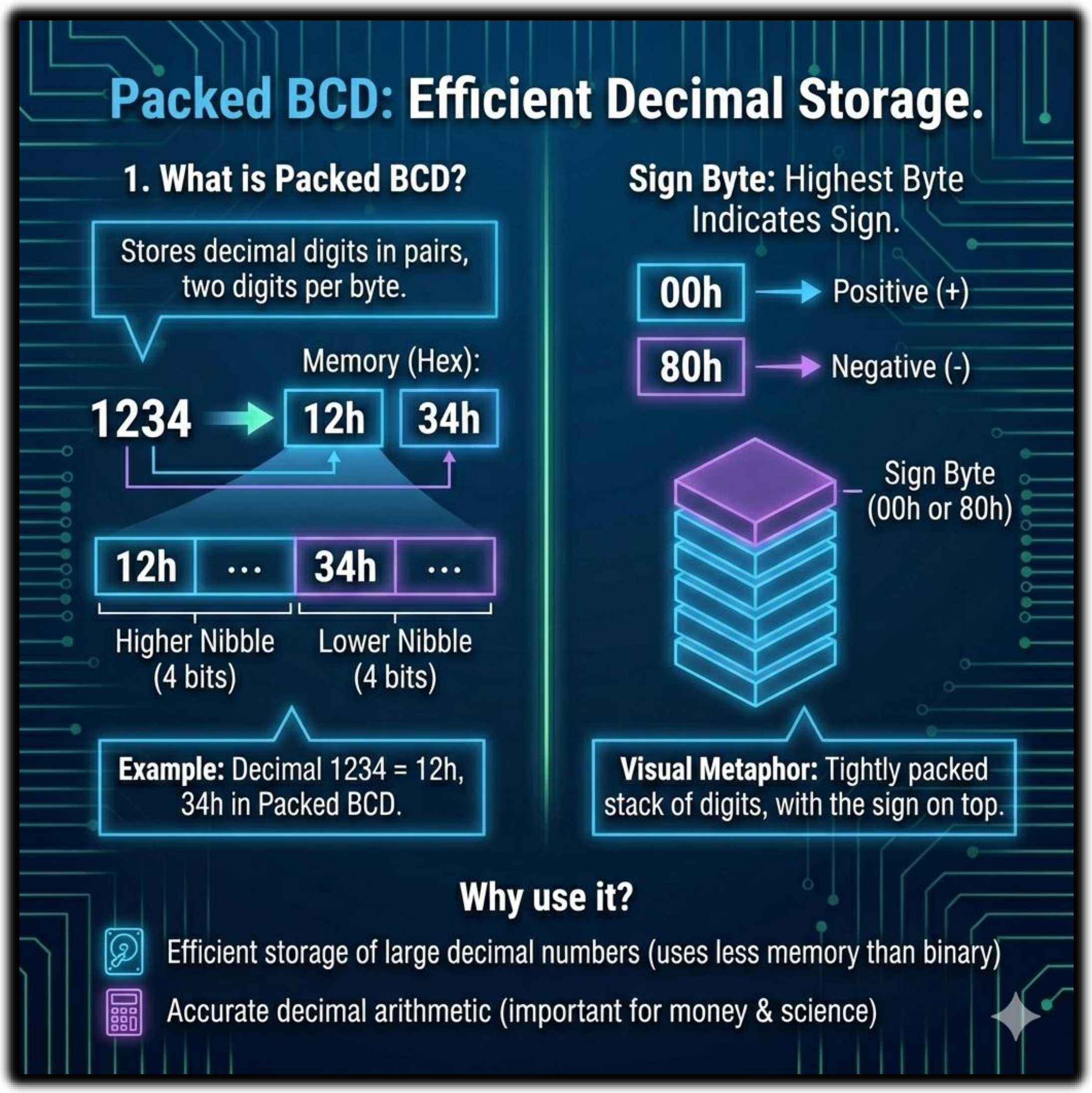
Example: The decimal number 1234 in packed BCD is stored as **34 12** (hex representation in memory).

- The **lower nibble** of a byte stores one digit.
- The **higher nibble** stores the next digit.

Sign byte: The highest byte of a packed BCD variable indicates the sign.

- 00h → Positive
- 80h → Negative

Think of it like a **tightly packed stack of digits**, with the sign sitting on top.



Why use it?

- Efficient storage of large decimal numbers (takes less memory than converting to binary integers).
- Accurate decimal arithmetic — important for **money calculations**, **scientific data**, and some **embedded systems**.

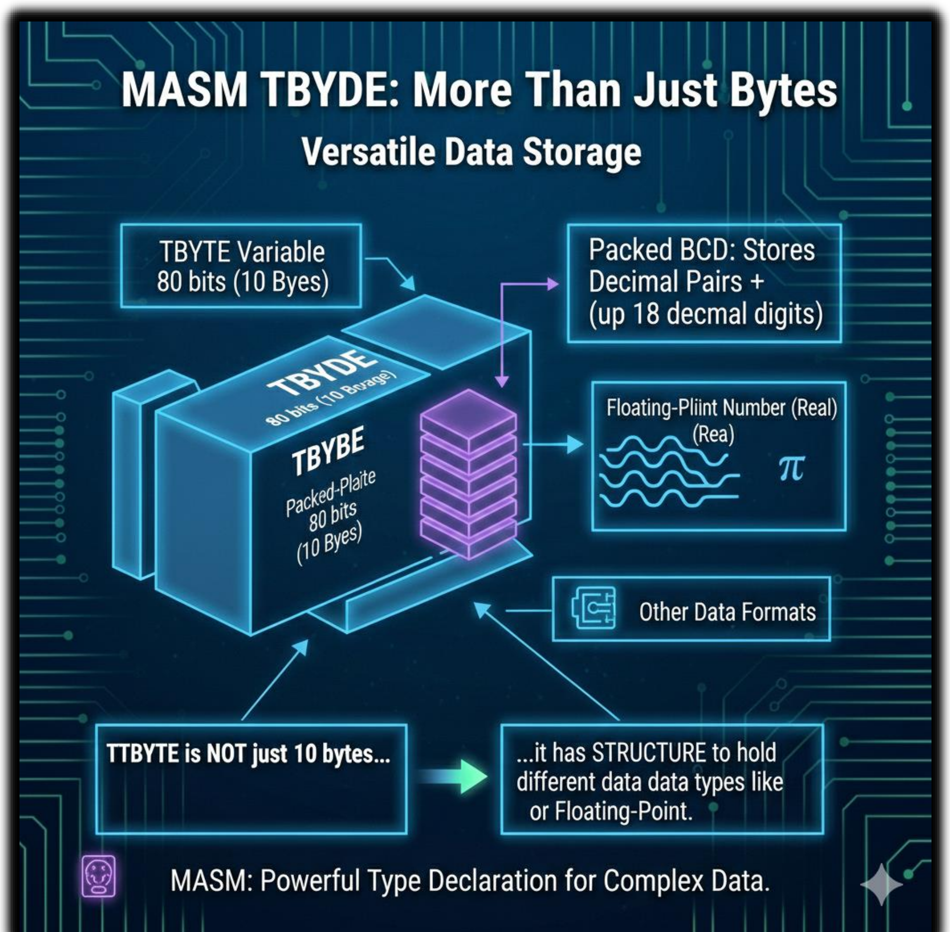
2. The TBYTE Directive

In MASM, **TBYTE** is used to declare variables that can store **packed BCD data**.

Even though TBYTE is **80 bits (10 bytes)**, it isn't just "10 bytes of storage" — it can also hold **floating-point numbers** or other data formats.

Memory layout for a TBYTE BCD number:

- **1st byte:** Sign
- **Next 9 bytes:** Decimal digits, 2 digits per byte



Example: Declaring a packed BCD variable

```
my_bcd_variable TBYTE 1234h    ; NOT correct, needs hex BCD
```

The correct way:

```
my_bcd_variable TBYTE 001234h  ; Positive 1234 in packed BCD
my_bcd_variable TBYTE 801234h  ; Negative 1234 in packed BCD
```

Important: MASM does **not** automatically convert decimal numbers to BCD. You must write them in **hexadecimal BCD form**.

3. Packed BCD in Memory

Let's look at **1234** as an example:

PACKED BCD REPRESENTATION — 32-BIT ENCODING

DECIMAL	PACKED BCD BYTES		
+1234	00	12	34
-1234	80	12	34

Sign Byte (00=+, 80=-) Data Nibbles (0-9)

- Each byte after the sign byte stores **two decimal digits**.
- Positive numbers start with 00h. Negative numbers start with 80h.

Visualizing storage:

BCD MEMORY MAPPING		
0000:	00	← SIGN BYTE (Positive)
0001:	12	← DIGITS 1 AND 2
0002:	34	← DIGITS 3 AND 4

If the number were larger, you'd continue storing 2 digits per byte.

4. Declaring Arrays of Packed BCD

You can use **DUP** with TBYTE too:

```
myBCDArray TBYTE 5 DUP(0)  ; 5 packed BCD variables, initialized to 0
```

- Each element takes **10 bytes**.
- Total memory: 5 × 10 = 50 bytes

Uninitialized array:

```
myBCDArray TBYTE 5 DUP(?)  ; 5 packed BCD variables, uninitialized
```

5. Converting Real Numbers to Packed BCD

Sometimes, you have **floating-point numbers** (REAL4, REAL8, etc.) and want them as packed BCD. This is done using **FPU instructions**:

```
posVal REAL4 1.5        ; a real number
bcdVal TBYTE ?          ; packed BCD variable

FLD posVal              ; load real number onto FPU stack
FBSTP bcdVal            ; convert to packed BCD, round to nearest integer
```

- FLD → Load floating-point number onto FPU stack
- FBSTP → Convert the value to **packed BCD** and store it in bcdVal

Example: If posVal = 1.5, then bcdVal will store 02 in packed BCD.

6. Why Packed BCD Matters

- **Efficiency:** Stores **two digits per byte** instead of wasting 8 bits for a single decimal digit.
- **Accuracy:** No rounding errors when doing **decimal math**, unlike floating-point binary.
- **Applications:** Financial apps, calculators, scientific measurements, embedded systems.

Analogy: Think of Packed BCD as **a neatly packed number stack**, where each box holds 2 digits, and the top box holds the sign. Computers can easily read, write, and calculate with these numbers without wasting memory.

7. Quick Reference

- **Directive:** TBYTE
- **Size:** 10 bytes (80 bits)
- **Sign byte:** First byte, 00h positive, 80h negative
- **Digits:** Next 9 bytes, 2 digits per byte
- **Initialization:** Must be in **hexadecimal**
- **Arrays:** Use DUP operator for multiple variables

✅ Example: Complete Packed BCD Declaration

```
; Positive 1234
myBCD1 TBYTE 001234h

; Negative 1234
myBCD2 TBYTE 801234h

; Array of 3 packed BCD numbers, uninitialized
myBCDArray TBYTE 3 DUP(?)
```

Memory usage:

- myBCD1 → 10 bytes
- myBCD2 → 10 bytes
- myBCDArray → 30 bytes (3 × 10)

Packed BCD is essentially **a super-efficient way to store decimal numbers** where every byte counts. The **TBYTE directive** is just your tool for declaring variables that can hold packed BCD or other 10-byte data types.

DEFINING FLOATING-POINT TYPES IN MASM

Floating-point numbers are used to represent **real numbers**, meaning numbers with fractional parts, like 1.23456789.

In MASM, there are **three main floating-point types**:

TYPE	SIZE	PRECISION	TYPICAL RANGE
REAL4	4 bytes	7 digits	±3.4E38 to ±1.2E-38
REAL8	8 bytes	15 digits	±1.7E308 to ±2.4E-308
REAL10	10 bytes	19 digits	±4.9E324 to ±1.1E-324

I. Single-Precision: REAL4

- **Size:** 4 bytes (32 bits)
- **Precision:** ~7 significant digits
- **Range:** $\pm 3.4\times10^{38}$ to $\pm 1.2\times10^{-38}$

Example:

```
rVal1 REAL4 -1.2    ; Declare a single-precision floating-point variable and initialize it to -1.2
```

- Memory usage: 4 bytes
- Good for general-purpose calculations where moderate precision is enough.

II. Double-Precision: REAL8

- **Size:** 8 bytes (64 bits)
- **Precision:** ~15 significant digits
- **Range:** $\pm 1.7\times10^{308}$ to $\pm 2.4\times10^{-308}$

Example:

```
rVal2 REAL8 3.2E-260  ; Declare a double-precision variable for extremely small values
```

- Memory usage: 8 bytes
- Use when **high precision** is required, such as scientific calculations or very small/large numbers.

III. Extended-Precision: REAL10

- **Size:** 10 bytes (80 bits)
- **Precision:** ~19 significant digits
- **Range:** $\pm 4.9\times10^{324}$ to $\pm 1.1\times10^{-324}$

Example:

```
rVal3 REAL10 4.6E+4096   ; Extended-precision variable for extremely large numbers
```

- Memory usage: 10 bytes
- Ideal for **high-precision math**, financial, or scientific computations where single- or double-precision isn't enough.

IV. Arrays of Floating-Point Numbers

You can use the **DUP operator** to declare arrays of floating-point variables:

```
ShortArray REAL4 20 DUP(0.0)  ; Array of 20 single-precision floats, all initialized to 0.0
```

- **Memory usage:** $20 \times 4 = 80$ bytes
- Efficient way to initialize large arrays of floating-point numbers.

V. Using DD, DQ, and DT Directives

MASM also allows you to declare floating-point numbers with **DD, DQ, and DT**, which are legacy equivalents:

DIRECTIVE	USE	SIZE
DD	Short Real (Single Precision)	4 bytes
DQ	Long Real (Double Precision)	8 bytes
DT	Extended Real	10 bytes

Note: DD stands for *Define Doubleword*, DQ for *Define Quadword*, and DT for *Define Ten-byte*.

Examples:

```
rVal1 DD -1.2        ; Single-precision
rVal2 DQ 3.2E-260    ; Double-precision
rVal3 DT 4.6E+4096   ; Extended-precision
```

This is equivalent to using **REAL4, REAL8, REAL10.** Use whichever style you prefer, but **REALx directives are clearer** for readability.

VI. Precision vs Range

- **Precision**: Number of significant digits the type can represent.
- **Range**: Maximum and minimum values it can store.

TYPE	SIGNIFICANT DIGITS	APPROXIMATE RANGE
REAL4	7	±3.4E38 to ±1.2E-38
REAL8	15	±1.7E308 to ±2.4E-308
REAL10	19	±4.9E324 to ±1.1E-324

Tip: Extended-precision is overkill for most applications but is useful for **scientific or financial computing**.

VII. Real Numbers vs Floating-Point Numbers

- **Real Numbers (math concept)**: Infinite precision and size. Can include fractions, irrational numbers (like π), etc.
- **Floating-Point Numbers (computer representation)**: Approximation of real numbers. Finite precision and range, limited by storage size (4, 8, or 10 bytes).

Key points:

- Floating-point types approximate real numbers.
- Precision is **limited.**
- They can represent extremely large or small numbers, but not perfectly.

✅ Quick Example Summary

```
; Single-precision float
rVal1 REAL4 -1.2

; Double-precision float
rVal2 REAL8 3.2E-260

; Extended-precision float
rVal3 REAL10 4.6E+4096

; Array of 20 single-precision floats
ShortArray REAL4 20 DUP(0.0)
```

- **Memory usage:** 4, 8, 10 bytes for each variable
- **Arrays**: multiply size by element count

Summary:

Floating-point types in MASM (REAL4, REAL8, REAL10) let you store real numbers of varying precision. Choose **REAL4** for normal calculations, **REAL8** for high-precision scientific data, and **REAL10** for extreme precision. Arrays can be initialized using **DUP**, and legacy directives **DD, DQ, DT** are equivalent but less readable.

ADD NUMBERS PROGRAM (ADDING INTEGER VARIABLES)

This program shows how to add **three 32-bit integers stored in memory** and store the result in a fourth variable.

```
; AddVariables.asm
.386
.model flat, stdcall
.stack 4096

ExitProcess PROTO, dwExitCode:DWORD
```

Explanation:

- .386: Enables 80386 instructions, meaning we can use 32-bit registers like EAX.
- .model flat, stdcall: Flat memory model (all memory in one linear space) with the stdcall calling convention.
- .stack 4096: Reserves a 4 KB stack for function calls and local variables.
- ExitProcess PROTO: Declares a prototype for the Windows API function ExitProcess, which terminates the program.

Declaring Data (Variables)

```
.data
firstval  DWORD 20002000h
secondval DWORD 11111111h
thirdval  DWORD 22222222h
sum       DWORD 0
```

- .data section: Where all global variables and constants are stored.
- DWORD: Each variable is **4 bytes (32 bits)**.
- Hexadecimal values like 20002000h are **base-16 numbers**, which the CPU stores as binary in memory.

Memory Layout (example):

VARIABLE	HEX VALUE	BINARY (32-BIT PATTERN)
firstval	20002000h	0010 0000 0000 0000 0010 0000 0000 0000
secondval	11111111h	0001 0001 0001 0001 0001 0001 0001 0001
thirdval	22222222h	0010 0010 0010 0010 0010 0010 0010 0010
sum	00000000h	0000 0000 0000 0000 0000 0000 0000 0000

Each value occupies 4 bytes in memory, stored consecutively unless alignment or padding is introduced.

Code Section (Adding the Variables)

```
.code
main PROC
    mov eax, firstval    ; Load firstval into the EAX register
    add eax, secondval   ; Add secondval to EAX
    add eax, thirdval    ; Add thirdval to EAX
    mov sum, eax         ; Store the final result in sum
    INVOKE ExitProcess, 0
main ENDP
END main
```

Step-by-Step Explanation:

1. **mov eax, firstval**
    - Moves the value of firstval (20002000h) into the **32-bit register EAX**.
2. **add eax, secondval**
    - Adds secondval (11111111h) to the current value in EAX.
    - EAX now holds 20002000h + 11111111h.
3. **add eax, thirdval**
    - Adds thirdval (22222222h) to EAX.
    - EAX now holds the **sum of the three variables**.
4. **mov sum, eax**
    - Moves the value in EAX into the variable sum in memory.
5. **INVOKE ExitProcess, 0**
    - Calls the Windows API function to terminate the program.
    - The program exits cleanly with return code 0.

Key Points to Understand

Registers vs Memory:

- Registers (EAX) are **fast temporary storage** inside the CPU.
- Memory (firstval, sum) is slower but permanent for the program.

Hexadecimal Representation:

- Each hex digit represents **4 bits**, so 8 digits = 32 bits = 1 DWORD.

Adding Variables:

- You **can't directly add memory-to-memory** in x86 assembly.
- You must move one value to a register (EAX), then add the others.

Storing Result:

- Once the calculation is done in the register, move it back to memory with mov sum, eax.

Optional Visual Memory Diagram

```
Memory Layout (.data section)
Address      Variable      Value (Hex)
0000         firstval      20002000
0004         secondval     11111111
0008         thirdval      22222222
000C         sum           00000000  ; Will store the result after addition
```

- After execution: sum = 20002000h + 11111111h + 22222222h = 53315333h

✅ Summary:

1. Define variables in .data using DWORD for 32-bit integers.
2. Use a register (EAX) to perform arithmetic.
3. Use mov and add instructions to manipulate and sum values.
4. Store the result back to memory.

This is the **memory + register way** to add numbers in assembly.