Software RE
Rev II

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REVERSE ENGINEERING
PHILADELPHIA UNIVERSITY, JORDAN
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References

- Reversing: Secrets of Reverse Engineering by Eldad Eilam. Published by Wiley Publishing 2005
- Reversing: Reverse Engineering, Recent Advances and Applications edited by Telea. Published by InTech 2012
- Reverse Engineering for Beginners by Dennis Yurichev 2015

Software is Everywhere

- PCs and Laptops
- Mobile phones
- Networks
- Washing machines
- Microwaves
- Automated Industry Controllers
- Automobiles
- Airplanes
- Spaceships

Software is Everywhere

We rely on too much software that we do not understand and do not know very well at all.

- We buy software packages.
- We run setup utilities that install numerous files, change system settings, delete or disable older versions , and modify critical registry files.
- We access websites that might interact with programs
- We purchase CD games
- We download programs , updates, and patches

S/W Reverse Engineering

- S/W RE is **the process of analyzing a system to identify its components and their interrelationships and to create representations of the system in another form or at a higher level of abstraction** -- IEEE 1990

- S/W RE is about opening up a program's "box" and looking inside

- S/W Reverse engineering is a critical **set of techniques and tools for understanding** what **software** is really all about.

S/W Reverse Engineering

- The techniques of analysis, and the application of automated tools for software examination, give us a reasonable way to comprehend the complexity of the software and to uncover its truth.
- Reverse engineering occurs every time someone looks at someone else's code.
- Reverse engineering is a discovery process.

What does this program do?

```
int A[SIZE] = {54,15,32,78,23,90,48,86,23,65};
int i, j, min, temp;

for (i = 0; i < SIZE - 1; i++){
    min = i;

    for (j = i+1; j < SIZE; j++){
        if (A[j] < A[min]){
            min = j;
        }
    }

    temp = A[i];
    A[i] = A[min];
    A[min] = temp;
}
```

S/W RE

- S/W RE involves skills:
  - Code breaking
  - Puzzle solving
  - Programming
  - Logical analysis

Applications

- There are two main categories of reverse engineering applications:
  - Security-related
  - Software development–related.

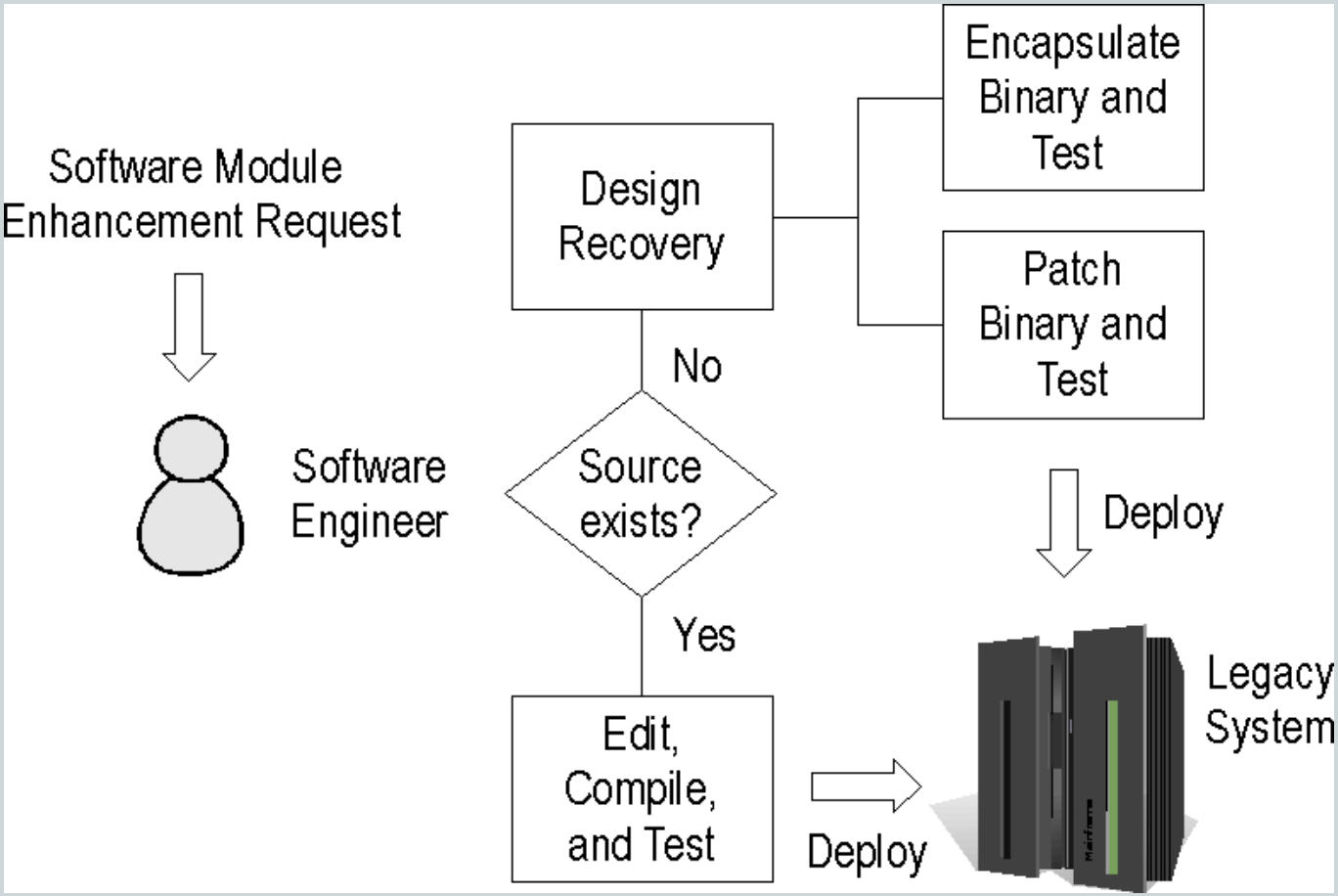
Security Applications

- **Finding malicious code**
  - RE can be used to detect viruses and worms by understanding how the code is structured and functions.
- **Discovering unexpected flaws and faults**
  - RE can help identify flaws and faults (bugs) in application software before they are released to the public.
- **Cracking**
  - To crack a program, means to trace and use a serial number or any other sort of registration information, required for the proper operation of a program.
  - RE can provide that information by decompiling a particular part of the program.

Software Development Applications

- **Learning from others' programs**
  - Re-use the code in other programs
  - Learn and build on a growing body of code knowledge.
  - RE techniques can enable the study of advanced software approaches.
- **Discovering features or opportunities**
  - Existing techniques can be reused in new contexts.
  - RE can lead to new discoveries about software and new opportunities for innovation.
- **Developing Competing Software**
  - Observe and understand competitor's design
  - Determine if another company used your code

Legacy Software Development Process

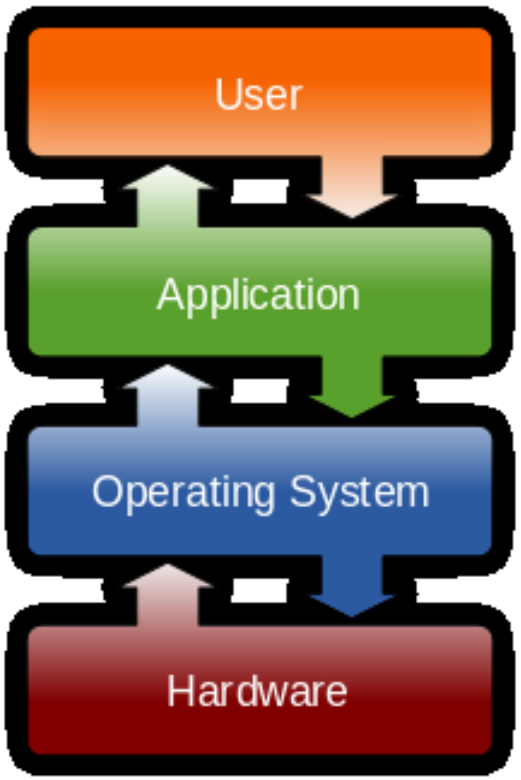


Reference: Teodoro Cipresso, St. Jose State University

S/W RE Basics

- In order to perform software RE, a good understanding of the computer H/W and S/W is needed.
- The following slides provide some basics about
  - Assembly Language
  - Operating Systems

Software Layers



Hardware	lowest level, machine code x86 / CISC / RISC / etc.
Assembly languages	software level, drivers NASM / TASM
System languages	OS level, high performance C / C++ / C# / Go
Application languages	productivity, portability, business logic Java / PHP / Visual Basic

Low Level Software

- Computers and **software are built layers upon layers**.
  - At the bottom layer, there is the microprocessor
  - At the top layer, there are some elegant looking graphics, a keyboard, and a mouse—the user experience.
- Most software developers use high-level languages that take easily understandable commands and execute them.
- Reversing requires a solid understanding of the lower layers.
- Reversers must literally be aware of anything that comes between the program source code and the CPU.

Assembly Language

- The lowest level in the software chain
- If software performs an operation, it must be visible in the assembly language code.
- Assembly language is *the language of reversing*.
- Assembly language vs. Machine Code

Assembly Language

- An ***assembler program*** translates the textual assembly language code into binary code, which can be decoded by a CPU.

- A ***disassembler does the exact opposite***. *It reads object code and generates the textual* mapping of each instruction in it.
  - **Disassemblers are a key tool for reverse engineers**

Compilers

- A text file containing instructions that describe the program in a high-level language is fed into a *compiler*.
- *A **compiler** is a program that takes a source file* and generates a corresponding machine code file while ***Decompilers*** do the opposite
- Depending on the high-level compilers for programming languages (such as C and C++), decompilers generate machine-readable object code from the textual source code.

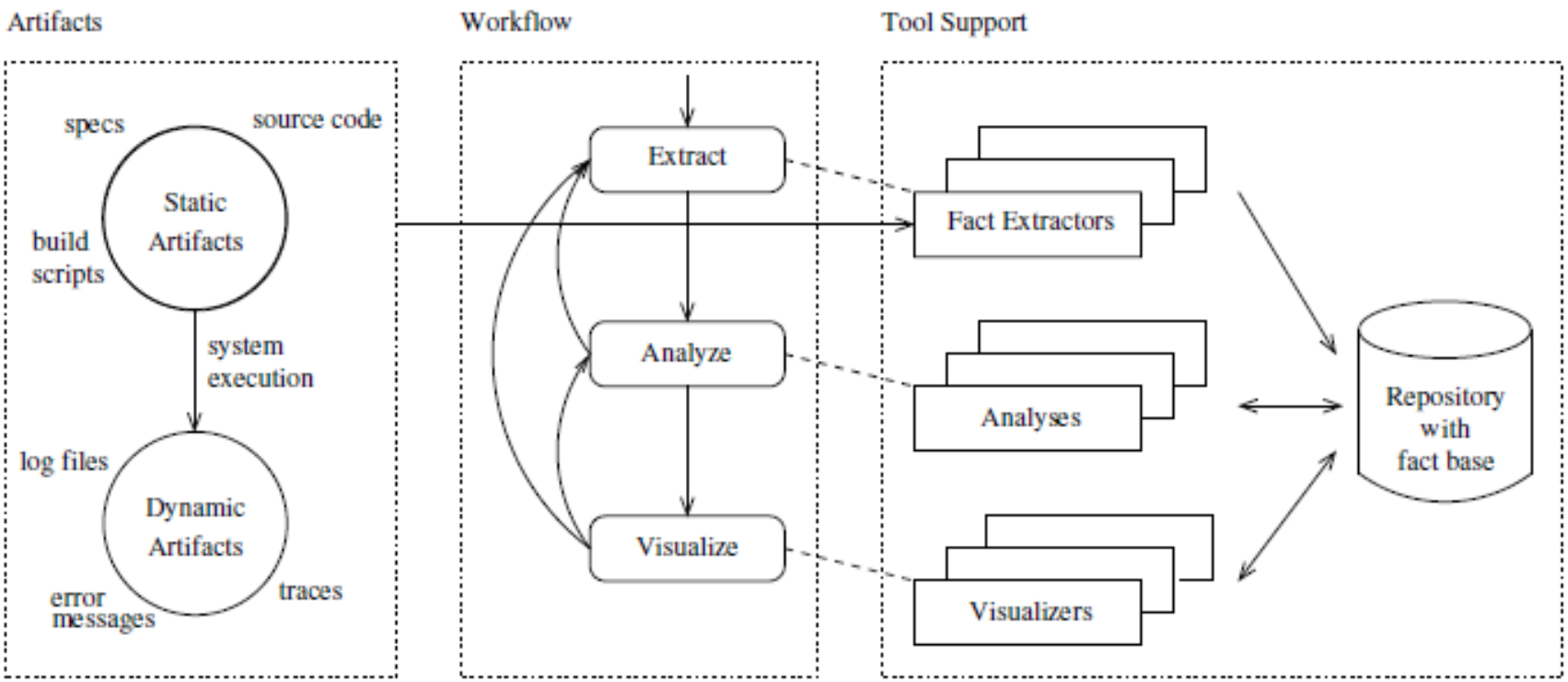
Operating Systems

- An operating system is a program that **manages** the computer, including the **hardware** and **software applications**.
- An operating system takes care of many different tasks and can be seen as a kind of coordinator between the different elements in a computer.
- Operating systems are such a **key element** in a computer that any reverser must have a good understanding of what they do and how they work

RE Process

- RE can be divided into two separate phases.
  - ***System-level reversing techniques*** help determine the general structure of the program and sometimes even locate areas of interest within it.
  - ***Code-level reversing techniques*** provides detailed information on a selected code chunk

RE Process



Ref: Software RE in Domain of Complex Embedded Systems
by Kienle, Kraft and Muller

System Level RE

- **System-level reversing** involves running various tools on the program and utilizing various operating system services to obtain information, inspect program executables, track program input and output, and so forth.

- Most of this information comes from the operating system, because by definition every interaction that a program has with the outside world must go through the operating system.

Code Level RE

- **Code-level reversing** observes the code from a very low-level
- Software can be highly complex
  - Even with access to a program's well-written and properly-documented source code can be difficult to comprehend
- Extracting design concepts and algorithms from a program binary is a complex process that requires a mastery of reversing techniques along with a solid understanding of software development, the CPU, and the operating system.

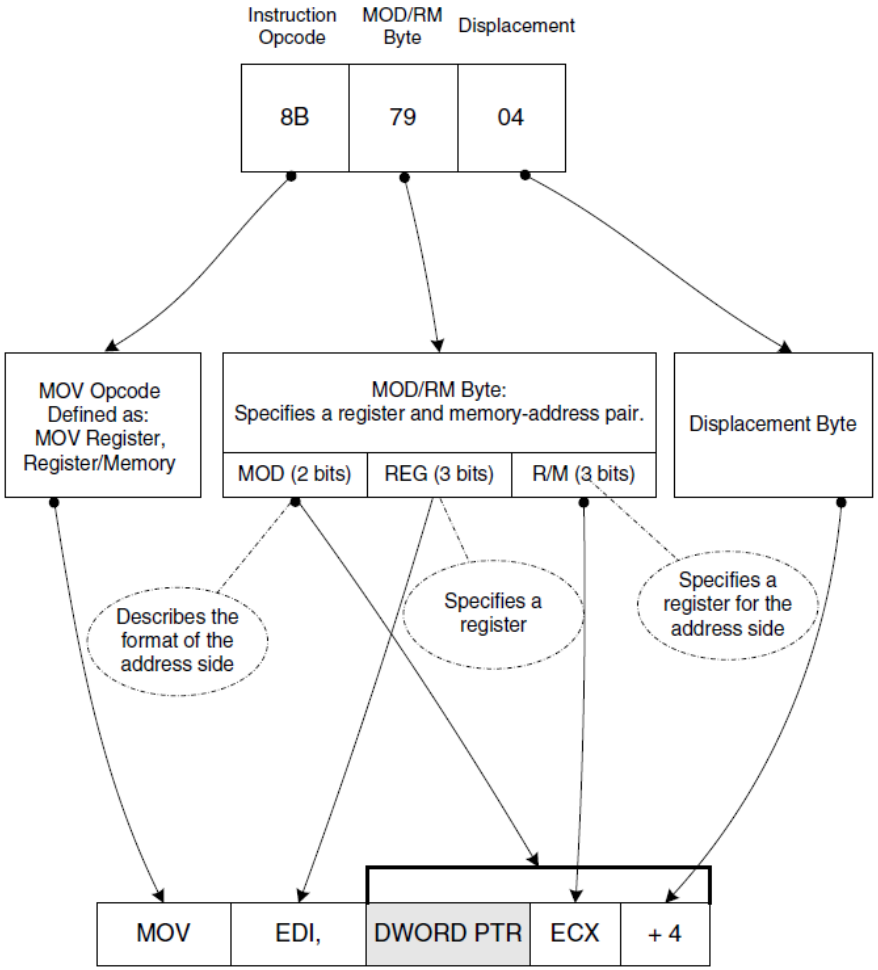
RE Tools

- Disassemblers
- Debuggers
- Decompilers
- System Monitoring Tools

Disassemblers

- A disassembler **decodes binary machine code into a readable assembly language** text.
- The disassembler process
  - Looks up the opcode in a translation table that contains the textual name of each instructions along with their formats.
  - Analyze which operands are used in a particular instruction.
- The specific instruction encoding format and the resulting textual representation are entirely platform-specific.

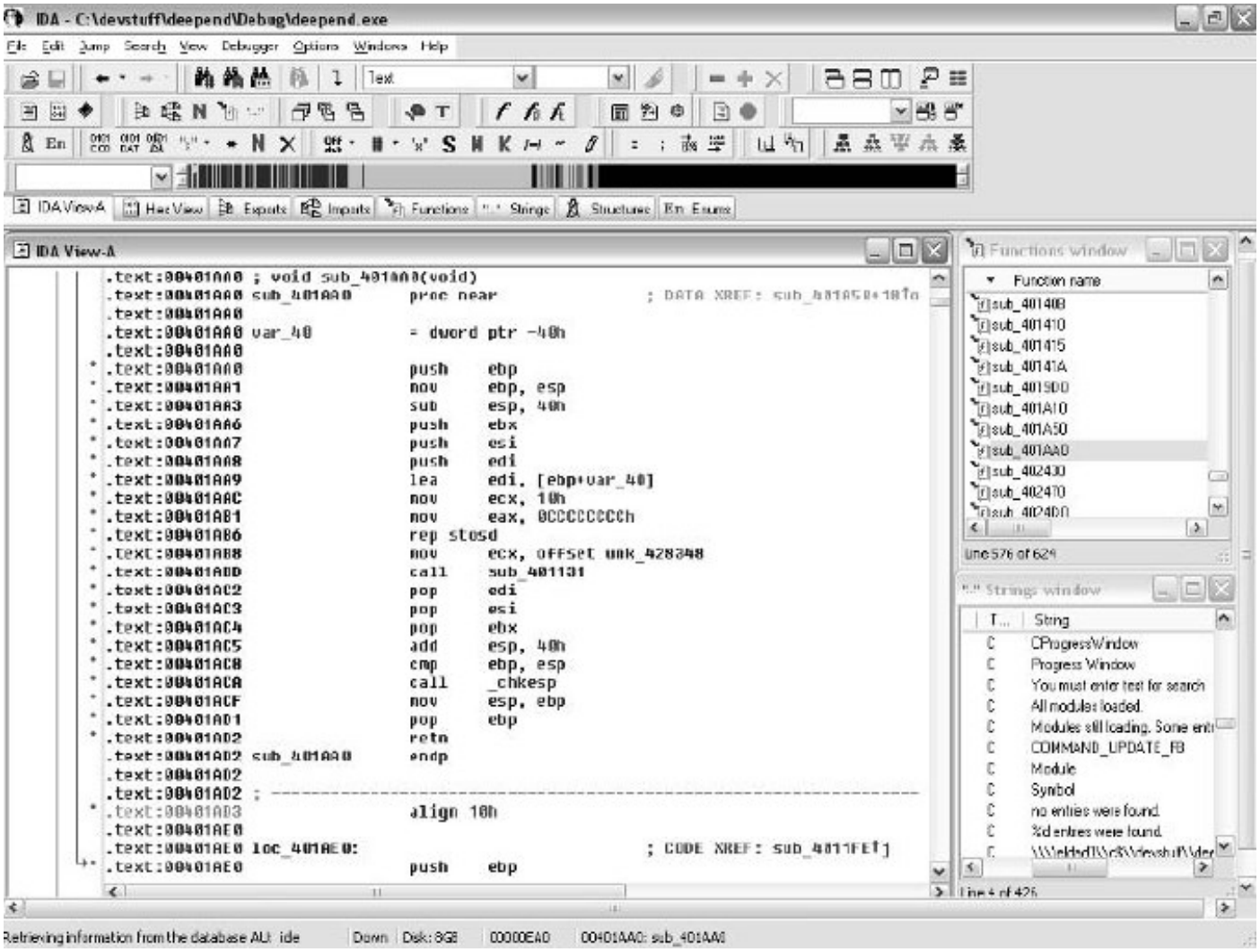
Disassemblers



Example: IDA Pro

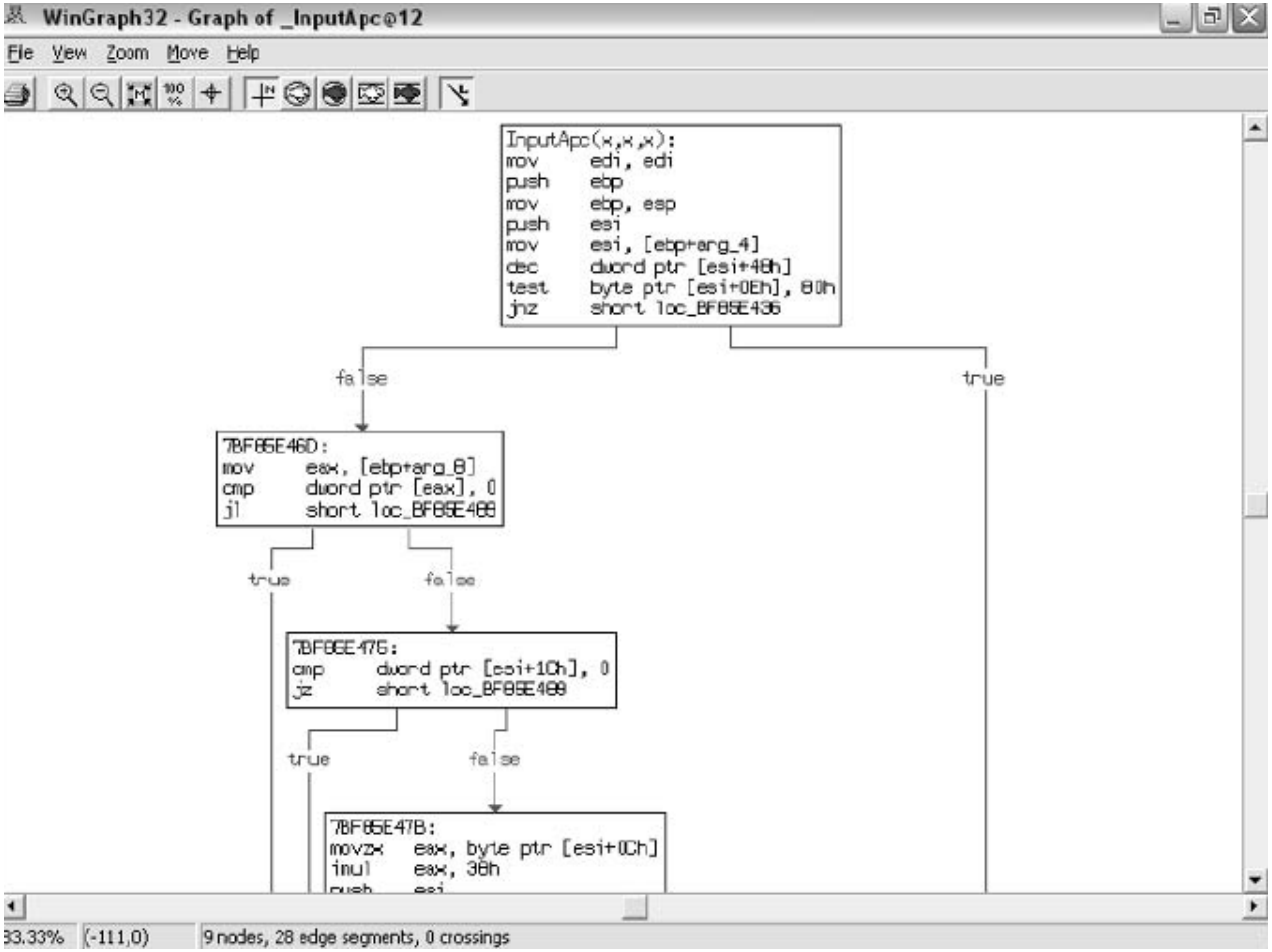
- IDA (Interactive Disassembler) by DataRescue is an extremely powerful disassembler that supports:
  - A variety of processor architectures : IA-32, IA-64 (Itanium), AMD64, and many others.
  - A variety of executable file formats, such as PE (Portable Executable, used in Windows), ELF (Executable and Linking Format, used in Linux), and even XBE, which is used on Microsoft's Xbox.
- IDA is capable of producing flowcharts for a given function. These are essentially logical graphs that show chunks of disassembled code and provide a visual representation of the program flow

Example: IDA Pro



IDA Pro screen showing: code disassembly, function and string lists

Example: IDA Pro



IDA-generated function flow

Debuggers

- Debuggers exist primarily to assist software developers with locating and correcting errors in their programs, but they can also be used as powerful reversing tools.

- The idea is that the debugger provides a disassembled view of the currently running function and allows the user to step through the disassembled code and see what the program does at every line.

Important Debugger Features

- **Powerful Disassembler**
  - View the code clearly, with cross-references that reveal which branch goes where and where a certain instruction is called from.
- **View of Registers and Memory**
  - Provide a good visualization of the important CPU registers and of system memory.
- **Process Information**
  - Most basic ones are a list of the currently loaded executable modules and the currently running threads

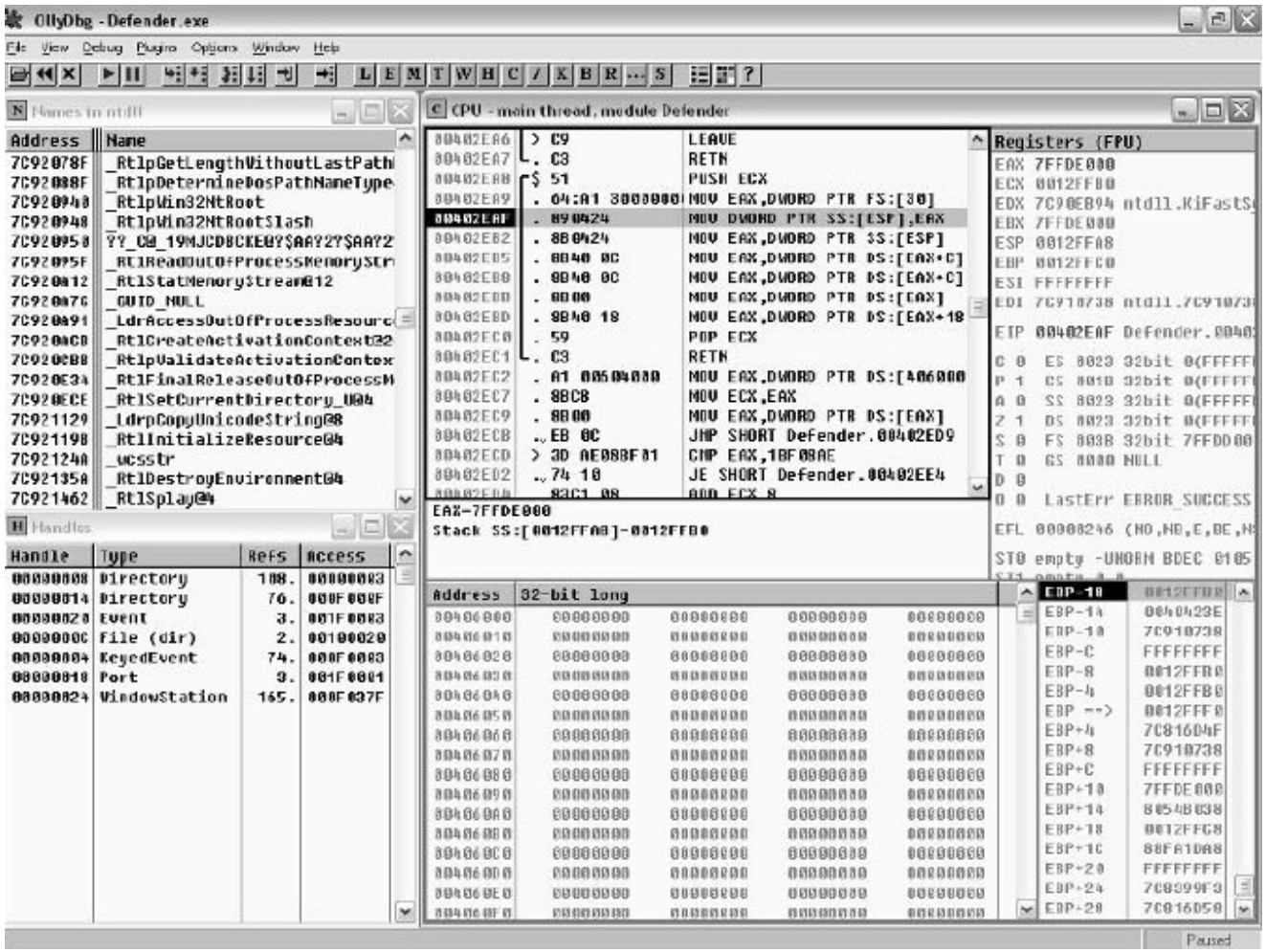
Important Debugger Features

- **Software and Hardware Breakpoints**
  - Software breakpoints are instructions added into the program's code by the debugger at runtime. These instructions make the processor pause program execution and transfer control to the debugger when they are reached during execution.
  - Hardware breakpoints are a special CPU feature that allow the processor to pause execution when a certain memory address is accessed, and transfer control to the debugger.

Example: OllyDbg

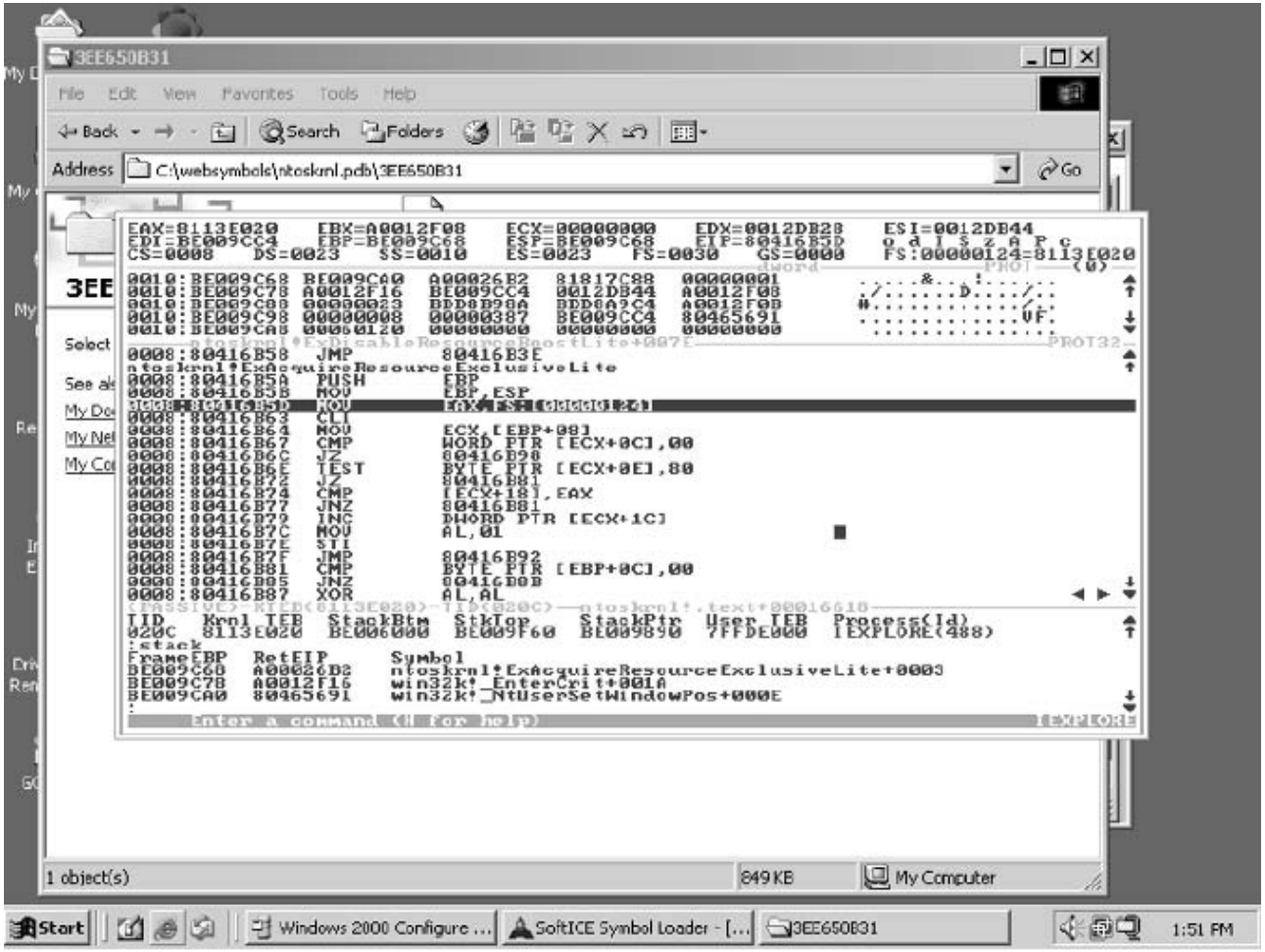
- OllyDbg includes a powerful disassembler
- Its code analyzer can identify loops, switch blocks, and other key code structures.
- It shows parameter names for all known functions and APIs, and supports searching for cross-references between code and data—in all possible directions.
- It supports a wide variety of views, including listing imports and exports in modules
- It also includes a built-in assembling and patching engine

Example: OllyDbg



Typical OllyDbg Screen

Example: SoftICE



Decompilers

- Decompilers attempt to produce a high-level language source-code-like representation from a program binary.

- It is never possible to restore the original code in its exact form because the compilation process always removes some information from the program.

System Monitoring Tools

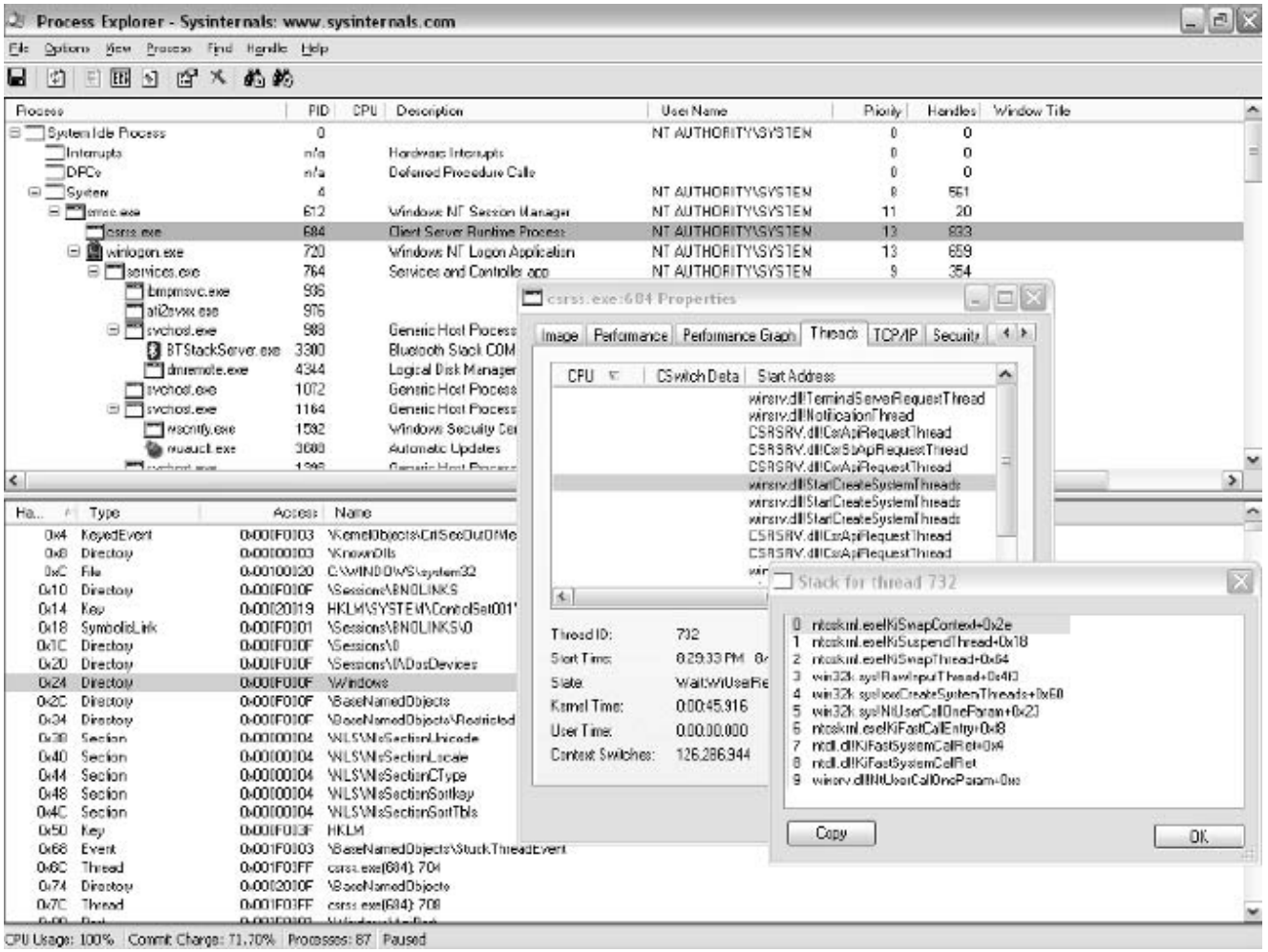
- System-monitoring tools is a general category of software tools that observe the various channels of I/O that exist between applications and the operating system.
- These are tools such as file access monitors that display every file operation (such as file creation, reading or writing to a file, and so on) made from every application on the system.
- This is done by hooking certain low-level components in the operating system and monitoring any relevant calls made from applications.

Example: Process Explorer

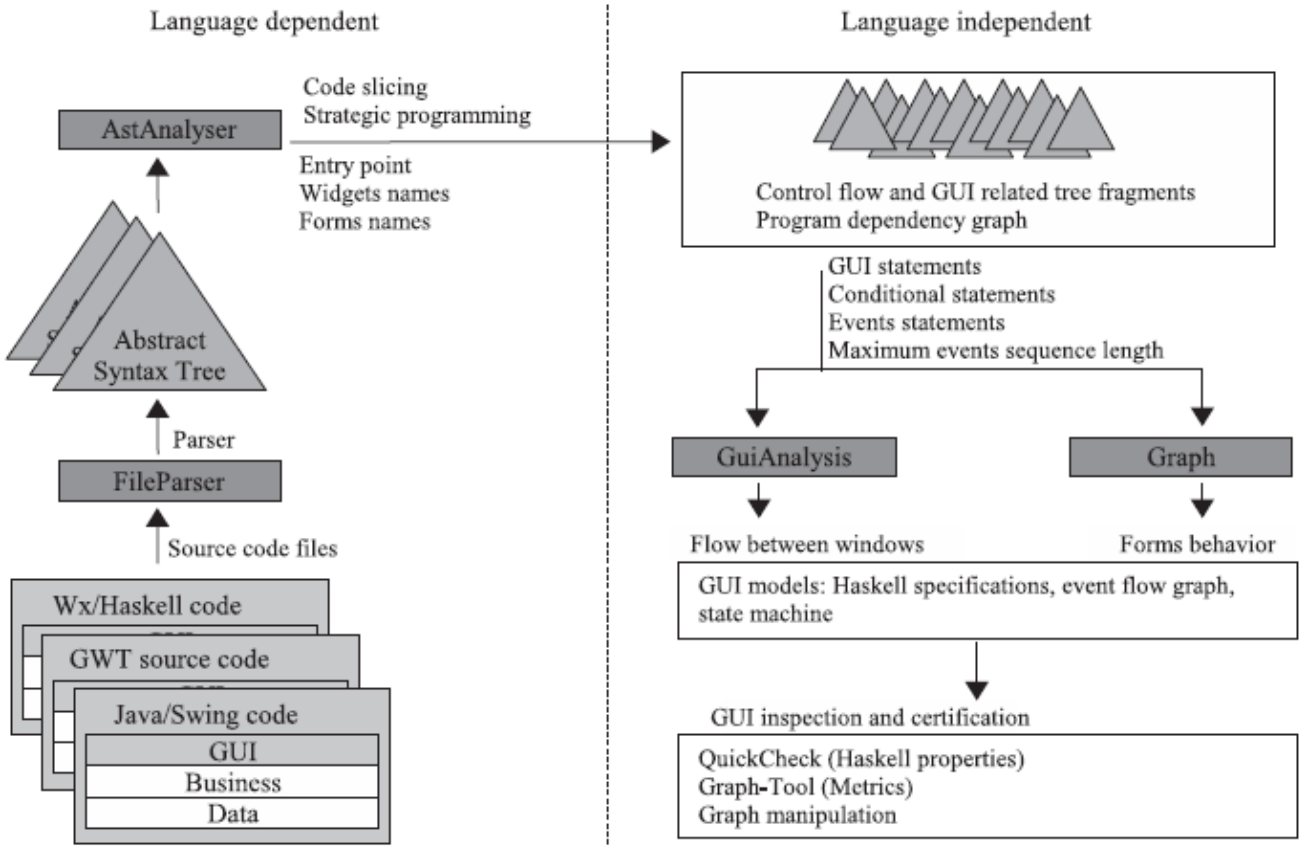
- Process Explorer is like a turbo-charged version of the built-in Windows Task Manager, and was actually designed to replace it.

- Process Explorer can show processes, DLLs loaded within their address spaces, handles to objects within each process, detailed information on open network connections, CPU and memory usage graphs, and the list just goes on and on.

Example: Process Explorer



Other RE Tools: GUISURFER



Ref.: GUIsurfer: A Reverse Engineering Framework for User Interface Software by Campos, Saraiva, and Silva

FIRMWARE RE
FOR
PIC MICROCONTROLLER

Microchip PICKit Debugger / Programmer

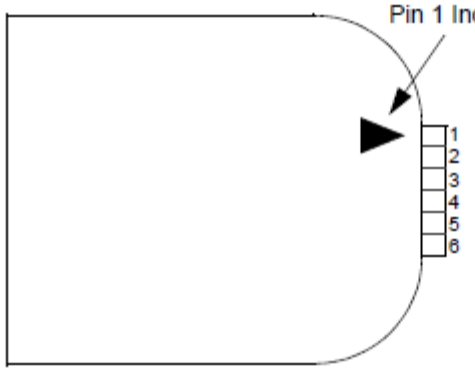
- The PICkit 3 debugger was developed for **programming and debugging embedded processors** with debug functions.

- The PICkit 3 features include:
  - Full-speed USB support using Windows standard drivers
  - Real-time execution
  - Processors running at maximum speeds
  - Built-in over-voltage/short circuit monitor
  - Low voltage to 5V (1.8-5V range)
  - Diagnostic LEDs (power, active, status)
  - **Read/write program and data memory of microcontroller**
  - Erasing of all memory types (EEPROM, ID, configuration and program) with verification
  - Peripheral freeze at breakpoint

PICKit Debugger

Legend:

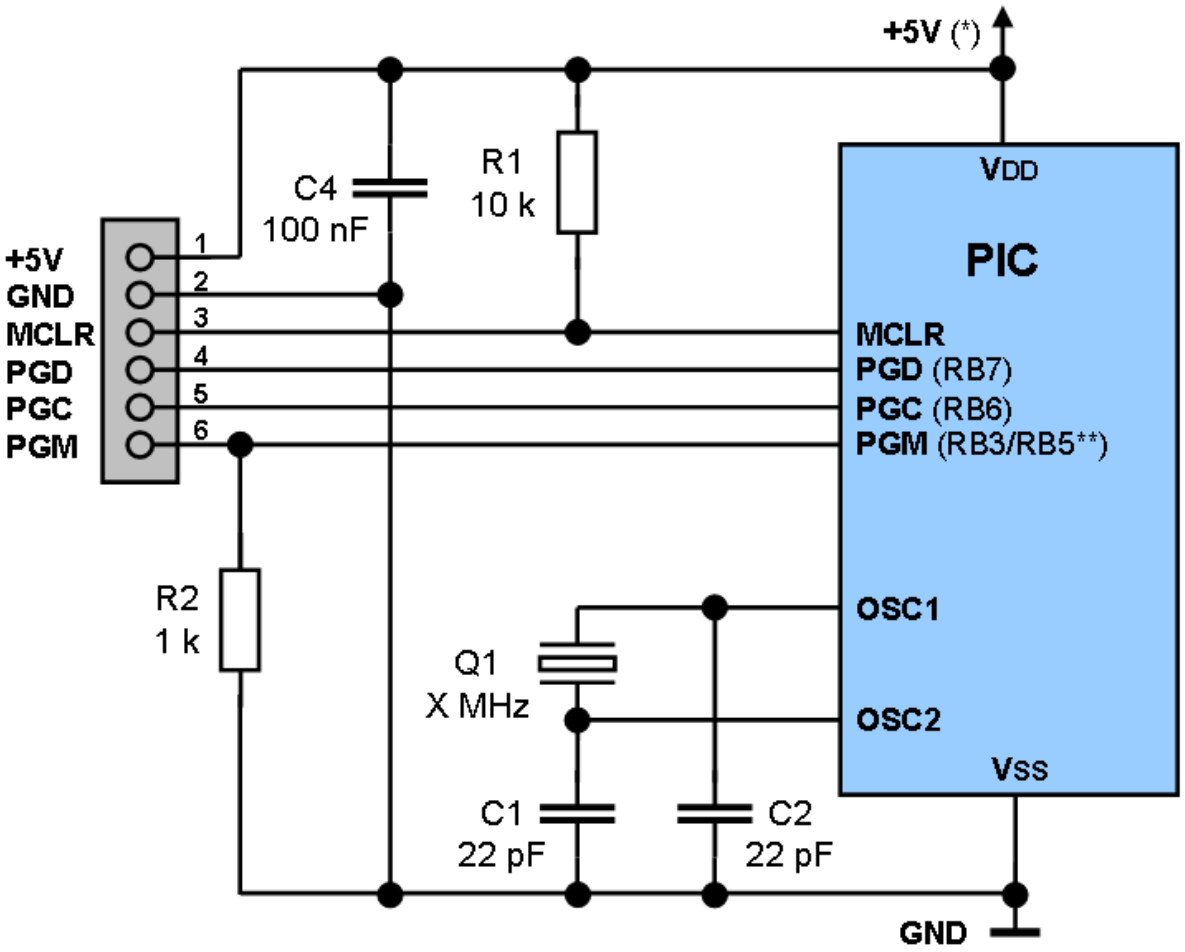
1 – Lanyard Loop
2 – USB Port Connection
3 – Pin 1 Marker
4 – Programming Connector
5 – Indicator LEDs
6 – Push Button



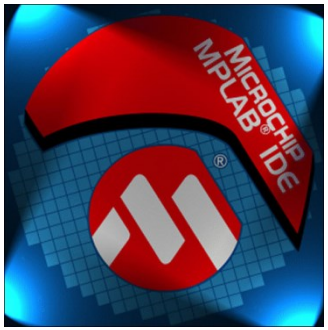
Pin Description*

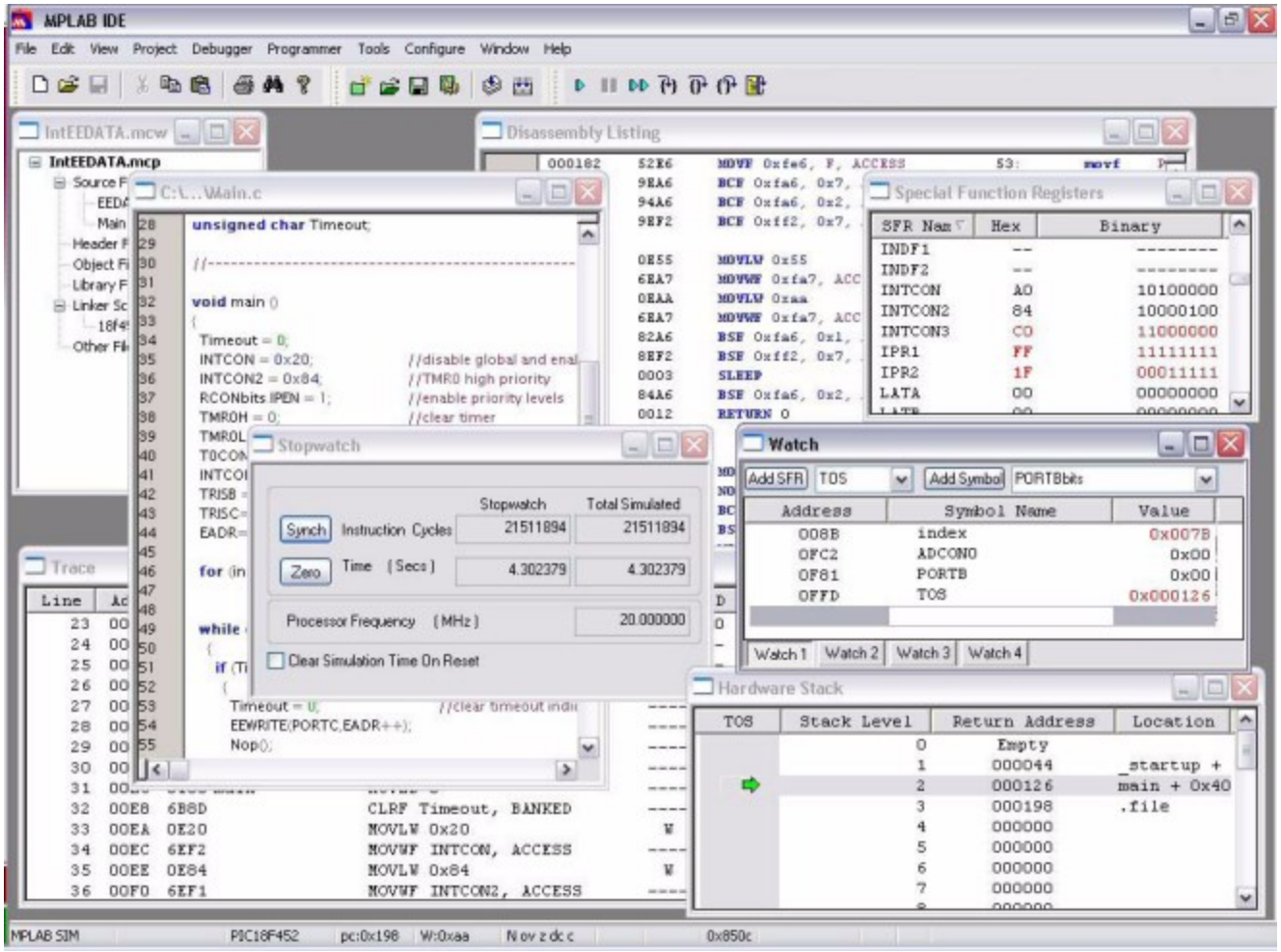
1 = $\overline{\text{MCLR}}$/VPP
2 = VDD Target
3 = Vss (ground)
4 = PGD (ICSPDAT)
5 = PGC (ICSPCLK)
6 = PGM (LVP)

PIC – Debugger Connection



MPLAB


MICROCHIP
MPLAB® IDE


MPLAB IDE
File Edit View Project Debugger Programmer Tools Configure Window Help
IntEEDATA.mcw
IntEEDATA.mcp
Disassembly Listing
C:\...\Main.c
unsigned char Timeout;
void main ()
Timeout = 0;
INTCON = 0x20; //disable global and enal
INTCON2 = 0x84; //TMR0 high priority
RCONbits.IPEN = 1; //enable priority levels
TMR0H = 0; //clear timer
for (in
while
if (Ti
Timeout = 0; //clear timeout indi
EEWRITE(PORTC,EADR++);
Nop();
Special Function Registers
SFR Nam | Hex | Binary
INDF1 -- --------
INDF2 -- --------
INTCON A0 10100000
INTCON2 84 10000100
INTCON3 C0 11000000
IPR1 FF 11111111
IPR2 1F 00011111
LATA 00 00000000
Stopwatch
Stopwatch Total Simulated
Synch Instruction Cycles 21511894 21511894
Zero Time (Secs) 4.302379 4.302379
Processor Frequency (MHz) 20.000000
Clear Simulation Time On Reset
Watch
Add SFR TOS Add Symbol PORTBbits
Address Symbol Name Value
008B index 0x007B
0FC2 ADCON0 0x00
0F81 PORTB 0x00
0FFD TOS 0x000126
Watch 1 Watch 2 Watch 3 Watch 4
Trace
Line
23 00
24 00
25 00
26 00
27 00
28 00
29 00
30 00
31 00
32 00E8 6B8D CLRF Timeout, BANKED
33 00EA 0E20 MOVLW 0x20
34 00EC 6EF2 MOVWF INTCON, ACCESS
35 00EE 0E84 MOVLW 0x84
36 00F0 6EF1 MOVWF INTCON2, ACCESS
Hardware Stack
TOS Stack Level Return Address Location
0 Empty
1 000044 _startup +
2 000126 main + 0x40
3 000198 .file
4 000000
5 000000
6 000000
7 000000
MPLAB SIM PIC18F452 pc:0x198 W:0xaa N ov z dc c 0x850c

Machine Code vs. Assembly Language

Memory address	*Machine code*	Assembly		Meaning
000	3000	MOVLW	00	Load working register (W) with number 0
001	0066	TRIS	06	Store W in Port B direction code register
002	0186	CLRF	06	Clear Port B data register
003	0A86	INCF	06	Increment Port B data register
004	2803	GOTO	03	Jump back to address 0003 above

Conclusion

- S/W are used in many products and therefore S/W RE has gained much attention in the industry and research.

- S/W RE requires
  - In-depth knowledge in software construction (such as Assembly Language and O/S).
  - Great skills in puzzle solving and code breaking.
  - Knowledge and skills in identifying and using RE tools.