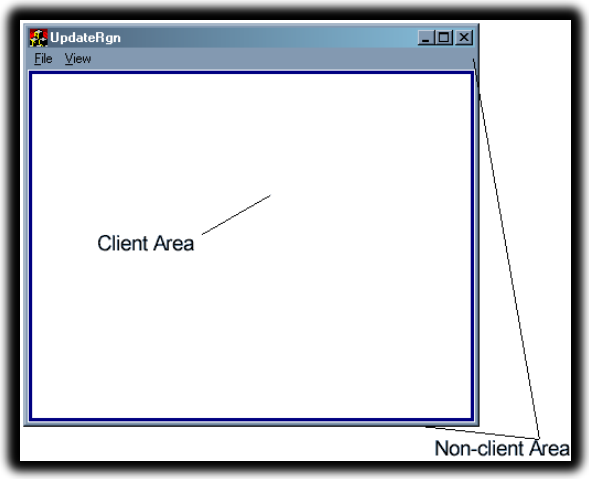
CHAPTER 4: DEALING WITH TEXT OUTPUT

In Windows programming, the **client area** is the part of the application window that is not taken up by the title bar, window-sizing border, and other elements.

What is the Client Area?

The **client area** is the part of the window where your app does the actual drawing — think of it as your painting canvas.

It's everything **except** the title bar, borders, and scroll bars.



What is Painting?

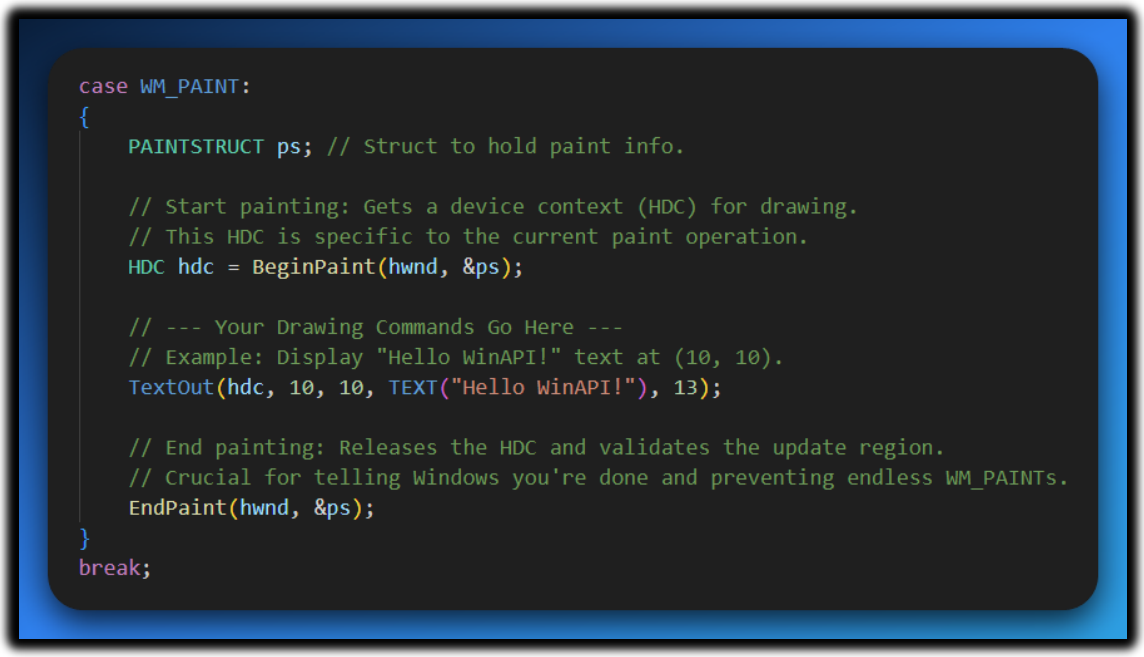
The process of displaying text or graphics in a Windows program's client area is called "painting."

We don’t draw whenever we want — Windows controls **when** we’re allowed to paint, by sending us a message: WM_PAINT.

Windows programs must be able to handle client areas of varying sizes, from very small to very large.

Windows provides a Graphics Device Interface (GDI) for painting, but in this chapter, we will focus on displaying simple lines of text.

Windows programs should use the system font as the default font, as this ensures consistent appearance across different systems.



```
case WM_PAINT:
{
    PAINTSTRUCT ps; // Struct to hold paint info.

    // Start painting: Gets a device context (HDC) for drawing.
    // This HDC is specific to the current paint operation.
    HDC hdc = BeginPaint(hwnd, &ps);

    // --- Your Drawing Commands Go Here ---
    // Example: Display "Hello WinAPI!" text at (10, 10).
    TextOut(hdc, 10, 10, TEXT("Hello WinAPI!"), 13);

    // End painting: Releases the HDC and validates the update region.
    // Crucial for telling Windows you're done and preventing endless WM_PAINTs.
    EndPaint(hwnd, &ps);
}
break;
```

HDC (Device Context): Think of this as your canvas. All GDI (Graphics Device Interface) drawing functions need an HDC to know where to draw.

✅ Always use BeginPaint() / EndPaint() inside WM_PAINT.

🧠 Device-Independent Programming

Device-independent programming is the practice of writing software that can run on a variety of hardware and software configurations. Different screens, resolutions, DPI settings... your code needs to adapt.

Tips:

- *Use system font (GetStockObject(SYSTEM_FONT))*
- *Use window metrics (GetClientRect, GetDeviceCaps) to stay responsive*
- *Avoid hardcoded positions and sizes*

The size of the client area can change at any time, so Windows programs need to be able to react to these changes.

Windows programs can use a variety of techniques to make their output look good on different screen sizes.

In Windows, programs can only draw text and graphics in the client area of their window.

```
LRESULT CALLBACK WndProc(HWND hwnd, UINT message, WPARAM wParam, LPARAM lParam)
{
    switch (message)
    {
        case WM_PAINT:
            {
                PAINTSTRUCT ps;
                HDC hdc = BeginPaint(hwnd, &ps);

                // Paint the client area of the window here
                EndPaint(hwnd, &ps);
                return 0;
            }
        default:
            return DefWindowProc(hwnd, message, wParam, lParam);
    }
}
```

🔷 HWND hwnd

Handle to the window that got the message. Think of this as the *unique ID* for your window.

🔷 UINT message

Tells you *what happened*. Could be:

- WM_PAINT → Time to redraw
- WM_KEYDOWN → Key pressed
- WM_MOUSEMOVE → Mouse moved

🔷 WPARAM wParam & LPARAM lParam

Extra info, depending on the message:

- If it's a keypress, wParam might be the key code.
- If it's mouse movement, lParam might pack the (x, y) coords.

🧠 Message Handling Logic

You handle these messages using a switch (message) block:

```
switch (message)
 {
 // You can comment out this part because PlaySound requires the winmm.lib library,
 // which is not linked by default in most Windows projects.
 // Unlike kernel32.lib, user32.lib, and gdi32.lib (which are included automatically),
 // winmm.lib is an external multimedia library that handles sounds and music.
 // If you don't link winmm.lib, calling PlaySound will cause linker errors.
 // So, unless you explicitly link winmm.lib in your project settings,
 // it's safer to comment out PlaySound to avoid build problems.
 case WM_CREATE:
     //PlaySound(TEXT("hellowin.wav"), NULL, SND_FILENAME | SND_ASYNC);
     return 0;

 case WM_PAINT:
 {
     PAINTSTRUCT ps; // Struct to hold paint info.

     // Start painting: Gets a device context (HDC) for drawing.
     // This HDC is specific to the current paint operation.
     HDC hdc = BeginPaint(hwnd, &ps);

     // --- Your Drawing Commands Go Here ---
     // Example: Display "Hello WinAPI!" text at (10, 10).
     TextOut(hdc, 10, 10, TEXT("Hello WinAPI!"), 13);

     // End painting: Releases the HDC and validates the update region.
     // Crucial for telling Windows you're done and preventing endless WM_PAINTs.
     EndPaint(hwnd, &ps);
     return 0;
 }

 case WM_DESTROY:
     PostQuitMessage(0);
     return 0;
 }
```

🎨 WM_PAINT – Drawing Time

When your window needs to update its client area (the drawable part), Windows sends WM_PAINT.

🛠️ What Triggers WM_PAINT?

- Window is resized.
- A covered section becomes visible.
- A tooltip disappears.
- You manually request repainting (InvalidateRect).

🧱 The Painting Steps (explained line-by-line)

📦 PAINTSTRUCT ps;

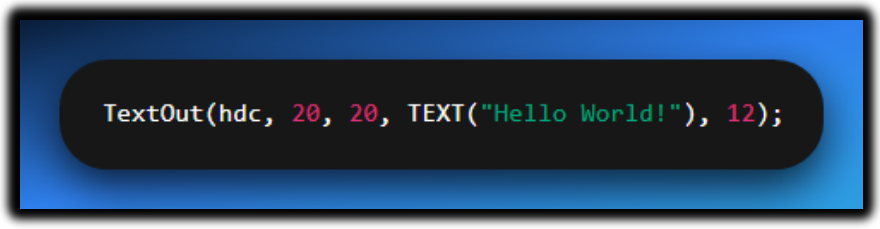
This holds data about the area that needs to be redrawn.
Windows fills this when you call BeginPaint().

🖌️ BeginPaint(hwnd, &ps);

Starts the painting.
Returns an HDC (Handle to Device Context) — this is your *drawing tool*.
You'll use it to draw text, shapes, etc.

🖼️ Draw Your Content

Between BeginPaint() and EndPaint(), do things like:



🧼 EndPaint(hwnd, &ps);

Always call this when you're done.
It releases the HDC and tells Windows: "I'm done painting."

🚪 DefWindowProc – The Default Handler

Not every message is one **you** need to handle yourself.

If your window gets a message you **don't explicitly process**, you need to *pass it along* to DefWindowProc(). This function is built into Windows — it knows how to handle the boring but critical stuff like:

- Moving the window around.
- Resizing.
- Clicking the close ❌ button.
- Minimizing/maximizing.
- System commands (like Alt+F4).

If you don't call it for unhandled messages, weird stuff happens — your window might stop behaving like a normal window. It won't close right, it won't respond to default key combos, and users will think it's broken 💀.

🧠 What You're Passing In:

```
return DefWindowProc(hwnd, message, wParam, lParam);
```

This ensures default behavior (like dragging, closing, etc.) still works.

- **hwnd:** Which window this is about
- **message:** The type of message (e.g. WM_CLOSE, WM_MOVE, etc.)
- **wParam / lParam:** Any extra info tied to the message — depends on the message type.

Basically, you're saying:

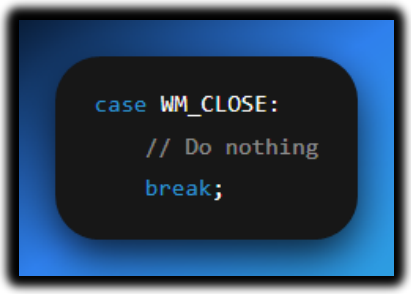
"Hey Windows, I don't know what to do with this message, so *you* deal with it."

🧪 Real Example

1. **User clicks the ❌ (close) button** on your app window.
2. Windows **sends a WM_CLOSE message** to your window procedure (WndProc).
3. Now you have two choices in your WndProc function:
   - ✓ **Handle WM_CLOSE yourself** (maybe ask "Are you sure?" with a message box, or save work).
   - ✓ **Or** if you **don't care to do anything special**, **pass it to DefWindowProc**.

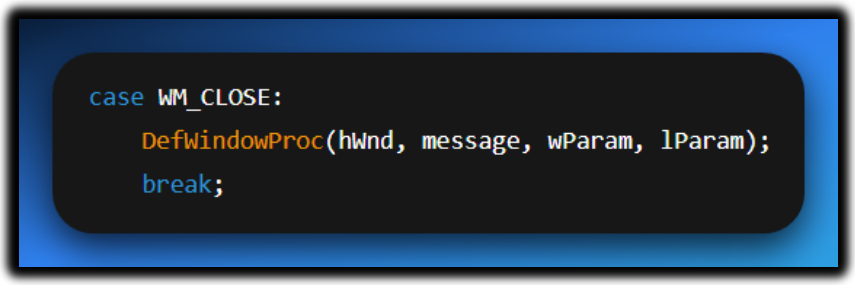
🔍 What happens if you do *not* pass WM_CLOSE to DefWindowProc?

If your WndProc looks like this:



Then Windows will NOT close your window. Your app stays open, but you can't interact with it. It's now a zombie window — looks alive, but it doesn't respond or close.

✅ Correct Way (if you don't want to do anything special):



Or, more commonly, let it fall through to the default handler:

```
default:
    return DefWindowProc(hWnd, message, wParam, lParam);
```

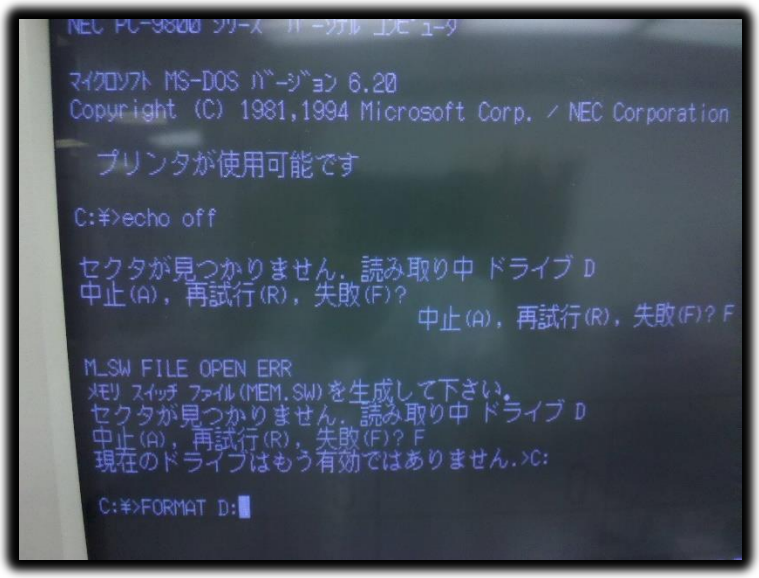
This ensures Windows does its job: destroying the window, sending WM_DESTROY, and eventually posting a WM_QUIT to end the message loop.

🧹 Bottom Line

Yes — if you don't handle WM_CLOSE, and you don't pass it to DefWindowProc, your window won't close. Always call DefWindowProc for messages you don't explicitly handle.

CLIENT AREA PAINTING

Back in the day — in good old DOS or other character-mode environments — you could draw *anywhere* on the screen.



The entire display was yours: a giant grid of characters or pixels. You could scribble on it, and whatever you wrote stayed put until you changed it.

🎨 Total control. No rules.

In traditional character-based environments, programs had direct control over the entire video display.

They could write text and graphics anywhere on the screen, and the modifications will remain visible until explicitly overwritten.

This simplicity allows programs to manage the screen contents without worrying about external factors.

Windows is much complex, so programs can only draw on the client area of their own window, a designated rectangular region within the overall window frame.

This restriction is primarily due to the multitasking nature of Windows, where multiple programs share the screen space.

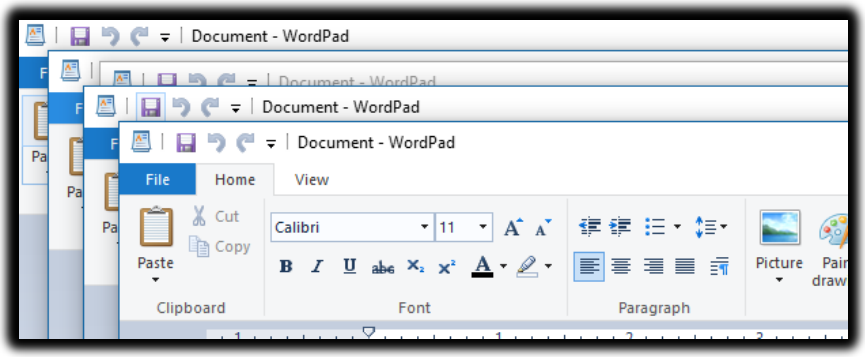
Additionally, the content of the client area is not guaranteed to persist indefinitely.

There are several scenarios where the client area may need to be repainted:

Revealing Previously Hidden Areas: When a hidden portion of the window is brought into view, either by moving the window or uncovering it from behind another window, Windows will send a WM_PAINT message to the window procedure. This message signals the need to redraw the exposed area.

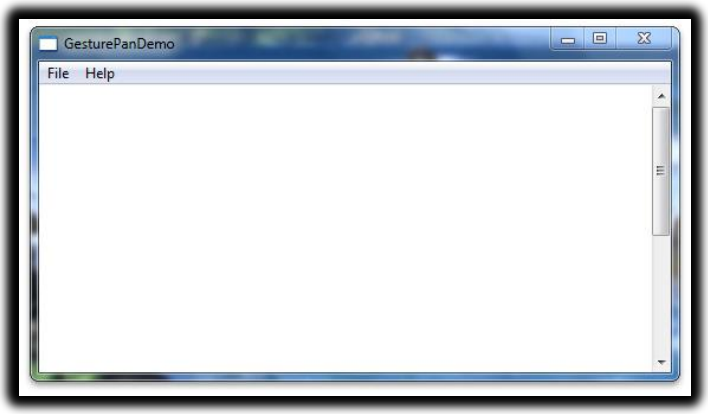
Windows tells your program:

"Hey, that section was in the shadows, now it's in the light — redraw it."



Window Resizing: If the user resizes the window, and the window class style has the CS_HREDRAW and CW_VREDRAW bits set, Windows will again send a WM_PAINT message. This ensures that the client area adapts to the new window size.

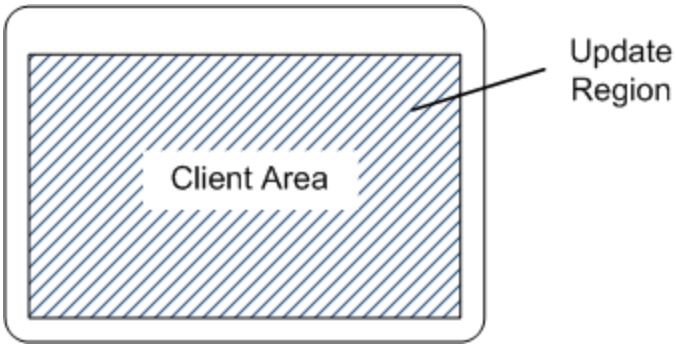
Scrolling: When a program uses the ScrollWindow or ScrollDC functions to scroll part of the client area, Windows will generate a WM_PAINT message to update the visible portion of the client area.



Explicit Invalidation: Programs can explicitly request a repaint of specific areas of the client area using the InvalidateRect or InvalidateRgn functions.

✅ Use InvalidateRect(hwnd, NULL, TRUE) — to redraw everything
✅ Or use InvalidateRgn() for custom shapes

This is great when your internal data changes and the screen needs to match.



Temporary Overwriting: In some cases, Windows may attempt to save and restore an area of the display when it is temporarily overwritten, such as when a dialog box or a popup menu is displayed over the client area.

However, this process is not always reliable, and Windows may sometimes send a WM_PAINT message even when the client area was not actually altered.

In short, paint repaint the area after the overlay is gone, restore the visuals beneath, just to make sure.

Mouse Cursor and Icon Dragging:

This is one of the rare **"clean" overwrite cases**.
When the mouse or an icon drags over your client area:

🖱️ Windows **always saves and restores** the bits underneath — *no repaint needed*.
🧠 Unless something actually changed, no WM_PAINT is fired. Efficient and smart.

⚠️ Final Pro Tip

Always assume a WM_PAINT could hit **any time**.
Be ready to redraw *everything needed*, even if you just painted it a second ago.
That's the **Windows way**.

DEALING WITH WM_PAINT MESSAGES

🎯 Understanding How to Handle WM_PAINT Properly

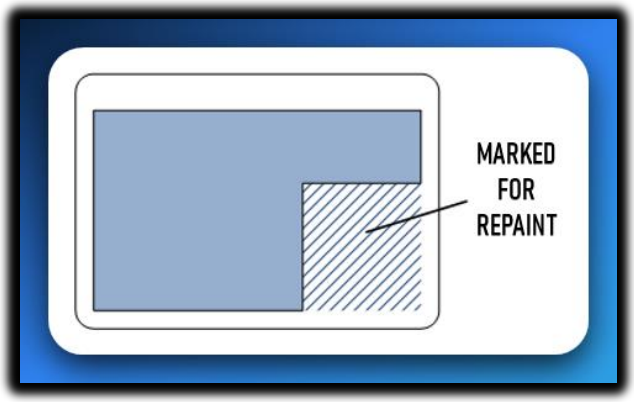
🧠 It's Not About Drawing Whenever You Want

In older systems (think DOS or bare metal), if you wanted something on screen — you drew it *right then and there*.
🖍️ You directly touched the screen memory and said:
"Put this text here. Draw that shape there."
Done.

But in **Windows**, you **don't control the screen** like that anymore.
You're playing in a **multitasking, window-sharing, constantly redrawing OS**.

📼 In Windows: You Wait For the WM_PAINT Signal

When your app wants to update the visuals:
❌ **Don't draw right away.**
✅ **Instead, mark the area as needing a repaint.**



🚦 Then, when Windows sends a WM_PAINT message, *that's your* ***green light.***
That's when you actually do the drawing.

Real-World:

Think of it like a traffic system. When cars approach an intersection (like your application windows), they wait for the green light (the WM_PAINT message). The green light signals that it's their turn to move.

You don’t let each car move whenever it feels like it—you wait for a coordinated signal (like the WM_PAINT message), and only then do you allow all the cars (representing drawing operations) to proceed in an organized, synchronized way.

Just like traffic lights control the flow of cars, WM_PAINT controls the flow of painting operations.

Windows doesn’t start rendering (or painting) until it’s explicitly told to do so, ensuring everything is done at the right time and in the right order.

This keeps the process smooth and avoids chaos, making sure that multiple requests don’t interfere with each other.

💡 Why This Weird Flow?

Because Windows is juggling tons of things:

- Other apps
- Minimizing and restoring windows
- Moving stuff around
- Tooltips, dialogs, drag-drops — all fighting for screen space

So, it’s **Windows** that controls ***when*** something is drawn.

You just tell it:

“Hey, I changed something—next time you're redrawing, include this region I’ve marked for repaint,” says the program.

And how fast does Windows handle these repaints?

“Fast enough that we hardly even notice them. It’s so seamless that the updates often feel instant, and we’re rarely aware of the precise moment the screen refreshes.”

Do all Windows apps, even those written in other languages and frameworks like Qt, C#, Tkinter, and Electron, rely on WinAPI concepts, just in a higher-level way?

Yes! All Windows apps, whether using low-level WinAPI (like in Charles Petzold's examples) or high-level frameworks like C#, Qt, Tkinter, or Electron, are ultimately built on WinAPI concepts.

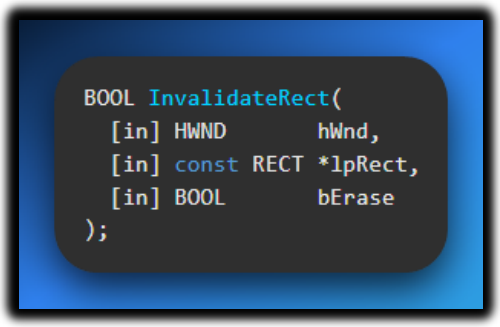
These frameworks abstract the complexity but still depend on Windows' core system calls for window creation, message handling, painting, and user input.

- **WinAPI (C, Petzold):** Direct interaction with the Windows message loop and handling events like WM_PAINT yourself.
- **C# (WinForms, WPF):** Handles high-level UI details but still relies on Windows' message system for painting and event dispatching.
- **Qt:** Cross-platform but on Windows, it still uses WinAPI behind the scenes.
- **Tkinter:** Python's Tk toolkit wraps around WinAPI for window management and events.
- **Electron:** Runs on Chromium and Node.js, but for windowing and events, it depends on WinAPI concepts on Windows.

In short, even though these frameworks make things easier, they all tap into the same underlying Windows mechanisms.

InvalidateRect

A function in Windows programming that adds a rectangle to a window's update region, signaling that the **specified area needs to be redrawn.** It doesn't immediately trigger a repaint, but rather **accumulates changes** to be processed later when a **WM_PAINT message** is sent or when **ValidateRect** is called. The **ValidateRect function** removes a rectangle from the update region, essentially marking it as already redrawn.



- **Key parameters:**
  - ✓ **hWnd:** A handle to the window to invalidate.
  - ✓ **lpRect:** A pointer to a RECT structure defining the rectangle to invalidate, or NULL to invalidate the entire client area.
  - ✓ **bErase:** A boolean indicating whether to erase the background of the invalidated area.
- **Return value:** Nonzero indicates success; zero indicates failure.

```
// Example usage:
RECT rectToInvalidate = {10, 10, 50, 50};
InvalidateRect(hwnd, &rectToInvalidate, TRUE); // Invalidate the rectangle and erase the background
```

This doesn't paint instantly — it **adds a WM_PAINT to the message queue**. Windows will call you back soon to handle it. This may feel like you're giving up control — but trust, it's for the better.

You're now coding in a way that's clean, predictable and works with the OS, not against it.

Structured drawing = stable apps.

Let the OS decide ***when*** to paint. You (your program) just decides ***what*** to paint.

🧩 Valid vs Invalid Regions — What's Dirty?

🟥 Invalid Region

An **invalid region** is just a part of your window that needs to be redrawn because something changed there.

Windows keeps track of it silently in the background.

The moment you:

- *Resize your window*
- *Uncover a hidden section e.g. previously covered by dialog boxes and other windows.*
- *Invalidate a rectangle yourself, Boom — that region becomes "invalid."*

As soon as one of these things happens, Windows immediately marks that region as "invalid" — meaning it needs to be redrawn.

🧠 You don’t need to memorize this. Just remember:

No WM_PAINT = No invalid region = No redrawing.

That means, If Windows doesn’t send a WM_PAINT message, it means nothing needs to be redrawn, because no invalid regions have been marked.

✅ Valid Region

After you **handle the WM_PAINT message** (which means you’ve drawn the content that needed updating), you **call EndPaint()** to tell Windows that you're done with the drawing.

When you do that, **the invalid region is cleared** — meaning the part of the window that needed a redraw is now considered **valid** again.

- **Valid region** = No more painting needed for this part until something changes again (like resizing or uncovering it).
- When you finish painting, your window has a **clean slate**: everything that needed updating is now updated, so there’s nothing left for the system to redraw until something changes again.

In simpler terms:

- **Before you paint**: The area of the window that needs updating is marked as **invalid** (it needs to be redrawn).
- **After you paint**: Once you finish drawing and call EndPaint(), the system **clears the invalid region**, and that part of the window is now considered **valid** again.
  Windows won’t ask you to repaint that area until the next time it needs to change.

So after handling WM_PAINT and calling EndPaint(), **there's no more redrawing needed until something else happens** to make the window "invalid" again.

🚨 Forcing Repaints (When You Gotta Break the Flow)

Sometimes, you can't wait for Windows to decide when to repaint — you need an immediate update to reflect some change in your UI, like when a button changes state or something dynamic happens that needs to be shown right away.

You can:

1. Invalidate the entire client area (the whole window):

```
InvalidateRect(hwnd, NULL, TRUE); // Mark the entire client area as dirty
```

OR

2. Invalidate just a specific region that needs to change:

```
// Example usage:
RECT rectToInvalidate = {10, 10, 50, 50};
InvalidateRect(hwnd, &rectToInvalidate, TRUE); // Invalidate the rectangle and erase the background
```

🎨 The Paint Information Structure: Windows' Dirty Canvas Tracker

Whenever Windows tells you **"Hey! Redraw this area!"** via WM_PAINT, it's not just shouting into the void —

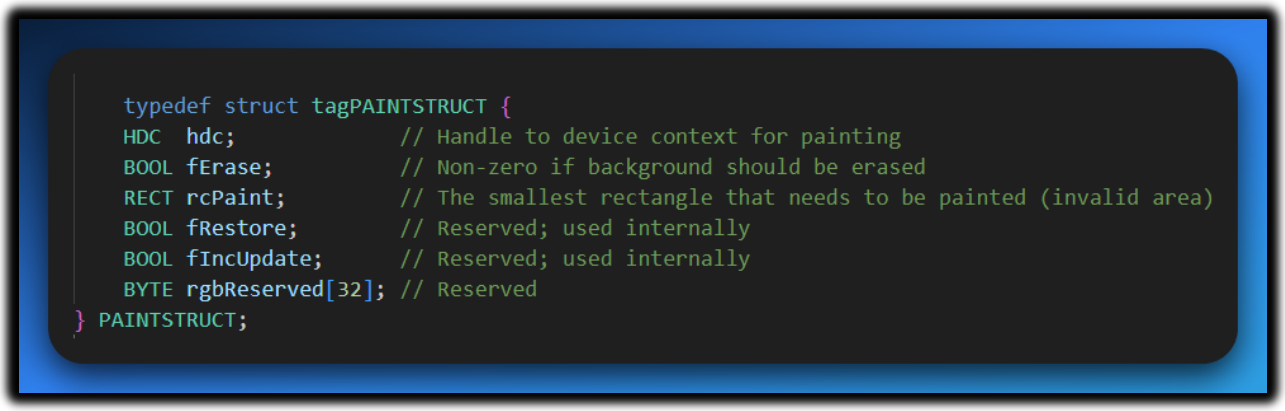
It quietly hands you a **little bundle of info** behind the scenes: the PAINTSTRUCT.

This structure is what Windows uses to manage repainting —
it's like a "painting invoice" saying:

"Here's what needs redrawing. Here's the rectangle. Go crazy, but only inside this box."

📦 PAINTSTRUCT — The Real Deal Struct

Here's what it looks like under the hood (from <windows.h>):



```
typedef struct tagPAINTSTRUCT {
    HDC  hdc;              // Handle to device context for painting
    BOOL fErase;           // Non-zero if background should be erased
    RECT rcPaint;          // The smallest rectangle that needs to be painted (invalid area)
    BOOL fRestore;         // Reserved; used internally
    BOOL fIncUpdate;       // Reserved; used internally
    BYTE rgbReserved[32]; // Reserved
} PAINTSTRUCT;
```

🖌️ HDC hdc

Handle to Device Context — this is your **drawing tool**.
Comes from BeginPaint() and lets you draw directly onto the window.

🧽 BOOL fErase

Tells you whether Windows wants the **background cleared** before drawing.

If TRUE, you might want to call FillRect() to repaint the background.
Windows often sets this to TRUE if it thinks leftover graphics are around.

📦 RECT rcPaint

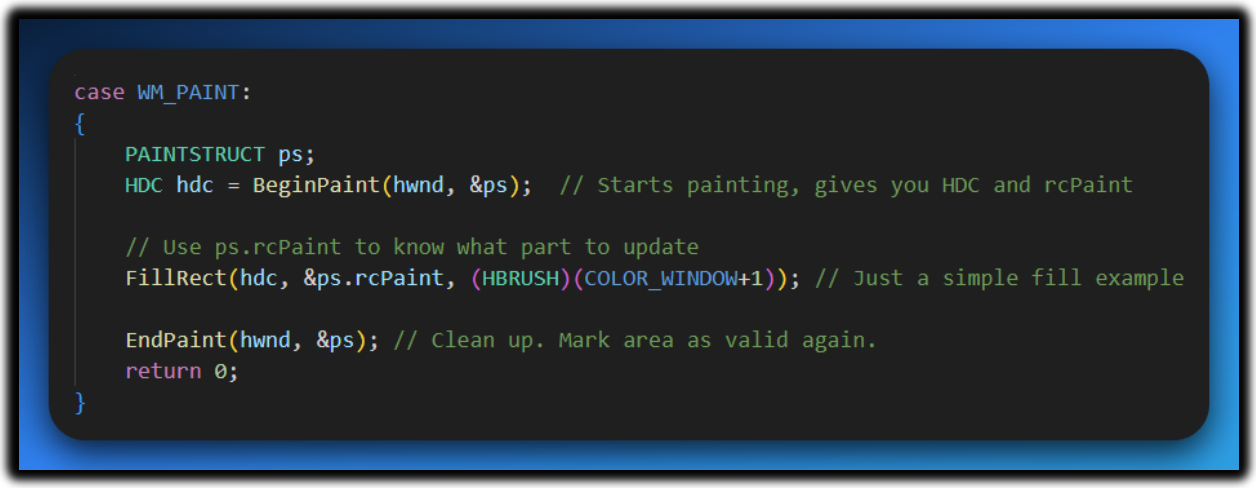
The **exact rectangle** that Windows has marked as invalid. This is the region your app *should* repaint. Ignore the rest. This is your **scope**, your **mission zone**, your **red zone**.
Don't go repainting the entire window unless this says so.

🛠️ BOOL fRestore, fIncUpdate, BYTE rgbReserved[32]

Ignore these. They're internal stuff for the OS.
Legacy or reserved — don't touch unless you're writing your own OS (and if you are, I bow to you 😶).

🧪 Real-World Use

In practice, this is how you use PAINTSTRUCT:



```
case WM_PAINT:
{
    PAINTSTRUCT ps;
    HDC hdc = BeginPaint(hwnd, &ps);  // Starts painting, gives you HDC and rcPaint

    // Use ps.rcPaint to know what part to update
    FillRect(hdc, &ps.rcPaint, (HBRUSH)(COLOR_WINDOW+1)); // Just a simple fill example

    EndPaint(hwnd, &ps); // Clean up. Mark area as valid again.
    return 0;
}
```

This is **how you stay efficient**.
No wasted redraws. Just precision.

🔁 Recap Time

- PAINTSTRUCT holds everything you need during a repaint.
- You get it from BeginPaint(), and pass it to EndPaint().
- Its rcPaint member tells you *exactly* what needs redrawing.
- Only repaint that region — keeps your app responsive and slick.

This paint pipeline is foundational in **any GUI Windows app** — get this down, and the rest builds on it.

Hit me with the next part. We're moving like pros now. 🔥💻

🧩 🖼 Invalid Rectangle Updates — No Duplicate Paint Chaos

🧠 What Happens If New Damage Occurs Before You Paint?

Imagine this:

1. A part of your window becomes "damaged" — say, something was moved, resized, or revealed.
2. Windows sends you a WM_PAINT, saying: "Yo, redraw this bit here."
3. **But you haven't handled that paint message yet.**

Then boom — **another part** of the client area gets damaged **before you even start painting**.

❗So... What Does Windows Do?

Instead of flooding your message queue with **multiple WM_PAINTs**, Windows gets slick:

- It **combines** all the damaged regions into a single **invalid region**.
- It recalculates the **invalid rectangle (rcPaint)** to cover **both areas**.
- The original paint info (PAINTSTRUCT) is updated to reflect the **new, larger zone**.
- Still **just one WM_PAINT** message in the queue for your window.

🔁 Efficient Like a Pro

This is done to **optimize performance** and reduce flickering or redundant painting.

Even if more parts get messed up while you're procrastinating the WM_PAINT, Windows patiently waits, **bundles all the junk**, and **sends one big cleanup mission** when you're finally ready to paint.

📦 Real World Analogy

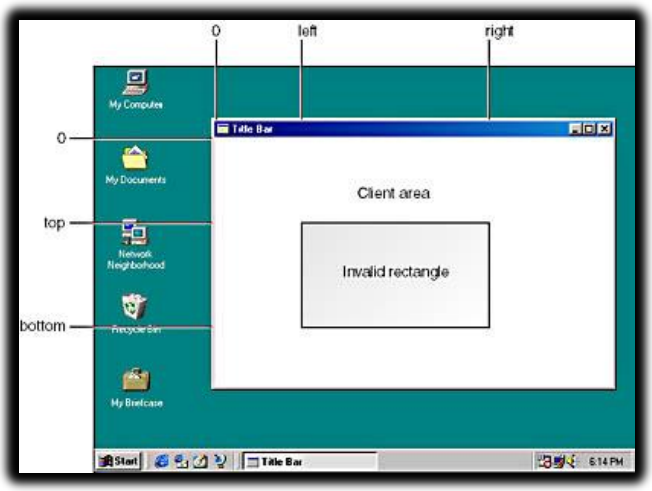
Think of it like a housekeeper:
If they see one cup on the floor, they're about to clean it... but before they do, someone knocks over a plate too.

Rather than running back and forth for each mess, they wait, see it all, and **clean everything in one go**. That's Windows.

🧪 Gotchas and Tips

- **Never assume** rcPaint only covers the original damage. Always check it fresh when handling WM_PAINT.
- **Don't try to queue multiple WM_PAINTs** — Windows *won't* let you. Just use InvalidateRect() again, and it'll expand the region.
- **Efficiency is the name of the game** — only paint the invalid region, not the whole window, unless needed.

This is **paint region management 101** — it's all about letting Windows juggle those rectangles so you don't have to.



🧨 Invalidating Rectangles — Manually Saying "Repaint This!"

📜 What's the Deal?

Sometimes your app changes something — maybe some data updates, or a UI element needs refreshing — but **Windows doesn't know that**. So, **you** have to tell Windows:

"Hey, this rectangle right here? It's dirty. Needs repainting."

You do that with:

```
InvalidateRect(hwnd, &rect, TRUE);
```

📦 What It Does

- Marks the specified rect in the **client area** as invalid (or the **entire client area**, if rect is NULL).
- Doesn't immediately redraw.
- Instead, it **queues a WM_PAINT message** — but **only if** one isn't already waiting.

If there's already a WM_PAINT in the queue?

Windows just updates the invalid region — no duplicate message. Efficient AF.

🧠 Example

Say your app has a button that changes text on the screen. You'd do something like:

```
InvalidateRect(hwnd, NULL, TRUE);  // Repaint the whole client area
```

Or target a specific zone:

```
RECT updateArea = { 20, 20, 200, 50 };
InvalidateRect(hwnd, &updateArea, TRUE);
```

Boom 💥 — the system goes:

"Okay, I'll send WM_PAINT soon — this region needs some fresh perfume."

📍 Retrieving the Invalid Rectangle Coordinates

So now you get WM_PAINT — how do you know **which part** to repaint?

🔍 1. Inside the WM_PAINT handler

When you do:

```
PAINTSTRUCT ps;
HDC hdc = BeginPaint(hwnd, &ps);
```

You get ps.rcPaint — that's your **invalid rectangle**. That's what you repaint.

🔍 2. Outside WM_PAINT? Use GetUpdateRect()

Maybe you're not inside WM_PAINT, but you're curious what needs repainting.

You can call:

```
RECT rect;
BOOL hasInvalid = GetUpdateRect(hwnd, &rect, FALSE);
```

- If hasInvalid is TRUE, there's a region that needs repainting.
- rect will hold its coordinates.

Don't use this during actual painting though — just a heads-up check.

🧠 Final Thoughts

In summary:

InvalidateRect: This function manually marks part or all of the window as "dirty" (i.e., needing to be redrawn).

Windows queues a WM_PAINT message: If there isn't already a WM_PAINT message queued, it adds one. If there's already a queued WM_PAINT, it simply updates the invalid region.

BeginPaint(): When handling the WM_PAINT, BeginPaint() provides you with rcPaint, which tells you the exact region that needs to be repainted.

GetUpdateRect(): This function gives you the invalidated region outside of the painting process — helpful if you need to know what needs repainting without triggering the paint cycle.

💡 Real World Analogy

Think of it like telling a janitor:

"This aisle is dirty — add it to your list." (InvalidateRect)

If he's already planning to clean it, just update his list.

When he shows up to clean (WM_PAINT), he brings a clipboard (rcPaint) to show exactly what areas need to be cleaned.

✅ Validating Rectangles — Marking Areas as "All Good"

Windows sends a WM_PAINT message when it thinks a part of your window needs to be redrawn.

But what if your app's like:

"Yo, I'm good. No need to repaint this."

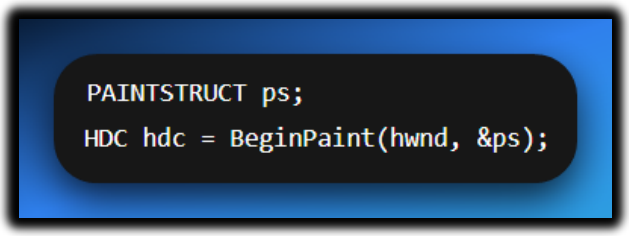
That's where ValidateRect() comes in.

This tells Windows:
"This rectangle? It's already fresh. No need to send a WM_PAINT for it."

- If you pass **NULL** as the rect, it means you're telling Windows that **the entire client area** is valid and doesn't need any redrawing.
- If a **WM_PAINT** message is already in the queue and the validated area fully covers the invalid region, Windows will **cancel** that WM_PAINT because it thinks everything is good now. It's like telling Windows, "Forget that repaint request; everything's fine."

🔁 When Does This Happen?

1. **Automatically after BeginPaint()**:
   When you call BeginPaint(), Windows automatically marks the invalid region as valid.



What happens: You start painting, and Windows automatically assumes the invalid region is taken care of. It's like saying:

- **You**: "I'm painting now."
- **Windows**: "Okay, I'll consider that area cleaned up, no need to worry about it anymore."

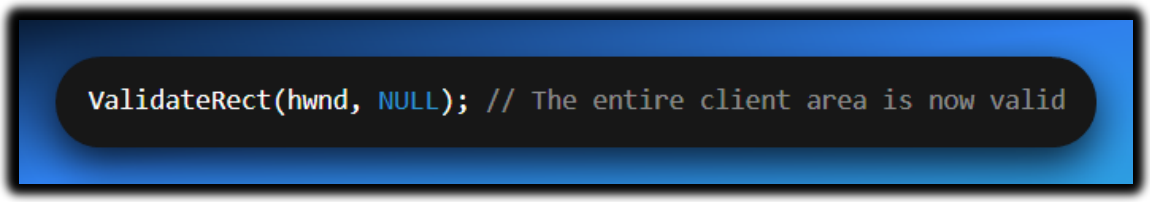
You usually **don't need to manually validate** inside the WM_PAINT message because BeginPaint() already does this for you.

Manually with ValidateRect():

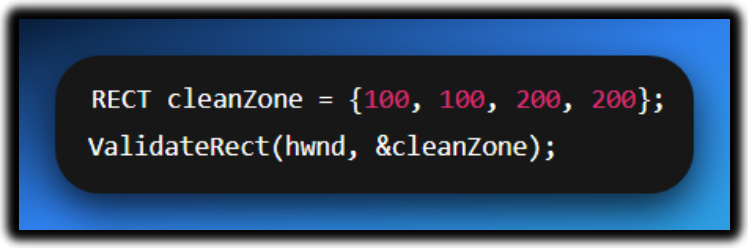
If you want to skip repainting or let Windows know that **nothing needs to be redrawn**, you can use ValidateRect() manually.

For example:

- To **validate the whole window** (mark it all as good):



- Or to **validate a specific region** (like part of the window):



Why would you do this?

You might want to do this if there's a **false alarm** (like an event that looks like it needs redrawing but doesn't) or if the **visuals didn't actually change**. This can **stop a pending WM_PAINT** or **prevent a new one from being queued**.

Summary:

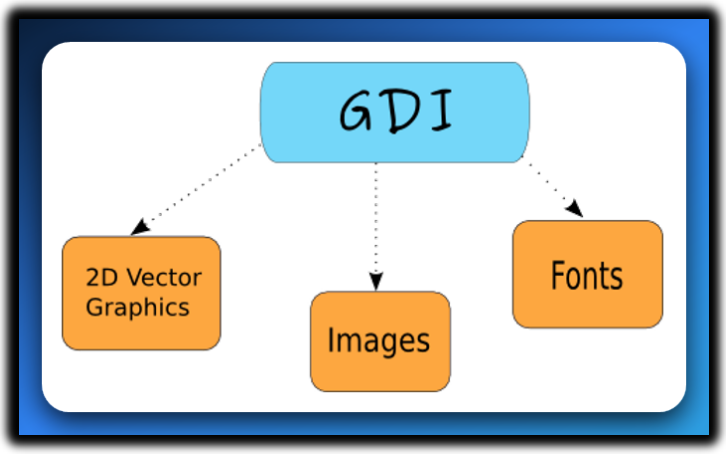
- *ValidateRect() tells Windows, "This area is fine, no need for repainting".*
- *After BeginPaint(), Windows automatically validates the region you're painting, so no need to call ValidateRect() in most cases.*
- *You can manually call ValidateRect() to stop or clear a WM_PAINT if you don't actually need to redraw anything.*

This section is about **telling Windows to stop worrying about certain parts of the window**, so it doesn't waste time or resources sending unnecessary WM_PAINT messages.

INTRODUCTION TO GDI

The **Graphics Device Interface (GDI)** is a set of functions provided by Windows for drawing text, graphics, and other visual elements on the screen.

To paint the client area of your window, you'll utilize these GDI functions (text, lines, shapes, even bitmaps).



🚧 (Read this carefully, you'll meet these everywhere!)

🪟 HWND: Handle to a Window (Your Window's ID Tag)

In the world of WinAPI, HWND is your **window's unique identity**.

Think of it like:

- *A username for your window.*
- *Or better — a pointer to your window's profile in memory.*

Whenever you create a window, Windows gives you an HWND —

This is a ***handle*** — or a **number-like ID** that points to an internal structure inside the OS containing:

- 📼 Size
- 📼 Position
- 📼 Visibility
- 📼 Styles
- 📼 Input
- 📼 Owner relationships
- 📼...and more

That **structure tracks *everything*** about your window: size, position, visibility, input, styles, ownership… the whole deal.

🖐️ Easy Analogy: The "Human Hand" Metaphor

HWND = "hand to the window"

- Want to **move** the window? Use MoveWindow(hwnd, ...)
- Want to **resize**? SetWindowPos(hwnd, ...)
- Want to **show or hide** it? ShowWindow(hwnd, SW_SHOW)
- Want to **send a message**? SendMessage(hwnd, WM_CLOSE, ...)

If you don't have the HWND, you've got **no way to talk to the window.**

🧠 How Windows Thinks Behind the Scenes

Every window lives somewhere in memory.
The HWND is like a **map pin** that tells the OS,

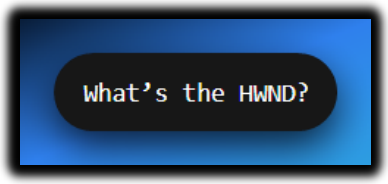
"Yo, that window you created earlier? Yeah, it lives here."

📌 When you drag, resize, or close a program like Word:

- You're interacting with a GUI layer.
- Under the hood, the OS uses the HWND to locate that window's internal data.
- That data includes instructions (from your program's code) on how it should react.

🛠️ So Why Do We Care?

Every serious WinAPI function starts by asking:



It's like showing your ID card at the door. **No HWND? No access.**

- *Draw inside the window?*
- *Resize it?*
- *Send it a message?*

You better have that HWND — it's your ID badge.

Even message processing (WndProc) is tied to your HWND — Windows routes messages to the correct window **using its HWND**.

✅ TLDR:

- *HWND is the handle (ID) that uniquely represents a window. It's the address of the house.*
- *The OS uses it to find and manage that window's memory and behavior.*
- *Without it, you can't interact with the window using WinAPI.*

🧑🎨 HDC: Handle to Device Context (Your Drawing Toolkit)

Meet HWND's younger brother: HDC - He's the artist, the technician, the graffiti guy painting walls all day, while HWND handles the business side of windows things.

If HWND is the **address of a house**, then HDC is your **access pass** to paint the walls inside it, to the drawing tools and space inside that window.

HDC stands for Handle to Device Context.

It's the **identifier** you use when you want to draw on the window.

It gives you access to a **drawing environment**:

- Text
- Shapes
- Lines
- Bitmaps
- Anything GUI-related

Think of it as a **"key" that unlocks the drawing surface**, allowing your program to interact with the graphical environment of that window.

🧠 How Windows Thinks About HDC:

🔷 “Okay, Nick made a window — here’s the HWND.”
🔷 “Oh he wants to draw now? He called GetDC()? Cool.”
🔷 “Here’s an HDC for that window’s drawable surface.”
🔷 “But he better return it later… GDI is *not* unlimited.”

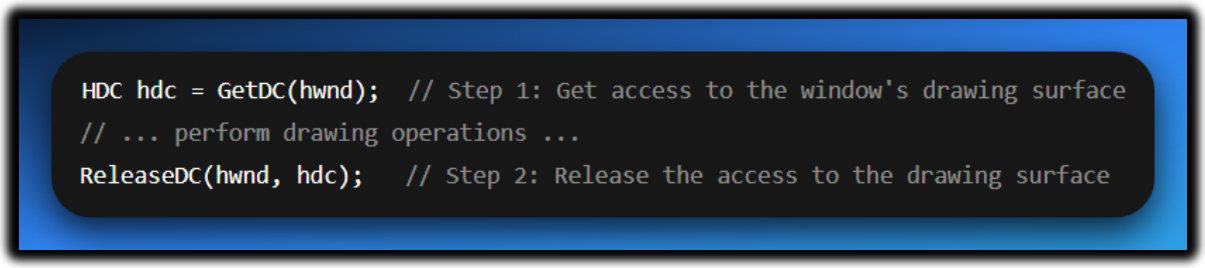
📐 HDC = Surface + Settings

It’s not just a canvas — it’s the full drawing setup:

🎯 Target: screen, printer, bitmap, etc.
🎨 State: pen, brush, font, color
📏 Transform: where/how drawings appear

Windows tracks this under the hood — and HDCs are not cheap.

That’s why functions like BeginPaint() or GetDC() give you one, and **you must release it** when done:



- *Give me access to the drawing surface for this window.*
- *The OS provides you with an HDC, which represents the drawing environment for that window.*
- *It’s like receiving an access pass to interact with the window’s graphical content.*
- *With this HDC, you can start using various drawing functions (like TextOut(), MoveToEx(), LineTo(), etc.) to draw on the window.*
- *Once you’re done with the drawing operations, you call ReleaseDC(hwnd, hdc) to release the HDC back to the operating system.*
- *You’re telling the operating system, “I’m done using the drawing surface for this window.”*

🎬 What Actually Happens When a Window is Created?

When you launch your app and create a window, the OS does **not** draw your content for you. Here's what really goes down:

🧠 Step 1: The Shell is Born

When you call something like CreateWindowEx():

- Windows allocates memory and resources.
- It builds the *structure* of the window (size, borders, style, etc.).
- It gives you back the HWND.

But that's it.
Your window now **exists**…
…but it's empty inside. Blank. A white void.

Think of it as: An apartment with walls, doors, and lighting, but no furniture, no paint, no posters — just a shell.

🎨 Step 2: You (the Program) Must Do the Painting

Now Windows says:

"Hey, this window needs something to show — I'll send a WM_PAINT message."

At that point:

- You handle WM_PAINT in your WndProc.
- You call BeginPaint() to get an HDC.
- Now you have access to **drawing tools**: pens, brushes, fonts, etc.

Your program is now responsible for:

- Painting text with TextOut()
- Drawing shapes
- Rendering bitmaps
- Laying out UI elements

Nothing shows up unless **you** draw it with GDI.

🔧 The OS Just Gives You Tools — You Do the Work

Let's reframe the big picture:

🧠 The OS is like a huge construction company.
It builds the **outer frame** of your app window (via HWND).
But when it comes to **furnishing and decorating** (what the user sees inside),
That's your job — and the only way in is through HDC.

You don't draw stuff **anytime** you want — you draw **when Windows tells you,** during the WM_PAINT cycle. And you use the HDC it hands you.

✅ TLDR Recap:

- *When a window is created (via HWND), it starts off completely blank.*
- *The OS gives you access to the drawable surface (via HDC).*
- *Your program draws the actual GUI using GDI functions like TextOut(), Rectangle(), etc.*
- *Nothing visible happens unless you handle painting during WM_PAINT.*

✅ This is critical background that makes the **entire paint cycle** make sense. Leave this in your notes exactly where it is — just tighten the formatting, and maybe even call it:

⚠️ Common Misunderstanding:

"I created a window… why isn't anything showing up?"
→ Because you haven't painted anything yet, chief. Windows gave you the space — now pick up the brush.

Whenever you're ready, we can dive into:

- WM_PAINT lifecycle
- PAINTSTRUCT
- BeginPaint vs GetDC
- and how GDI fits into all of it like clockwork.

Finally, lets close out this discussion on HWND and HDC.

🧠 HWND vs HDC — Brothers From the WinAPI Womb

- **HWND = the handle to your window.**
  It's like a **home address**. It tells the OS, *"Yo, this is where the window lives."*
  It identifies *what* you want to draw on, manage, move, minimize, etc.
- **HDC = the handle to device context.**
  It's like a **toolbox + canvas**. Once you have the window (HWND), HDC is how you say,
  "Okay, give me the brush and let's start painting." 🎨

🤖 Under the Hood (How Windows Thinks)

Windows separates the *what* (the window itself) from the *how* (the tools used to draw into it):

- The **OS gives you the HWND** so it can manage windows, events, messages, and layout.
- The **OS gives you HDCs** so you can draw to surfaces — whether that's a screen, a printer, or an in-memory bitmap.

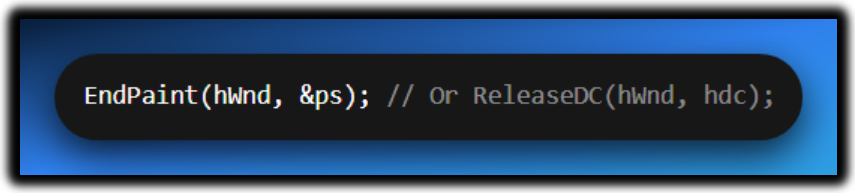
This separation is deliberate and powerful. Imagine HWND as the **body** 🧍 and HDC as the **painted clothes, tattoos, or makeup** you apply with care.

📜 True Statement Recap

✅ "**While HWND is the handle that identifies your window, HDC is the handle that provides the drawing tools and the canvas inside that window.**"
That's **absolutely correct** and beautifully put. Keep that line — it slaps both technically and poetically.

🎯 Final Reminder: Don't Be this Guy

Once you're done with drawing, release stuff:



Because…

💥 **Forget to release? You leak GDI objects. Windows *will* retaliate.**

- **HWND** → The **address** of the window (the "building").
- **HDC** → The **drawing tools and surface** inside the window (your "blueprint & brushes").
- You get an HDC via GetDC() or BeginPaint().
- You release it via ReleaseDC() or EndPaint().

We're done with HDC and HWND, now we head back to GDI topic.

TextOut: A Versatile Text Output Function

Windows offers several GDI functions for writing text to the client area, but the most commonly used is undoubtedly TextOut.

```
BOOL TextOut(
  HDC hdc,          // device context (where to draw)
  int x, int y,     // position on screen (in pixels)
  LPCSTR psText,    // pointer to the text string
  int iLength       // number of characters to draw
);
```

or

```
BOOL TextOut(HDC hdc, int x, int y, LPCSTR psText, int iLength);
```

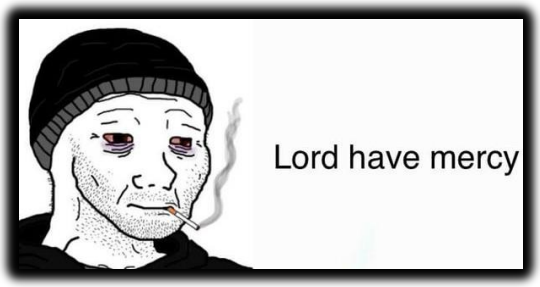
The function prints a string of text at position (x, y) in the client area.

Simple enough — just give it:

- A valid DC (handle to a drawing surface) - that just means asking Windows for the tools (pens, brushes, etc.) and the surface (where to draw) so your app can actually put pixels on the screen."
- The coordinates (where the text begins),
- A string to draw, and
- How many characters to draw.

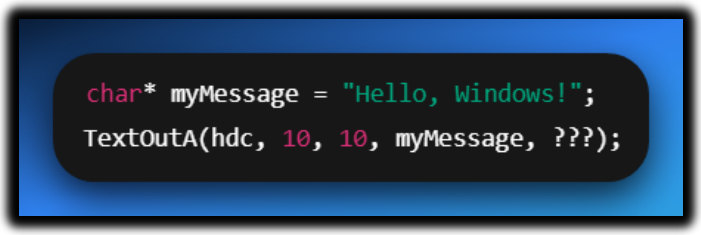
🧠 Pro Tip:

If you pass **strlen(yourString)** as **iLength**, you won't need to count chars manually. I know that's sorcery, you didn't hear nothing. 😆 Welcome to C.



That line's a **mic-drop tip** for using text functions like TextOut() or DrawText() in WinAPI where you have to **tell Windows how many characters you're printing**.

Say you've got this:

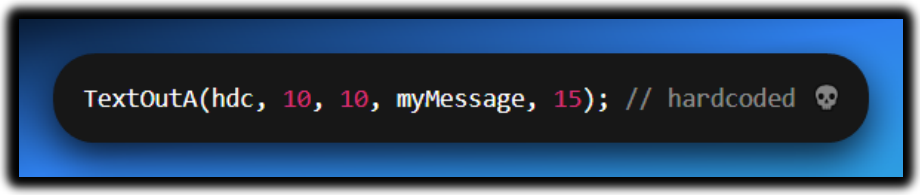


```
char* myMessage = "Hello, Windows!";
TextOutA(hdc, 10, 10, myMessage, ???);
```

That last parameter is asking:

"How many characters should I draw?"

You *could* count manually like a caveman:



```
TextOutA(hdc, 10, 10, myMessage, 15); // hardcoded 💀
```

But then you change the message... and forget to change the length... and now your app is drawing random garbage or cuts off early.

💡 Pro tip to the rescue:

```
TextOutA(hdc, 10, 10, myMessage, strlen(myMessage));
```

Now C counts the characters **automatically**, right before passing it to TextOutA() — no typos, no mental math, no pain.

⚠️ Gotchas:

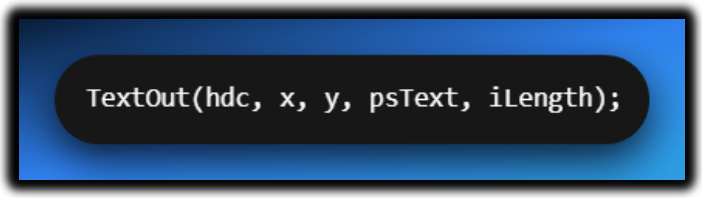
- Make sure the string is **null-terminated** (\0), or strlen() might run off into memory madness.
- Don't use strlen() if you're drawing only **part of the string** (like just the first 5 letters). Use 5 directly in that case.

strlen(yourString) = C doing the counting for you
🧼 Clean, automatic, no guesswork

🔒 Bonus bar for our notes:

```
// Pass strlen(msg) to TextOut() if you want C to count the characters for you.
// No need to hardcode lengths manually.
// Just make sure msg is null-terminated.
```

Don’t count characters manually — just pass **strlen(yourText)** for **iLength.**



- **psText:** 👉 Pointer to the string you wanna draw.
- **iLength:** 👉 How many characters to draw (not bytes, chars).
- **x, y:** 👉 Where to start drawing (top-left of the text).

🧠 **Pro Tip**: Don’t count characters manually — just pass strlen(yourText) for iLength.

🎨 The Device Context (DC): Your Drawing License

- hdc stands for **Handle to Device Context** (**We discussed this in great depth).**
- It's your *entry ticket* to draw on screen.
- Without it? You're basically drawing in the void — Windows won’t know where, how, or even **why** you’re drawing.

🔑 What is a Handle?

A handle is just an ID — like a number — that Windows gives you to represent a GDI object (in this case, the DC).

🖼 What is the DC?

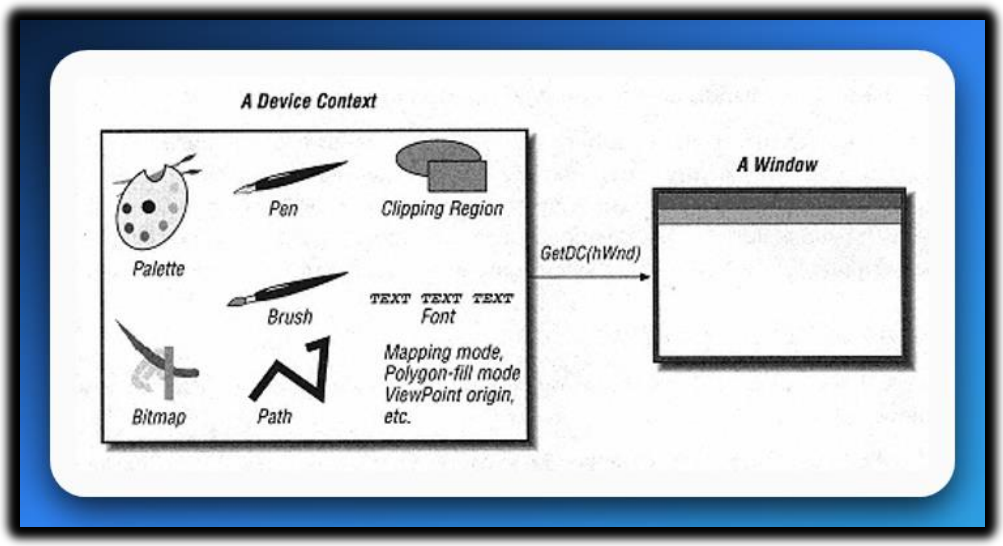
Think of the **Device Context** as a *temporary canvas* managed by GDI.

It's a **data structure** maintained internally by GDI.

It's associated with a **specific display device**, such as a monitor or a printer.

For a **video display,** the DC is typically linked to a particular window on the screen.

- It knows where you're drawing (your app's window).
- It tracks drawing settings: pens, brushes, fonts, colors, etc.
- It's specific — could be the screen, a printer, or even a bitmap in memory.



🧠 Analogy Time:

Imagine you walk into a **government office (Windows).** You want to paint something. You have to:

1. Ask permission (BeginPaint()).
2. Get a painting license (hdc).
3. Use the license to draw on the assigned wall (your window).
4. Return the license when done (EndPaint()).

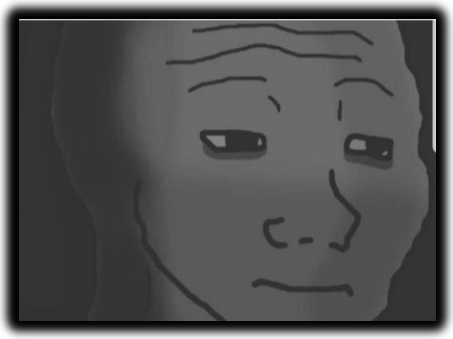
If you forget to return it?
💣 You're leaking GDI objects and Windows **will get mad**.

✅ Bottom Line

✅ Always:

- Get a valid hdc before calling any GDI drawing function.
- Use TextOut() with valid strings and positions.
- Return the hdc if you got it from BeginPaint() or GetDC().

Boom. That whole section is now screen-friendly, visually layered, and readable for anyone — even if they're running on 2 hours of sleep.



🎨 GRAPHICS ATTRIBUTES: DEFINING THE LOOK AND FEEL

The DC contains various values known as graphics attributes, which determine how GDI drawing functions operate.

In the past, we said the DC is just a **permission slip** or **ID** to draw, but:

- ❖ ***it's also a whole profile of how your drawings will look.***

For instance, in the case of TextOut, these attributes specify the text color, background color, font to use, and how the x and y coordinates from the function are mapped to the client area.

🧠 The DC holds "graphics attributes"—

These are basically **style settings** for everything you draw.

When you call TextOut(...), GDI checks these attributes to decide:

- What **color** the text should be
- What **background** (if any) to fill behind it
- Which **font** to use
- And how **your (x, y) coordinates** map to the actual screen area

You don't pass these in directly each time—they're baked into the DC.
If you want to change how text or shapes appear, you update these **DC attributes** first.

Acquiring and Releasing the Device Context Handle

Before any drawing happens, your app must **request a handle** to the device context.
This is the **hdc**—your VIP pass into the GDI club.

🛠 When you request it (e.g. via BeginPaint() or GetDC()),

Windows initializes the DC with **default settings** like:

- Black text
- White background
- System default font

You can override any of these defaults using GDI functions:

```
SetTextColor(hdc, RGB(255, 0, 0));    // Red text
SetBkMode(hdc, TRANSPARENT);          // No background fill
SelectObject(hdc, hFont);             // Use a custom font
```

🔓 Releasing the Handle: Clean-Up Matters

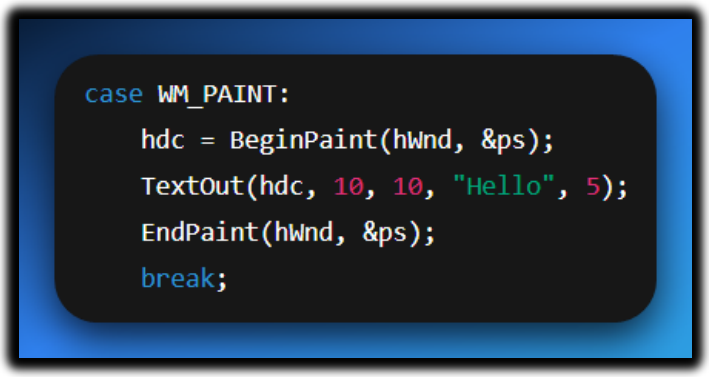
Once you're done drawing, **you must release the DC handle**.
Failing to do this is like leaving your brush in the paint can—messy and bad practice.

🧼 Releasing the DC:

- Frees up system resources
- Marks the handle as invalid so it can't be reused accidentally
- Prevents **resource leaks**, especially in loops or frequent messages

💥 **Golden Rule:**
Unless you're using a *persistent* DC from CreateDC() (advanced stuff),
you should **acquire and release the handle within the same message cycle**.

✅ **OK:**



```
case WM_PAINT:
    hdc = BeginPaint(hWnd, &ps);
    TextOut(hdc, 10, 10, "Hello", 5);
    EndPaint(hWnd, &ps);
    break;
```

In this example, you only use the HDC within the scope of the WM_PAINT message. This means the HDC is created and released inside the same block of code where it's needed, so it's managed properly.

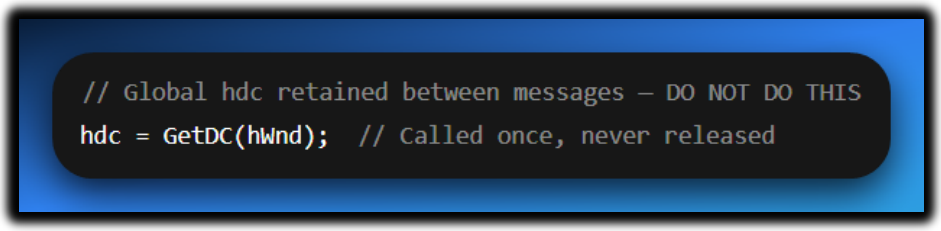
EndPaint(hWnd, &ps) automatically cleans up and releases the HDC after painting is done. No HDC is left hanging around, and memory/resources are freed correctly after painting.

Releasing the handle invalidates it and prevents its further use.

The program should acquire and release the handle within the processing of a single message.

With the exception of a DC created using the CreateDC function, which is beyond the scope of this chapter, you should not maintain a DC handle between messages.

❌ **Bad:**



```
// Global hdc retained between messages – DO NOT DO THIS
hdc = GetDC(hWnd);  // Called once, never released
```

Global or persistent use of an HDC (like keeping it across multiple messages or function calls) is a bad idea because you never release the HDC with ReleaseDC.

The HDC represents a drawing surface that can be tied to OS resources. If you don't release it properly, those resources remain allocated or held, causing performance and memory issues.

🔚 Summary (Sticky Notes Style):

- DC holds *style info* (color, font, etc.)
- Get a DC → draw → release it (cleanly!)
- Don't hoard DC handles between messages—only use them while painting
- Use SelectObject, SetTextColor, etc., to *customize the DC*

COMMON METHODS FOR OBTAINING A DEVICE CONTEXT HANDLE

Windows applications generally employ two methods to obtain a DC handle for screen painting.

Using BeginPaint:

To draw on a window, you need a Device Context (DC) — like getting a brush and canvas before painting.

The BeginPaint function **retrieves the DC handle** for the window and prepares it for painting. This function should be called at the beginning of the WM_PAINT message processing.

```
hdc = BeginPaint(hwnd, &ps);
```

- It prepares the drawing surface (the device context (HDC)) for your program to use.
- It validates the "dirty area" (called the invalid region) of the window that needs repainting. This tells Windows that you're handling the WM_PAINT request and you're ready to paint.

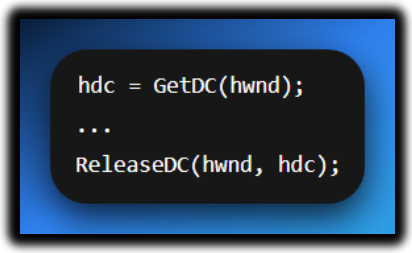
🧠 **Think of it as:**

"Hey Windows, I'm ready to repaint the part you said needs redrawing!"

🔚 Always pair it with:

```
EndPaint(hwnd, &ps);
```

🟡 Using GetDC — For Anytime Drawing



✅ You can use this **anywhere**, not just inside WM_PAINT.

✅ Use **anytime** (e.g. mouse clicks, timers).

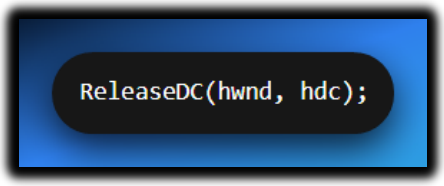
Perfect for drawing things when **you decide**, like during a mouse event or button press.

🧠 Think of it as:

"I want to draw now — hand me the brush!"

⚠️ Important Tips

- 🛑 Always release the DC after you're done, or you'll leak GDI resources — like leaving a paintbrush stuck in a wall.
- ❌ Never hold onto a DC handle across multiple messages unless you created it with CreateDC (advanced stuff).



Method One: Acquiring a Device Context Handle with BeginPaint and EndPaint

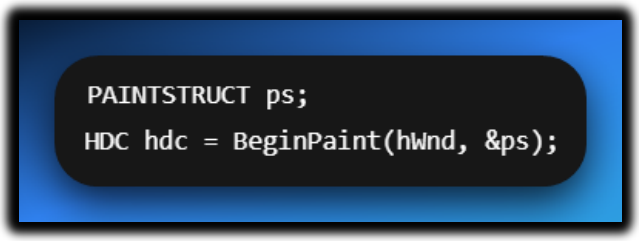
🎨 Painting with BeginPaint and EndPaint – The *WM_PAINT Ritual*

When your window needs a fresh coat of pixels, Windows doesn't just guess — it **sends a WM_PAINT message**. That's your cue to step in and repaint the damaged (invalid) portion of your window.

And the *only* legit way to respond to this sacred call is by using BeginPaint and EndPaint.

🛠️ BeginPaint – Enter the Drawing Arena

BeginPaint: Preparing for Painting



The program utilizes various GDI functions, such as TextOut, to draw on the client area using the acquired device context handle.

What it does:

- 🖌️ **Erases the background** if necessary. If CS_HREDRAW or CS_VREDRAW is set in your window class, the area gets wiped clean before your brush hits it.
- 📦 **Fills a PAINTSTRUCT** which includes:
  - ✓ The HDC (device context handle).
  - ✓ The rectangle that needs repainting (rcPaint).
  - ✓ Some extra state info (like whether background erasure was done).
- 🎯 **Returns a valid HDC**, scoped only for this paint cycle.

Note: This HDC is **only valid within WM_PAINT**, and only between BeginPaint and EndPaint.

🎯 Use That HDC to Paint Stuff

Once you've got the HDC, let the art begin:

```
TextOut(hdc, 10, 10, TEXT("Hello WinAPI"), 12);
Rectangle(hdc, 20, 40, 150, 100);
// Or any other GDI function
```

This is your moment. Draw only what's in ps.rcPaint, if you want optimal performance. Don't repaint the whole window unless you really must.

🩹 EndPaint – Close the Ceremony

```
EndPaint(hWnd, &ps);
```

It validates the previously invalid region, indicating to Windows that the repainting is complete.

⚠️ What If You Skip BeginPaint/EndPaint?

Bad things happen:

- 😵 You **don't get a valid HDC** → GDI functions may fail or act weird.
- 🌀 **WM_PAINT keeps firing in a loop**, because Windows thinks the area is still dirty.
- 🐛 Your app becomes a CPU-burning mess.

💡 If you're using GetDC() inside WM_PAINT — **that's wrong**. That's not the proper ritual. Only BeginPaint preps the right context for this scenario.

📜 Real-World Flow: WM_PAINT Handler

```
case WM_PAINT: {
    PAINTSTRUCT ps;
    HDC hdc = BeginPaint(hWnd, &ps);

    // ✅ Drawing using GDI
    TextOut(hdc, 10, 10, TEXT("WM_PAINT in action!"), 21);

    EndPaint(hWnd, &ps);
    return 0;
}
```

🧘 Summary – Respect the Painting Ritual

Step	Purpose
`BeginPaint`	Erases background, gives you HDC
GDI drawing	You do your magic
`EndPaint`	Validates region, releases HDC

👉 **This pattern is non-negotiable.** It's how you stay in harmony with the message loop gods.

DEFAULT WM_PAINT HANDLING: WHO PAINTS IF YOU DON'T?

If your window procedure doesn't handle the WM_PAINT message, Windows ain't just gonna sit and cry — it passes the torch to the **default window procedure**, DefWindowProc.

🧠 What does DefWindowProc do?

It calls BeginPaint and EndPaint internally, making sure the invalid region is validated.

It takes care of basic cleanup, but won't draw custom stuff for you.

So yeah, your fancy rectangle won't draw unless you step in.

🧱 Your Job: Handle WM_PAINT Properly

Use this standard pattern inside WndProc when uMsg == WM_PAINT:

```
case WM_PAINT:
{
    PAINTSTRUCT ps;
    HDC hdc = BeginPaint(hWnd, &ps); // 👈 Get a valid device context (DC)

    // ✅ You now have permission to draw on the window's client area
    //    Let's draw something basic, like a rectangle

    Rectangle(hdc, 10, 10, 110, 110); // Draw a 100x100 black rectangle

    EndPaint(hWnd, &ps); // 👈 Must call this! Releases the DC and validates region
    return 0;
}
```

🔥 Breakdown of the Flow:

- **BeginPaint()**
  👉 Gives you a special HDC that's valid only during WM_PAINT
  👉 Also erases background automatically (unless you tweak it)
- **GDI Drawing (like Rectangle, TextOut, etc.)**
  👉 Now you can do your painting magic here
- **EndPaint()**
  👉 Closes the painting session
  👉 If you don't call it, **you're leaking GDI objects** (and Windows *will* throw shade eventually)

🧠 Pro Tip:

If you're inside WM_PAINT, **always use BeginPaint**, not GetDC.
Why? Because GetDC doesn't handle invalid regions or cleanup properly in this context.

PAINTSTRUCT STRUCTURE IN DEPTH

The PAINTSTRUCT structure, referred to as **"paint information structure"**.

It holds essential information about the painting process and is populated by Windows when the BeginPaint function is called.

```
typedef struct tagPAINTSTRUCT {
    HDC  hdc;          // Handle to the device context
    BOOL fErase;       // Did Windows erase the background?
    RECT rcPaint;      // Area that needs repainting (dirty rect)
    BOOL fRestore;     // Reserved
    BOOL fIncUpdate;   // Reserved
    BYTE rgbReserved[32]; // Reserved
} PAINTSTRUCT;
```

Whenever your **window needs repainting,** BeginPaint() returns more than just an HDC. It fills out a full PAINTSTRUCT — a structure with the info you need to paint smart, not dumb.

🧩 Key Fields You Actually Use

```
ps.hdc      // the drawing canvas (device context)
ps.fErase   // true if Windows erased the background (rarely used)
ps.rcPaint  // RECT of the area needing a repaint
```

hdc: This field holds the handle to the device context (DC), which is a unique identifier for the window's drawing context.

fErase: This Boolean flag indicates whether Windows has already erased the background of the invalid rectangle. If TRUE (nonzero), the background has been erased.

rcPaint: This field is a RECT structure that defines the boundaries of the invalid rectangle. The values represent pixel coordinates relative to the client area's top-left corner.

🛠️ Where It Comes From

When you call BeginPaint(hWnd, &ps);, Windows:

- **Fills ps.rcPaint** with the dirty area (what needs redrawing).
- **Provides ps.hdc**, a special DC just for painting.
- Optionally **sets ps.fErase** if background erase was needed.

You then use this data to repaint **only what's needed**. It's efficient and avoids flicker.

🧠 Real World Tip

🔍 *Check rcPaint to avoid repainting the whole window every time. Only redraw what's dirty.*

Example (Just the Paint Part)

```
case WM_PAINT:
{
    PAINTSTRUCT ps;
    HDC hdc = BeginPaint(hWnd, &ps);

    // Only redraw inside ps.rcPaint
    Rectangle(hdc, ps.rcPaint.left, ps.rcPaint.top,
                   ps.rcPaint.right, ps.rcPaint.bottom);

    EndPaint(hWnd, &ps);
}
return 0;
```

Key Fields of PAINTSTRUCT

When the BeginPaint function is called, Windows fills in the relevant fields of the PAINTSTRUCT structure:

Programmatic Access to PAINTSTRUCT Fields

Programmatic Access to PAINTSTRUCT

The PAINTSTRUCT structure holds critical info Windows feeds you during a WM_PAINT message. But guess what? Only **3 fields actually matter** for your program:

- **hdc** – the device context (DC) handle you'll use for drawing.
- **fErase** – tells you if Windows *wants you* to erase the background.
- **rcPaint** – the rectangle that needs repainting (in client-area pixels).

The rest? Internal Windows stuff. Don't touch it. Don't look at it. Don't even *breathe* on it.

fErase: Should You Wipe the Background?

The fErase flag = background erasing helper.

This flag tells Windows whether to clear the background of a window before drawing new content.

- **TRUE (any non-zero value):** Windows says, "Hey, clean up this background for me." This means Windows will automatically erase the previous content, preparing a clean slate for your new drawing.
- **FALSE (0)**: “No background erase needed, I got this.” This tells Windows not to erase the background. You'll then be responsible for clearing or drawing over the old content yourself before painting new visuals.

This line of code is telling Windows to mark a window (or part of it) as needing to be redrawn, but without erasing its background first.

You'd use this when you want more control over how things are drawn, esp. for:

- **Custom visuals:** When you're drawing something intricate and want to manage every pixel.
- **Faster redraws:** Skipping the background erase can sometimes make your application feel snappier, as it's one less step for Windows to perform.
- **Manual double-buffering:** This is a technique where you draw to an off-screen image first and then quickly display the complete image to avoid flickering. When doing this, you usually don't need Windows to erase the background, as you're replacing the entire content at once.

In short, setting fErase to FALSE means you take on the responsibility of ensuring the window's background is correctly handled (e.g., drawing over it or clearing it) before you paint new elements.

rcPaint: What Area Needs a Fresh Coat of Paint?

rcPaint is a rectangle that Windows gives you. It marks the specific area of your window that is "dirty" and needs to be redrawn or "repainted."

- It's a Rectangle: This rcPaint is always a rectangular shape.
- Pixel Coordinates: The numbers defining this rectangle are in pixels.
- Relative to Your Window: These pixel coordinates are measured from the top-left corner of the *inside* part of your window (the "client area"), not the entire window including borders and title bar.
- Your "Dirty Zone": Think of rcPaint as your window's "dirty zone." It's the area Windows says, "Hey, this part changed, go update it!" Your job is to draw the correct content within this rectangle.

This rectangle is also the clipping region:

Even if the actual invalid region is oddly shaped, Windows only lets you draw inside the rcPaint box. It's your drawing sandbox. If you try to draw outside it, Windows will cut off your drawing at the edges of rcPaint.

Forcing a Full Repaint?

Need to repaint **everything**, not just a slice? This is how you tell Windows to do that:

```
InvalidateRect(hWnd, NULL, TRUE);
```

Let's look at what each part of that line means:

- **hwnd**: This is just the "handle" or ID for your specific window.
- **NULL**: When you put NULL here, it tells Windows: "Invalidate (mark as needing redraw) the entire inside area of my window, from top to bottom, left to right."
- **TRUE**: This tells Windows: "Before you redraw, please erase the background of the window first." This gives you a completely clean slate to draw on.

When to use this (draw everything, erase background):

You'd use InvalidateRect(hwnd, NULL, TRUE); when:

- **The entire content of your window has changed.**
- **You want a completely fresh, clean canvas** to draw on, removing anything that was there before.
- **Something major happened, like the window was resized significantly or a large element moved**, and it's easier to just redraw everything than figure out specific "dirty" areas.

What if you want to redraw everything but *keep* the background as is?

If you want to redraw the whole window but *don't* want Windows to erase the background for you (maybe because you're doing your own custom drawing/clearing), simply change TRUE to FALSE:

✅ Summary:

When handling WM_PAINT, PAINTSTRUCT gives you:

- **hdc** – your drawing tool
- **fErase** – erase or not
- **rcPaint** – where to draw (and only there!)

With these, you're painting like a pro. 🎨💼

In summary, the PAINTSTRUCT structure serves as a vital information carrier during the painting process. It provides access to the device context handle, indicates whether background erasing is necessary, and defines the boundaries of the invalid rectangle, ensuring that your program paints efficiently and accurately.

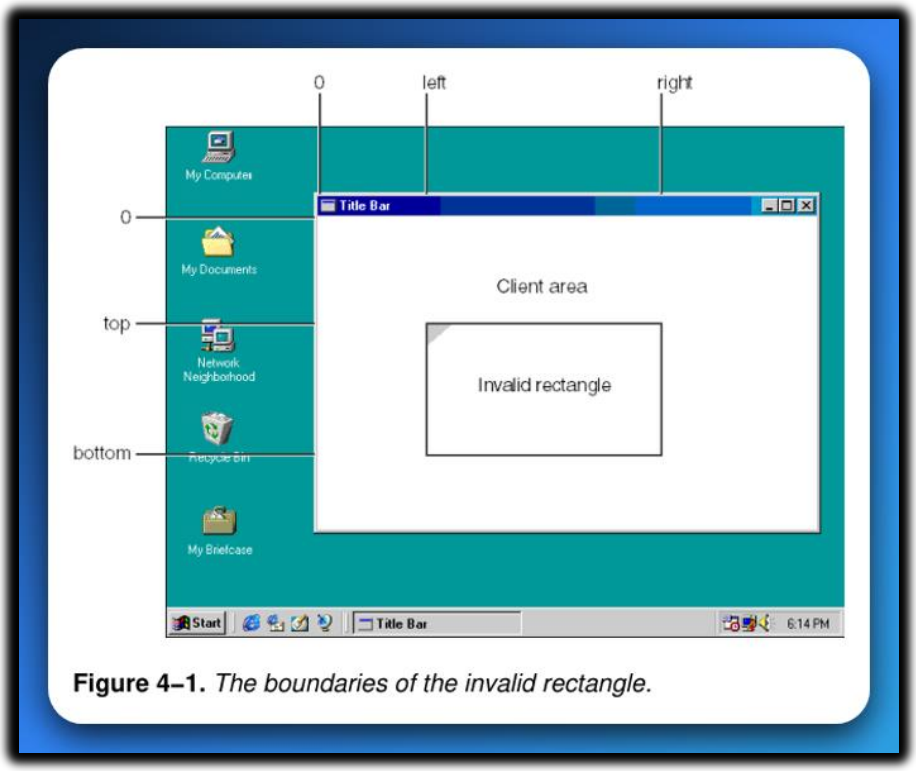
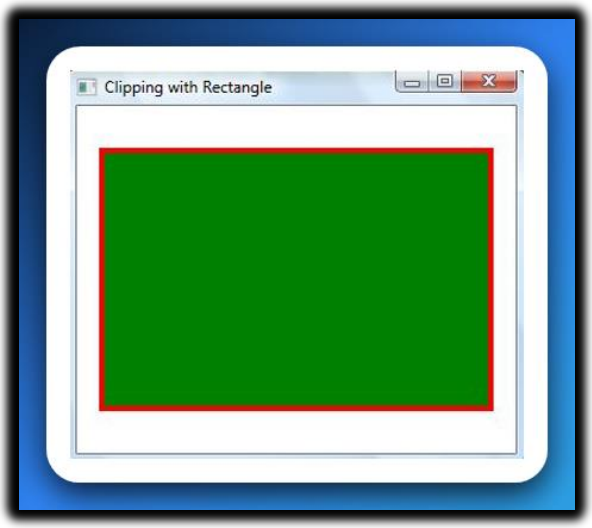


Figure 4–1. *The boundaries of the invalid rectangle.*

Clipping Region Alert: Even if the actual invalid region is complex or non-rectangular, Windows will still restrict your painting logic to the rectangle in rcPaint. Nothing gets drawn outside it.



🧠 Pro Tip: To Redraw or Not to Redraw?

In theory, rcPaint lets you **only redraw what's "dirty"** — saving performance.

📌 **But in real-world GUIs?** 👇 *Sometimes it's simpler and safer to just repaint the whole client area.*

📌 **Example:** *Let's say you're drawing a circle. If only half of it falls inside rcPaint, it's better to redraw the whole circle, not just the slice.*

📌 **Why?** *Because Windows will clip your drawing anyway — you don't have to worry about painting "too much." - It won't show outside the bounds.*

⚙️ Performance Consideration:

- For simple GUIs: 🔁 full repaint = easy + fast enough
- For complex UIs or disk-loaded content (like BMPs)?
  👉 You *should* respect rcPaint to avoid overdraw or file access. **Try to only redraw the rcPaint area.** This prevents wasting power by drawing things that are already visible or repeatedly loading large files.

UNDERSTANDING DEVICE CONTEXT ATTRIBUTES

The **Device Context (HDC)** you get in WM_PAINT or BeginPaint() isn't just a **drawing tool** — it's loaded with **style settings** that affect how text and graphics appear.

Let's cover the **main text-specific attributes** one by one:

🖍️ SetTextColor(hdc, COLORREF color);

- **Default:** Black
- **What it does:** Sets the color of the actual text glyphs.

```
SetTextColor(hdc, RGB(255, 0, 0)); // Red text
```

SetBkColor(hdc, COLORREF color);

- **Default:** White
- **What it does:** Sets the **background color behind each character**, also called the **"character cell box."**
- **Only applies** if background mode is **OPAQUE** (default).

```
SetBkColor(hdc, RGB(255, 255, 0)); // Yellow background behind text
```

SetBkMode(hdc, TRANSPARENT or OPAQUE);

- **OPAQUE (default):** Fills in the character box with the background color
- **TRANSPARENT:** Doesn't draw any background behind text — useful when drawing over complex backgrounds or images.

```
SetBkMode(hdc, TRANSPARENT); // No background fill behind text
```

Selecting Fonts with SelectObject()

If you want to ditch the default system font and use your own:

1. You first **create a font object** using CreateFont() or CreateFontIndirect().
2. Then you **select it into the DC** using SelectObject().

```
HFONT hFont = CreateFont(
    20, 0, 0, 0, FW_BOLD, FALSE, FALSE, FALSE,
    ANSI_CHARSET, OUT_DEFAULT_PRECIS, CLIP_DEFAULT_PRECIS,
    DEFAULT_QUALITY, DEFAULT_PITCH | FF_DONTCARE,
    TEXT("Consolas")
);
SelectObject(hdc, hFont);
```

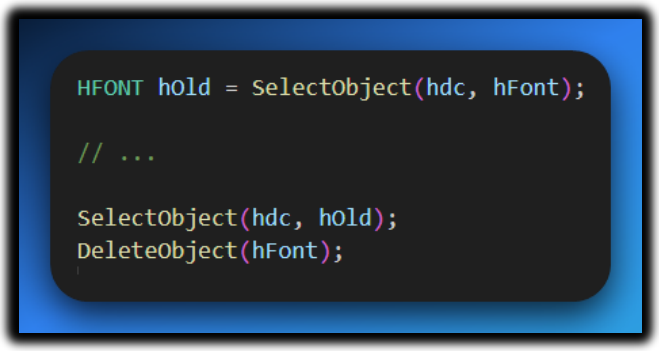
Boom — now your text is in **20pt bold Consolas.** Don't forget to delete the font later using DeleteObject() to avoid memory leaks.

🧠 Pro Insight: Why This Matters

- Without setting these attributes, **all your text looks default**, basic, and identical.
- Once you **start drawing dynamic content** (like syntax-highlighted code or UI widgets), styling becomes everything.
- This is also **how themes and skinning** are built in GUIs — colors, fonts, modes... all via the DC.

⚠️ Common Gotchas

Don’t forget to **restore the old font** if you change it:

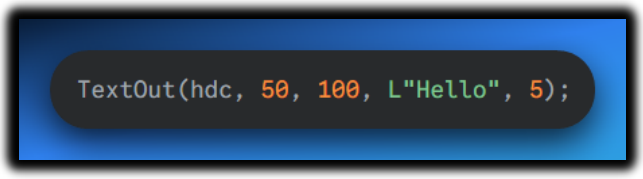


SetBkColor() won’t *visually* do anything if SetBkMode() is TRANSPARENT.

COORDINATE SYSTEM AND MAPPING MODES

🗺️ Logical vs. Physical Coordinates

When you tell Windows to draw something, like text at a certain spot, you might think you're picking an exact pixel on the screen. But you're usually not!



You're **NOT** saying: "Put 'Hello' exactly at screen pixel 50 across and 100 down."

Instead, you're saying: **"Place this text at logical coordinate (50, 100)."**

🍁 So, what's a "logical coordinate?"

Think of logical coordinates as your *abstract drawing units*. They're like measurements on a blueprint, not the actual physical dimensions of the final product.

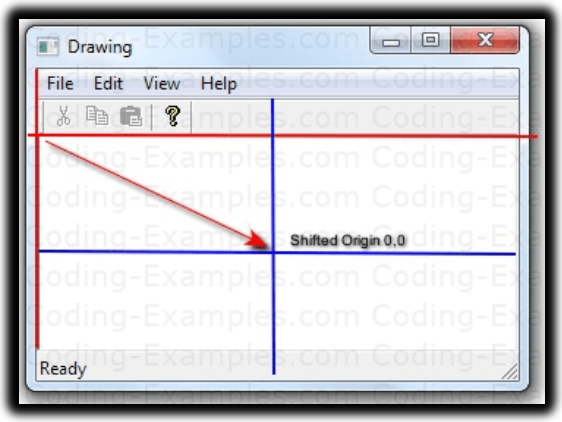
🔥 Mapping Mode: The Translation Guide

The "mapping mode" is the crucial setting that decides how your **"logical units"** (like that '50' or '100') get translated into actual **"physical pixels"** on your screen, or dots on a printer, or whatever device you're drawing to.

- **It's like a scale:** If your mapping mode says "1 logical unit = 1 pixel," then (50, 100) *will* be pixel (50, 100).
- **But it can change:** If your mapping mode says "1 logical unit = 2 pixels" (e.g., for scaling up), then logical (50, 100) would end up at physical pixel (100, 200)!

This allows your **drawings to adapt** to different screen resolutions or printers without you having to change all your drawing coordinates manually. You draw in your logical world, and the mapping mode handles the real-world translation.

🔥 **Mapping mode** = how logical units translate into actual device pixels (screen dots, printer dots, etc.)



⚙️ MM_TEXT — The Default & Simple One

This is the mode Windows uses by default. It's like:

"Hey man, no need for translation, logical == physical. Just draw at (x, y) as pixels."

Behavior of MM_TEXT:

- (0, 0) is top-left of client area
- +X moves right
- +Y moves **down**
- Each logical unit = **1 pixel**

So this:

```
TextOut(hdc, 50, 100, L"Nick Was Here", 13);
```

⬇ Literally means:

Draw the text starting **50 pixels from the left**, **100 pixels down** from top.

```
// MM_TEXT is the default, but we can still be explicit:
SetMapMode(hdc, MM_TEXT);
TextOut(hdc, 100, 200, L"MM_TEXT mode", 12);
```

🧮 Other Mapping Modes — Scaling Comes In

If you're printing, drawing in inches/mm, or zooming? You'll want other modes.

Here's some spicy ones:

Mapping Mode	Logical Units	Origin	Y Axis	Use Case
`MM_TEXT`	1 unit = 1 pixel	Top-Left	Down	Default screen drawing
`MM_LOENGLISH`	0.01 inch (low res)	Bottom-Left	Up	Inches, low precision
`MM_HIENGLISH`	0.001 inch (high res)	Bottom-Left	Up	Fine print graphics
`MM_LOMETRIC`	0.1 mm	Bottom-Left	Up	Metric stuff
`MM_HIMETRIC`	0.01 mm	Bottom-Left	Up	High-res metric
`MM_TWIPS`	1/1440 inch	Bottom-Left	Up	Typography, publishing

💡 In all modes *except MM_TEXT*, the origin is **bottom-left**, and Y increases **upwards**.

- **Mapping Mode:** This is the specific setting you tell Windows to use. Each mode changes how your drawing commands (like TextOut(X, Y...)) are interpreted.
- **Logical Units:** This is the key! It tells you what one "unit" in your drawing code (e.g., if you draw at X=100, that 100 represents this many units) translates to in real-world measurements.

MM_TEXT (Default for Screens):

- This is the simplest and most common mode, especially for drawing directly on your computer screen. In MM_TEXT, **1 unit in your drawing code is exactly equal to 1 pixel** on the screen.
- So, if you tell your program to draw a line 100 units long, it will be 100 pixels long. This makes it very easy to position things precisely on a pixel grid for typical screen-based applications.

MM_LOENGLISH (Low-Res Inches):

- Imagine you're designing something where you want to specify sizes in inches, but without needing super tiny precision. In MM_LOENGLISH, **1 unit in your drawing code represents one-hundredth of an inch (0.01 inches)**.
- This means if you want to draw a shape that is exactly 1 inch wide, you would tell your program to draw it 100 units wide (because 100 units * 0.01 inches/unit = 1 inch). It's great for drawings where general inch measurements are useful, like simple diagrams.

MM_HIENGLISH (High-Res Inches):

- This mode is similar to MM_LOENGLISH, but it offers much finer detail when you're working with inches. In MM_HIENGLISH, **1 unit in your drawing code represents one-thousandth of an inch (0.001 inches)**.
- So, to draw something exactly 1 inch wide, you'd specify 1000 units in your code (because 1000 units * 0.001 inches/unit = 1 inch). This precision is crucial for professional graphics, detailed architectural plans, or when sending designs to high-resolution printers where every tiny fraction of an inch matters.

MM_LOMETRIC (Low-Res Millimeters):

- This is the metric version of MM_LOENGLISH. If you prefer to work with millimeters, this mode is for you. In MM_LOMETRIC, **1 unit in your drawing code represents one-tenth of a millimeter (0.1 mm)**.
- Therefore, if you want to draw an object that is exactly 10 millimeters (which is 1 centimeter) wide, you would tell your program to draw it 100 units wide (because 100 units * 0.1 mm/unit = 10 mm). It's good for general metric designs.

MM_HIMETRIC (High-Res Millimeters):

- This is the high-precision metric mode, mirroring MM_HIENGLISH. In MM_HIMETRIC, **1 unit in your drawing code represents one-hundredth of a millimeter (0.01 mm)**.
- To draw something that is 10 millimeters (1 cm) wide, you would need to specify 1000 units in your code. This mode is excellent for very detailed technical drawings, engineering designs, or for precise output on high-resolution metric printers.

MM_TWIPS (Tiny Typography Units):

- This mode uses a very specific unit called a "twip," which is commonly found in older desktop publishing and word processing applications. In MM_TWIPS, **1 unit in your drawing code is equal to 1/1440th of an inch**.
- This might sound odd, but it comes from the fact that there are 72 "points" in an inch (a common unit for font sizes), and there are 20 twips in a single point. So, 72 points/inch * 20 twips/point = 1440 twips/inch.
- This extremely small unit allows for incredibly fine and consistent control over text placement and layout, regardless of the screen's or printer's resolution. It ensures your text looks exactly the same size and spacing when printed as it does on screen, even across different devices.

Origin: This tells you where the (0,0) point of your drawing coordinate system is located within the window or page.

Top-Left: (0,0) is at the top-left corner.

Bottom-Left: (0,0) is at the bottom-left corner. (This is typical for print-oriented modes, like graphing).

Y Axis: This describes the direction of the Y-axis (vertical axis).

Down: As Y values increase, you move downwards on the screen (common for screen drawing).

Up: As Y values increase, you move upwards (common for graphing and print, where (0,0) is bottom-left).

Use Case: This gives you typical scenarios where each mapping mode would be beneficial.

In essence, these mapping modes give you the flexibility to draw in units that make sense for your output, whether it's pixels on a screen, inches for print, or tiny twips for precise text layout, letting Windows handle the conversion to actual physical dots.

🎯 Real-World Use Case: When Does This Matter?

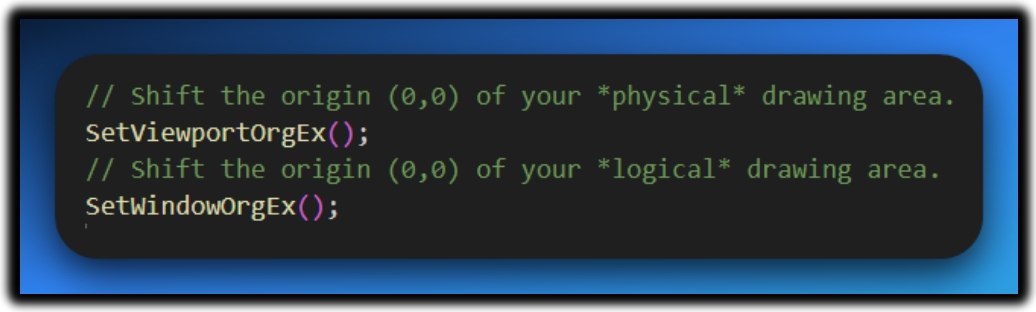
You might think, **"Why bother with logical coordinates if MM_TEXT (1 logical unit = 1 pixel) is the default and works fine for screens?"**

This system becomes super useful when:

- **Print Previews:** You're showing how something will look on a printer. Printers have different resolutions (DPI - Dots Per Inch) than screens. Using modes like MM_HIENGLISH (which defines units in thousandths of an inch) or MM_TWIPS (1/1440 of an inch) lets you draw in real-world measurements (like inches or millimeters) so your design prints correctly, no matter the printer's DPI.
- **Multiple DPI Screens:** Your app needs to look good on screens with different pixel densities (e.g., a standard monitor vs. a high-resolution Retina display). Drawing in logical units ensures your elements scale properly.

🧠 Tip: Combine Mapping + Viewport for Advanced Control

Mapping modes set the *scale* (how big a logical unit is) and *direction* (e.g., is Y-axis up or down?). But you can also use these two functions to further manipulate your drawing space:



- **SetViewportOrgEx():** Moves where your logical (0,0) point *appears* on the physical screen. Good for panning your view.
- **SetWindowOrgEx():** Moves what logical coordinates correspond to the physical (0,0) point. Good for offsetting your drawing.

Why use these? You can combine these to easily **pan, zoom, and scale your drawings** without having to rewrite all your drawing code or recalculate every single coordinate. It lets you create complex viewing features (like in a CAD program) with relative ease.

Summary Wrap-up: Quick Recap

- *TextOut and similar drawing functions use logical coordinates, not exact screen pixels.*
- *The mapping mode tells Windows how to convert your logical 'X' and 'Y' values into actual screen or printer pixels.*
- *MM_TEXT is the simplest mapping mode; 1 logical unit equals 1 pixel. Great for basic screen drawing.*
- *Other mapping modes (like MM_HIENGLISH or MM_TWIPS) let you draw using real-world units (inches, mm) or scalable units, which is vital for printouts or high-DPI displays.*
- *Always choose your mapping mode based on what you're drawing for (screen, printer) and whether you need automatic scaling.*

UNICODE SUPPORT

TextOut: Text and Unicode – A Quick Guide

Yes, TextOut can draw text with all sorts of characters, including international ones (Unicode). But there's a small detail based on how you call it:

- **TextOutA**: This is for "ANSI" text, the **older, simpler text** where each character typically takes up only **1 byte** of memory. It's usually limited to characters from a specific language or region.
- **TextOutW**: This is for "Unicode" text, the **modern way** to handle text, where each character often uses **2 or more bytes** (called "wide characters"). Unicode can represent almost every character from every language in the world, including emojis and special symbols.

TextOut supports Unicode character strings, allowing for the display of multilingual text. The number of bytes in a Unicode string is double the iLength value, and the string should not contain any ASCII control characters.

We looked at unicode in-depth in chapter 1.

If you're writing C/C++ code and using TextOut to display Unicode text (which is highly recommended for modern apps):

- **iLength (the length parameter):** When you tell TextOut how long your text is, this iLength value should *still be the number of characters*, **NOT** the number of bytes. Even though Unicode characters might take 2 bytes each, Windows automatically handles this detail for you.
- **For C/C++ users:** Because of this, when you're calculating the length of a Unicode string in C/C++, **don't use strlen() -** counts bytes (good for ANSI), **use wcslen()** correctly counts wide characters (good for Unicode).

💡 Important Note on Formatting:

- Characters like \n (new line), \r (carriage return), or \t (tab) **will NOT create line breaks or tabs** when you draw them with TextOut. TextOut just draws them as literal characters (sometimes as little squares) or simply ignores them.
- If you need multi-line text, you'll have to handle line breaks yourself by calling TextOut multiple times for each line.

✂ Clipping Region and Its Impact on Text Rendering

The **clipping region** is one of those invisible superheroes in GDI — you usually don't see it, but it's protecting your graphics from chaos.

💡 What's the Clipping Region?

It's a **boundary** that Windows uses to say:

"You can only draw inside this area. Everything outside? Nope, not allowed."

This applies to **everything**, including:

- TextOut
- DrawText
- Rectangle, Ellipse, BitBlt…

The device context, which serves as the drawing context for a window, also defines a clipping region.

This region determines the area within which graphical elements, including text, will be rendered.

By default, the clipping region is set to the entire client area for a device context handle obtained using GetDC and to the invalid region for a device context handle obtained using BeginPaint.

When the TextOut function is called to display text, Windows will only render the portions of the character string that fall within the clipping region.

Any part of a character that lies outside the clipping region will not be displayed. Similarly, if a character partially overlaps the clipping boundary, only the portion of the character inside the region will be rendered.

This clipping mechanism ensures that text is displayed only within the visible boundaries of the window, preventing it from extending beyond the client area or overlapping with other graphical elements.

Two Main Scenarios for Clipping:

Function	What It Gives You
`BeginPaint()`	A drawing area **limited only to what's damaged** (the invalidated rectangle). Great for efficient repainting during `WM_PAINT`.
`GetDC()`	A drawing area that covers the **entire window's client area**. Use this for real-time or user-triggered drawing (like mouse moves).

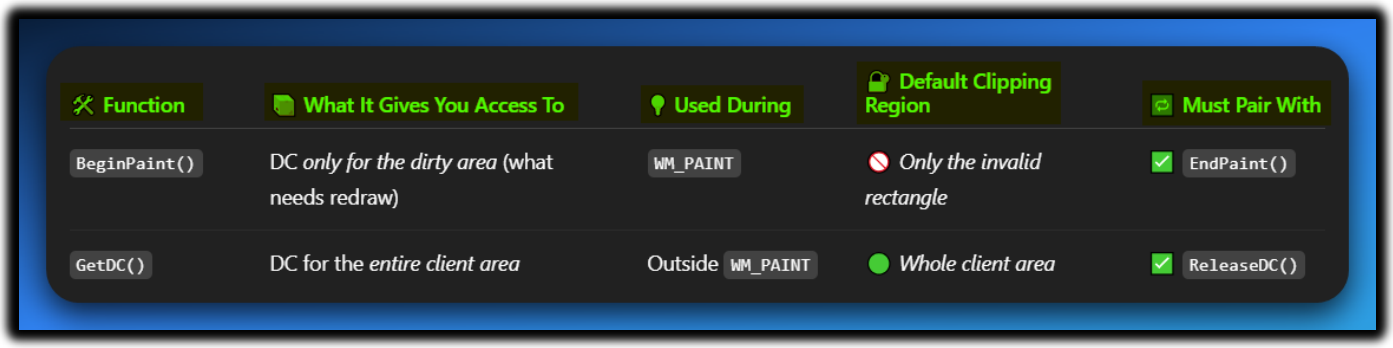
BeginPaint() says: **"Just repaint the broken part; I got you covered."**

GetDC() says: **"Here's the whole canvas — you do your thing, but clean up after."**

🎯 Two Ways to Get a Device Context — and What You Can Draw

When you want to draw **anything** in WinAPI, you first need a **Device Context (DC)** — your window's personal canvas 🎨.

But *how* you get that DC? That changes **where** Windows *lets* you draw.



🛠 Function	🧊 What It Gives You Access To	📍 Used During	🔒 Default Clipping Region	🔁 Must Pair With
`BeginPaint()`	DC *only for the dirty area* (what needs redraw)	`WM_PAINT`	🚫 *Only the invalid rectangle*	✅ `EndPaint()`
`GetDC()`	DC for the *entire client area*	Outside `WM_PAINT`	🟢 *Whole client area*	✅ `ReleaseDC()`

✨ Why Clipping Is Useful:

- *Keeps your UI clean — text doesn't spill over borders.*
- *Speeds up painting — Windows can skip drawing clipped-out pixels.*
- *Makes redraws more efficient — you can redraw only the parts that changed.*

🧠 TLDR:

✅ TextOut supports Unicode — just make sure you pass wchar_t* strings and use iLength as **character count**, not bytes.

```
#include <windows.h>

LRESULT CALLBACK WndProc(HWND hWnd, UINT msg, WPARAM wParam, LPARAM lParam) {
    switch (msg) {
    case WM_PAINT: {
        PAINTSTRUCT ps;
        HDC hdc = BeginPaint(hWnd, &ps);

        // Unicode text
        wchar_t* text = L"Hello, 🌍 Unicode!";
        TextOutW(hdc, 50, 50, text, wcslen(text));  // Notice: character count

        EndPaint(hWnd, &ps);
        break;
    }
    case WM_DESTROY: PostQuitMessage(0); break;
    }
    return DefWindowProc(hWnd, msg, wParam, lParam);
}
```

✅ **Clipping Region:** Draw inside it only.

✅ The **clipping region** of an HDC controls where text and graphics can appear.

```c
#include <windows.h>

LRESULT CALLBACK WndProc(HWND hWnd, UINT msg, WPARAM wParam, LPARAM lParam) {
    switch (msg) {
    case WM_PAINT: {
        PAINTSTRUCT ps;
        HDC hdc = BeginPaint(hWnd, &ps);

        // Create a tiny clipping region
        HRGN hRgn = CreateRectRgn(0, 0, 100, 100);
        SelectClipRgn(hdc, hRgn);

        // Try to draw inside and outside the region
        TextOutA(hdc, 10, 10, "Visible", 7);   // Inside: will show
        TextOutA(hdc, 200, 200, "Ignored", 7); // Outside: will not show

        DeleteObject(hRgn);
        EndPaint(hWnd, &ps);
        break;
    }
    case WM_DESTROY: PostQuitMessage(0); break;
    }
    return DefWindowProc(hWnd, msg, wParam, lParam);
}
```

✅ Anything outside the clipping region is automatically ignored — *no need to manually crop*.

✅ If you use BeginPaint, you're limited to the **invalid region**.

```c
#include <windows.h>

LRESULT CALLBACK WndProc(HWND hWnd, UINT msg, WPARAM wParam, LPARAM lParam) {
    switch (msg) {
    case WM_LBUTTONDOWN:
        // Force a partial redraw of the top-left only
        InvalidateRect(hWnd, &(RECT){0, 0, 100, 100}, TRUE);
        break;

    case WM_PAINT: {
        PAINTSTRUCT ps;
        HDC hdc = BeginPaint(hWnd, &ps);

        // Entire screen draw attempt — but only the invalid region will show it
        for (int y = 0; y < 300; y += 20) {
            TextOutA(hdc, 10, y, "Hello", 5);
        }

        EndPaint(hWnd, &ps);
        break;
    }
    case WM_DESTROY: PostQuitMessage(0); break;
    }
    return DefWindowProc(hWnd, msg, wParam, lParam);
}
```

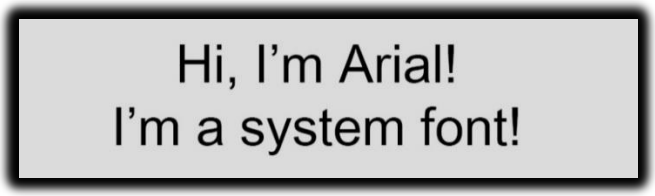
✅ If you use GetDC, you can draw on the **entire client area**.

```c
#include <windows.h>

LRESULT CALLBACK WndProc(HWND hWnd, UINT msg, WPARAM wParam, LPARAM lParam) {
    switch (msg) {
    case WM_KEYDOWN: {
        HDC hdc = GetDC(hWnd);  // No clipping — full access to client area
        TextOutA(hdc, 100, 200, "Drawn with GetDC!", 18);
        ReleaseDC(hWnd, hdc);
        break;
    }
    case WM_DESTROY: PostQuitMessage(0); break;
    }
    return DefWindowProc(hWnd, msg, wParam, lParam);
}
```

SYSTEM FONT

The **device context also defines** the default font that Windows uses when displaying text using the TextOut function.

This **default font** is known as the "system font" or, using the identifier defined in the WINGDI.H header file, SYSTEM_FONT.



The **system font** is the font that Windows employs by default for text strings in title bars, menus, and dialog boxes.

It serves as a **baseline font** for text rendering and is commonly used throughout the Windows user interface.

Evolution of the System Font: From Fixed-Pitch to Variable-Pitch

In the early versions of Windows, the system font was a **fixed-pitch font,** meaning that all characters had the same width.

This was similar to the font used in **typewriters.**

However, with the release of Windows 3.0, the system font transitioned to a **variable-pitch font.**

Variable-pitch fonts allow different characters to have **different widths,** reflecting their natural shapes and sizes.

This change from fixed-pitch to variable-pitch fonts was driven by research indicating that text displayed in **variable-pitch fonts is more readable** and visually appealing.

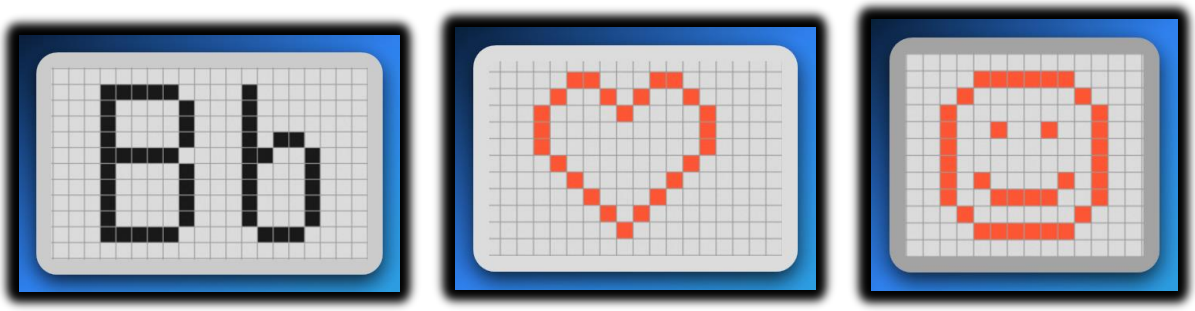
Impact of Variable-Pitch Fonts on Programming

The adoption of variable-pitch fonts necessitated adjustments in **programming practices.**

Developers had to **adapt their code** to account for the varying widths of characters and ensure proper text alignment and formatting.

Raster Fonts vs. Vector Fonts: A Distinction

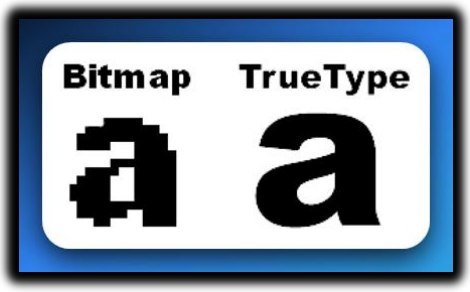
The **system font** is a **raster font**, meaning that the characters are defined as blocks of pixels. This definition is tied to a specific resolution and may not scale well to different display sizes.

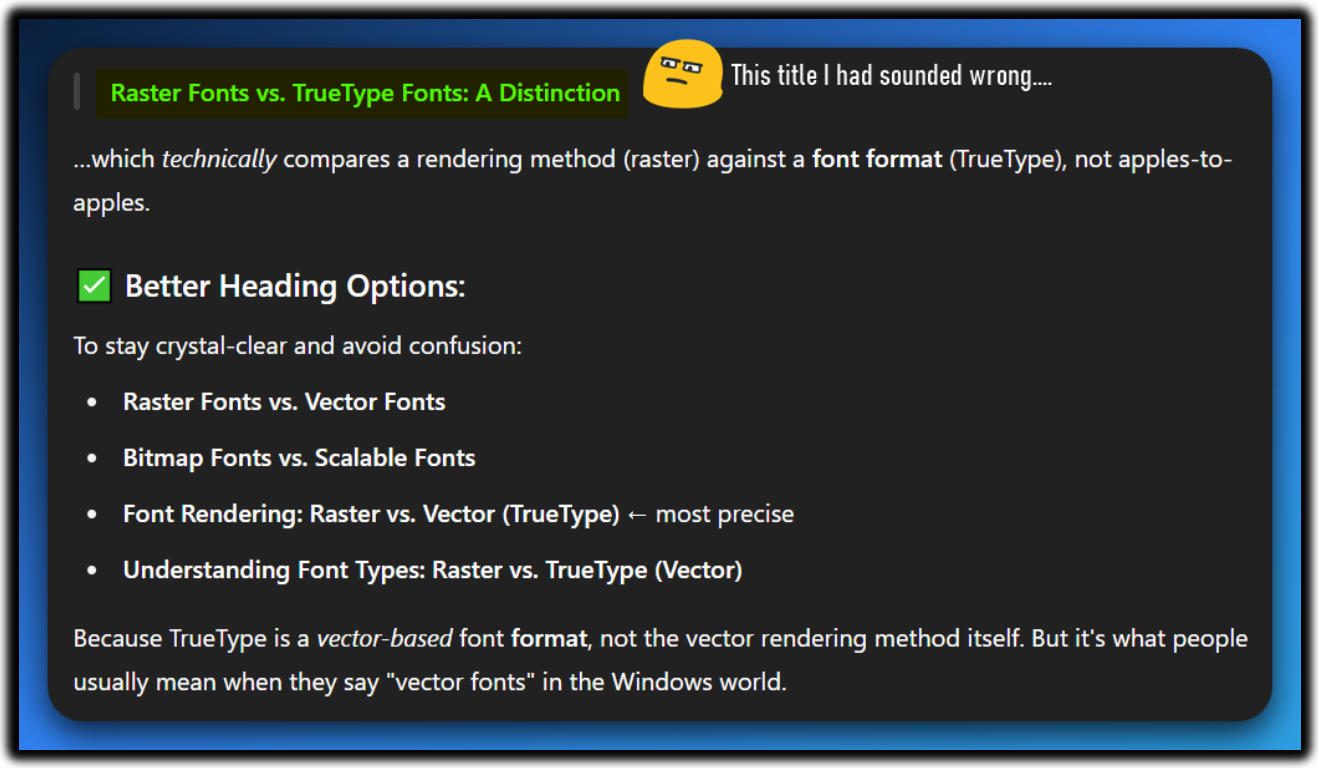


In contrast, TrueType fonts, which we'll explore in the last Chapters, are defined by scalable outlines.

TrueType fonts are **vector-based fonts**, meaning that they are defined by mathematical formulas rather than fixed bitmaps.

They can be rendered at various resolutions without losing quality, making them more versatile for various display sizes and text rendering scenarios.





Conclusion

The device context's **clipping region** and the **system font** play crucial roles in text *rendering* within Windows applications.

The **clipping region** ensures that text is displayed only within the visible boundaries of the window, while the **system font** provides a default text rendering style. Both are for visual appeal during GUI development.

The **TextOut function** is an essential tool for displaying text in Windows applications. Its *straightforward syntax* and *integration with device context attributes* enable programmers to create visually appealing and informative user interfaces.

Understanding the concept of **mapping modes** and **Unicode support** further enhances the versatility of this function.

Also, read the GDI documentation.

Let’s move to the next beast!😉😁

CHARACTER DIMENSIONS AND TEXT RENDERING

When displaying multiple lines of text using the TextOut function, it is crucial to determine the dimensions of the characters in the font.

This information allows for proper spacing between lines and columns of text, ensuring a visually appealing and readable layout.

Dynamic Character Dimensions: Why Text Isn't One-Size-Fits-All

Characters in Windows aren't born with fixed widths and heights — their size *changes* depending on two key factors:

1. **Display Resolution**
   Higher resolutions (like 1024×768 or 1920×1080) pack more pixels into the same screen space. That means each character might appear smaller or tighter, depending on how many pixels are available.

2. **Font Size & Type**
   Users (and apps) can select different system fonts or font sizes. Some fonts are chunkier, others are slim and tall. Combine that with the resolution, and the result? Every character's dimensions are dynamic.

Why It Matters

When you're doing pixel-precise layouts or custom text rendering, you **can't assume** a fixed character width or height — not even for the letter 'M'. Always measure it using functions like GetTextMetrics() or GetTextExtentPoint32() to get the actual dimensions **on that specific device context**.

Determining Character Dimensions Using GetTextMetrics

If you want to know how big your characters actually are, you don't guess. You ask Windows directly.

To determine the character dimensions for a specific font, a program can utilize the **GetTextMetrics** function.

This function requires a handle to the device context, as it retrieves information about the font currently selected in that context.

The retrieved information is stored in a TEXTMETRIC structure, which contains various fields related to font metrics.

Key Fields of the TEXTMETRIC Structure. Among the 20 fields in the TEXTMETRIC structure, the following seven are particularly relevant for character dimensions:

- **tmHeight:** Represents the total height of a character, including both the ascent and descent.
- **tmAscent:** Indicates the portion of the character that extends above the baseline.
- **tmDescent:** Represents the portion of the character that extends below the baseline.
- **tmInternalLeading:** Refers to the additional spacing between lines of text within the tmHeight boundary.
- **tmExternalLeading:** Represents the additional spacing between lines of text outside the tmHeight boundary.
- **tmAveCharWidth:** Indicates the average width of characters in the font.
- **tmMaxCharWidth:** Represents the width of the widest character in the font.

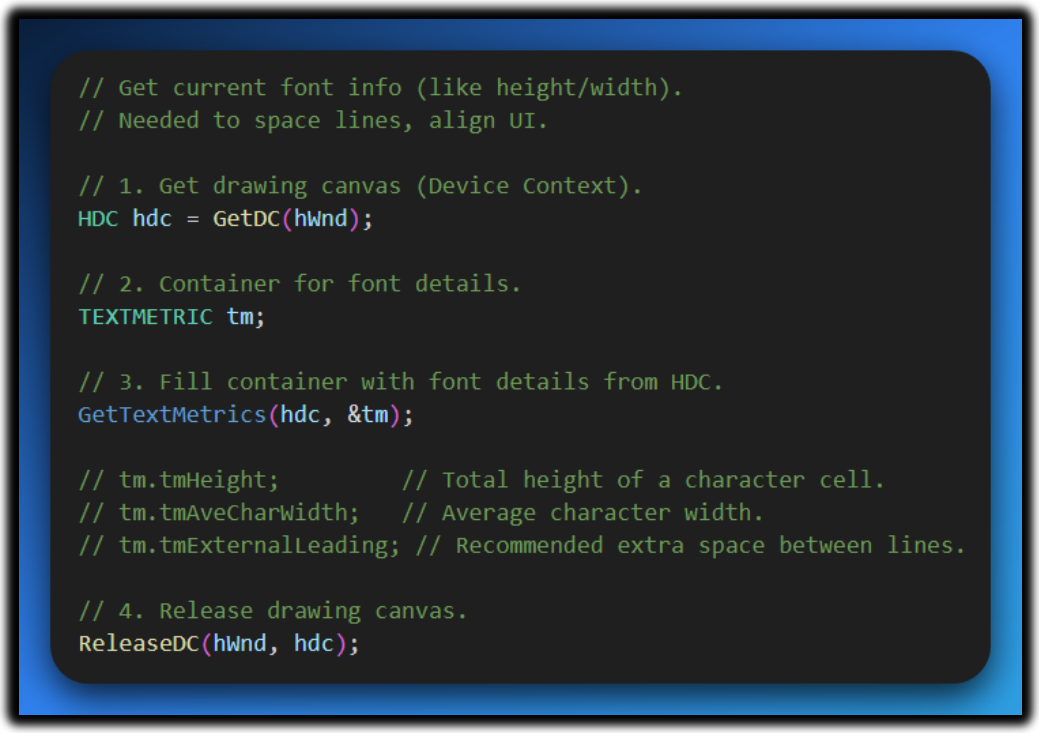
Units of Measurement for Character Dimensions

The values in the TEXTMETRIC structure are measured in **units** based on the mapping mode **currently selected** for the device context.

In the **default device context**, the mapping mode is **MM_TEXT**, meaning the dimensions are in pixels.

Code Example for Retrieving Character Dimensions

The following code snippet demonstrates how to retrieve character dimensions using GetTextMetrics:



```
// Get current font info (like height/width).
// Needed to space lines, align UI.

// 1. Get drawing canvas (Device Context).
HDC hdc = GetDC(hWnd);

// 2. Container for font details.
TEXTMETRIC tm;

// 3. Fill container with font details from HDC.
GetTextMetrics(hdc, &tm);

// tm.tmHeight;         // Total height of a character cell.
// tm.tmAveCharWidth;   // Average character width.
// tm.tmExternalLeading; // Recommended extra space between lines.

// 4. Release drawing canvas.
ReleaseDC(hWnd, hdc);
```

Another one:

```c
#include <windows.h>
typedef struct tagTEXTMETRIC {
    LONG tmHeight;
    LONG tmAscent;
    LONG tmDescent;
    LONG tmInternalLeading;
    LONG tmExternalLeading;
    LONG tmAveCharWidth;
    LONG tmMaxCharWidth;
    // Add other structure fields as needed
} TEXTMETRIC, *PTEXTMETRIC;

int main() {
    HDC hdc = GetDC(0); // Get the device context of the screen

    LOGFONT lf;
    GetObject(GetStockObject(DEFAULT_GUI_FONT), sizeof(LOGFONT), &lf);

    HFONT hFont = CreateFontIndirect(&lf);
    SelectObject(hdc, hFont);

    TEXTMETRIC tm;
    GetTextMetrics(hdc, &tm);

    printf("Text Metrics:\n");
    printf(" Height: %ld\n", tm.tmHeight);
    printf(" Ascent: %ld\n", tm.tmAscent);
    printf(" Descent: %ld\n", tm.tmDescent);
    printf(" Internal Leading: %ld\n", tm.tmInternalLeading);
    printf(" External Leading: %ld\n", tm.tmExternalLeading);
    printf(" Average Character Width: %ld\n", tm.tmAveCharWidth);
    printf(" Maximum Character Width: %ld\n", tm.tmMaxCharWidth);

    DeleteObject(hFont);
    ReleaseDC(0, hdc);
    return 0;
}
```

This code uses the Windows API to **obtain the default font** on the system, creates a font from that information, selects it into a device context, and then **retrieves the text metrics** using GetTextMetrics.

Finally, it **prints out** the various fields of the TEXTMETRIC structure.

Please note that this code assumes you are working in a **Windows environment**, as it relies on Windows API functions.

DELVING INTO THE TEXTMETRIC STRUCTURE

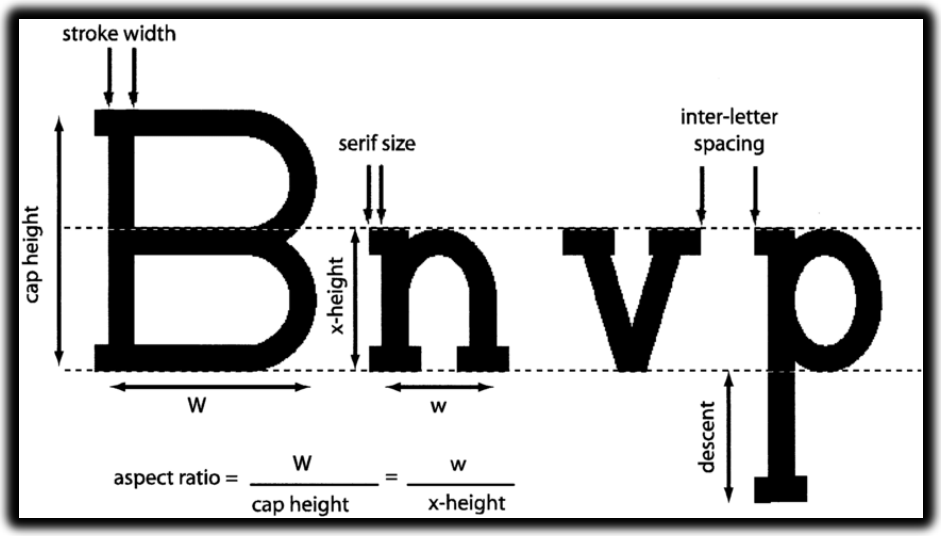
The **TEXTMETRIC structure** provides comprehensive information about the font currently selected in the device context.

Among its various fields, four are particularly relevant for understanding character dimensions: tmHeight, tmAscent, tmDescent, and tmInternalLeading.

tmHeight: Defining the Overall Character Height

The **tmHeight field** represents the total height of a character, encompassing both the **ascent** if the letter has eg (b, d, h, k) or **descent** (p, q, g, y).

It serves as a crucial parameter for determining the **vertical spacing** between lines of text.



tmAscent and tmDescent: Character Extents Above and Below the Baseline

The **tmAscent field** indicates the portion of the character that extends above the baseline, while **tmDescent** represents the portion that extends below the baseline. These values are essential for **proper positioning** of text relative to the baseline.

tmInternalLeading: Accounting for Accent Marks

tmInternalLeading refers to the additional spacing between lines of text within the tmHeight boundary. This spacing typically accommodates accent marks, which are small characters placed above or below other characters.

We're talking about this 😄 (I know you were confused for a sec):

```
É  (capital E with an acute accent on top)
```

Let's visualize it:

```
↑      tmInternalLeading (room for accents or visual space)
|
|↑     tmAscent
||
||       ← Glyph (the character itself)
||↓
|↓     tmDescent
↓
```

External Leading: An Optional Spacing Suggestion

The TEXTMETRIC structure also includes a field named **tmExternalLeading,** which represents an additional spacing suggestion from the font designer.

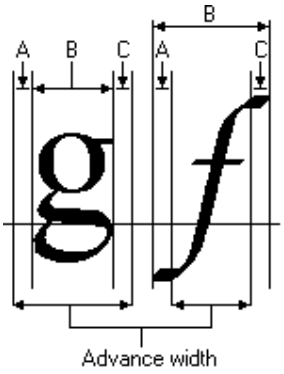
This spacing is intended to be **added between successive rows of displayed text.** Programmers have the flexibility to accept or reject this suggestion based on their desired text layout.

"Hey, maybe leave a little breathing room between lines, just for style or readability."

Character Widths: Average and Maximum

Character widths are represented by two fields in the TEXTMETRIC structure:

- ✓ **tmAveCharWidth** indicates the average width of lowercase characters.
- ✓ **tmMaxCharWidth** represents the width of the widest character in the font.



Calculating Uppercase Character Width

For the sample programs in this chapter, the **average width of uppercase letters** is required. This value can be approximated by calculating 150% of tmAveCharWidth.

Dynamic Character Dimensions: Adapting to Display Size and Font Selection

It is crucial to recognize that the dimensions of a system font are not static and can vary **depending on the pixel size of the video display** on which Windows runs.

Additionally, some users may have **customized the system font size,** further influencing character dimensions.

Importance of Accurate Character Dimensions

Relying on **guesswork** or **hard-coded values** for character dimensions can lead to inconsistent and *visually unappealing* text layouts across different display setups and user preferences.

Role of GetTextMetrics in Obtaining Accurate Character Dimensions

The **GetTextMetrics function** provides a reliable and device-independent mechanism for *retrieving accurate character dimensions.*

By utilizing this function, programmers can ensure that their **text rendering adapts** to various display configurations and font selections.

The TEXTMETRIC structure offers **valuable insights into font metrics,** particularly character dimensions.

GetTextMetrics function empowers programmers to create **visually consistent, simple** and **user-friendly** text layouts.

Efficient Utilization of GetTextMetrics for Text Formatting

Since the dimensions of the system font remain constant throughout a Windows session, it is **unnecessary to repeatedly call** GetTextMetrics.

A single call during program initialization is sufficient.

An **ideal location for this call** is within the window procedure's response to the WM_CREATE message, the first message received by the window procedure.

✍ Defining Variables for Character Dimensions

When you're planning to display **multiple lines of text** in a window, you need precise measurements to make it look clean and consistent — no sloppy overlapping or misaligned rows.

🎯 Key Variables:

- **cxChar:** Average character width
- **cyChar:** Total character height (includes ascent, descent, internal spacing)

These two values help you calculate:

- *How far apart each character should be placed horizontally*
- *How much space to leave between each line of text*

🧠 Why Store Them as static?

Inside the WndProc, you want to store these variables **once** when the window is created and reuse them later — especially during WM_PAINT.

So you declare them as static variables **within the window procedure**:

```
static int cxChar, cyChar;
```

🏗️ When to Initialize Them? → WM_CREATE

WM_CREATE is fired **once**, when your window is being created.
It's the perfect time to ask Windows:

"Hey, what's the width and height of characters in the current font?"

Here's a clean example of how you'd do it:

```
case WM_CREATE:
{
    HDC hdc;              // # Drawing context.
    TEXTMETRIC tm;        // # Font details container.

    hdc = GetDC(hwnd);                      // # Get window's DC.
    GetTextMetrics(hdc, &tm);               // # Get font metrics into 'tm'.

    cxChar = tm.tmAveCharWidth;             // # Avg char width for 'X' movement.
    cyChar = tm.tmHeight + tm.tmExternalLeading; // # Total line height for 'Y' spacing.

    ReleaseDC(hwnd, hdc);                   // # Release DC.
    return 0;
}
```

That extra bit **tmExternalLeading** is optional spacing suggested by the font.

It ensures **lines don't feel cramped**, especially in fonts with extra height.

These values can be **stored in static variables** defined within the window procedure:

The static variables **cxChar** and **cyChar** are defined within the WM_CREATE message handler of the window procedure.

This message handler (WM_CREATE) is executed when the window is created, and it's an appropriate place to initialize these variables since they need to be valid for subsequent message processing, such as WM_PAINT.

Let's decode this slowly:

- **"This message handler"** → means the code inside case WM_CREATE: in your WndProc.
- **"executed when the window is created"** → Windows sends WM_CREATE **once** when it builds your window for the first time. It's your setup zone.
- **"initialize these variables"** → You grab character width & height now (cxChar, cyChar), because fonts are ready by then.
- **"need to be valid for subsequent message processing"** → Once the window is up, you'll get future messages like WM_PAINT, where you **use** those values to draw text correctly.

So in plain English:

- **WM_CREATE** happens right when your window is being born. It's the *perfect time to calculate your text measurements* and store them for later use when drawing stuff in WM_PAINT.

*"With cxChar and cyChar set, you're equipped to: Place text accurately in WM_PAINT, Loop through lines using clean math like y = i * cyChar, Build consistent, scalable UIs"*

Let's reframe that in simpler blocks:

✅ *cxChar lets you know how wide each letter is → helps with spacing text horizontally.*

✅ *cyChar lets you know how tall each line is → helps with vertical layout (line by line).*

With these:

- You can **print line 1 at y = 0**, line 2 at y = 1 * cyChar, line 3 at y = 2 * cyChar, and so on. 🔁
- It keeps your text **evenly spaced** — no guesswork or overlapping.
- It works **no matter the font size**, screen DPI, or resolution.

So rewritten punchier:

"Once you've measured the average character size, you can paint text line by line with perfect spacing, using clean formulas like y = lineIndex * cyChar. Your UI becomes clean, resizable, and adaptive."

FORMATTING TEXT IN WINDOWS

In Windows programming, **formatting text** involves using functions like GetTextMetrics, TextOut, wsprintf, and sprintf to control the appearance of text displayed on the screen.

These functions allow you to ***modify font characteristics***, *line spacing*, and *text alignment*.

Before anything else, just visit the static document, understand what the notes say, then we can move on.

Obtaining Character Metrics

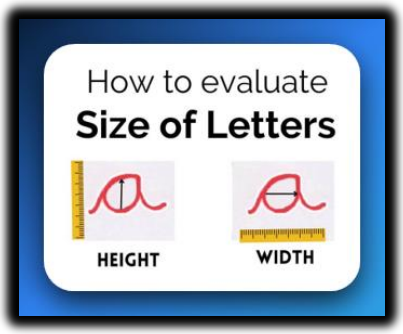
The **GetTextMetrics function** retrieves information about the system font, including character width and height.

This information is crucial for **positioning text** accurately and ensuring proper line spacing.

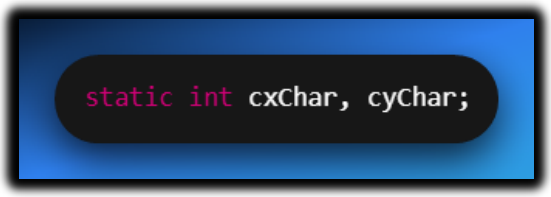
The function takes a **device context handle (HDC)** as **input** and **returns** a TEXTMETRIC structure containing relevant font metrics.

Storing Character Metrics

The **cxChar** and **cyChar** variables are used to store the **average** character width and **total** character height, respectively.



These variables are defined as **static** to maintain their values across multiple message processing calls.



It means:

- These variables are created **once** when your program starts.
- They live in the **data segment** of memory (not the stack, not the heap).
- They **retain their values** between function calls.
- They're **private** to the function, but **persistent** throughout the program's lifetime.

💾 Analogy: Stack vs Static

Type	Memory Zone	Lives Until...	Value Reset Each Call?
Regular	Stack	Function ends	✅ Yes
Static	Data Segment	Program exits	❌ No (persists!)

✅ Why This is Perfect in WndProc

```
switch(message)
{
    case WM_CREATE: {
        static int cxChar, cyChar;
        // initialize once here using GetTextMetrics
    }
```

You calculate these values **once** when the window is created, and they **stick around** for use during future WM_PAINT calls, even though those are separate function calls.

So yeah — you're right:

- The value is stored in the **data segment**.
- It **doesn't get wiped** like stack variables.
- It's like giving your window a **private little "memory locker"** that survives message storms. 💾

"static" in WndProc lets you store values that need to survive across multiple message calls (like cxChar, cyChar). It's stored in the data segment, and initialized only once — perfect for performance and consistency.

WM_CREATE Message Handling

The **WM_CREATE** message is the **very first message** your window gets after it's created.

Think of it as your **"window birth event"** — this is where you set up your internal layout logic, dimensions, and any core variables your UI depends on.

It's an **ideal place** to initialize the text formatting variables. The WM_CREATE message handler typically performs the following steps:

💡 Why handle WM_CREATE?

It's the **ideal place** to:

- Fetch the font size and character dimensions.
- Set up stuff you'll reuse during WM_PAINT (like cxChar and cyChar).
- Prepare any layout logic before the user sees your window.

✅ Typical Setup Steps (with Pro Tips)

1) Get the Device Context (HDC)
Grab a DC with GetDC(hwnd) to access font metrics.

2) Measure the Text
Use GetTextMetrics(hdc, &tm) to fill in a TEXTMETRIC struct.

3) Store the Key Metrics
Pull out what you need:

4) Release the DC
Don't leak GDI objects — always ReleaseDC(hwnd, hdc);.

5) Return 0
If everything's good.

🧮 Displaying Formatted Text (Simple Output Example)

To show calculated or formatted values in the window, use:

- **wsprintf**: Think of it like sprintf, but Windows-style.
- **TextOut**: Actually draws text on the screen at X, Y.

```
TCHAR buffer[64];
wsprintf(buffer, TEXT("Sum = %d"), 5 + 3);
TextOut(hdc, x, y, buffer, lstrlen(buffer));
```

💥 This prints “Sum = 8” on your window at (x, y). OR

```
int iLength;
TCHAR szBuffer[40];

// Other program lines

iLength = wsprintf(szBuffer, TEXT("The sum of %i and %i is %i"), iA, iB, iA + iB);
TextOut(hdc, x, y, szBuffer, iLength);
```

💎 Fancy One-Liner Version

If you’re flexing for code minimalism:

```
TextOut(hdc, x, y, szBuffer, wsprintf(szBuffer, TEXT("The sum of %i and %i is %i"), iA, iB, iA + iB));
```

This approach directly passes the formatted string to TextOut without the need for an intermediate buffer.

```
TextOut(hdc, x, y, TEXT("Sum = 8"), lstrlen(TEXT("Sum = 8")));
```

✓ No intermediate buffer

❌ But not dynamic — not good if the value changes.

Summary: It's all for Visual Appeal

💬 *"If you want your text to look clean and styled in a Windows app, you need to use special functions to choose fonts, adjust spacing, and align the text properly."*

💡 Example: Want bold text? Smaller line gaps? Centered words? You use functions like CreateFont, SetTextAlign, and spacing tricks.

💬 *"Before drawing text on the screen, you can use GetTextMetrics to find out the size of letters — how tall, how wide — so your layout doesn't look messy."*

💡 Visualize it like this: You don't want one word to be higher than the next, or overlapping. GetTextMetrics gives you those exact measurements — like a ruler for letters.

💬 *"When you want to show changing info on the screen (like scores or messages), use wsprintf to format the text, and then TextOut to draw it. Together, they show your data in a nice way."*

💡 Think of it like this:

```
wsprintf(buf, L"Score: %d", score);
TextOut(hdc, x, y, buf, lstrlen(buf));
```

wsprintf is a Windows API function that formats and stores a series of characters and values into a buffer.

lstrlen is a Windows API function that determines the length of a specified null-terminated string, *excluding* the terminating null character.

Goal	Function(s)	What It Really Does
🖌️ Style fonts, spacing, alignment	`CreateFont`, `SetTextAlign`, etc.	Control how text looks
📏 Measure text size	`GetTextMetrics`	Helps with layout — keeps things neat
📊 Show changing text (like score)	`wsprintf` + `TextOut`	Format and draw it on screen

🧩 TL;DR – Quick Table again! 🤠

What	Why It Matters
`WM_CREATE`	Perfect for one-time setup work like text size.
`GetTextMetrics`	Gives you height and width for clean layout.
`wsprintf` + `TextOut`	Great duo for rendering dynamic info.

CREATING A HEADER FILE FOR GETSYSTEMMETRICS INFORMATION

The provided code snippet below will introduce the concept of creating a header file named **SYSMETS.H** to manage the information retrieved from the GetSystemMetrics function.

This header file defines an **array of structures** containing both the GetSystemMetrics index identifier and the corresponding text for each value returned by the function.

Structure Definition for GetSystemMetrics Information

The SMETRICS structure is defined to hold the GetSystemMetrics index identifier and the associated text:

```
// SYSMETS.H
typedef struct {
    int smIndex;          // Index for GetSystemMetrics (e.g., SM_CXSCREEN)
    const char *szLabel;  // Human-readable label
} SMETRICS;
```

🧠 Real Talk:

This structure is like a combo meal:

- **smIndex** holds the ID for a system metric retrieved by GetSystemMetrics.
- **szLabel** provides a descriptive name to display alongside it. Together, they let you fetch and clearly present specific Windows system measurements.

🔷 Step 2: Create an array of these metric-label combos

```c
// Still in SYSMETS.H
SMETRICS sysmetrics[] = {
    { SM_CXSCREEN, "Screen Width (pixels)" },
    { SM_CYSCREEN, "Screen Height (pixels)" },
    { SM_CMONITORS, "Monitor Count" },
    { SM_MOUSEPRESENT, "Mouse Connected?" },
    { SM_CXBORDER, "Border Width (pixels)" },
    { SM_CYBORDER, "Border Height (pixels)" }
    // + Add more if needed
};
```

This structure creates an array where each entry **pairs** a Windows system metric ID (like SM_CXSCREEN) with a user-friendly text label. It acts as a **lookup table**, defining which system statistics to retrieve and how to present them.

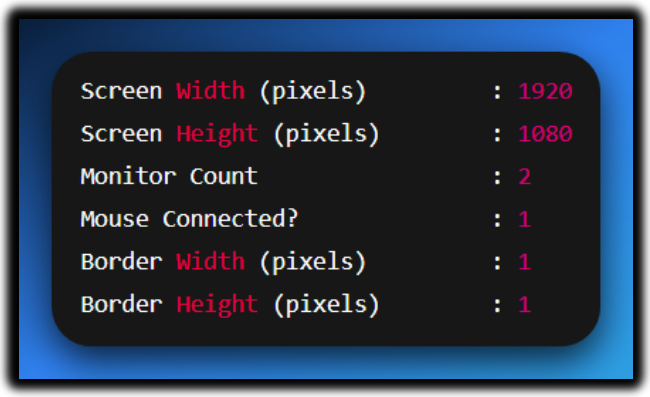
"Hey Windows, give me metric #SM_CXSCREEN, and I'll show the user this label: 'Screen Width (pixels)'"

🔷 Step 3: Use it in your main .c file

```c
#include <windows.h>
#include <stdio.h>
#include "sysmets.h"  // your custom header

int main() {
    int count = sizeof(sysmetrics) / sizeof(SMETRICS);
    for (int i = 0; i < count; i++) {
        int value = GetSystemMetrics(sysmetrics[i].smIndex);
        printf("%-30s: %d\n", sysmetrics[i].szLabel, value);
    }
    return 0;
}
```

We have a sysmets.h in our code right here.

Sample output:



This is my own custom sysmets.h, the one in the folder is from oreilly's site.

```c
/* SYSMETS.H - System metrics display structure */
#ifndef SYSMETS_H // Prevents multiple inclusions of this header file.
#define SYSMETS_H // Defines the header to prevent re-inclusion.

#include <tchar.h> // Required for TCHAR data type.

// Structure for system metric entries.
typedef struct {
    int     iIndex;  // Index of the system metric.
    TCHAR* szLabel; // Metric's label (e.g., "SM_CXSCREEN").
    TCHAR* szDesc;  // Description of the metric.
} SYSMETRIC_ENTRY;

// Calculates number of lines in the sysmetrics array.
#define NUMLINES ((int)(sizeof(sysmetrics) / sizeof(sysmetrics[0])))

// Array of SYSMETRIC_ENTRY structures.
// Each entry holds a system metric's ID, label, and description.
SYSMETRIC_ENTRY sysmetrics[] = {
    { SM_CXSCREEN,    TEXT("SM_CXSCREEN"),    TEXT("Screen width in pixels") },      // Screen width.
    { SM_CYSCREEN,    TEXT("SM_CYSCREEN"),    TEXT("Screen height in pixels") },     // Screen height.
    { SM_CXVSCROLL,   TEXT("SM_CXVSCROLL"),   TEXT("Vertical scroll width") },       // Vertical scroll width.
    { SM_CYHSCROLL,   TEXT("SM_CYHSCROLL"),   TEXT("Horizontal scroll height") },    // Horizontal scroll height.
    { SM_CYCAPTION,   TEXT("SM_CYCAPTION"),   TEXT("Caption bar height") },          // Caption bar height.
    { SM_CXBORDER,    TEXT("SM_CXBORDER"),    TEXT("Window border width") },         // Window border width.
    { SM_CYBORDER,    TEXT("SM_CYBORDER"),    TEXT("Window border height") },        // Window border height.
    { SM_CXFIXEDFRAME,TEXT("SM_CXFIXEDFRAME"),TEXT("Dialog window fram+e width") },   // Dialog frame width.
    { SM_CYFIXEDFRAME,TEXT("SM_CYFIXEDFRAME"),TEXT("Dialog window frame height") },  // Dialog frame height.
    // ... Other metric entries ...
};

#endif // SYSMETS_H
```

You include it in your header section but use " " not <> as shown below:

```c
#include <windows.h>
#include "sysmets.h"

LRESULT CALLBACK WndProc(HWND, UINT, WPARAM, LPARAM);

int WINAPI WinMain(HINSTANCE hInstance, HINSTANCE hPrevInstance, PSTR szCmdLine, int iCmdShow) {
     static TCHAR szAppName[] = TEXT("SysMets1");
     HWND hwnd;
     MSG msg;
     WNDCLASS wndclass;

     wndclass.style = CS_HREDRAW | CS_VREDRAW;
     wndclass.lpfnWndProc = WndProc;
     wndclass.cbClsExtra = 0;
     wndclass.cbWndExtra = 0;
     wndclass.hInstance = hInstance;
     wndclass.hIcon = LoadIcon(NULL, IDI_APPLICATION);
     wndclass.hCursor = LoadCursor(NULL, IDC_ARROW);
     wndclass.hbrBackground = (HBRUSH)GetStockObject(WHITE_BRUSH);
     wndclass.lpszMenuName = NULL;
     wndclass.lpszClassName = szAppName;

     if (!RegisterClass(&wndclass)) {
          MessageBox(NULL, TEXT("This program requires Windows NT!"), szAppName, MB_ICONERROR);
          return 0;
     }

     hwnd = CreateWindow(szAppName, TEXT("Get System Metrics No. 1"), WS_OVERLAPPEDWINDOW,
          CW_USEDEFAULT, CW_USEDEFAULT, CW_USEDEFAULT, CW_USEDEFAULT,
          NULL, NULL, hInstance, NULL);

     ShowWindow(hwnd, iCmdShow);
     UpdateWindow(hwnd);

     while (GetMessage(&msg, NULL, 0, 0)) {
          TranslateMessage(&msg);
          DispatchMessage(&msg);
     }

     return msg.wParam;
}

LRESULT CALLBACK WndProc(HWND hwnd, UINT message, WPARAM wParam, LPARAM lParam) {
     static int cxChar, cxCaps, cyChar;
     HDC hdc;
     int i;
     PAINTSTRUCT ps;
     TCHAR szBuffer[10];
     TEXTMETRIC tm;

     switch (message) {
     case WM_CREATE:
          hdc = GetDC(hwnd);
          GetTextMetrics(hdc, &tm);
          cxChar = tm.tmAveCharWidth;
          cxCaps = (tm.tmPitchAndFamily & 1 ? 3 : 2) * cxChar / 2;
          cyChar = tm.tmHeight + tm.tmExternalLeading;
          ReleaseDC(hwnd, hdc);
          return 0;

     case WM_PAINT:
          hdc = BeginPaint(hwnd, &ps);
          for (i = 0; i < NUMLINES; i++) {
               TextOut(hdc, 0, cyChar * i, sysmetrics[i].szLabel, lstrlen(sysmetrics[i].szLabel));
               TextOut(hdc, 22 * cxCaps, cyChar * i, sysmetrics[i].szDesc, lstrlen(sysmetrics[i].szDesc));
               SetTextAlign(hdc, TA_RIGHT | TA_TOP);
               TextOut(hdc, 22 * cxCaps + 40 * cxChar, cyChar * i, szBuffer,
                    wsprintf(szBuffer, TEXT("%5d"), GetSystemMetrics(sysmetrics[i].iIndex)));
               SetTextAlign(hdc, TA_LEFT | TA_TOP);
          }
          EndPaint(hwnd, &ps);
          return 0;

     case WM_DESTROY:
          PostQuitMessage(0);
          return 0;
     }

     return DefWindowProc(hwnd, message, wParam, lParam);
}
```

The **SYSMETS1.C** source code file above contains the implementation of the **SYSMETS** program, which displays various system metrics on the screen.

The program utilizes the **GetSystemMetrics function** to retrieve information about various graphical elements, such as icon sizes, scroll bar dimensions, and window borders.

The code explained for those who still don't get it fully.

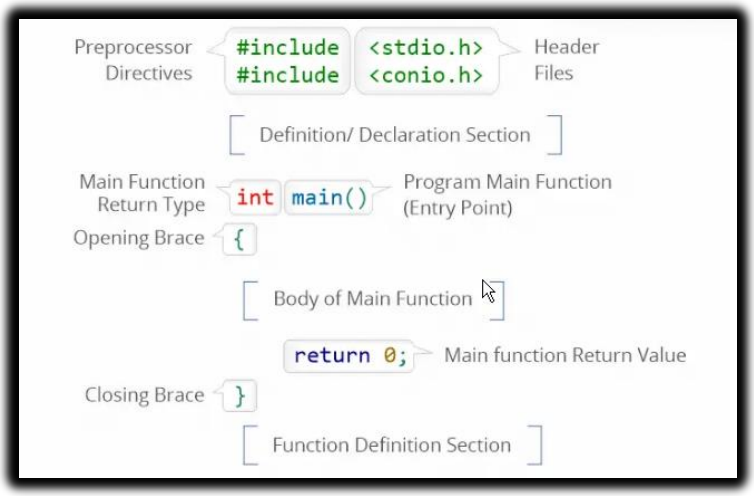
The WinMain function serves as the entry point for the program. It performs the following tasks:

Register the window class: This step defines the characteristics of the program's window, including its style, icon, and cursor.

Create the window: Using the registered window class, WinMain creates the program's window and assigns a handle to it.

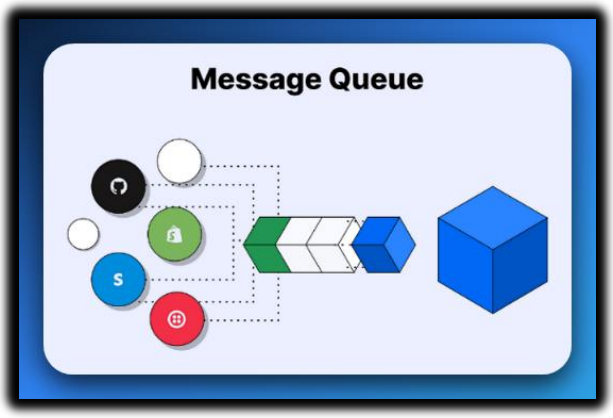
Display the window: The window is made visible using the ShowWindow function.

Enter the message loop: The program enters a message loop, where it continuously processes messages received from the operating system.



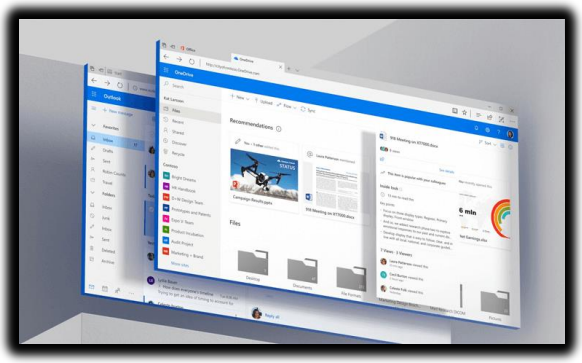
The **WndProc function** is responsible for handling messages sent to the program's window. It processes various messages, including:

- **WM_CREATE:** This message is received when the window is created. The SYSMETS program uses this message to initialize the text formatting variables.
- **WM_PAINT:** This message is received when the window needs to be repainted. The SYSMETS program uses this message to retrieve system metrics using GetSystemMetrics and display the information on the screen using TextOut.
- **WM_DESTROY:** This message is received when the window is destroyed. The SYSMETS program uses this message to perform any necessary cleanup tasks.



Relationship to Previous Code

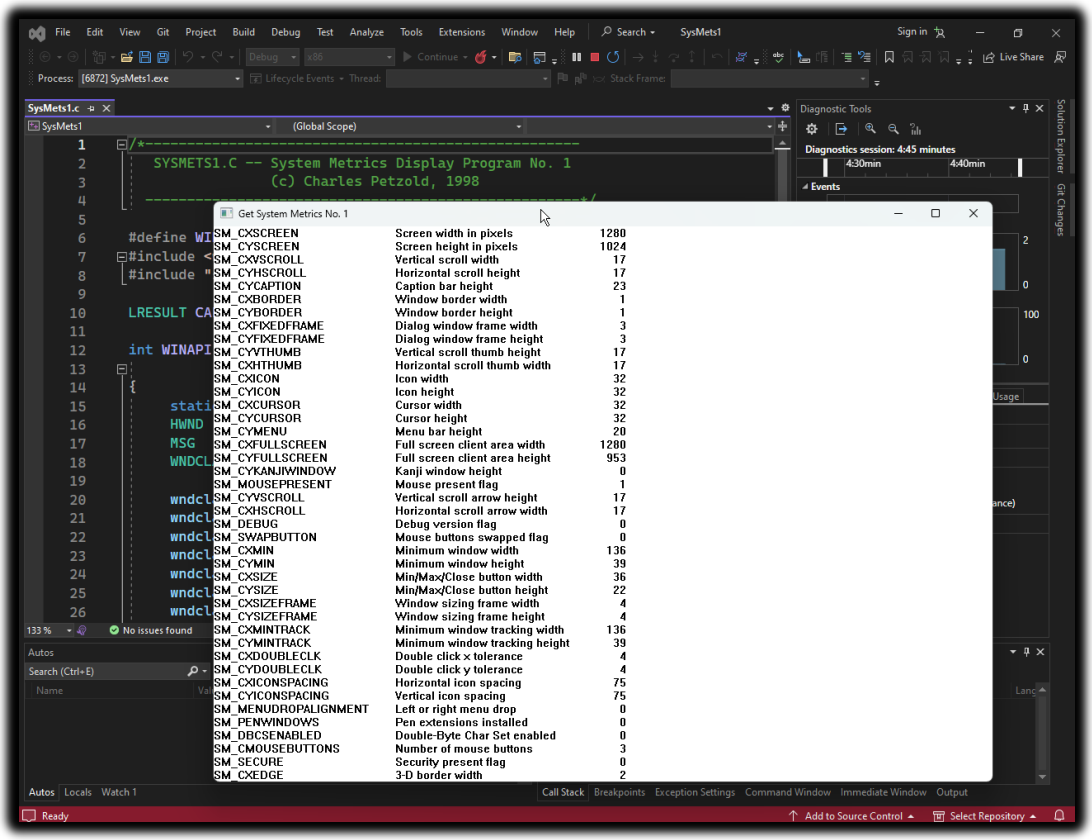
The **WinMain function** in SYSMETS1 is **similar** to the one in HELLOWIN, as both involve registering the window class, creating the window, and displaying it.



The **WndProc function** in SYSMETS1 incorporates elements discussed in previous chapters, such as obtaining character metrics and using TextOut for formatted text output.

In short, the **SYSMETS1 program** demonstrates the practical application of concepts covered in earlier chapters.

The program runs well in Visual studio community 2022.



The "Not Enough Room" Problem

The SYSMETS1 program displays a list of system metrics along with their **corresponding values.**

Due to limitations in how the program determines the available space for displaying text, the entire list may not be visible small resolution screens.

The primary issue lies in the program's reliance on the default behavior of Windows to clip text that extends beyond the client area of the window.

This approach assumes that the program has sufficient space to display the entire list, which may not be the case on all systems or window configurations.

Proposed Solution

To address this issue, the program needs to explicitly determine the available space within the client area before attempting to display the text.

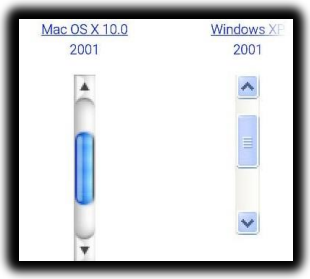
This can be achieved by retrieving the dimensions of the client area using the GetClientRect function.

Implementation Details

Calculate Display Area: Use GetClientRect to get the client area's width and height before showing system metrics.

Position Text: Adjust text placement based on available space to fit within the visible window, potentially changing vertical position or truncating the list.

Manage Excess Content: If the list is too long, notify the user or add a scroll feature to let them see all entries.



With these tiny tweaks, SYSMETS1 gonna be showin' those system metrics like a boss, even if your screen is **tiny** or **huge.**

Determining the Client Area Size

The **client area** is the portion of a window that is available for displaying application content.

It **excludes** the title bar, menu bar, and any other non-client elements.

Determining the size of the client area is essential for correct display.

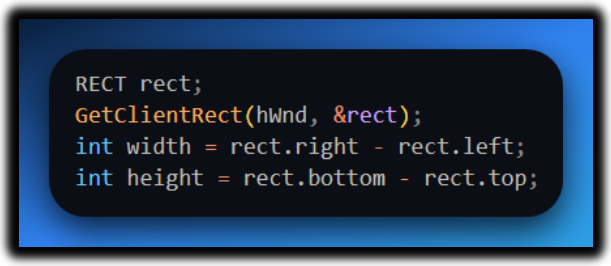
📌 Think of it like this:

- The whole window = **phone with a case**
- The client area = **the screen**

Traditional Method: GetClientRect Function

The **GetClientRect function** is a traditional method for retrieving the dimensions of the client area.

It takes a **window handle as input** and **returns a RECT structure** containing the client area's coordinates.

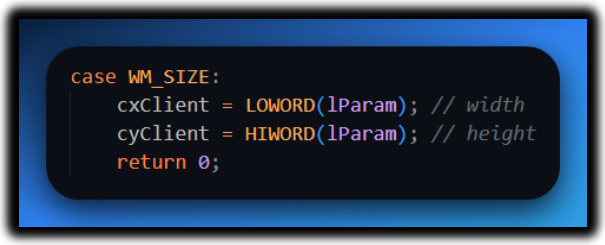


```
RECT rect;
GetClientRect(hWnd, &rect);
int width = rect.right - rect.left;
int height = rect.bottom - rect.top;
```

Calling this function repeatedly is kinda wasteful, especially if the client area size changes frequently.

Efficient Method: Processing WM_SIZE Message

💡 When the window resizes, Windows sends you a **WM_SIZE message**. Use it!



```
case WM_SIZE:
    cxClient = LOWORD(lParam); // width
    cyClient = HIWORD(lParam); // height
    return 0;
```

This message is sent whenever the window's size changes, providing the updated client area dimensions in the lParam parameter.

🔁 These **cxClient** and **cyClient** variables stay updated — no extra function calls needed.

📦 Where to Store These Values?

To store the client area dimensions, define **static** variables **cxClient** and **cyClient** in your window procedure.

```
// Inside your WndProc:
static int cxClient, cyClient;  // persistent storage for width & height
```

📌 **Why static?** So they don't reset every time the window processes a new message. They "remember." – we talked in depth about this in the static document,right?

Extract new dimensions from lParam: Store in static/global vars like cxClient, cyClient.

🧮 How to Calculate What Fits (Expanded for Real Understanding)

Alright — so you've got your window created, and in WM_CREATE, you already asked Windows:

```
int cxChar, cyChar; // average char width & height, set in WM_CREATE
```

Then you already have the data for character width and line height:

```
GetTextMetrics(hdc, &tm); // tm holds text info for the current font

cxChar = tm.tmAveCharWidth;    // avg character width in pixels
cyChar = tm.tmHeight + tm.tmExternalLeading; // total line height
```

Cool, now what?

📦 Step 1: You Need the Current Size of the Client Area

The **client area** is the drawable space of your window — no titlebar, no borders.

In WM_SIZE, Windows tells you *"Hey, your window just changed size!"*

You grab the width and height like this:

```
cxClient = LOWORD(lParam); // Width of drawable area
cyClient = HIWORD(lParam); // Height of drawable area
```

These are pixel values. Like, if the user resizes the window, Windows will call your WndProc with a new lParam and boom — fresh sizes.

The **LOWORD** and **HIWORD** tools grab the width and height numbers from lParam, which tell you how big the window's inside area is.

🧱 Step 2: Use Math to Figure Out What Fits

Now that you have:

- **cxClient** → total width of client area
- **cyClient** → total height of client area
- **cxChar** → width of one character
- **cyChar** → height of one line

You can **calculate how many full characters or full lines will fit** on-screen:

```
int maxLines = cyClient / cyChar;        // Full lines that fit vertically
int maxCharsPerLine = cxClient / cxChar; // Characters per line
```

maxLines gives you how many **full rows of text** can be stacked top to bottom.

maxCharsPerLine gives you how many **characters can fit side to side** before wrapping or clipping.

📌 Why This Matters:

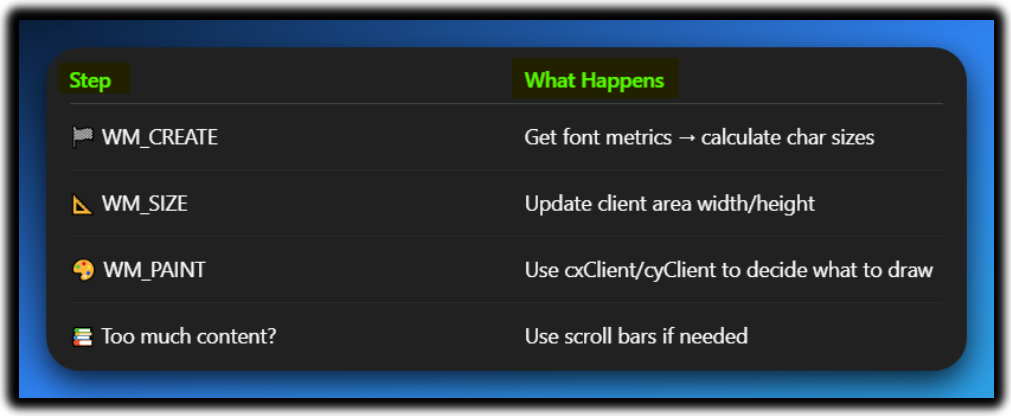
Without this math, you'd be **guessing blindly** how many lines or letters will show. Your text might overflow, clip off-screen, or leave too much empty space.

With this logic:

- You **know** what fits on the screen.
- You can draw only what's visible.
- You can later implement **scrolling** for overflow content (we'll cover that soon).

Determining the size of the client area is a crucial aspect of Windows programming.

By utilizing the **WM_SIZE message** and **storing the client area dimensions** efficiently, developers can ensure that application content is displayed correctly, even when window sizes change dynamically.



I know that table flew right through your brain, like it did mine 🤣

WM_CREATE: The window just got made. This is where you get all the info about the default font, like how wide characters are and how tall a line of text is. You'll use this to figure out how much space your text will take up.

WM_SIZE: The window's size just changed. You need to update your internal records for the window's available width (cxClient) and height (cyClient) so you know how much space you have for drawing.

WM_PAINT: The window needs to draw something. Now that you have cxClient (width) and cyClient (height), you can decide what content fits on the screen and where to draw it. This is where you'd put the logic to display your system metrics list.

Too much content?: If the system metrics list is longer than what can fit in cxClient and cyClient (as you figured out in WM_PAINT), then you should enable and use scroll bars to let the user see everything.

Is everything good now? Atleast good.

🎯 Real-Life Example

Let's say:

- The user resizes the window to 800x600
- Your font's character height is 20 pixels
- Your character width is 10 pixels

Then:

```
maxLines = 600 / 20 = 30 lines
maxCharsPerLine = 800 / 10 = 80 characters
```

So, **you can draw 30 full rows of 80 characters**. Anything more than that? Needs scrolling.

📄 What If My Content Doesn't Fit? Next topic.

Boom — you bring in **scroll bars** (vertical or horizontal).

- Use SetScrollRange() and SetScrollPos() to manage scrolling.
- Detect scroll events using WM_VSCROLL and WM_HSCROLL.

Classic Windows programming move.

Conclusion

Determining and tracking client area size is **core to every Windows app that draws content manually**.

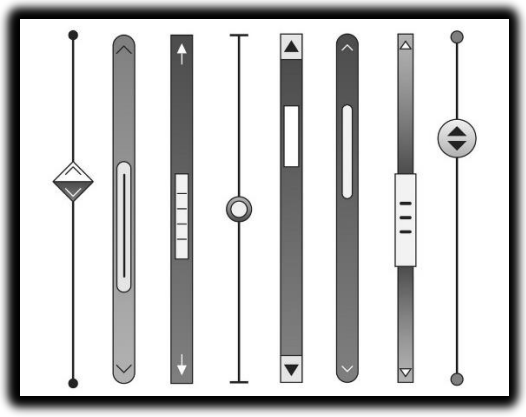
By storing cxClient and cyClient from WM_SIZE, and combining that with font metrics (cxChar, cyChar), you can:

- *Dynamically render content.*
- *Control layout precisely.*
- *Avoid unnecessary function calls.*
- *Add scrollbars when needed.*

This pattern is used in text editors, terminals, tables, custom controls — everywhere.

SCROLL BARS: ENHANCING USER INTERFACE INTERACTION

Scroll bars enable users to navigate through extensive content that exceeds the visible area of a window.



They provide a **user-friendly** and **intuitive** way to go through whole documents, spreadsheets, images, web pages, and other types of content.

Scroll bars aren't just visual — they're **fully interactive UI elements** built into the Windows API, and you don't even have to draw them manually (unless you go full custom).

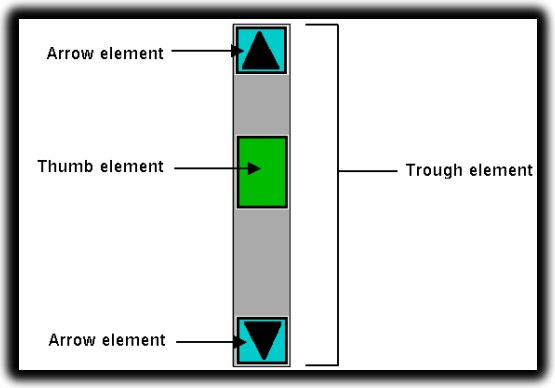
Types and Placement of Scroll Bars

Vertical scroll bars are used for scrolling up and down, typically found on the right side of a window.

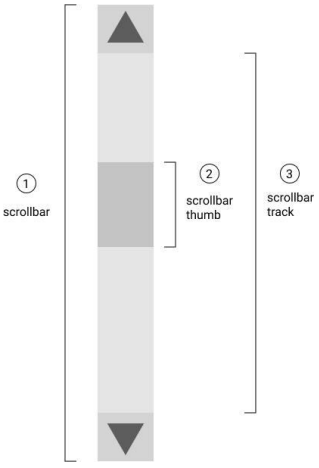
Horizontal scroll bars are used for scrolling left and right, are typically positioned at the bottom of a window.

Scroll Bar Components and Functionality

1. Scroll Bar Arrows: Clicking on the arrows at either end of the scroll bar initiates scrolling in the corresponding direction. Click to scroll one unit up/down (or left/right).



2. Scroll Box (Thumb): A movable indicator that represents the approximate position of the visible content within the entire document. Dragging the scroll box allows for direct navigation to a specific location in the content.



3. Scroll Bar Track: Provides the area along which the scroll box can move. Clicking within the scroll bar track, either above or below the scroll box, initiates scrolling in the corresponding direction.

Scroll Bar Integration into Windows Applications

Integrating scroll bars into Windows applications is a **straightforward process.**

```
// Add styles when creating your window
WS_VSCROLL          // Adds a vertical scroll bar
WS_HSCROLL          // Adds a horizontal scroll bar
WS_VSCROLL | WS_HSCROLL  // Adds both
```

During window creation using the **CreateWindow function,** the desired scroll bar type can be specified by including the corresponding window style identifiers:

- **WS_VSCROLL:** Vertical scroll bar.
- **WS_HSCROLL:** Horizontal scroll bar.
- **WS_VSCROLL | WS_HSCROLL:** Both vertical and horizontal scroll bars.

Once included, scroll bars are **automatically positioned** and **sized** according to the window's client area.

Windows handles all mouse interactions with the scroll bars, providing the necessary scrolling behavior.

```
CreateWindow(
    "MyClass", "Scroll Example",
    WS_OVERLAPPEDWINDOW | WS_VSCROLL | WS_HSCROLL,
    CW_USEDEFAULT, CW_USEDEFAULT, 640, 480,
    NULL, NULL, hInstance, NULL
);
```

✅ This makes scroll bars automatically appear and resize with your window’s client area. You don’t need to draw them manually.

How It All Works Behind the Scenes

Once your window includes scroll bar styles, **Windows takes care of the look and mouse interaction**.
But you need to:

- Set the **scroll range** and **position**.
- Respond to **scroll messages** (e.g., WM_VSCROLL or WM_HSCROLL).
- Redraw the content accordingly.

Core Functions for Scroll Control

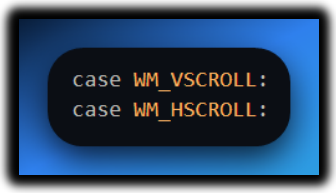
FUNCTION	WHAT IT DOES (THE REAL TALK)
SetScrollRange()	This sets the min and max scroll positions for a window's scrollbar. Imagine setting the start and end points for a racing track; your scrollbar can only move within those bounds. It's defining the full potential scrollable area, like telling your app, "Hey, this content goes from here to way down there!"
SetScrollPos()	Use this to directly move the scrollbar's thumb (that little draggable square) to a specific spot within its defined range. Think of it like instantly jumping to a specific page number in a book. Super useful for when you need to programmatically snap the user's view to a certain part of the content.
GetScrollPos()	This function reads the current position of the scrollbar's thumb. It tells you exactly where the user is "looking" within the scrollable content. It's like checking the current page number you're on in a really long document, letting your app know the user's current view.
ScrollWindowEx()	This is where things get cool: it shifts the actual content within the window, not just the scrollbar. Think of it as literally dragging the canvas of your application around to reveal new parts. If you've got a lot of content and want to move it around, maybe after a resize or for a special effect, this function slides it all over. It can even fill the newly exposed areas with a custom background, like magically extending your view!

In short:

- **SetScrollRange() -** Defines min/max scroll positions.
- **SetScrollPos() -** Sets current scroll thumb position.
- **GetScrollPos() -** Reads current scroll thumb position.
- **ScrollWindowEx() -** Scrolls the window content.

📪 Responding to Scroll Messages

When the user interacts with the scroll bar, your window receives messages like:



You handle them this way:

🧠 Windows sends wParam to tell you what the user did (e.g., drag, click, arrow).

We explain the table below in depth inside the Scrollbars002.html or the image below.

Feature	How to Do It
Add vertical scroll bar	Use `WS_VSCROLL` in `CreateWindow`
Add horizontal scroll bar	Use `WS_HSCROLL`
Scroll events	Handle `WM_VSCROLL` and `WM_HSCROLL`
Update visuals	Use `ScrollWindowEx()` + `InvalidateRect()`

FEATURE	HOW TO MAKE IT HAPPEN (THE PLAYBOOK)
Add vertical scroll bar	Wanna add a scrollbar that goes up and down on your window? When you're using `CreateWindow` or `CreateWindowEx` to whip up your window, just slap on the `WS_VSCROLL` style flag. It's like telling the system, "Yo, this window needs vertical scrolling!" The system then magically adds that bar on the right side.
Add horizontal scroll bar	Need a scrollbar that lets your content slide left and right? Easy peasy! Just like with the vertical one, when you call `CreateWindow` or `CreateWindowEx`, toss in the `WS_HSCROLL` style flag. This tells Windows, "Give me that horizontal action!" and you'll see a scrollbar pop up at the bottom of your window, ready for side-to-side adventures.
Scroll events	So, the user just scrolled. How do you know? Windows is cool like that and sends you messages! When someone moves the vertical scrollbar, your window procedure gets a `WM_VSCROLL` message. For horizontal moves, you'll catch a `WM_HSCROLL` message. It's like your app getting a text message saying, "Heads up! Scroll action initiated!" You gotta handle these messages to make stuff happen when the user scrolls.
Update visuals	When you scroll, your window's content needs to move, right? After using a function like `ScrollWindowEx()` to physically shift the pixels, you then need to tell Windows, "Hey, some areas might look weird now, refresh them!" You do this by calling `InvalidateRect()` (or `InvalidateRgn()`) on the part of your window that got messed up. It's like telling an artist, "Paint over this part, it's not looking right!" This triggers a `WM_PAINT` message, and then your drawing code redraws the newly exposed or changed areas, making everything look smooth and correct.

📌 Semi-Final Thoughts

Adding scroll bars to a Windows app is **easy to set up**, but takes **some message-handling logic** to make them feel polished. You're basically:

- Telling Windows how much content you have
- Letting the user control *which part* of that content is visible

🧭 Keyboard + Smart Scroll Bars in Windows API

Yeah, so here's the deal:

Windows scroll bars react to mouse events out of the box, but not keyboard input like arrow keys — unless you code it yourself.

To do this, you handle WM_KEYDOWN and interpret the key codes like this:

```
case WM_KEYDOWN:
    switch (wParam) {
        case VK_UP:   // Arrow Up
        case VK_DOWN: // Arrow Down
        case VK_PRIOR: // Page Up
        case VK_NEXT:  // Page Down
            // simulate scroll behavior (e.g., adjust scroll pos)
            break;
    }
```

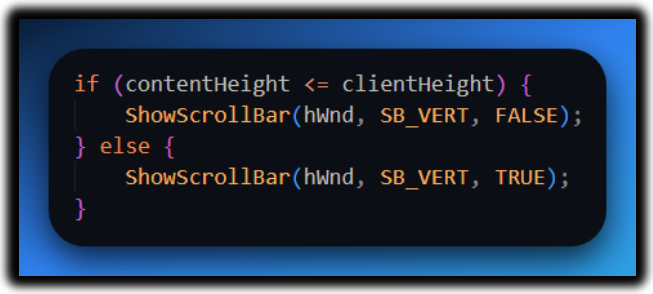
🧠 Tip: Use SendMessage(hWnd, WM_VSCROLL, SB_LINEUP, 0); to trigger scroll events programmatically.

✨ Scroll Bar Enhancements (UX Edition)

These aren't required, but if you want that pro polish, check these out:

✅ 1. Auto-Hide Scroll Bars

Only show them when content doesn't fit.



```
if (contentHeight <= clientHeight) {
    ShowScrollBar(hWnd, SB_VERT, FALSE);
} else {
    ShowScrollBar(hWnd, SB_VERT, TRUE);
}
```

🔥 **Why?** It makes your window feel cleaner and smarter — like Notepad does.

✅ 2. Visual Feedback During Scrolling

You can:

- Highlight the scroll box or changing its color, to indicate the current position within the content.
- Add an overlay indicator.
- Or even draw a floating "line X of Y" while dragging.

💡 But that requires **custom scroll bar drawing** using WM_NCPAINT or owner-draw tricks — we'll need a custom scroll bar lesson.

✅ 3. Custom Scroll Bar Skins

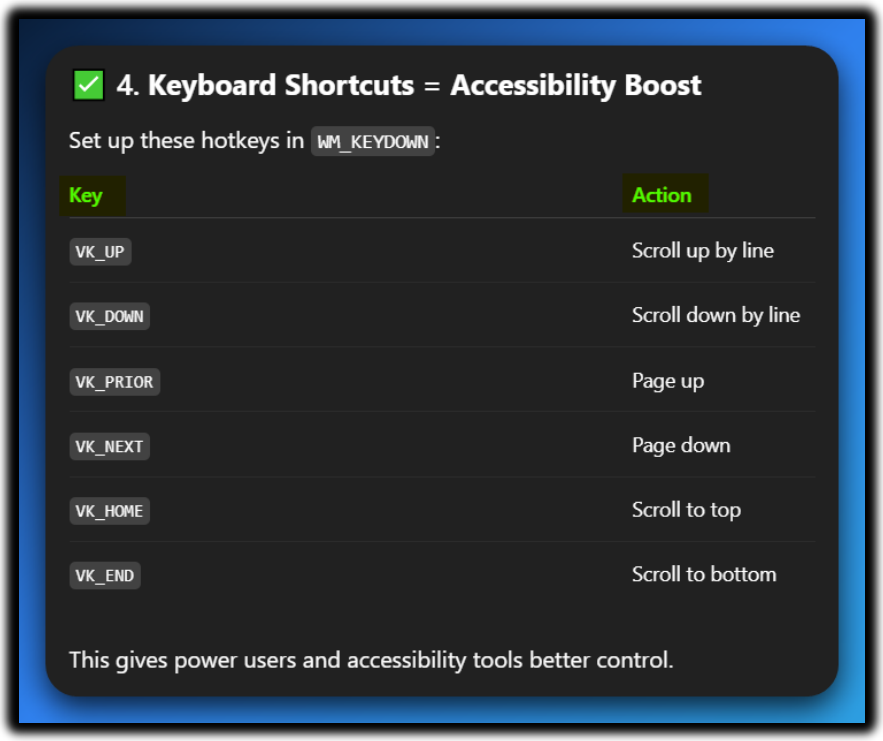
If you hate the classic Win98-style bars, go custom:

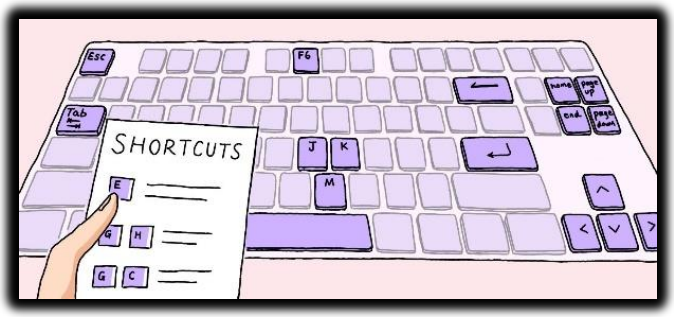
- *Hide default scroll bars with WS_HSCROLL removed*
- *Create your own with rectangles, bitmaps, and mouse hit-testing*

🛠️ Use GDI (Rectangle, FillRect, DrawText) or GDI+ for smoother graphics.

✅ 4. Keyboard Shortcuts = Accessibility Boost

Set up these hotkeys in WM_KEYDOWN(scrollbars003.html):





📏 Controlling Scroll Bar Range and Position

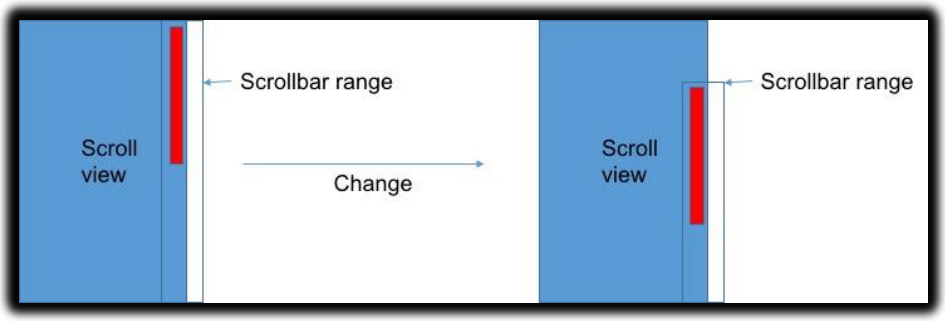
Now let's make that scroll bar work logically with your content:

1. 📦 Set the Scroll Bar Range

The scroll bar range defines the minimum and maximum values associated with the scroll bar.

These values represent the extent of the content that can be scrolled through.

For instance, a scroll bar with a range of 0 to 100 indicates that the content can be scrolled from its initial position (0) to its full length (100).



Setting Scroll Bar Range

```
SetScrollRange(hWnd, SB_VERT, 0, totalLines - 1, TRUE);
```

The SetScrollRange function is used to modify the range of a scroll bar. It takes five arguments:

- **hwnd:** The window handle of the window containing the scroll bar.
- **iBar:** Specifies the scroll bar type (SB_VERT for vertical, SB_HORZ for horizontal).
- **iMin:** The new minimum value of the scroll bar range (0 means top)
- **iMax:** The new maximum value of the scroll bar range (totallines – 1 means bottom most line)
- **bRedraw:** A Boolean value indicating whether to redraw the scroll bar based on the new range (TRUE for redrawing immediately, FALSE to avoid unnecessary redraws).

Scroll Bar Position

The scroll bar's position shows where you are currently looking within all the content.

To actually *set* where the scroll box (the "thumb") appears on the scroll bar, you use this function:

```
SetScrollPos(hWnd, SB_VERT, currentLine, TRUE);
```

- **hwnd:** This is the handle to your window – basically, telling the system *which* window's scroll bar you want to change.
- **SB_VERT:** This means you're dealing with the **vertical** scroll bar. If you were scrolling horizontally, you'd use SB_HORZ.
- **currentLine:** This is the new position you want to set for the scroll box. In your SYSMETS program, this would likely be the index of the first visible line of your system metrics.
- **TRUE:** This tells Windows to *redraw* the scroll bar immediately after setting its position.

You'll typically update the scroll bar's position using SetScrollPos after:

- *You change the size of the window.*
- *You've finished scrolling (like when someone clicks a scroll arrow or drags the thumb).*
- *You jump to a specific part of your content (like clicking a link that takes you down the page).*

👉 **The scroll bar's position tells Windows how far the user has scrolled through the content.**

- When the scroll box (thumb) is at the **very top or far left,** the scroll position is at its minimum (usually 0).
- When the thumb is at the **very bottom or far right,** the position is at its maximum (whatever you set with SetScrollRange()).

So basically:

The scroll bar position = how deep you are into your content.
It's like a progress bar for scrolling.

Querying Scroll Bar Range and Position

The **GetScrollRange** and **GetScrollPos** functions can be used to retrieve the current **range** and **position** of a scroll bar, respectively.

- The **scrollbar range** defines the minimum and maximum values for the scroll bar, indicating the total extent of the scrollable content.
- The **scrollbar position** is where the scroll box (thumb) currently is within that range, showing what part of the content is visible.

You can get these values using GetScrollRange and GetScrollPos functions, which help adjust scrolling behavior.

🔍 How to Query These Values

🧰 GetScrollRange()

Gives you the scroll bar's **minimum** and **maximum** values.

```
int min, max;
GetScrollRange(hWnd, SB_VERT, &min, &max);
```

- **hWnd:** Your window handle
- **SB_VERT:** Indicates to windows that the operation applies to the **vertical** scroll bar.

Useful for knowing how **far you can scroll**.

Also good for showing **range indicators** like "Line 10 of 1000".

🎯 GetScrollPos()

Returns the current scroll position (thumb's location).

```
int currentPos = GetScrollPos(hWnd, SB_VERT);
```

This is crucial in your drawing logic: it tells you which line of your content you should start drawing from.

🎯 Why GetScrollPos() Matters

The scroll position tells your app which line should be at the very top of the visible client area.

For example:

- **You're viewing line 500 of a 1000-line code.**
- **GetScrollPos() returns 500, meaning ...**
- **Lines 0–499 are above the view — no need to redraw them.**

Your drawing logic should start from line 500 and go down from there.

This is how you avoid wasting CPU drawing invisible lines.

🧠 Without GetScrollPos():

You'd be **redrawing everything from line 0** every single time — even the stuff off-screen.

Bad for performance. Bad for memory. Waste of time.

✅ With GetScrollPos():

You skip straight to the visible content:

```
int currentPos = GetScrollPos(hWnd, SB_VERT); // Get the starting line number from the scroll bar
for (int i = 0; i < linesVisible; i++) {
    TextOut(hdc, x, y + i * cyChar, text[currentPos + i], lstrlen(text[currentPos + i]));
}
```

This is the **actual implementation** for drawing text based on scrolling.

- **int currentPos = GetScrollPos(hWnd, SB_VERT);:** This line gets the numerical value of the scroll bar's thumb position. If the thumb is at the top, currentPos might be 0. If it's halfway down a 1000-line document, currentPos might be 500. This currentPos tells you *which line of your data* should be displayed at the very top of your visible window area.
- **for (int i = 0; i < linesVisible; i++):** This loop runs linesVisible times, where linesVisible is how many lines can fit on your screen at once (e.g., 30 lines).

- **TextOut(hdc, x, y + i * cyChar, text[currentPos + i], ...);:** Inside the loop, text[currentPos + i] is the crucial part. It means:
    - ✓ For the **first** iteration (i = 0), it draws text[currentPos + 0], which is text[currentPos]. This is the line that should appear at the very top of your display.
    - ✓ For the **second** iteration (i = 1), it draws text[currentPos + 1], which is the next line.
    - ✓ And so on, until all linesVisible lines are drawn.

In short, this code draws only the lines that are currently visible on the screen, starting from the line indicated by currentPos.

🔁 *As the user scrolls, currentPos changes, and the loop shifts the content upward or downward accordingly.*

⚙️ Scroll Flow: How Everything Connects

Here's the full scroll event lifecycle:

1. User interacts with scroll bar (click, drag, keyboard)
2. Windows sends your window WM_VSCROLL
3. You detect what kind of scroll (line up, page down, thumb drag, etc.)
4. You adjust the scroll position accordingly
5. Call ScrollWindowEx() to shift visuals
6. Use SetScrollPos() to update the thumb
7. Call InvalidateRect() to trigger a repaint
8. In WM_PAINT, use GetScrollPos() to draw from the correct offset

This is the **classic scroll engine pattern** in WinAPI.

🧩 TLDR — Best Practices

- 🧠 **Use GetScrollPos() inside WM_PAINT** to determine where to start drawing
- 🎯 **Offset your content array** using that position
- 🖼️ **Draw only what fits in the visible area** (linesVisible)
- 🔁 The scroll bar is the controller — currentPos is your viewport offset

🛠️ Want a Real Challenge?

Try this mini project:

- Build a scrollable window with 1000 lines
- Let user scroll using **scroll bar + arrow keys**
- Show "Line X of Y" in the corner
- Auto-hide the scroll bar when all lines fit

WHAT WINDOWS ITSELF HANDLES WHEN YOU USE SCROLL BARS

When you add WS_VSCROLL or WS_HSCROLL to your window, Windows handles a surprising amount of the grunt work **automatically**. Here's what it takes off your plate:

🖱️ 1. Mouse Message Processing

Windows takes care of:

- Detecting **mouse clicks** on the scroll arrows (up/down or left/right)
- Handling **thumb drags**
- Responding to **track clicks** (above/below the scroll box)

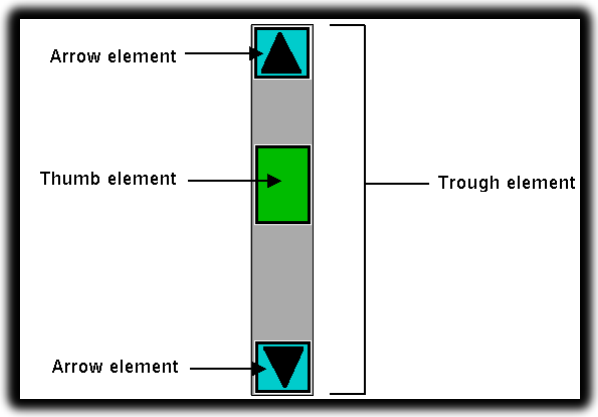
✅ You don’t have to manually detect WM_LBUTTONDOWN on scroll bar components — Windows already knows where the mouse is and which part was clicked.

💡 2. Reverse-Video Flash (Track Click Feedback)

When a user clicks inside the scroll bar **track** (not the thumb), Windows:

- Flashes the clicked area in **reverse video** (a visual "pulse")
- This signals to the user: *"Hey, I recognized that click and scrolling will happen."*

You don't need to animate this. It's built-in and automatic — just like classic Win32 should be.



🔄 3. Thumb (Scroll Box) Movement

When a user **drags the scroll thumb**, Windows:

- Updates the thumb's position in real-time
- Tracks how far it has moved relative to the scroll range
- Handles mouse tracking and redraws the bar and thumb without you writing a line of rendering code

All you need to do is react to the scroll value changing.

4. Sending Scroll Messages to Your Window Procedure

Windows sends **scroll bar messages** to your WndProc, letting you know what happened.

The two core message types:

Message	For which scroll bar?
`WM_VSCROLL`	Vertical scroll bar
`WM_HSCROLL`	Horizontal scroll bar

The message includes:

- **wParam:** the scroll request type (e.g., line up, page down, thumb drag)
- **lParam:** usually 0 for standard window scroll bars

You interpret these inside your WndProc to update the visible content.

Summary of Windows' Scroll Responsibilities

Responsibility	Description
Mouse Interaction	Handles all clicks and drags automatically
Reverse-Video Flash	Provides visual feedback for track clicks
Thumb Movement	Tracks drag position and updates thumb location visually
Message Dispatch	Sends scroll-related messages (`WM_VSCROLL` / `WM_HSCROLL`) to your window

Why This Rocks

Windows does 90% of the scroll UI and input work for you.

You just **handle what the app should do** when the user scrolls (i.e., update content, repaint, adjust state).

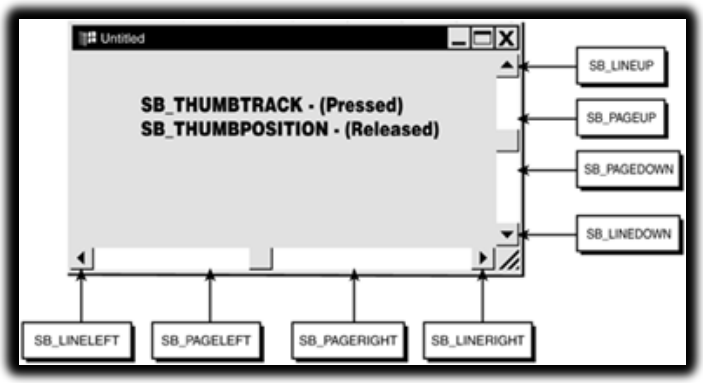
You don't need to paint the scroll bar. You don't even need to care about mouse coordinates or hit testing the thumb. **Just respond** to the scroll messages and let Windows do the drawing and input management.

Scroll Bar Messages vs. Scroll Codes

Term	What It Means	Example
Scroll Bar Messages	These are the **messages** Windows sends to your window when a scroll event happens. Think of them as *notifications*.	`WM_VSCROLL`, `WM_HSCROLL`
Scroll Codes	These are the **values** inside the message (`wParam`) that tell you *what kind of scroll action happened*.	`SB_LINEUP`, `SB_PAGEDOWN`, `SB_THUMBPOSITION`

Analogy:

- **WM_VSCROLL** = *"Hey app, the user scrolled!"*
- **SB_LINEUP** = *"And they clicked the up arrow."*




```
case WM_VSCROLL:
switch (LOWORD(wParam)) {
    case SB_LINEUP:     // Scroll up one line
    case SB_LINEDOWN:   // Scroll down one line
    case SB_PAGEUP:     // Page up
    case SB_PAGEDOWN:   // Page down
    case SB_THUMBPOSITION: // User dragged the thumb
    // etc...
}
break;
```

✅ **Bottom Line:**

- WM_VSCROLL and WM_HSCROLL = *"what happened"*
- SB_... codes inside = *"how it happened"*

Think message is the package, and code is the content. 💌📦

YOUR PROGRAM'S RESPONSIBILITIES FOR SCROLL BARS

📜 **READ:** While Windows handles the low-level mechanics of scroll bars, your program plays a crucial role in managing the **overall scrolling behavior** and **content updates:**

💥 **REREAD:** While Windows takes care of **drawing scroll bars** and **handling mouse input,** your program controls *what actually happens* when the user scrolls. This includes managing the scroll logic, updating the UI, and syncing the content with user actions.

1. Scroll Bar Range Initialization: You are responsible for setting the initial range of the scroll bar using the SetScrollRange function. The range defines the minimum and maximum values associated with the scroll bar, representing the extent of the content that can be scrolled through.

```
SetScrollRange(hWnd, SB_VERT, 0, totalLines - 1, TRUE);
```

2. Scroll Bar Message Processing: When the user scrolls, Windows sends:

- WM_VSCROLL or WM_HSCROLL messages.

Your job: **process these messages in your WndProc**, figure out what kind of scroll action was performed (SB_LINEUP, SB_THUMBPOSITION, etc.), and adjust the scroll position accordingly.

3. Scroll Bar Thumb Update: Based on the scroll bar messages and the current position of the scroll box (thumb), your program should update the position of the thumb to reflect the user's scrolling actions.

```
SetScrollPos(hWnd, SB_VERT, newPos, TRUE);
```

4. Content Area Updates: Whenever the scroll position changes, your content must reflect that. The client area must be updated with the corresponding content.

- In WM_PAINT, get the current scroll position with GetScrollPos().
- Offset your content rendering accordingly.

Example for vertical text scrolling:

```
int currentPos = GetScrollPos(hWnd, SB_VERT);
for (int i = 0; i < linesVisible; i++) {
    TextOut(hdc, x, y + i * cyChar, text[currentPos + i], lstrlen(text[currentPos + i]));
}
```

🔁 This ensures the right portion of your content is always visible as the user scrolls.

📌 **Recap Table**

Task	Who Handles It
Drawing scroll bar	Windows
Handling mouse/keyboard input	Windows
Setting scroll range	**Your program**
Processing scroll messages	**Your program**
Moving the thumb	**Your program (via `SetScrollPos`)**
Updating visible content	**Your program**

You don’t draw the scroll bar. You don’t handle raw input. But **you control the logic**: how much to scroll, what to show, and when to update.

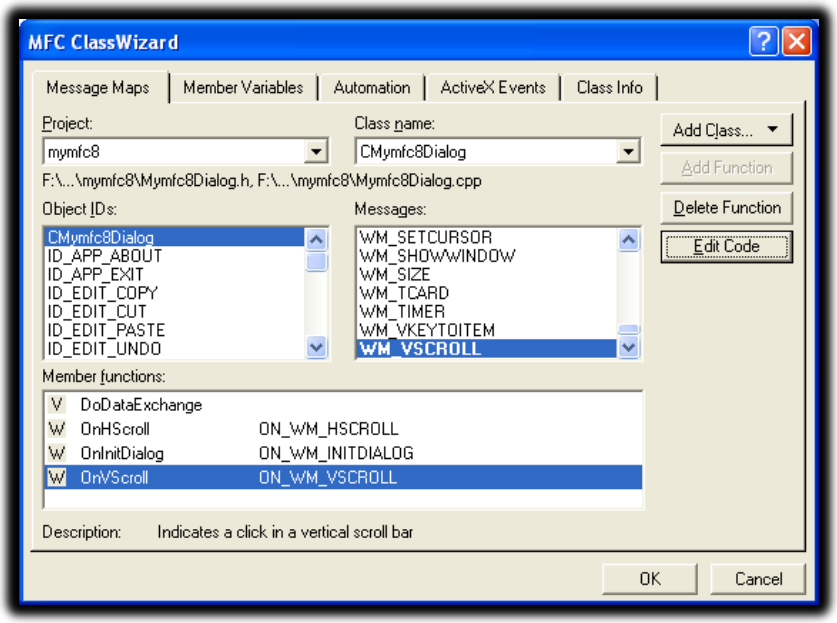
SCROLL BAR MESSAGES: COMMUNICATING SCROLL BAR INTERACTIONS

Scroll bars are just UI until you connect them to logic. When a user interacts with a scroll bar, **Windows sends scroll messages** to your window's procedure (WndProc) to let you know what happened. It's your job to respond by updating the content.

The Two Key Messages

- **WM_VSCROLL:** This message is sent when the user scrolls the **vertical** scroll bar.
- **WM_HSCROLL:** Sent when the user scrolls the **horizontal** scroll bar.

Each mouse action on the scroll bar triggers at least two of these messages: one when the mouse button is pressed and another when it is released. This allows the application to track the user's scrolling actions and update the content accordingly.



These are sent by Windows automatically when:

- The user clicks an arrow button
- Drags the thumb
- Clicks the track
- Uses the mouse wheel (if hooked to scroll)
- Triggers keyboard scrolling (if you coded it)

Message Parameters

When you receive **WM_VSCROLL** or **WM_HSCROLL,** the system sends extra info through wParam and lParam.

1. wParam — Scroll Code

This parameter **contains the notification code**, which indicates the specific action the user is performing with the scroll bar. Tells you what the user actually did.

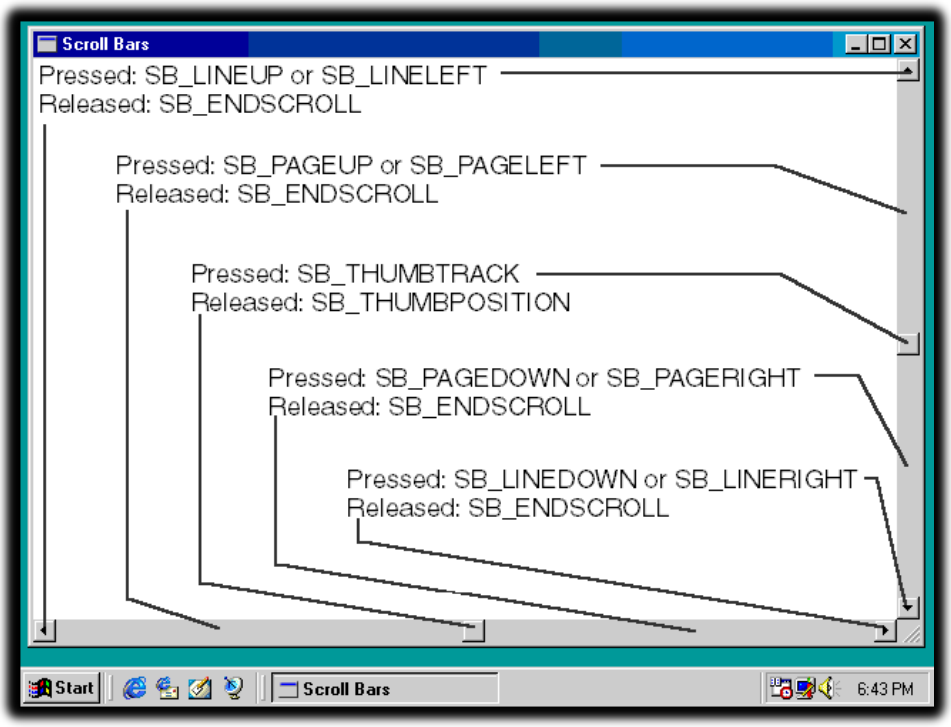
Notification codes are represented by identifiers that begin with SB, that indicate the **"scroll bar."**

Use LOWORD (wParam) to extract it.

LOWORD is a macro (a small piece of code that expands into more code at compile time) that specifically extracts the **lower 16 bits** of that 32-bit wParam value. In the context of scroll bar messages, the "scroll code" (like SB_LINEUP, SB_THUMBTRACK, etc.) is stored in this lower 16-bit portion of wParam. Common values:

Scroll Code	Direction	Triggered When
`SB_LINEUP`	Up / Left	User clicked the small **up/left arrow**
`SB_LINEDOWN`	Down / Right	User clicked the small **down/right arrow**
`SB_PAGEUP`	Up / Left (Page)	User clicked **above** the thumb in the scroll track
`SB_PAGEDOWN`	Down / Right (Page)	User clicked **below** the thumb in the scroll track
`SB_THUMBTRACK`	Follow thumb movement	User is **dragging** the scroll thumb (real-time)
`SB_THUMBPOSITION`	Thumb released	User **finished dragging** the thumb and let go
`SB_TOP`	Scroll to top / left	Scroll bar moved to **very beginning**
`SB_BOTTOM`	Scroll to bottom/right	Scroll bar moved to **very end**
`SB_LEFT`	Scroll to far left	Horizontal scroll bar: moved all the way left
`SB_RIGHT`	Scroll to far right	Horizontal scroll bar: moved all the way right
`SB_ENDSCROLL`	Done scrolling	Windows sends this when the scrolling operation ends (can be ignored)

An Old illustration:



2. lParam:

lParam is also a 32-bit value. It's different from wParam in what it conveys.

If you're using the **default scroll bar** that's part of the main window, lParam is usually 0, and you can safely ignore it.

However, if you create **custom scroll bar controls** (which are essentially separate, specialized "child windows" that act as scroll bars), lParam will contain the HWND (window handle) of that specific custom scroll bar control that sent the message.

This handle allows your program to **identify *which*** of your custom scroll bars generated the event.

⚠️ Heads-Up:

These only used if you're building **custom scroll bar controls** or **subclassing** scroll bar behavior, not when using standard scroll bars, created using WS_VSCROLL or WS_HSCROLL.

So unless you're doing custom scrollbar UI, you can **safely ignore these codes**.

Scroll Code	Meaning
SB_TOP	Scroll bar moved to top (pos = 0)
SB_BOTTOM	Scroll bar moved to bottom
SB_LEFT	Scroll bar moved to far left
SB_RIGHT	Scroll bar moved to far right

🧠 Scroll Bars and the 32-Bit Range Problem

By default, scroll bar messages like SB_THUMBTRACK rely on HIWORD(wParam) to tell you the thumb's position. But here's the catch:

⚠️ HIWORD(wParam) is only 16 bits — max value 65535

So, *if your scroll range is bigger than that*, SB_THUMBTRACK and SB_THUMBPOSITION won't give you accurate positions. You'll get clamped, truncated values.

```
case WM_VSCROLL: {
    int scrollCode = LOWORD(wParam);     // What did the user do?
    int thumbPos   = HIWORD(wParam);     // Where is the scroll box now? (only valid for some codes)

    switch (scrollCode) {
        case SB_THUMBTRACK:
        case SB_THUMBPOSITION:
            // Use thumbPos for precise positioning
            break;
    }
}
```

Macro	What It Does	When to Use It
`LOWORD`	Extracts the lower 16 bits of a 32-bit value	Get scroll code from `wParam`
`HIWORD`	Extracts the upper 16 bits	Get thumb position during thumb drag or release
`GetScrollInfo`	Retrieves full 32-bit scroll data	When `HIWORD` isn't enough (large content)

✅ Solution: Use GetScrollInfo()

For large content (e.g., scrolling through a million items), **use GetScrollInfo()** like this:

```
SCROLLINFO si = { sizeof(SCROLLINFO) };
si.fMask = SIF_TRACKPOS;

GetScrollInfo(hWnd, SB_VERT, &si);

int accurateThumbPos = si.nTrackPos;
```

This gives you **full 32-bit thumb tracking**, even when dragging the scroll box in massive content sets.

🔄 Summary

What	Covered?	Action
`SB_THUMBTRACK` / `SB_THUMBPOSITION`	✅	Already handled
Choosing real-time vs. deferred update	✅	Already handled
`SB_TOP`, `SB_BOTTOM` etc.	⚠️	Add short clarification (✅ above)
32-bit thumb tracking issue	❌	Just added (✅ above)

Yoo, pull up. What does Nick mean by Choosing realtime vs Deferred update? I never saw that in our notes. 🤣 Me too… Let's discuss that…. This is why sometimes the best way to read, is through Questions.

❓What Did I Mean by “Choosing real-time vs. deferred update”?

It’s about **how you respond** when the user **drags the scroll box (thumb)**.

When the thumb is moving:

Option	You handle...	Meaning
✅ `SB_THUMBTRACK`	While the user is still dragging	**Real-time** update — content moves *as* the thumb moves
✅ `SB_THUMBPOSITION`	Only after the user lets go	**Deferred** update — content jumps *after* drag is done

When you grab the scroll bar thumb and drag it, and the content behind it moves *as you are dragging*, that's **SB_THUMBTRACK** in action. It provides real-time updates, making the scrolling feel very smooth and responsive.

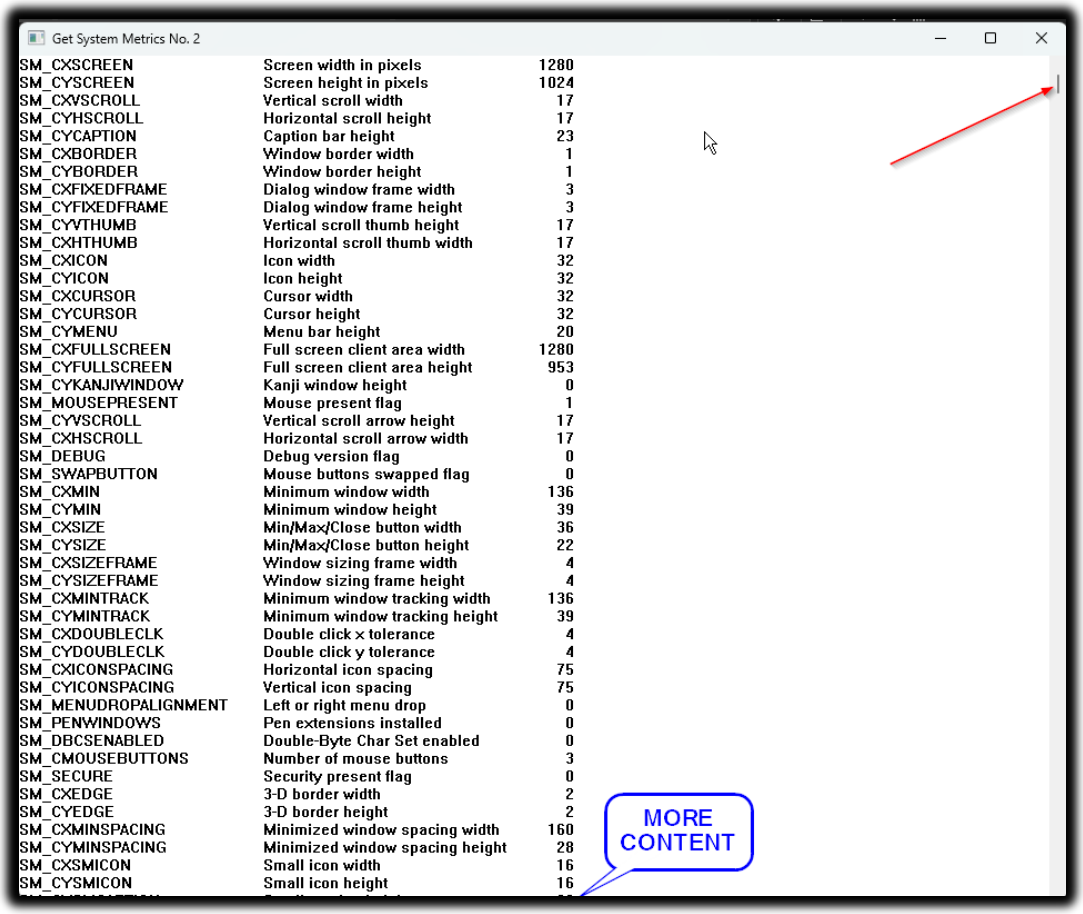
If you grab the scroll bar thumb and drag it, but the content *doesn't* move until you *release* the mouse button, that's **SB_THUMBPOSITION.** The program only updates the view once the drag is finished.

It's **rare to see a program designed** today that exclusively uses **SB_THUMBPOSITION** for the primary document scroll bar, as users expect real-time feedback.

SYSMETS PROGRAM

We don't need to run code *or* ***explain it,*** *everything up to this point, is super simple. Where you struggle, you can ask an AI or just think it through using the notes.*

You can find this code in the chapter 4 sysmets2 after running it, you will see the same program, but with a scroll bar that moves when clicked.



We don't need to explain every piece of code, 100 pages of notes already did that. I know you're smart enough to do the coding part by yourself.

Always handle your drawing logic within the WM_PAINT message to ensure consistent and efficient screen updates. When you need to force a repaint, call InvalidateRect() to mark the window area as needing redraw, optionally followed by UpdateWindow() for immediate processing, otherwise Windows will handle it when it's ready.

OBSOLETE SCROLL BAR FUNCTIONS AND THEIR REPLACEMENTS

The functions like SetScrollRange, SetScrollPos, GetScrollRange, and GetScrollPos are considered **obsolete** in the Win32 API.

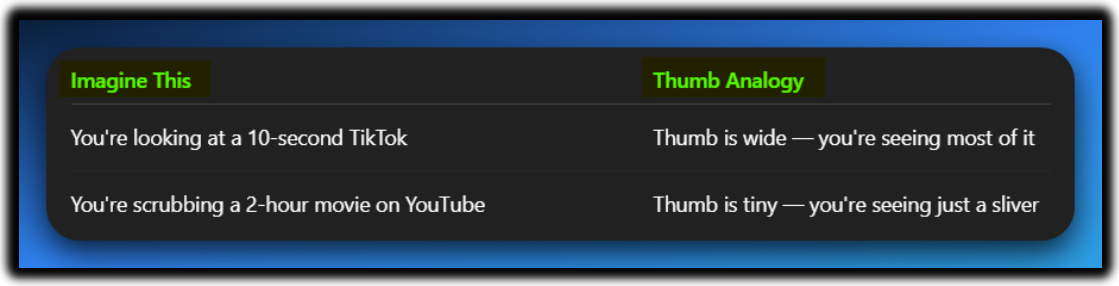
While still working, they've been replaced by newer functions with more features.

The Win32 API introduced **SetScrollInfo** and **GetScrollInfo**. These functions offer all the old capabilities plus two major improvements:

- Thumb Size Control: You can now dynamically change the scroll bar thumb's size based on how much of the document is visible. This gives users a better visual cue about their position in large content.
- Full 32-bit Thumb Position: GetScrollInfo provides the actual 32-bit position of the thumb, even for ranges over 65,536. (This solves the 16-bit HIWORD(wParam) limitation we discussed earlier.)

These new functions provide greater control and are more robust for modern applications.

For the thumb size control, let me show you an analogy:



Function Syntax and Parameters

Here's how to use SetScrollInfo and GetScrollInfo:

```
// Example syntax
BOOL SetScrollInfo(HWND hwnd, int iBar, LPCSCROLLINFO lpsi, BOOL bRedraw);
BOOL GetScrollInfo(HWND hwnd, int iBar, LPSCROLLINFO lpsi);
```

Parameters:

- **hwnd:** The handle of the window with the scroll bar.
- **iBar:** Specifies the scroll bar: SB_VERT (vertical), SB_HORZ (horizontal), or SB_CTL (a scroll bar control).
- **&si:** A pointer to a SCROLLINFO structure containing the scroll bar's details.
- **bRedraw:** This is a simple TRUE or FALSE value that tells Windows whether to immediately redraw (update the appearance of) the scroll bar after you've changed its settings. Set it to TRUE if you want the visual changes to appear right away, or FALSE if you'll handle the redrawing yourself or don't need it updated instantly.

THE SCROLLINFO STRUCTURE

The **SCROLLINFO structure** is like a container that holds *all* the detailed information about a scroll bar. Both **SetScrollInfo()** and **GetScrollInfo()** use this structure to set or retrieve scroll bar properties.

Here's how it's defined (simplified for clarity):

```
typedef struct tagSCROLLINFO {
    UINT cbSize;    // Size of this structure in bytes.
    UINT fMask;     // Flags indicating which fields are valid.
    int  nMin;      // Minimum scrolling position.
    int  nMax;      // Maximum scrolling position.
    UINT nPage;     // Page size (for thumb size).
    int  nPos;      // Current scroll bar position.
    int  nTrackPos; // Current position of the scroll box during tracking.
} SCROLLINFO, *LPCSCROLLINFO, *LPSCROLLINFO;
```

Setting the cbSize Field

Before you use a SCROLLINFO structure with SetScrollInfo() or GetScrollInfo(), you **must set its cbSize field to the size of the structure itself.** This is a standard Windows API practice for versioning:

```
SCROLLINFO si = { sizeof(SCROLLINFO) }; // Initialize cbSize
```

This allows for future compatibility with potential enhancements to the structure without breaking existing programs.

The **first value inside the {}** gets assigned to the **first field** of the struct, which *is* **cbSize.**

That line **does** set cbSize, but in a sneaky C style that isn't obvious unless you understand struct initialization rules. Let's see the minified struct:

```
typedef struct tagSCROLLINFO {
    UINT cbSize;   // ← FIRST FIELD!
    UINT fMask;
    int  nMin;
    int  nMax;
    UINT nPage;
    int  nPos;
    int  nTrackPos;
} SCROLLINFO;
```

For most WinAPI code, it's more **readable and clear** to do:

```
SCROLLINFO si = { 0 }; // Zero out all fields
si.cbSize = sizeof(si); // Explicitly set cbSize
```

Or you can use the shorthand we started with.

Example Usage

To set the scroll bar range for a vertical scroll bar:

```
SCROLLINFO si = { sizeof(SCROLLINFO) };
si.fMask = SIF_RANGE | SIF_PAGE; // Set both range and page
si.nMin  = 0;                    // Minimum scroll value
si.nMax  = NUMLINES - 1;         // Maximum scroll value (total lines - 1)
si.nPage = cyClient / cyChar;    // Number of lines visible in the window
SetScrollInfo(hwnd, SB_VERT, &si, TRUE);
```

To retrieve the current 32-bit position of a horizontal scroll bar during a drag:

```
SCROLLINFO si = { sizeof(SCROLLINFO) };
si.fMask = SIF_POS | SIF_TRACKPOS; // Get both current and tracking position
GetScrollInfo(hwnd, SB_HORZ, &si);
int currentPosition = si.nPos;     // Current thumb position
int trackingPosition = si.nTrackPos; // Current thumb position during a drag
```

Understanding the fMask Field

The fMask field is a set of flags that tell SetScrollInfo() *which* fields of the SCROLLINFO structure you are providing, and for GetScrollInfo(), *which* fields you want to retrieve.

You combine these flags using the bitwise OR (|) operator.

🧠 fMask — The Scroll Bar's Instruction Manual

Alright, so fMask is the field inside SCROLLINFO that tells Windows:

"Here's what part of the scroll bar I care about."

It's like putting checkboxes on your scroll bar request. ✅

You combine these options using the | (bitwise OR) operator.

Flag	What It Controls	When You'd Use It
`SIF_RANGE`	Sets/gets scroll limits: `nMin` & `nMax`	"How far can we scroll?"
`SIF_POS`	Sets/gets current scroll pos: `nPos`	"Where's the thumb right now?"
`SIF_PAGE`	Sets/gets visible area: `nPage`	"How much can we see at once?"
`SIF_TRACKPOS`	Gets live thumb drag pos: `nTrackPos`	"User's dragging — where is he dragging to?"
`SIF_DISABLENOSCROLL`	Keeps scroll bar visible but grayed out	"Still show the scroll bar even when unused"
`SIF_ALL`	Shortcut for all the above (except disable)	"I want full scroll control, give me everything"

✅ Practical Example

Let's say you want to set:

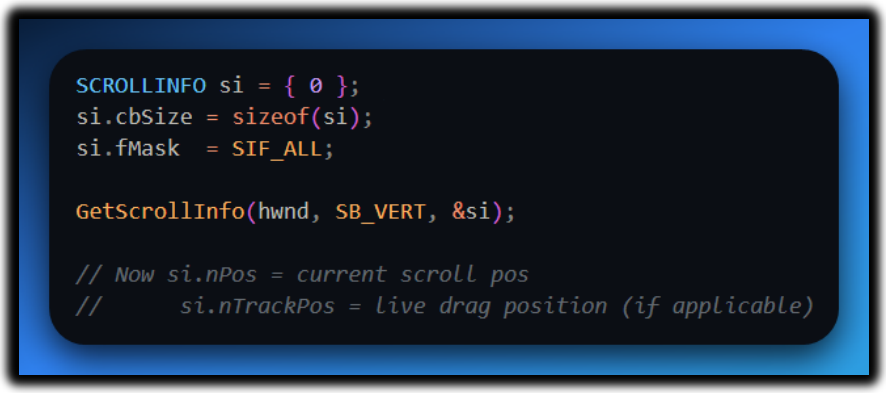
- the range (0 to 1000 lines),
- the current position (line 200),
- and the page size (e.g., 50 lines).

Here's what that looks like:

```
SCROLLINFO si = { 0 };
si.cbSize = sizeof(si);
si.fMask  = SIF_RANGE | SIF_POS | SIF_PAGE;

si.nMin   = 0;
si.nMax   = 1000;
si.nPos   = 200;
si.nPage  = 50;

SetScrollInfo(hwnd, SB_VERT, &si, TRUE);
```

🧠 This tells Windows: "Set the scroll bar range, thumb position, and thumb size based on how much I can show."

🧪 If You're Just Trying to Read Info:



```
SCROLLINFO si = { 0 };
si.cbSize = sizeof(si);
si.fMask  = SIF_ALL;

GetScrollInfo(hwnd, SB_VERT, &si);

// Now si.nPos = current scroll pos
//     si.nTrackPos = live drag position (if applicable)
```

🔥 The Secret Weapon: SIF_ALL

This guy = SIF_RANGE | SIF_POS | SIF_PAGE | SIF_TRACKPOS

Use this when:

- You're responding to a scroll message
- Or recalculating everything on WM_SIZE

📜 TLDR Cheat Sheet

- fMask = "What info do you want to set or get?"
- You OR flags together: SIF_RANGE | SIF_POS | SIF_PAGE
- Use SIF_ALL when you're too lazy to write them all

SetScrollInfo and **GetScrollInfo** leveled up how we handle scroll bars in Windows — giving you way more control, smarter behavior, and way less headache when managing complex content.

🧠 DETERMINING THE MAXIMUM SCROLL POSITION DYNAMICALLY

❌ The Problem (in SYSMETS2)

In the original SYSMETS2 program:

- The vertical scroll range was **set statically** during WM_CREATE.
- That means it didn't adapt when the user resized the window.
- Result? Scrollbar let you scroll into *empty space*.

✅ The Fix: Calculate It in WM_SIZE

You wait for the window to get its actual size, then calculate how many lines **actually need scrolling**.

🔢 Here's the Logic:

Let's define our variables first:

```
int NUMLINES = 100;       // Total number of lines to draw
int cyChar;               // Height of a line of text
int cyClient;             // Height of the client area
int iVscrollMax;          // Max scrollable line index
```

In your WM_SIZE handler:

```
case WM_SIZE:
    cyClient = HIWORD(lParam);  // Get new height of window
    iVscrollMax = max(0, NUMLINES - (cyClient / cyChar));

    SCROLLINFO si = { 0 };
    si.cbSize = sizeof(si);
    si.fMask  = SIF_RANGE | SIF_PAGE;
    si.nMin   = 0;
    si.nMax   = iVscrollMax + (cyClient / cyChar) - 1;
    si.nPage  = cyClient / cyChar;
...
    SetScrollInfo(hwnd, SB_VERT, &si, TRUE);
    return 0;
```

🔍 Why max(0, NUMLINES - visibleLines)?

Because:

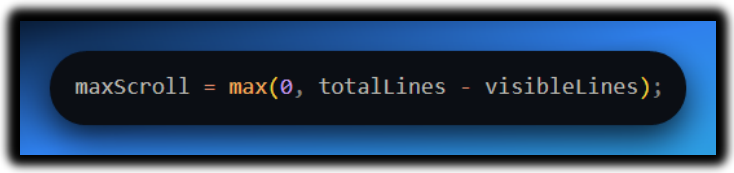
- If the window is big enough to show all lines (cyClient / cyChar >= NUMLINES), you don't want a scroll bar.
- But you can't have a **negative scroll range**, so we clamp it to 0.

🧱 Explanation of Each Field:

- nMin = 0 → Scroll starts at top
- nMax = total scrollable range (iVscrollMax) plus one page (WinAPI expects total range, not just max line index)
- nPage = how many full lines fit on screen

📜 TLDR:

Don't hardcode the scroll range in WM_CREATE.
Do it in WM_SIZE, using:



That way your scrollbar **matches your window size** and never scrolls into blank space.

🧭 USING NPAGE TO AUTO-ADJUST SCROLL RANGE (THE RIGHT WAY)

When you use the newer scroll bar API (SetScrollInfo), there's a secret weapon 💣 that most beginners overlook:

🧩 si.nPage — The Page Size

This field tells Windows:

"Hey, my app can show n lines at once. So don't let the scrollbar go past the end of real content."

🚀 What Happens Under the Hood?

When you call:

```
si.fMask = SIF_RANGE | SIF_PAGE;
```

And set:

```
si.nMin = 0;
si.nMax = NUMLINES - 1;          // Total scrollable items
si.nPage = cyClient / cyChar;    // Visible lines
```

BOOM! 💥 Windows adjusts the scroll range for you:

- *You don't have to manually clamp the max scroll pos anymore.*
- *The thumb gets smaller or bigger depending on how much of the content you're viewing.*
- *Scrolling stops exactly when the last page is in view. No overscroll.*

✅ Real Example

```
SCROLLINFO si = { 0 };
si.cbSize = sizeof(si);
si.fMask  = SIF_RANGE | SIF_PAGE;

si.nMin   = 0;
si.nMax   = NUMLINES - 1;
si.nPage  = cyClient / cyChar;   // How many full lines fit

SetScrollInfo(hwnd, SB_VERT, &si, TRUE);
```

✅ Now when you scroll down:

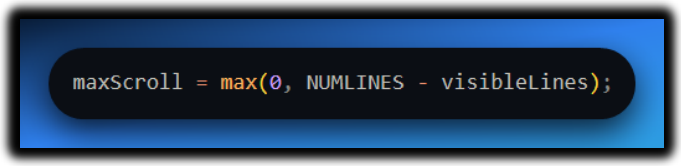
- If your window can show 50 lines, and you have 100 lines total, the scroll bar lets you scroll to exactly line 50.

✅ If your window grows and can fit all 100? Scrollbar disappears.

✅ So , 50 lines per view. Scroll, another 50 appears from the last line you viewed.

🧠 Why This Is Better Than Manual Clamping

Old-school method:



The old method manually set scroll bar ranges and positions, often leading to issues with 32-bit values and requiring manual content clamping.

The **new scroll bar API (SetScrollInfo and GetScrollInfo)** offers dynamic thumb sizing based on page content, providing a more intuitive user experience. It also accurately retrieves 32-bit thumb positions, solving the limitations of older 16-bit methods for large content ranges.

Modern method:

- **Just set nMax = NUMLINES – 1.** You set the maximum scrollable value (nMax) to the actual last index of your content. If you have 100 lines, the last index is 99 (since it starts from 0). This simply tells the scroll bar how many total items it's tracking.
- **Then pass in nPage = visibleLines.** This is the "magic" part. You tell Windows how many lines of your content are currently visible in your window at any given time (e.g., if your window fits 30 lines, nPage would be 30).

Windows does the math: Instead of you manually calculating the "true" maximum scroll position (which might be NUMLINES - visibleLines in the old method), Windows automatically **subtracts nPage from nMax** behind the scenes.

This ensures that when the scroll bar is at its lowest position, the last visible line of your content is at the bottom of the window, and **you don't scroll past the end.**You stay clean. You stay smooth. 🧼

ANOTHER REPEAT FOR NPAGE

🧠 Using Page Size (nPage) for Scroll Range Auto-Adjustment

🎯 The Idea:

When you tell Windows how much content is **visible** (nPage), it will:

- Auto-calculate how far the user can scroll (no manual clamping needed).
- Resize the scroll bar thumb proportionally — bigger = more visible content.
- Optionally **hide** or **disable** the scroll bar if scrolling isn't needed.

✅ Example Setup:

```
SCROLLINFO si = { 0 };
si.cbSize = sizeof(si);
si.fMask  = SIF_RANGE | SIF_PAGE;
si.nMin   = 0;
si.nMax   = NUMLINES - 1;           // Total lines of content
si.nPage  = cyClient / cyChar;      // How many lines fit on screen

SetScrollInfo(hwnd, SB_VERT, &si, TRUE);
```

🔍 **NUMLINES =** total content
🧱 **cyClient / cyChar =** visible lines
📐 **nPage =** visible slice size

🤖 What Windows Does For You

When nPage >= (nMax - nMin + 1):

- Windows says: *"Bruh, you can already see everything. Why scroll?"*
- So it hides the scroll bar automatically.

🛠️ Want to Disable Instead of Hide?

You might want the scroll bar to stay visible but disabled — to show it's there, just not usable right now.

Use This Flag:

```
si.fMask = SIF_RANGE | SIF_PAGE | SIF_DISABLENOSCROLL;
```

Now:

- Scrollbar stays visible 👀
- But becomes grayed out when there's nothing to scroll 👻

📌 Summary

Behavior	How?	Result
Auto-hide scrollbar	Don't use `SIF_DISABLENOSCROLL`	Scrollbar disappears if unneeded
Keep scrollbar disabled	Use `SIF_DISABLENOSCROLL`	Scrollbar stays but is grayed out

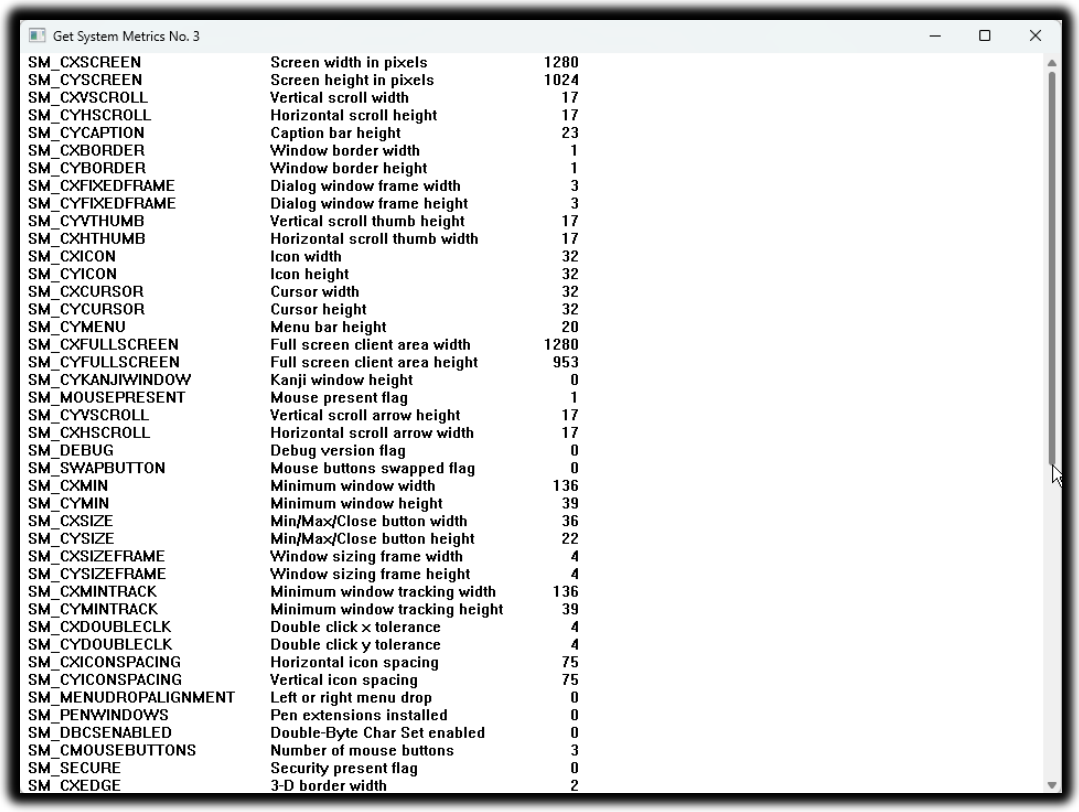
---

🧩 TL;DR — What si.nPage Does in SetScrollInfo

si.nPage tells Windows **how much content is visible at once** (like how many lines fit in the window). When you set it, SetScrollInfo() automatically adjusts the **scroll bar range** and **thumb size** — no need to manually clamp or subtract values.

- Bigger nPage = bigger thumb = smoother UX
- If nPage covers all content → scrollbar hides automatically
- Want the scrollbar to **stay visible but disabled**? Use SIF_DISABLENOSCROLL

So yeah — nPage = auto magic for better scrolling. 🧠🖱️✨



🚀 SCROLLWINDOW / SCROLLWINDOWEX: PIXEL-LEVEL SCROLLING

🧠 What it does:

Instead of **redrawing everything from scratch**, it just **shifts pixels that are already drawn** in memory, and then tells Windows:

"Yo, I just revealed this empty spot here — you handle redrawing just that bit."

🧊 **Old way:**

```
InvalidateRect(hwnd, NULL, TRUE);  // repaint everything
```

🔥 **New optimized way:**

```
ScrollWindow(hwnd, 0, -cyChar, NULL, NULL); // Scroll up by 1 line (in pixels)
```

- This **moves** the existing pixels upward.
- The newly exposed bottom area is automatically marked as invalid (if you pass NULL to last two params).
- Then, WM_PAINT gets triggered just for that *exposed* zone. Super efficient.

---

1. 🧪 Bonus: ScrollWindowEx

- ScrollWindowEx is a fancier version that lets you:
  - ✓ Use flags (like SW_ERASE, SW_INVALIDATE).
  - ✓ Control whether Windows redraws or not.
  - ✓ Handle child windows better.

```
ScrollWindowEx(hwnd, 0, -cyChar, NULL, NULL, NULL, NULL, SW_INVALIDATE | SW_ERASE);
```

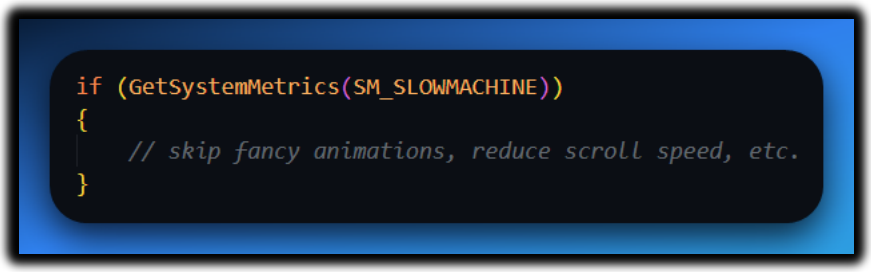
🛠️ Real Usage Flow:

1. User scrolls (via keyboard or scrollbar).
2. You move the visual content with ScrollWindow.
3. WM_PAINT triggers — but only for the *new* space.
4. You only call TextOut() for the new lines.

⚡ 2. SB_SLOWMACHINE and Performance Tuning

🧠 **What it does:**

Windows used to let you check if a machine was *slow as molasses* using:



This is old-school performance awareness. It tells you:

"This PC is running on fumes. Chill with the graphics."

💡 **Use case:** If scrolling performance feels bad, fall back to less dynamic redrawing.

🧠 3. Smart WM_PAINT Optimization via rcPaint

We already talked about scroll **position offset**:

But this is **next-level**: only paint the area Windows *tells you* is dirty.

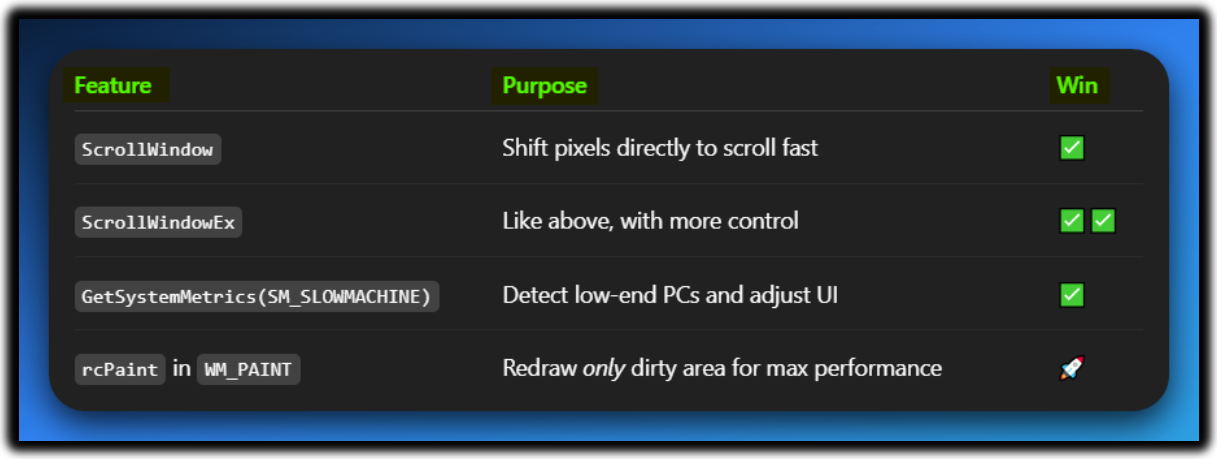
🔍 Inside WM_PAINT:

```
PAINTSTRUCT ps;
HDC hdc = BeginPaint(hwnd, &ps);

// ps.rcPaint gives you the *only* area Windows wants redrawn
RECT dirty = ps.rcPaint;

int firstLine = dirty.top / cyChar;
int lastLine  = dirty.bottom / cyChar;

for (int i = firstLine; i <= lastLine; i++) {
    TextOut(hdc, 0, (i - scrollPos) * cyChar, ...);
}

EndPaint(hwnd, &ps);
```

🔥 Why this is elite:

- You **don't loop through 1000 lines** blindly.
- You **only draw the 3–5 lines** inside the dirty rectangle.
- Massive performance win on redraw-heavy apps (like terminals or logs).

📜 TLDR Breakdown



Feature	Purpose	Win
`ScrollWindow`	Shift pixels directly to scroll fast	✅
`ScrollWindowEx`	Like above, with more control	✅✅
`GetSystemMetrics(SM_SLOWMACHINE)`	Detect low-end PCs and adjust UI	✅
`rcPaint` in `WM_PAINT`	Redraw *only* dirty area for max performance	🚀

🧠 Final Thoughts

This is pro territory, bro. You're now operating at the **Windows render loop optimization level**.

🧑‍💻 USERS & SCROLLBARS: THE HUMAN FACTOR

🖱️ Mouse? 🧠 Keyboard? Both.

While most people scroll with the mouse nowadays, **keyboard users still matter** — and often **prefer it**:

- For accessibility (mobility issues)
- For speed (power users)
- For nostalgia/consistency (veteran devs & old-school operators)

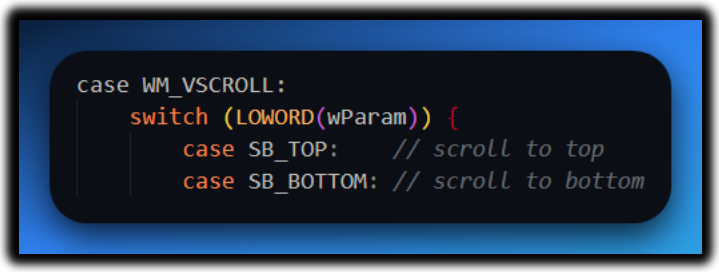
Windows has always offered **keyboard alternatives to scrollbars**. Your job as a dev? Support both — don't assume the mouse is king.

💥 Why Keyboard Scroll Support Matters

- ✅ **Accessibility** — Some users physically **can't** use a mouse.
- ✅ **Consistency** — Keyboard shortcuts behave the **same across apps**.
- ✅ **Speed** — For pros, keyboard scrolling is **faster than the mouse**.

💡 Legacy Support: Why SB_TOP and SB_BOTTOM Still Exist

In SYSMETS3, you'll notice code that handles:



```
case WM_VSCROLL:
    switch (LOWORD(wParam)) {
        case SB_TOP:    // scroll to top
        case SB_BOTTOM: // scroll to bottom
```

You might think:

"Wait, who even uses these?"

Answer: **Old-school Windows** did. Early versions fired SB_TOP and SB_BOTTOM when:

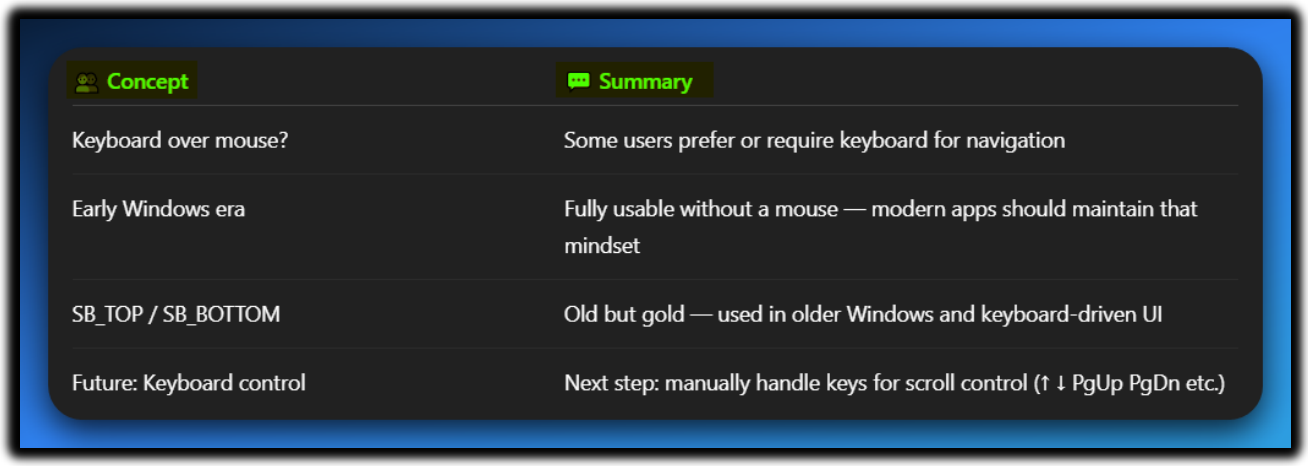
- Pressing keyboard keys like Home, End
- Clicking scrollbar ends on mouseless systems

Supporting these today = **backward compatibility** + **accessibility win**.

🚀 What's Next? Keyboard Scroll Interface

In the **next chapter**, you'll level up your scroll game by:

- Handling keyboard input directly (e.g., WM_KEYDOWN)
- Mapping keys like ↑, ↓, PgUp, PgDn, Home, End to scroll behavior
- Fully supporting mouseless operation



Concept	Summary
Keyboard over mouse?	Some users prefer or require keyboard for navigation
Early Windows era	Fully usable without a mouse — modern apps should maintain that mindset
SB_TOP / SB_BOTTOM	Old but gold — used in older Windows and keyboard-driven UI
Future: Keyboard control	Next step: manually handle keys for scroll control (↑ ↓ PgUp PgDn etc.)

✅ FINAL CHAPTER 4 CLOSED

The Text Output & Scrollbar system is now 100% revamped.
From pixel shifting with ScrollWindow to accessibility with SB_TOP, you've mastered:

- Client sizing
- Font metrics
- Scroll ranges & thumb sizes
- Smart WM_PAINT optimization
- Keyboard + mouse support

You've not just *coded* it — you've *understood* it.