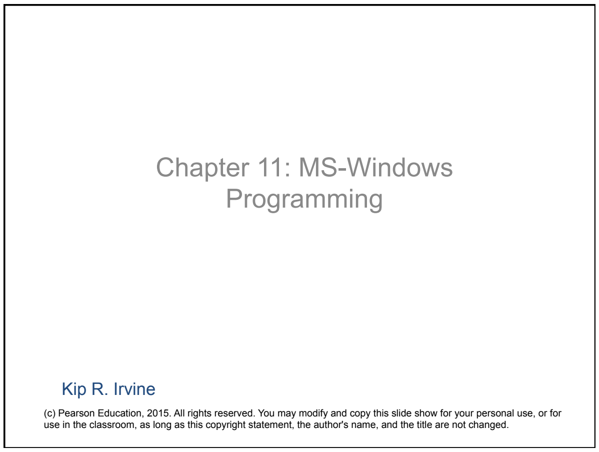
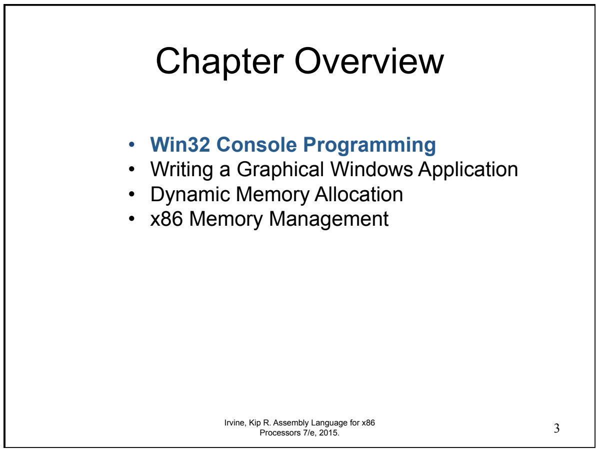


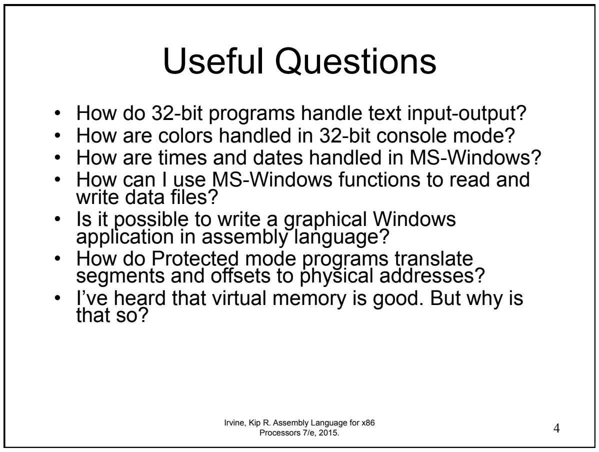
Chapter 11: MS-Windows Programming

Kip R. Irvine



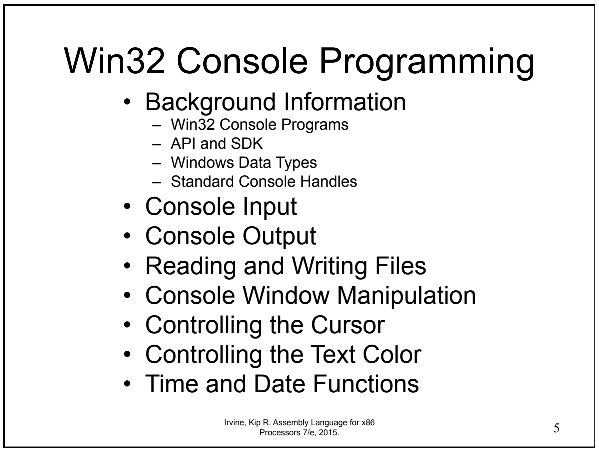
Chapter Overview

- **Win32 Console Programming**
- Writing a Graphical Windows Application
- Dynamic Memory Allocation
- x86 Memory Management



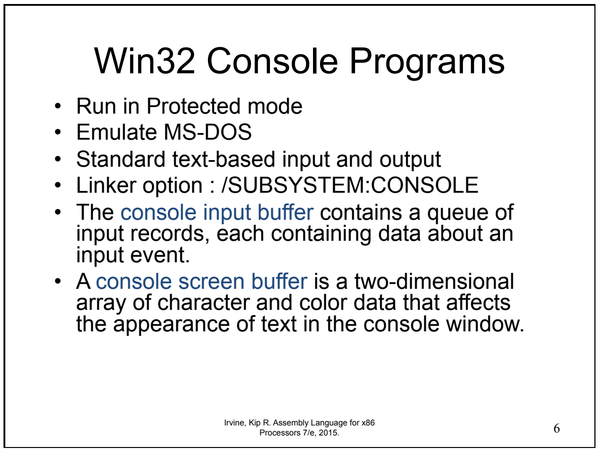
Useful Questions

- How do 32-bit programs handle text input-output?
- How are colors handled in 32-bit console mode?
- How are times and dates handled in MS-Windows?
- How can I use MS-Windows functions to read and write data files?
- Is it possible to write a graphical Windows application in assembly language?
- How do Protected mode programs translate segments and offsets to physical addresses?
- I've heard that virtual memory is good. But why is that so?



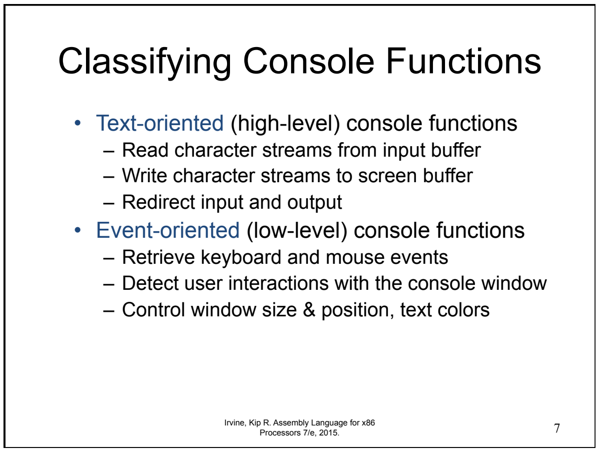
Win32 Console Programming

- Background Information
  - Win32 Console Programs
  - API and SDK
  - Windows Data Types
  - Standard Console Handles
- Console Input
- Console Output
- Reading and Writing Files
- Console Window Manipulation
- Controlling the Cursor
- Controlling the Text Color
- Time and Date Functions



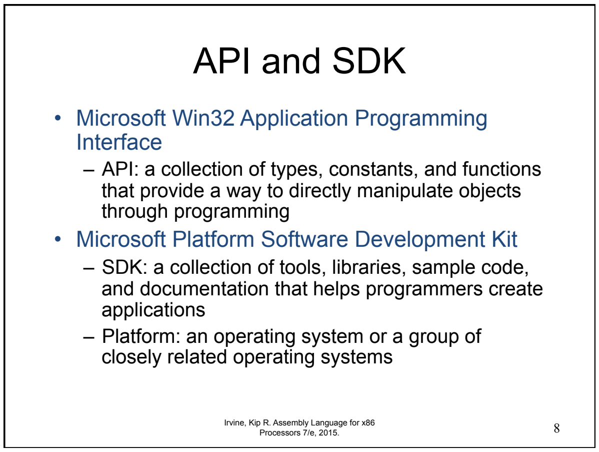
Win32 Console Programs

- Run in Protected mode
- Emulate MS-DOS
- Standard text-based input and output
- Linker option : /SUBSYSTEM:CONSOLE
- The console input buffer contains a queue of input records, each containing data about an input event.
- A console screen buffer is a two-dimensional array of character and color data that affects the appearance of text in the console window.



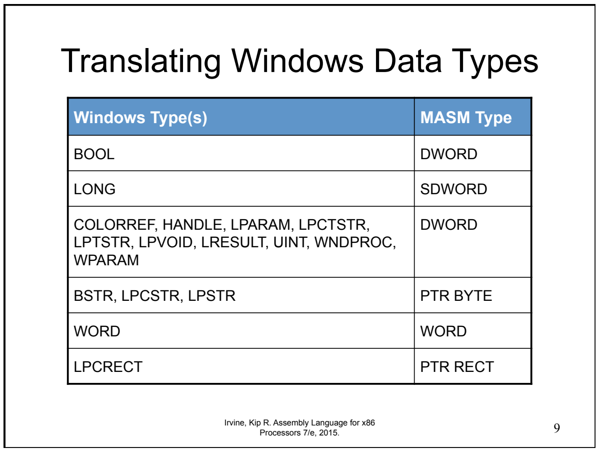
Classifying Console Functions

- Text-oriented (high-level) console functions
  - Read character streams from input buffer
  - Write character streams to screen buffer
  - Redirect input and output
- Event-oriented (low-level) console functions
  - Retrieve keyboard and mouse events
  - Detect user interactions with the console window
  - Control window size & position, text colors



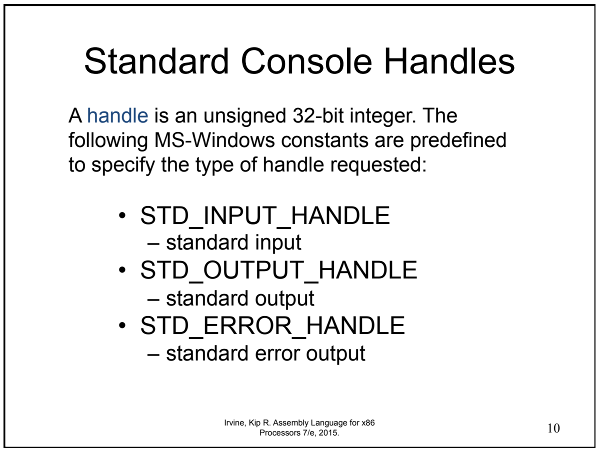
API and SDK

- Microsoft Win32 Application Programming Interface
  - API: a collection of types, constants, and functions that provide a way to directly manipulate objects through programming
- Microsoft Platform Software Development Kit
  - SDK: a collection of tools, libraries, sample code, and documentation that helps programmers create applications
  - Platform: an operating system or a group of closely related operating systems



Translating Windows Data Types

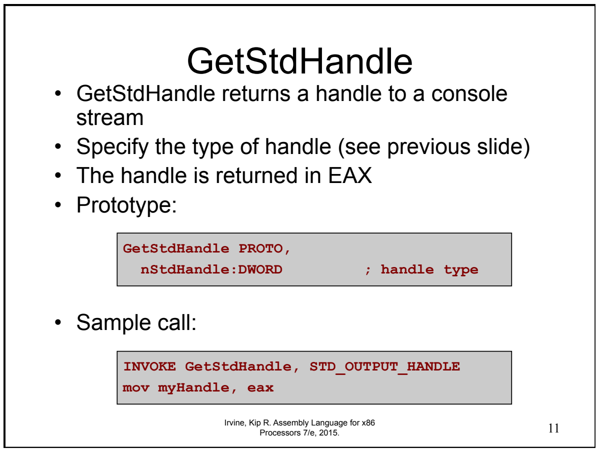
Windows Type(s)	MASM Type
BOOL	DWORD
LONG	SDWORD
COLORREF, HANDLE, LPARAM, LPCTSTR, LPTSTR, LPVOID, LRESULT, UINT, WNDPROC, WPARAM	DWORD
BSTR, LPCSTR, LPSTR	PTR BYTE
WORD	WORD
LPCRECT	PTR RECT



Standard Console Handles

A handle is an unsigned 32-bit integer. The following MS-Windows constants are predefined to specify the type of handle requested:

- STD_INPUT_HANDLE
  - standard input
- STD_OUTPUT_HANDLE
  - standard output
- STD_ERROR_HANDLE
  - standard error output



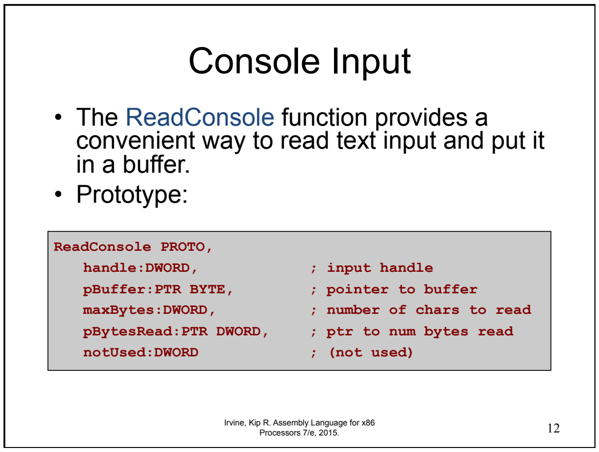
GetStdHandle

- GetStdHandle returns a handle to a console stream
- Specify the type of handle (see previous slide)
- The handle is returned in EAX
- Prototype:

```
GetStdHandle PROTO,
  nStdHandle:DWORD          ; handle type
```

- Sample call:

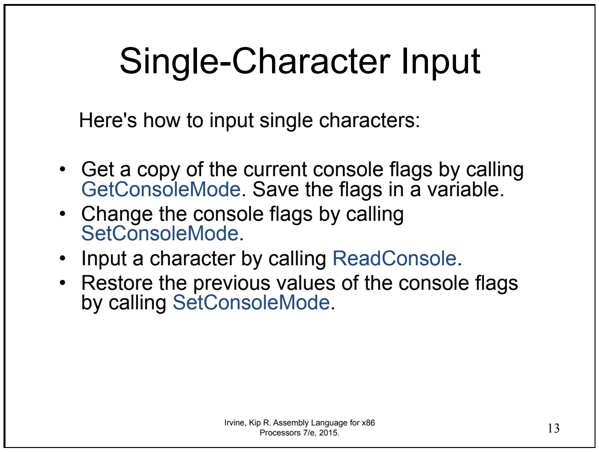
```
INVOKE GetStdHandle, STD_OUTPUT_HANDLE
mov myHandle, eax
```



Console Input

- The ReadConsole function provides a convenient way to read text input and put it in a buffer.
- Prototype:

```
ReadConsole PROTO,
   handle:DWORD,            ; input handle
   pBuffer:PTR BYTE,        ; pointer to buffer
   maxBytes:DWORD,          ; number of chars to read
   pBytesRead:PTR DWORD,    ; ptr to num bytes read
   notUsed:DWORD            ; (not used)
```



Single-Character Input

Here's how to input single characters:

- Get a copy of the current console flags by calling GetConsoleMode. Save the flags in a variable.
- Change the console flags by calling SetConsoleMode.
- Input a character by calling ReadConsole.
- Restore the previous values of the console flags by calling SetConsoleMode.

Excerpts from ReadChar (1 of 2)

From the ReadChar procedure in the Irvine32 library:

```
.data
consoleInHandle DWORD ?
saveFlags DWORD ?                  ; backup copy of flags

.code
; Get & save the current console input mode flags
INVOKE GetConsoleMode, consoleInHandle, ADDR saveFlags

; Clear all console flags
INVOKE SetConsoleMode, consoleInHandle,        0
```

Excerpts from ReadChar (2 of 2)

From the ReadChar procedure in the Irvine32 library:

```
; Read a single character from input
INVOKE ReadConsole,
      consoleInHandle,          ; console input handle
      ADDR buffer,              ; pointer to buffer
      1,                        ; max characters to read
      ADDR bytesRead,           ; return num bytes read
      0                         ; not used

; Restore the previous flags state
INVOKE SetConsoleMode, consoleInHandle,        saveFlags
```

COORD and SMALL_RECT

- The COORD structure specifies X and Y screen coordinates in character measurements, which default to 0-79 and 0-24.
- The SMALL_RECT structure specifies a window's location in character measurements.

```
COORD STRUCT
    X WORD ?
    Y WORD ?
COORD ENDS
```

```
SMALL_RECT STRUCT
  Left   WORD ?
  Top    WORD ?
  Right  WORD ?
  Bottom WORD ?
SMALL_RECT ENDS
```

WriteConsole

- The WriteConsole function writes a string to the screen, using the console output handle. It acts upon standard ASCII control characters such as tab, carriage return, and line feed.
- Prototype:

```
WriteConsole PROTO,
    handle:DWORD,              ; output handle
    pBuffer:PTR BYTE,          ; pointer to buffer
    bufsize:DWORD,             ; size of buffer
    pCount:PTR DWORD,          ; output count
    lpReserved:DWORD           ; (not used)
```

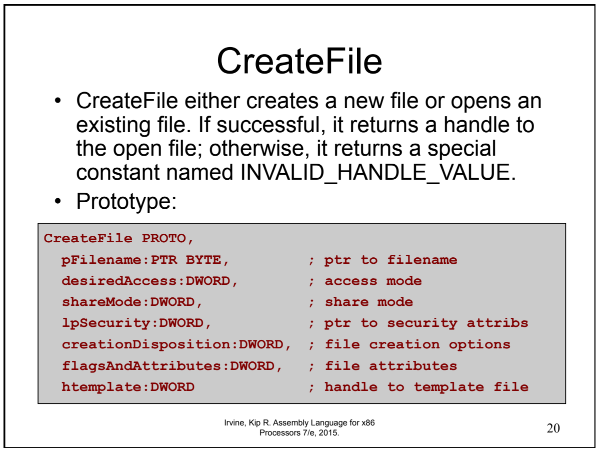
WriteConsoleOutputCharacter

- The WriteConsoleOutputCharacter function copies an array of characters to consecutive cells of the console screen buffer, beginning at a specified location.
- Prototype:

```
WriteConsoleOutputCharacter PROTO,
  handleScreenBuf:DWORD,    ; console output handle
  pBuffer:PTR BYTE,         ; pointer to buffer
  bufsize:DWORD,            ; size of buffer
  xyPos:COORD,              ; first cell coordinates
  pCount:PTR DWORD          ; output count
```

File Manipulation

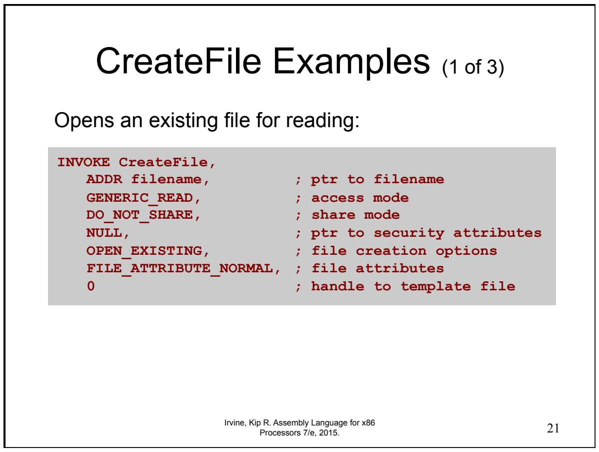
- Win32 API Functions that create, read, and write to files:
  - CreateFile
  - ReadFile
  - WriteFile
  - SetFilePointer



CreateFile

- CreateFile either creates a new file or opens an existing file. If successful, it returns a handle to the open file; otherwise, it returns a special constant named INVALID_HANDLE_VALUE.
- Prototype:

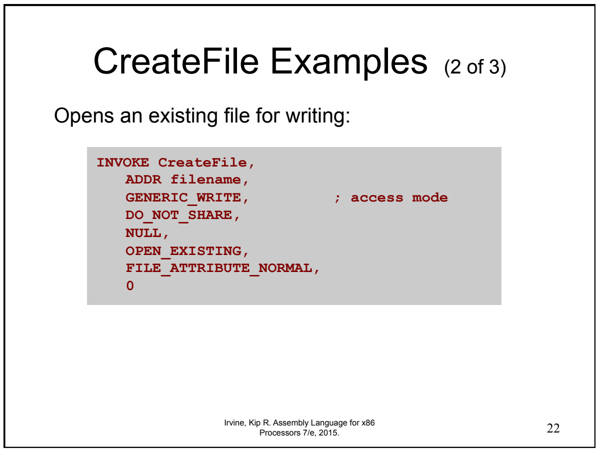
```
CreateFile PROTO,
  pFilename:PTR BYTE,          ; ptr to filename
  desiredAccess:DWORD,         ; access mode
  shareMode:DWORD,             ; share mode
  lpSecurity:DWORD,            ; ptr to security attribs
  creationDisposition:DWORD,   ; file creation options
  flagsAndAttributes:DWORD,    ; file attributes
  htemplate:DWORD              ; handle to template file
```



CreateFile Examples (1 of 3)

Opens an existing file for reading:

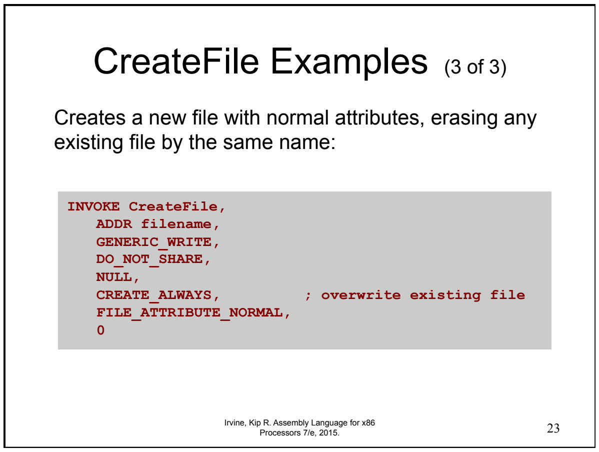
```
INVOKE CreateFile,
   ADDR filename,          ; ptr to filename
   GENERIC_READ,           ; access mode
   DO_NOT_SHARE,           ; share mode
   NULL,                   ; ptr to security attributes
   OPEN_EXISTING,          ; file creation options
   FILE_ATTRIBUTE_NORMAL,  ; file attributes
   0                       ; handle to template file
```



CreateFile Examples (2 of 3)

Opens an existing file for writing:

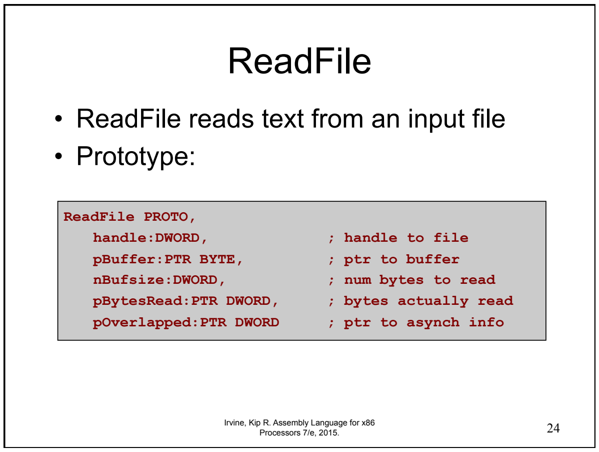
```
INVOKE CreateFile,
   ADDR filename,
   GENERIC_WRITE,          ; access mode
   DO_NOT_SHARE,
   NULL,
   OPEN_EXISTING,
   FILE_ATTRIBUTE_NORMAL,
   0
```



CreateFile Examples (3 of 3)

Creates a new file with normal attributes, erasing any existing file by the same name:

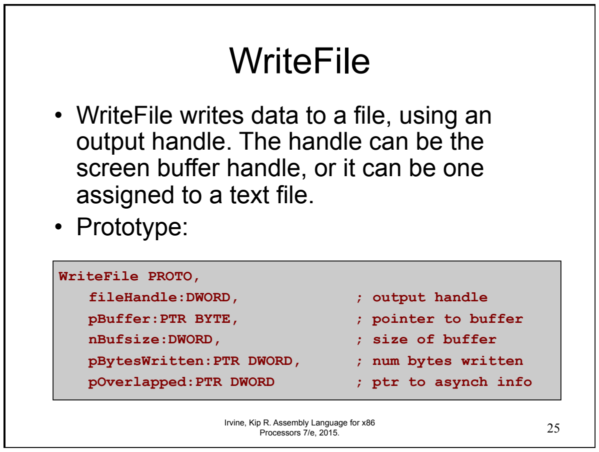
```
INVOKE CreateFile,
   ADDR filename,
   GENERIC_WRITE,
   DO_NOT_SHARE,
   NULL,
   CREATE_ALWAYS,          ; overwrite existing file
   FILE_ATTRIBUTE_NORMAL,
   0
```



ReadFile

- ReadFile reads text from an input file
- Prototype:

```
ReadFile PROTO,
   handle:DWORD,            ; handle to file
   pBuffer:PTR BYTE,        ; ptr to buffer
   nBufsize:DWORD,          ; num bytes to read
   pBytesRead:PTR DWORD,    ; bytes actually read
   pOverlapped:PTR DWORD    ; ptr to asynch info
```



WriteFile

- WriteFile writes data to a file, using an output handle. The handle can be the screen buffer handle, or it can be one assigned to a text file.
- Prototype:

```
WriteFile PROTO,
   fileHandle:DWORD,          ; output handle
   pBuffer:PTR BYTE,          ; pointer to buffer
   nBufsize:DWORD,            ; size of buffer
   pBytesWritten:PTR DWORD,   ; num bytes written
   pOverlapped:PTR DWORD      ; ptr to asynch info
```

SetFilePointer

SetFilePointer moves the position pointer of an open file. You can use it to append data to a file, and to perform random-access record processing:

```
SetFilePointer PROTO,
  handle:DWORD,               ; file handle
  nDistanceLo:SDWORD,         ; bytes to move pointer
  pDistanceHi:PTR SDWORD,     ; ptr to bytes to move
  moveMethod:DWORD            ; starting point
```

Example:

```
; Move to end of file:

INVOKE SetFilePointer,
  fileHandle,0,0,FILE_END
```

64-Bit Windows API

- Input and output handles are 64 bits
- Before calling a system function, reserve at least 32 bytes of shadow space by subtracting from the stack pointer (RSP).
- Restore RSP after the system call
- Pass integers in 64-bit registers
- First four arguments should be placed in RCX, RDX, R8, and R9 registers
- 64-bit integer values are returned in RAX

Example: Calling GetStdHandle

```
.data
STD_OUTPUT_HANDLE EQU -11
consoleOutHandle QWORD ?

.code
sub  rsp,40      ; reserve shadow space & align RSP
mov  rcx,STD_OUTPUT_HANDLE
call GetStdHandle
mov  consoleOutHandle,rax
add  rsp,40
```

Example: Calling WriteConsole

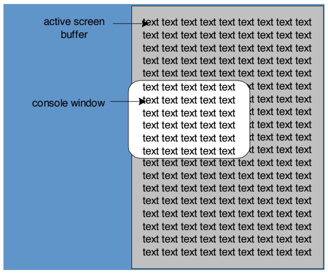
```
sub  rsp, 5 * 8     ; space for 5 parameters
movr cx,rdx
call Str_length  ; returns length of string in EAX
mov  rcx,consoleOutHandle
mov  rdx,rdx        ; string pointer
mov  r8, rax        ; length of string
lea  r9,bytesWritten
mov  qword ptr [rsp + 4 * SIZEOF QWORD],0 ; (always zero)
call WriteConsoleA
```

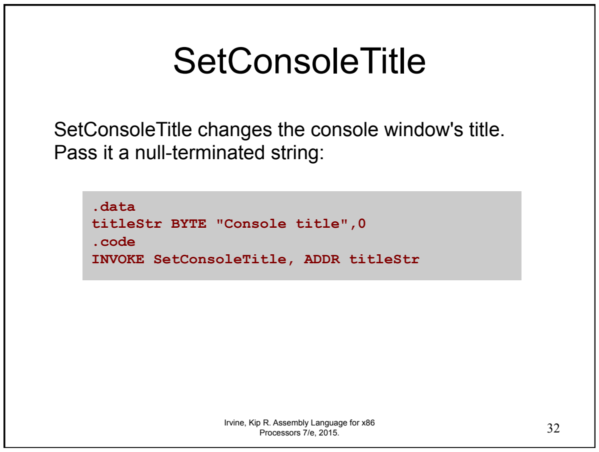
Console Window Manipulation

- Screen buffer
- Console window
- Controlling the cursor
- Controlling the text color

Screen Buffer and Console Window

- The active screen buffer includes data displayed by the console window.

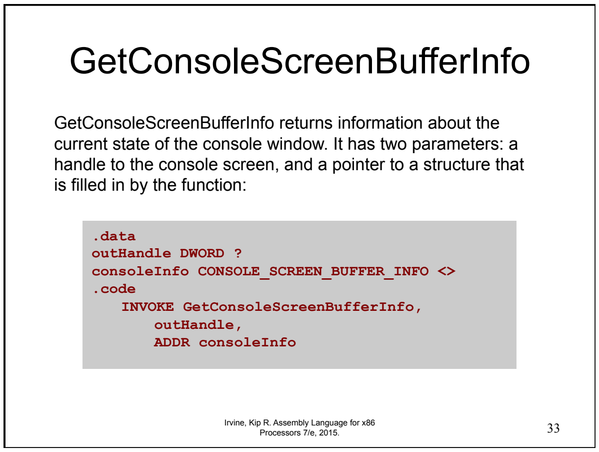




SetConsoleTitle

SetConsoleTitle changes the console window's title.
Pass it a null-terminated string:

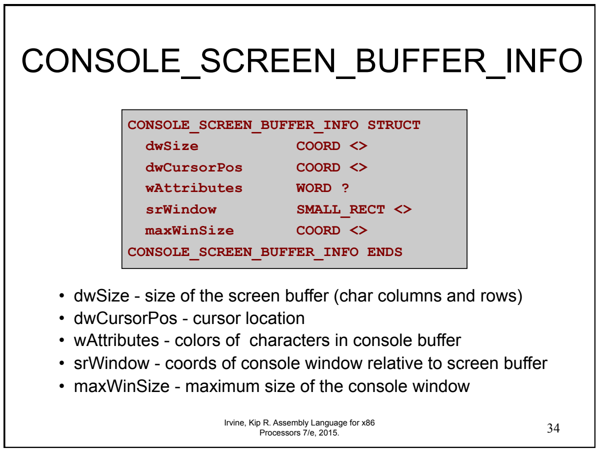
```
.data
titleStr BYTE "Console title",0
.code
INVOKE SetConsoleTitle, ADDR titleStr
```



GetConsoleScreenBufferInfo

GetConsoleScreenBufferInfo returns information about the current state of the console window. It has two parameters: a handle to the console screen, and a pointer to a structure that is filled in by the function:

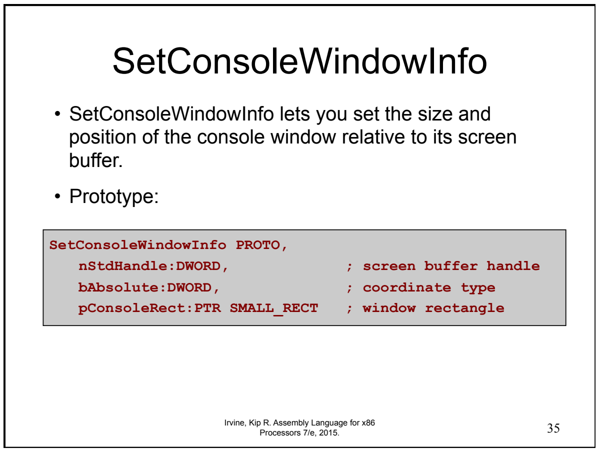
```
.data
outHandle DWORD ?
consoleInfo CONSOLE_SCREEN_BUFFER_INFO <>
.code
   INVOKE GetConsoleScreenBufferInfo,
       outHandle,
       ADDR consoleInfo
```



CONSOLE_SCREEN_BUFFER_INFO

```
CONSOLE_SCREEN_BUFFER_INFO STRUCT
  dwSize            COORD <>
  dwCursorPos       COORD <>
  wAttributes       WORD ?
  srWindow          SMALL_RECT <>
  maxWinSize        COORD <>
CONSOLE_SCREEN_BUFFER_INFO ENDS
```

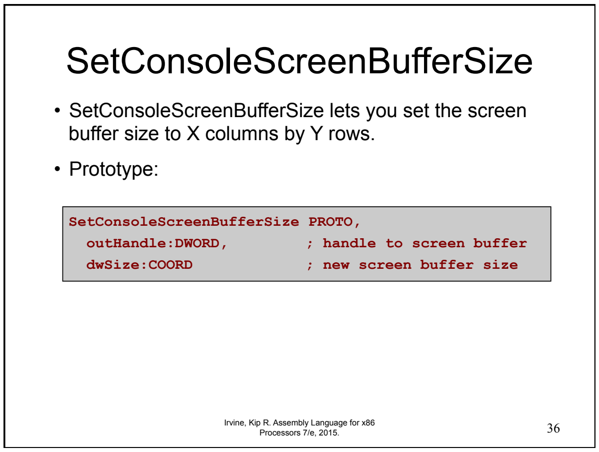
- dwSize - size of the screen buffer (char columns and rows)
- dwCursorPos - cursor location
- wAttributes - colors of characters in console buffer
- srWindow - coords of console window relative to screen buffer
- maxWinSize - maximum size of the console window



SetConsoleWindowInfo

- SetConsoleWindowInfo lets you set the size and position of the console window relative to its screen buffer.
- Prototype:

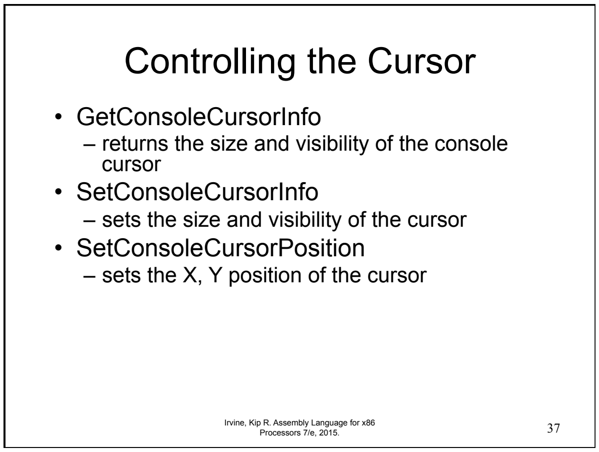
```
SetConsoleWindowInfo PROTO,
   nStdHandle:DWORD,             ; screen buffer handle
   bAbsolute:DWORD,              ; coordinate type
   pConsoleRect:PTR SMALL_RECT   ; window rectangle
```



SetConsoleScreenBufferSize

- SetConsoleScreenBufferSize lets you set the screen buffer size to X columns by Y rows.
- Prototype:

```
SetConsoleScreenBufferSize PROTO,
  outHandle:DWORD,         ; handle to screen buffer
  dwSize:COORD             ; new screen buffer size
```



Controlling the Cursor

- GetConsoleCursorInfo
  - returns the size and visibility of the console cursor
- SetConsoleCursorInfo
  - sets the size and visibility of the cursor
- SetConsoleCursorPosition
  - sets the X, Y position of the cursor

CONSOLE_CURSOR_INFO

- Structure containing information about the console's cursor size and visibility:

```
CONSOLE_CURSOR_INFO STRUCT
  dwSize   DWORD ?
  bVisible DWORD ?
CONSOLE_CURSOR_INFO ENDS
```

SetConsoleTextAttribute

- Sets the foreground and background colors of all subsequent text written to the console.
- Prototype:

```
SetConsoleTextAttribute PROTO,
    outHandle:DWORD,         ; console output handle
    nColor:DWORD             ; color attribute
```

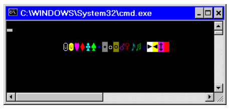
WriteConsoleOutputAttribute

- Copies an array of attribute values to consecutive cells of the console screen buffer, beginning at a specified location.
- Prototype:

```
WriteConsoleOutputAttribute PROTO,
    outHandle:DWORD,           ; output handle
    pAttribute:PTR WORD,       ; write attributes
    nLength:DWORD,             ; number of cells
    xyCoord:COORD,             ; first cell coordinates
    lpCount:PTR DWORD          ; number of cells written
```

WriteColors Program

- Creates an array of characters and an array of attributes, one for each character
- Copies the attributes to the screen buffer
- Copies the characters to the same screen buffer cells as the attributes
- Sample output:



(starts in row 2, column 10)

Time and Date Functions

- GetLocalTime, SetLocalTime
- GetTickCount, Sleep
- GetDateTime
- SYSTEMTIME Structure
- Creating a Stopwatch Timer

GetLocalTime, SetLocalTime

- GetLocalTime returns the date and current time of day, according to the system clock.
- SetLocalTime sets the system's local date and time.

```
GetLocalTime PROTO,
  pSystemTime:PTR SYSTEMTIME
```

```
SetLocalTime PROTO,
  pSystemTime:PTR SYSTEMTIME
```

GetTickCount, Sleep

- GetTickCount function returns the number of milliseconds that have elapsed since the system was started.
- Sleep pauses the current program for a specified number of milliseconds.

```
GetTickCount PROTO    ; return value in EAX
```

```
Sleep PROTO,
   dwMilliseconds:DWORD
```

GetDateTime

The GetDateTime procedure in the Irvine32 library calculates the number of 100-nanosecond time intervals that have elapsed since January 1, 1601. Pass it a pointer to an empty 64-bit FILETIME structure, which is then filled in by the procedure:

```
GetDateTime PROC,
   pStartTime:PTR QWORD
```

```
FILETIME STRUCT
    loDateTime DWORD ?
    hiDateTime DWORD ?
FILETIME ENDS
```

SYSTEMTIME Structure

- SYSTEMTIME is used by date and time-related Windows API functions:

```
SYSTEMTIME STRUCT
   wYear WORD ?              ; year (4 digits)
   wMonth WORD ?             ; month (1-12)
   wDayOfWeek WORD ?         ; day of week (0-6)
   wDay WORD ?               ; day (1-31)
   wHour WORD ?              ; hours (0-23)
   wMinute WORD ?            ; minutes (0-59)
   wSecond WORD ?            ; seconds (0-59)
   wMilliseconds WORD ?      ; milliseconds (0-999)
SYSTEMTIME ENDS
```

What's Next

- Win32 Console Programming
- **Writing a Graphical Windows Application**
- Dynamic Memory Allocation
- x86 Memory Management

Writing a Graphical Windows Application

- Required Files
- POINT, RECT Structures
- MSGStruct, WNDCLASS Structures
- MessageBox Function
- WinMain, WinProc Procedures
- ErrorHandler Procedure
- Message Loop & Processing Messages
- Program Listing

Required Files

- make32.bat - Batch file specifically for building this program
- WinApp.asm - Program source code
- GraphWin.inc - Include file containing structures, constants, and function prototypes used by the program
- kernel32.lib - Same MS-Windows API library used earlier in this chapter
- user32.lib - Additional MS-Windows API functions

POINT and RECT Structures

- POINT - X, Y screen coordinates
- RECT - Holds the graphical coordinates of two opposing corners of a rectangle

```
POINT STRUCT
  ptX  DWORD ?
  ptY  DWORD ?
POINT ENDS
```

```
RECT STRUCT
  left     DWORD ?
  top      DWORD ?
  right    DWORD ?
  bottom   DWORD ?
RECT ENDS
```

MSGStruct Structure

MSGStruct - holds data for MS-Windows messages (usually passed by the system and received by your application):

```
MSGStruct STRUCT
  msgWnd          DWORD ?
  msgMessage      DWORD ?
  msgWparam       DWORD ?
  msgLparam       DWORD ?
  msgTime         DWORD ?
  msgPt           POINT <>
MSGStruct ENDS
```

WNDCLASS Structure (1 of 2)

Each window in a program belongs to a class, and each program defines a window class for its main window:

```
WNDCLASS STRUC
  style          DWORD ?    ; window style options
  lpfnWndProc    DWORD ?    ; WinProc function pointer
  cbClsExtra     DWORD ?    ; shared memory
  cbWndExtra     DWORD ?    ; number of extra bytes
  hInstance      DWORD ?    ; handle to current program
  hIcon          DWORD ?    ; handle to icon
  hCursor        DWORD ?    ; handle to cursor
  hbrBackground DWORD ?    ; handle to background brush
  lpszMenuName   DWORD ?    ; pointer to menu name
  lpszClassName DWORD ?    ; pointer to WinClass name
WNDCLASS ENDS
```

WNDCLASS Structure (2 of 2)

- style is a conglomerate of different style options, such as WS_CAPTION and WS_BORDER, that control the window's appearance and behavior.
- lpfnWndProc is a pointer to a function (in our program) that receives and processes event messages triggered by the user.
- cbClsExtra refers to shared memory used by all windows belonging to the class. Can be null.
- cbWndExtra specifies the number of extra bytes to allocate following the window instance.
- hInstance holds a handle to the current program instance.
- hIcon and hCursor hold handles to icon and cursor resources for the current program.
- hbrBackground holds a background (color) brush.
- lpszMenuName points to a menu string.
- lpszClassName points to a null-terminated string containing the window's class name.

MessageBox Function

Displays text in a box that pops up and waits for the user to click on a button:

```
MessageBox PROTO,
   hWnd:DWORD,
   pText:PTR BYTE,
   pCaption:PTR BYTE,
   style:DWORD
```

hWnd is a handle to the current window. pText points to a null-terminated string that will appear inside the box. pCaption points to a null-terminated string that will appear in the box's caption bar. style is an integer that describes both the dialog box's icon (optional) and the buttons (required).

MessageBox Example

Displays a message box that shows a question, including an OK button and a question-mark icon:

```
.data
hMainWnd      DWORD ?
QuestionText  BYTE "Register this program now?"
QuestionTitle BYTE "Trial Period Has Expired"

.code
INVOKE MessageBox,
   hMainWnd,
   ADDR QuestionText,
   ADDR QuestionTitle,
   MB_OK + MB_ICONQUESTION
```

WinMain Procedure

Every Windows application needs a startup procedure, usually named WinMain, which is responsible for the following tasks:

- Get a handle to the current program
- Load the program's icon and mouse cursor
- Register the program's main window class and identify the procedure that will process event messages for the window
- Create the main window
- Show and update the main window
- Begin a loop that receives and dispatches messages

WinProc Procedure

- WinProc receives and processes all event messages relating to a window
  - Some events are initiated by clicking and dragging the mouse, pressing keyboard keys, and so on
- WinProc decodes each message, carries out application-oriented tasks related to the message

```
WinProc PROC,
   hWnd:DWORD,        ; handle to the window
   localMsg:DWORD,    ; message ID
   wParam:DWORD,      ; parameter 1 (varies)
   lParam:DWORD       ; parameter 2 (varies)
```

(Contents of wParam and lParam vary, depending on the message.)

Sample WinProc Messages

- In the example program from this chapter, the WinProc procedure handles three specific messages:
  - WM_LBUTTONDOWN, generated when the user presses the left mouse button
  - WM_CREATE, indicates that the main window was just created
  - WM_CLOSE, indicates that the application's main window is about to close

(many other messages are possible)

ErrorHandler Procedure

- The ErrorHandler procedure has several important tasks to perform:
  - Call GetLastError to retrieve the system error number
  - Call FormatMessage to retrieve the appropriate system-formatted error message string
  - Call MessageBox to display a popup message box containing the error message string
  - Call LocalFree to free the memory used by the error message string

(sample) →

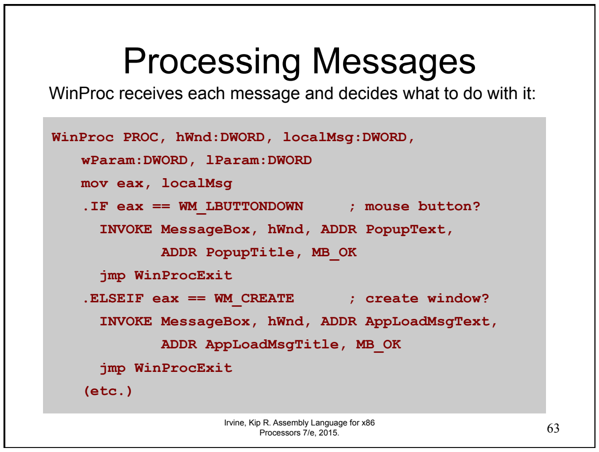
ErrorHandler Sample

```
INVOKE GetLastError        ; Returns message ID in EAX
mov messageID,eax

; Get the corresponding message string.
INVOKE FormatMessage, FORMAT_MESSAGE_ALLOCATE_BUFFER + \
  FORMAT_MESSAGE_FROM_SYSTEM, NULL, messageID, NULL,
  ADDR pErrorMsg, NULL, NULL

; Display the error message.
INVOKE MessageBox, NULL, pErrorMsg, ADDR ErrorTitle,
  MB_ICONERROR + MB_OK

; Free the error message string.
INVOKE LocalFree, pErrorMsg
```

Message Loop

In WinMain, the message loop receives and dispatches (relays) messages:

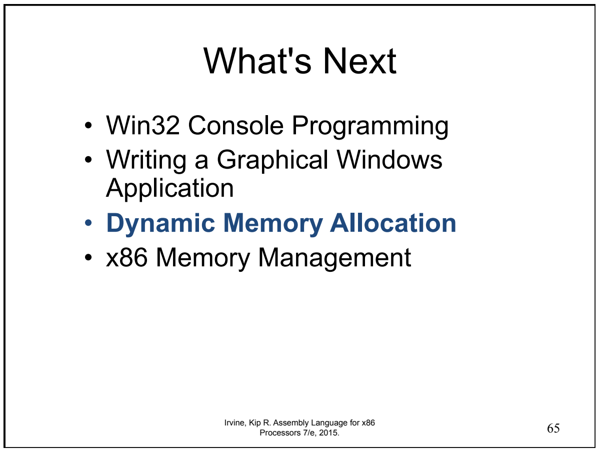
```
Message_Loop:
    ; Get next message from the queue.
    INVOKE GetMessage, ADDR msg, NULL,NULL,NULL

    ; Quit if no more messages.
    .IF eax == 0
      jmp Exit_Program
    .ENDIF

    ; Relay the message to the program's WinProc.
    INVOKE DispatchMessage, ADDR msg

    jmp Message_Loop
```



Processing Messages

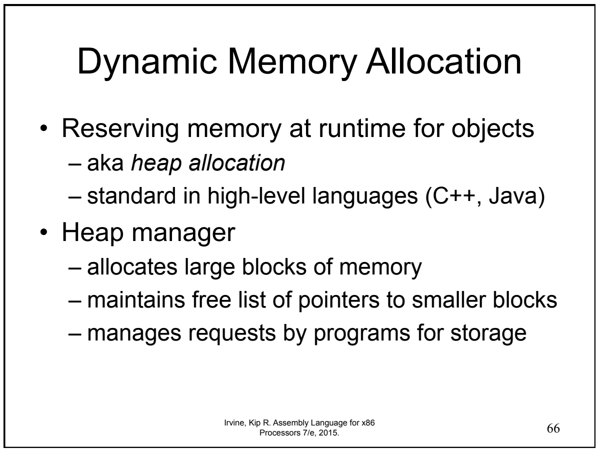
WinProc receives each message and decides what to do with it:

```
WinProc PROC, hWnd:DWORD, localMsg:DWORD,
   wParam:DWORD, lParam:DWORD
   mov eax, localMsg
   .IF eax == WM_LBUTTONDOWN      ; mouse button?
     INVOKE MessageBox, hWnd, ADDR PopupText,
            ADDR PopupTitle, MB_OK
     jmp WinProcExit
   .ELSEIF eax == WM_CREATE       ; create window?
     INVOKE MessageBox, hWnd, ADDR AppLoadMsgText,
            ADDR AppLoadMsgTitle, MB_OK
     jmp WinProcExit
   (etc.)
```



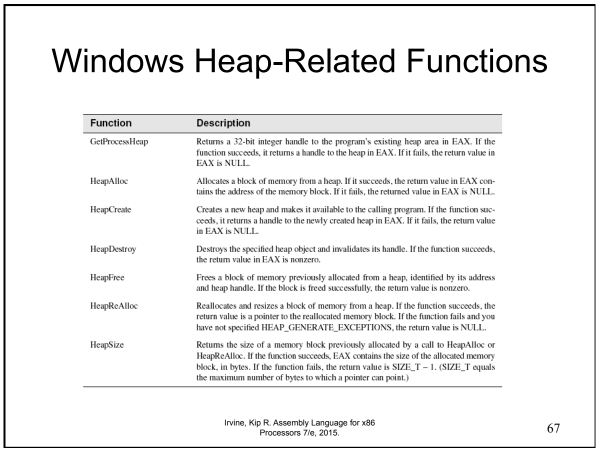
What's Next

- Win32 Console Programming
- Writing a Graphical Windows Application
- **Dynamic Memory Allocation**
- x86 Memory Management



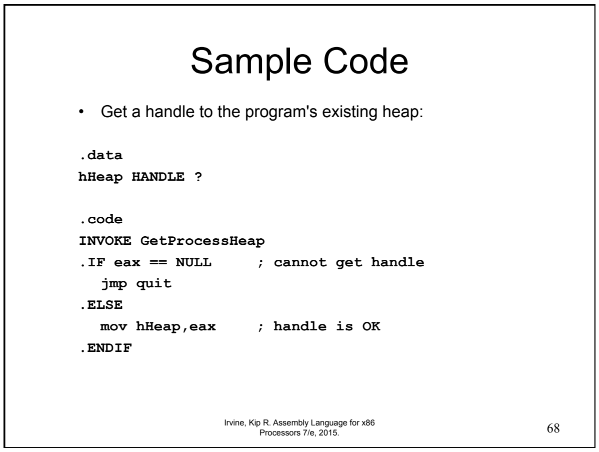
Dynamic Memory Allocation

- Reserving memory at runtime for objects
  - aka *heap allocation*
  - standard in high-level languages (C++, Java)
- Heap manager
  - allocates large blocks of memory
  - maintains free list of pointers to smaller blocks
  - manages requests by programs for storage



Windows Heap-Related Functions

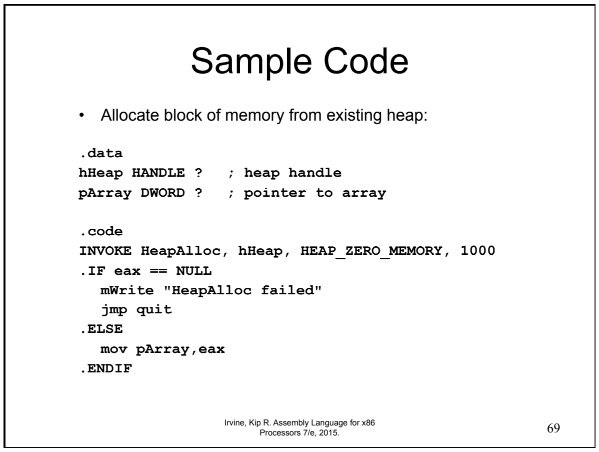
Function	Description
GetProcessHeap	Returns a 32-bit integer handle to the program's existing heap area in EAX. If the function succeeds, it returns a handle to the heap in EAX. If it fails, the return value in EAX is NULL.
HeapAlloc	Allocates a block of memory from a heap. If it succeeds, the return value in EAX contains the address of the memory block. If it fails, the returned value in EAX is NULL.
HeapCreate	Creates a new heap and makes it available to the calling program. If the function succeeds, it returns a handle to the newly created heap in EAX. If it fails, the return value in EAX is NULL.
HeapDestroy	Destroys the specified heap object and invalidates its handle. If the function succeeds, the return value in EAX is nonzero.
HeapFree	Frees a block of memory previously allocated from a heap, identified by its address and heap handle. If the block is freed successfully, the return value is nonzero.
HeapReAlloc	Reallocates and resizes a block of memory from a heap. If the function succeeds, the return value is a pointer to the reallocated memory block. If the function fails and you have not specified HEAP_GENERATE_EXCEPTIONS, the return value is NULL.
HeapSize	Returns the size of a memory block previously allocated by a call to HeapAlloc or HeapReAlloc. If the function succeeds, EAX contains the size of the allocated memory block, in bytes. If the function fails, the return value is SIZE_T – 1. (SIZE_T equals the maximum number of bytes to which a pointer can point.)



Sample Code

- Get a handle to the program's existing heap:

```
.data
hHeap HANDLE ?

.code
INVOKE GetProcessHeap
.IF eax == NULL      ; cannot get handle
  jmp quit
.ELSE
  mov hHeap,eax      ; handle is OK
.ENDIF
```



Sample Code

- Allocate block of memory from existing heap:

```
.data
hHeap HANDLE ?   ; heap handle
pArray DWORD ?   ; pointer to array

.code
INVOKE HeapAlloc, hHeap, HEAP_ZERO_MEMORY, 1000
.IF eax == NULL
  mWrite "HeapAlloc failed"
  jmp quit
.ELSE
  mov pArray,eax
.ENDIF
```

Sample Code

- Free a block of memory previously created by calling HeapAlloc:

```
.data
hHeap HANDLE ?      ; heap handle
pArray DWORD ?      ; pointer to array

.code
INVOKE HeapFree,
   hHeap,        ; handle to heap
   0,            ; flags
   pArray        ; pointer to array
```

What's Next

- Win32 Console Programming
- Writing a Graphical Windows Application
- Dynamic Memory Allocation
- **x86 Memory Management**

x86 Memory Management

- Reviewing Some Terms
- New Terms
- Translating Addresses
- Converting Logical to Linear Address
- Page Translation

Reviewing Some Terms

- Multitasking permits multiple programs (or tasks) to run at the same time. The processor divides up its time between all of the running programs.
- Segments are variable-sized areas of memory used by a program containing either code or data.
- Segmentation provides a way to isolate memory segments from each other. This permits multiple programs to run simultaneously without interfering with each other.
- A segment descriptor is a 64-bit value that identifies and describes a single memory segment: it contains information about the segment’s base address, access rights, size limit, type, and usage.

New Terms

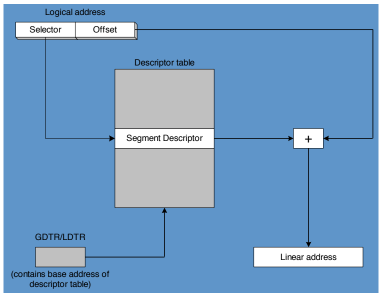
- A segment selector is a 16-bit value stored in a segment register (CS, DS, SS, ES, FS, or GS).
  - provides an indirect reference to a memory segment
- A logical address is a combination of a segment selector and a 32-bit offset.

Translating Addresses

- The x86 processor uses a one- or two-step process to convert a variable's logical address into a unique memory location.
- The first step combines a segment value with a variable’s offset to create a linear address.
- The second optional step, called page translation, converts a linear address to a physical address.

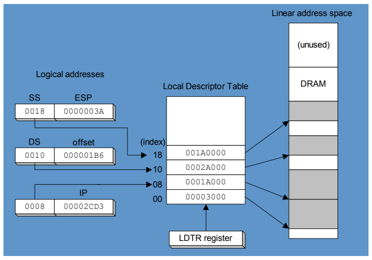
Converting Logical to Linear Address

The segment selector points to a segment descriptor, which contains the base address of a memory segment. The 32-bit offset from the logical address is added to the segment's base address, generating a 32-bit linear address.



Indexing into a Descriptor Table

Each segment descriptor indexes into the program's local descriptor table (LDT). Each table entry is mapped to a linear address:



Paging (1 of 2)

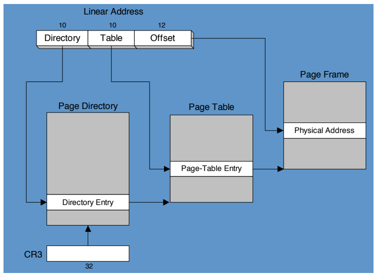
- Paging makes it possible for a computer to run a combination of programs that would not otherwise fit into memory.
- Only part of a program must be kept in memory, while the remaining parts are kept on disk.
- The memory used by the program is divided into small units called pages.
- As the program runs, the processor selectively unloads inactive pages from memory and loads other pages that are immediately required.

Paging (2 of 2)

- OS maintains page directory and page tables
- Page translation: CPU converts the linear address into a physical address
- Page fault: occurs when a needed page is not in memory, and the CPU interrupts the program
- OS copies the page into memory, program resumes execution

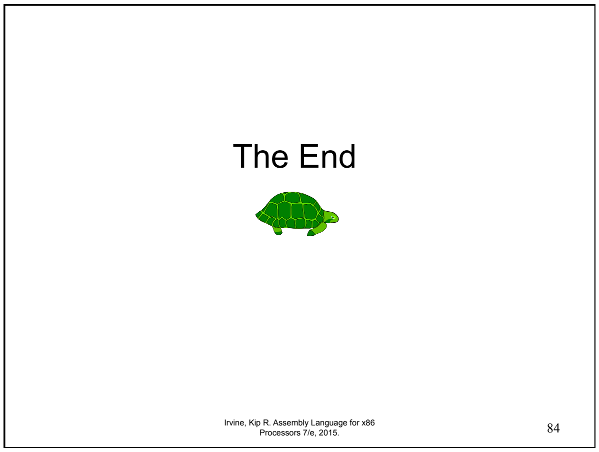
Page Translation

A linear address is divided into a page directory field, page table field, and page frame offset. The CPU uses all three to calculate the physical address.



Summary

- 32-bit console programs
  - read from the keyboard and write plain text to the console window using Win32 API functions
- Important functions
  - ReadConsole, WriteConsole, GetStdHandle, ReadFile, WriteFile, CreateFile, CloseHandle, SetFilePointer
- Dynamic memory allocation
  - HeapAlloc, HeapFree
- x86 Memory management
  - segment selectors, linear address, physical address
  - segment descriptor tables
  - paging, page directory, page tables, page translation



The End

Irvine, Kip R. Assembly Language for x86 Processors 7/e, 2015.

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