CSC 6580
Spring 2020

Instructor: Stacy Prowell

gdb

Using gdb

You can use gdb to debug your assembly programs. To debug the `binary` program you could use:

```
$ gdb binary
```

Or you can load `binary` after starting gdb with `file binary`.

Run with `run`.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
sprowell@sanders:~/CSC6580-2020-Spring/02-06$ gdb
GNU gdb (Ubuntu 8.2.91.20190405-0ubuntu3) 8.2.91.20190405-git
Copyright (C) 2019 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word".
(gdb) file binary
Reading symbols from binary...
(No debugging symbols found in binary)
(gdb) disass main
Dump of assembler code for function main:
   0x0000000000401b80 <+0>:     movabs rdi,0xff00f043210099aa
   0x0000000000401b8a <+10>:    call   0x401b9a <write_binary_qword>
   0x0000000000401b8f <+15>:    call   0x401c1d <write_endl>
   0x0000000000401b94 <+20>:    mov    eax,0x0
   0x0000000000401b99 <+25>:    ret
End of assembler dump.
(gdb)
```

Using gdb

Instead of referring to line numbers you use addresses or labels. For instance, to see the code starting at the label main, use:

```
disassemble main
```

You can abbreviate `disassemble` as `disass`.

The disassembly will be "around" the address you give (or if none, around `RIP`), or you can give a range, or an address. Include `/r` to see the bytes.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
sprowell@sanders:~/CSC6580-2020-Spring/02-06$ gdb
GNU gdb (Ubuntu 8.2.91.20190405-0ubuntu3) 8.2.91.20190405-git
Copyright (C) 2019 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word".
(gdb) file binary
Reading symbols from binary...
(No debugging symbols found in binary)
(gdb) disass main
Dump of assembler code for function main:
   0x0000000000401b80 <+0>:     movabs rdi,0xff00f043210099aa
   0x0000000000401b8a <+10>:    call   0x401b9a <write_binary_qword>
   0x0000000000401b8f <+15>:    call   0x401c1d <write_endl>
   0x0000000000401b94 <+20>:    mov    eax,0x0
   0x0000000000401b99 <+25>:    ret
End of assembler dump.
(gdb)
```

Using gdb

Set breakpoints with `break` (or just `b`) followed by a location. Use an asterisk (`*`) for a memory expression.

```
b main
b *main+20
```

List breakpoints with `info b`, and delete them with `d` and their number.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from binary...
(No debugging symbols found in binary)
(gdb) b main
Breakpoint 1 at 0x401b80
(gdb) b *main+20
Breakpoint 2 at 0x401b94
(gdb) info b
Num     Type           Disp Enb Address            What
1       breakpoint     keep y   0x0000000000401b80 <main>
2       breakpoint     keep y   0x0000000000401b94 <main+20>
(gdb) run
Starting program: /home/sprowell/snap/odrive-unofficial/2/Google Drive/CSC6580-2020-
Spring/02-06/binary

Breakpoint 1, 0x0000000000401b80 in main ()
(gdb) cont
Continuing.
1111 1111 0000 0000 1111 0000 0100 0011 0010 0001 0000 0000 1001 1001 1010 1010

Breakpoint 2, 0x0000000000401b94 in main ()
(gdb) d 1
(gdb) info b
Num     Type           Disp Enb Address            What
2       breakpoint     keep y   0x0000000000401b94 <main+20>
        breakpoint already hit 1 time
(gdb)
```

Using gdb

Catch signals with `catch`. You can catch all the usual signal, or you can catch specific signals by name or number. Of particular interest:

```
catch signal SIGSEGV
```

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
Register group: general
rax            0x2                 2
rbx            0x7fffffffdf50      140737488346960
rcx            0x0                 0
rdx            0x4059000000000000  4636737291354636288
rsi            0xffff00000000      4503595332403200
rdi            0x4c40f0            4997360
rbp            0x7fffffffde20      0x7fffffffde20
rsp            0x7fffffffdd18      0x7fffffffdd18

   0x414ceb <printf+27>    mov    QWORD PTR [rsp+0x48],r9
   0x414cf0 <printf+32>    test   al,al
   0x414cf2 <printf+34>    je     0x414d2b <printf+91>
 > 0x414cf4 <printf+36>    movaps XMMWORD PTR [rsp+0x50],xmm0
   0x414cf9 <printf+41>    movaps XMMWORD PTR [rsp+0x60],xmm1
   0x414cfe <printf+46>    movaps XMMWORD PTR [rsp+0x70],xmm2
   0x414d03 <printf+51>    movaps XMMWORD PTR [rsp+0x80],xmm3
   0x414d0b <printf+59>    movaps XMMWORD PTR [rsp+0x90],xmm4
   0x414d13 <printf+67>    movaps XMMWORD PTR [rsp+0xa0],xmm5
native process 27528 In: printf                          L??   PC: 0x414cf4
(gdb) run
Starting program: /home/sprowell/snap/odrive-unofficial/2/Google Drive/CSC6580-2020-
Spring/02-06/sqrt_list
[Inferior 1 (process 27523) exited normally]
(gdb) run 100
Starting program: /home/sprowell/snap/odrive-unofficial/2/Google Drive/CSC6580-2020-
Spring/02-06/sqrt_list 100

Catchpoint 1 (signal SIGSEGV), 0x0000000000414cf4 in printf ()
(gdb)
```

Using gdb

Find out what's on the stack with `where`.

Look at that! The stack is not aligned. Use `up` to move up a stack frame (assuming that what's on the stack is a correct stack frame).

There's the problem! The `push rax` mis-aligns the stack.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
Register group: general
rax            0x2                 2
rbx            0x7fffffffdf50      140737488346960
rcx            0x0                 0
rdx            0x4059000000000000  4636737291354636288
rsi            0xffff00000000      4503595332403200
rdi            0x4c40f0            4997360
rbp            0x7fffffffde20      0x7fffffffde20
rsp            0x7fffffffddf8      0x7fffffffddf8

   0x401c26 <loop+47>      mov    eax,0x2
   0x401c2b <loop+52>      push   rax
   0x401c2c <loop+53>      call   0x414cd0 <printf>
 > 0x401c31 <loop+58>      add    rbx,0x8
   0x401c35 <loop+62>      jmp    0x401bf7 <loop>
   0x401c37 <good>         mov    eax,0x0
   0x401c3c <done>         leave
   0x401c3d <done+1>       ret
   0x401c3e <done+2>       xchg   ax,ax
native process 27528 In: loop                          L??   PC: 0x401c31
#2  0x0000000000000002 in ?? ()
#3  0x0000000000402b80 in ?? ()
#4  0x0000000000402c10 in ?? ()
#5  0xffffdf5040590000 in ?? ()
#6  0x0000000200007fff in ?? ()
#7  0x0000000000402b80 in ?? ()
#8  0x0000000000402440 in __libc_start_main ()
--Type <RET> for more, q to quit, c to continue without paging--
#9  0x0000000000401aea in _start ()
(gdb)
```

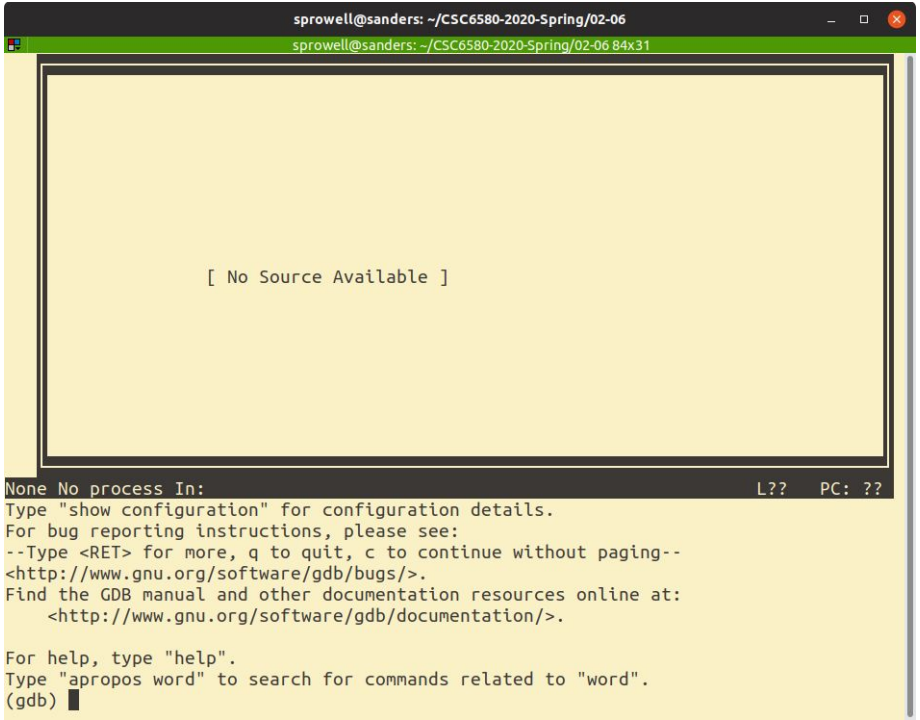
Using gdb

Use the Text User Interface (TUI) mode.

- `gdbtui`
- `gdb -tui`
- `gdb` and then `ctrl+x ctrl+a` (toggle)

Also:

- `tui enable` / `tui disable`
- `tui reg`

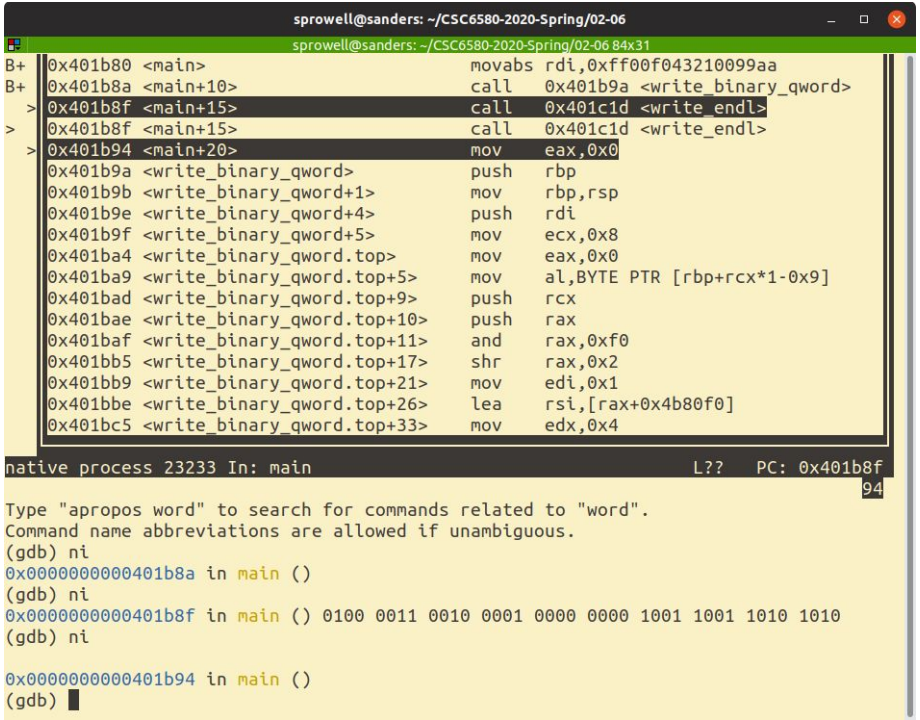


Using gdb

The interface can get messed up when it scrolls. You can refresh it with `ctrl+l` or with `refresh`.

A trick some folks use is to create a *user hook* for commands that will automatically call refresh.

```
define hook-nexti
  refresh
end
```



Using gdb

Switch to the assembly layout or to register layout.

```
layout asm
layout regs
```

The display follows `RIP`… but you can scroll around, too, with the arrow keys. You can change the focused window with `focus`.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
┌─Register group: general──────────────────────────────────────────────────────
r13            0x0                 0
r14            0x4c4018            4997144
r15            0x0                 0
rip            0x401c31            0x401c31 <loop+58>
eflags         0x10202             [ IF RF ]
cs             0x33                51
ss             0x2b                43
ds             0x0                 0
   0x401c1c <loop+37>      movabs rdi,0x4c40f0
   0x401c26 <loop+47>      mov    eax,0x2
   0x401c2b <loop+52>      push   rax
   0x401c2c <loop+53>      call   0x414cd0 <printf>
 > 0x401c31 <loop+58>      add    rbx,0x8
   0x401c35 <loop+62>      jmp    0x401bf7 <loop>
   0x401c37 <good>         mov    eax,0x0
   0x401c3c <done>         leave
   0x401c3d <done+1>       ret
native process 27528 In: loop                                  L??   PC: 0x401c31
#6  0x0000000200007fff in ?? ()
#7  0x0000000000402b80 in ?? ()
#8  0x0000000000402440 in __libc_start_main ()
--Type <RET> for more, q to quit, c to continue without paging--
#9  0x0000000000401aea in _start ()
(gdb) focus regs
Focus set to regs window.
(gdb) focus asm
Focus set to asm window.
(gdb)
```

Using gdb

Use Intel syntax with
`set disassembly-flavor intel`.

Put this (and other commands) in your
`.gdbinit`.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
Register group: general
rax            0x0                 0
rbx            0x0                 0
rcx            0x0                 0
rdx            0x0                 0
rsi            0x0                 0
rdi            0x0                 0
rbp            0x0                 0x0
rsp            0x7fffffffdf40      0x7fffffffdf40

 > 0x401a60 <_start>        xor    ebp,ebp
   0x401a62 <_start+2>      mov    r9,rdx
   0x401a65 <_start+5>      pop    rsi
   0x401a66 <_start+6>      mov    rdx,rsp
   0x401a69 <_start+9>      and    rsp,0xfffffffffffffff0
   0x401a6d <_start+13>     push   rax
   0x401a6e <_start+14>     push   rsp
   0x401a6f <_start+15>     mov    r8,0x402be0
   0x401a76 <_start+22>     mov    rcx,0x402b50
native process 24211 In: _start                          L??   PC: 0x401a60
(gdb) starti
Starting program: /home/sprowell/snap/odrive-unofficial/2/Google Drive/CSC6580-2020-
Spring/02-06/binary

Program stopped.
0x0000000000401a60 in _start ()
(gdb)
```

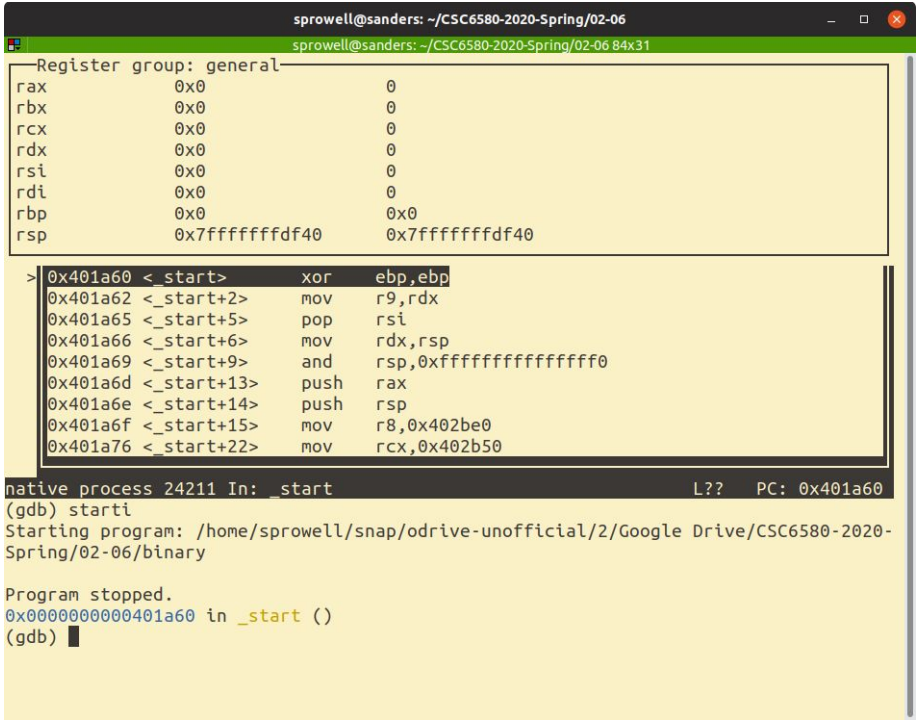
Using gdb

See what's in a register with `print` (or `p`). There are many optional modifiers you can add after `print`; for instance, `/x` prints hexadecimal.

```
print $rsp
print /x $rsp
```

Use * to try to dereference pointers. Use parens to cast.

```
print *(int)$rip
```



Using gdb

Watch a value with `display`.

```
display $rsp
display /s $rdi
display $rsp
```

Remove a display with `undisplay` and the display number (or remove them all).

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
   0x401bd8 <main+8>       je     0x401bf3 <main.okay>
>  0x401bda <main+10>      movabs rdi,0x4b8132
   0x401be4 <main+20>      call   0x411960 <puts>
   0x401be9 <main+25>      mov    eax,0x1
   0x401bee <main+30>      jmp    0x401c95 <main.done>
   0x401bf3 <main.okay>    sub    rsp,0x10
   0x401bf7 <main.okay+4>  push   rsi
   0x401bf8 <main.okay+5>  mov    rdi,rsi
   0x401bfb <main.okay+8>  mov    rdi,QWORD PTR [rdi+0x8]
   0x401bff <main.okay+12> call   0x40f1f0 <atol>
   0x401c04 <main.okay+17> mov    QWORD PTR [rbp-0x8],rax
   0x401c08 <main.okay+21> pop    rdi
   0x401c09 <main.okay+22> mov    rdi,QWORD PTR [rdi+0x10]
   0x401c0d <main.okay+26> call   0x40f1f0 <atol>
   0x401c12 <main.okay+31> mov    QWORD PTR [rbp-0x10],rax
   0x401c16 <main.okay+35> movabs rdi,0x4b815a
   0x401c20 <main.okay+45> call   0x411960 <puts>
   0x401c25 <main.okay+50> mov    rdi,QWORD PTR [rbp-0x8]
native process 31339 In: main                          L??   PC: 0x401bda
3: $rdi = 1
4: $rsi = 140737488346952
(gdb) layout asm
(gdb) ni
0x0000000000401bda in main ()
1: $rip = (void (*)()) 0x401bda <main+10>
2: $rsp = (void *) 0x7fffffffde20
3: $rdi = 1
4: $rsi = 140737488346952
(gdb)
```

Using gdb

Similarly, see what's in memory with `x`. Expect strings with `/s`.

```
x $rip
x /s $rdi
```

Several other options. See `help x` and `help print` for more.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
Register group: general
r13            0x0                 0
r14            0x4c4018            4997144
r15            0x0                 0
rip            0x401c31            0x401c31 <loop+58>
eflags         0x10202             [ IF RF ]
cs             0x33                51
ss             0x2b                43
ds             0x0                 0

   0x401c0e <loop+23>      call   0x401c40 <sqrtf64>
   0x401c13 <loop+28>      movsd  xmm1,xmm0
   0x401c17 <loop+32>      movsd  xmm0,QWORD PTR [rbp-0x14]
   0x401c1c <loop+37>      movabs rdi,0x4c40f0
   0x401c26 <loop+47>      mov    eax,0x2
   0x401c2b <loop+52>      push   rax
   0x401c2c <loop+53>      call   0x414cd0 <printf>
 > 0x401c31 <loop+58>      add    rbx,0x8
   0x401c35 <loop+62>      jmp    0x401bf7 <loop>

native process 27528 In: loop                          L??   PC: 0x401c31
(gdb) refresh
(gdb) print $rip
$11 = (void (*)()) 0x401c31 <loop+58>
(gdb) x $rip
0x401c31 <loop+58>:     "H\203\303\b\353\300\270"
(gdb) x /x $rip
0x401c31 <loop+58>:     0x48
(gdb) x /s $rdi
0x4c40f0:       "sqrt(%f) = %f\n"
(gdb)
```

Using gdb

Modify the content of registers with set.

```
set $edi = 0x21aae436
set $rsi = $rdi + 100
```

Yes, this includes `RIP` and `RSP`.

```
sprowell@sanders: ~/CSC6580-2020-Spring/02-06
sprowell@sanders: ~/CSC6580-2020-Spring/02-06 84x31
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from ./sqrt_list...
(No debugging symbols found in ./sqrt_list)
(gdb) catch signal SIGSEGV
Catchpoint 1 (signal SIGSEGV)
(gdb) layout regs
(gdb) disass
Dump of assembler code for function main:
   0x0000000000401be0 <+0>:     push   rbp
   0x0000000000401be1 <+1>:     mov    rbp,rsp
   0x0000000000401be4 <+4>:     sub    rsp,0x20
=> 0x0000000000401be8 <+8>:     mov    DWORD PTR [rbp-0x4],edi
   0x0000000000401beb <+11>:    add    rsi,0x8
   0x0000000000401bef <+15>:    mov    QWORD PTR [rbp-0xc],rsi
   0x0000000000401bf3 <+19>:    mov    rbx,QWORD PTR [rbp-0xc]
End of assembler dump.
(gdb) set $edi = 10
(gdb) print $edi
$1 = 10
(gdb)
```

Using gdb

Running the program:

- `starti`
- `stepi`
- `nexti (ni)`
- `down / up`
- `b / info b / delete`

Use a leading asterisk with an address.

Getting information:

- `info registers / info files`
- `print $rip`
- `print/d $rip`
- `print/x $rip`
- `x/16xg $rip`

o(octal), x(hex), d(decimal), u(unsigned decimal), t(binary), f(float), a(address), *i(instruction)*, c(char), s(string) and z(hex, zero padded on the left)

b(byte), h(halfword), w(word), g(giant, 8 bytes)

Using gdb

You can script gdb in several ways. One of the easiest is to use the `-ex` switch to run a command.

```
gdb -batch -ex "file addsub" -ex "disass main"
gdb -batch -ex "disass/r main" addsub
```

(The `-batch` causes gdb to exit after it runs the commands.)

```
function main() { gdb -batch -ex "file $1" -ex "disass main" ; }
```

Anti-Disassembly

Basic Blocks

A **basic block** is a sequence of code that has a single entry, single exit, and exactly one path from beginning to end.

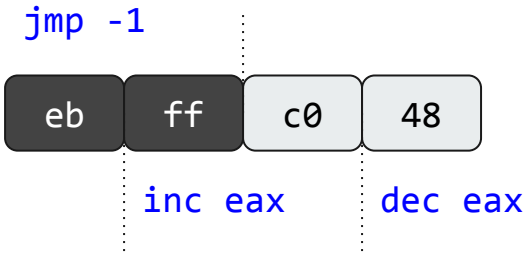
Basic Blocks

```
section .data
    msg db "Hello, world!", 0x0a
    len equ $ - msg
    stdout equ 1
    sys_exit equ 60
    sys_write equ 1

section .text
global _start
_start:
    mov rbp, rsp        ; Helps the debugger.

    ; Print the string.
    mov rdi, stdout
    mov rsi, msg
    mov rdx, len
    mov rax, sys_write
    syscall

    ; Exit with the length as the exit value.
    mov rdi, len
    mov rax, sys_exit
    syscall
    ret
```

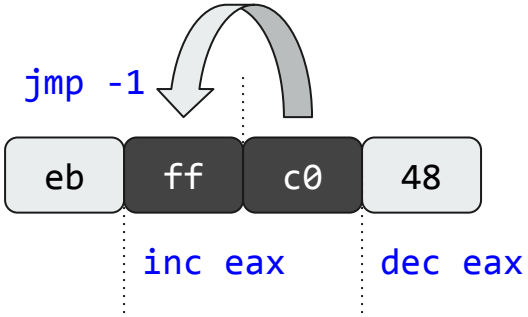
Confuse

- The **machine state** is the truth. Everything else is (potentially) a lie. Or at least, misleading.
- Assembly (and disassembly) is treated as if it were execution… but it is more akin to compilation (or decompilation).
- Almost all disassemblers **assume** that an address should appear only once in a listing. This is not true. It isn't even true that an address always corresponds to a single instruction!

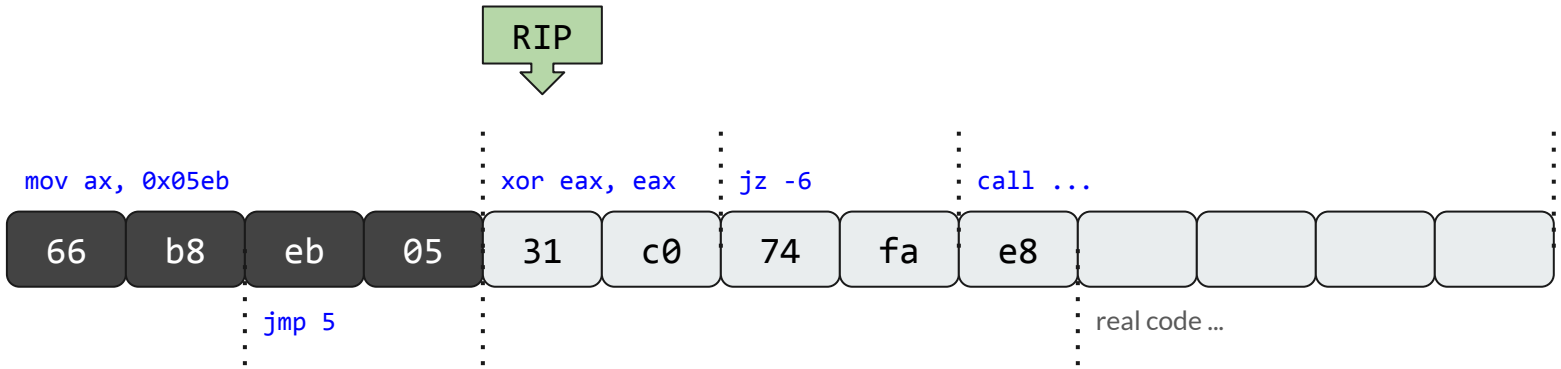
Linear disassembly



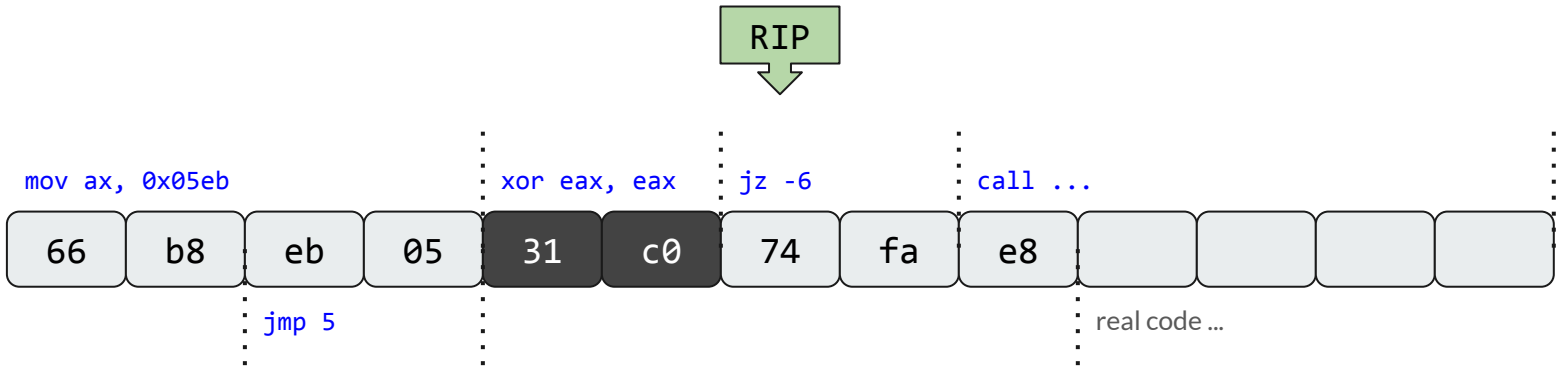
Linear disassembly



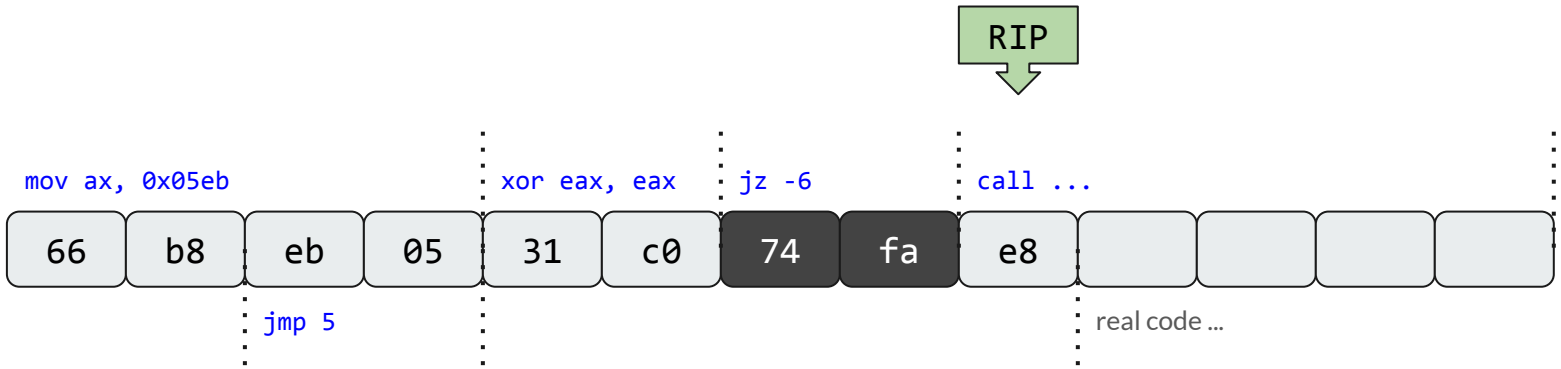
Things can get arbitrarily complex



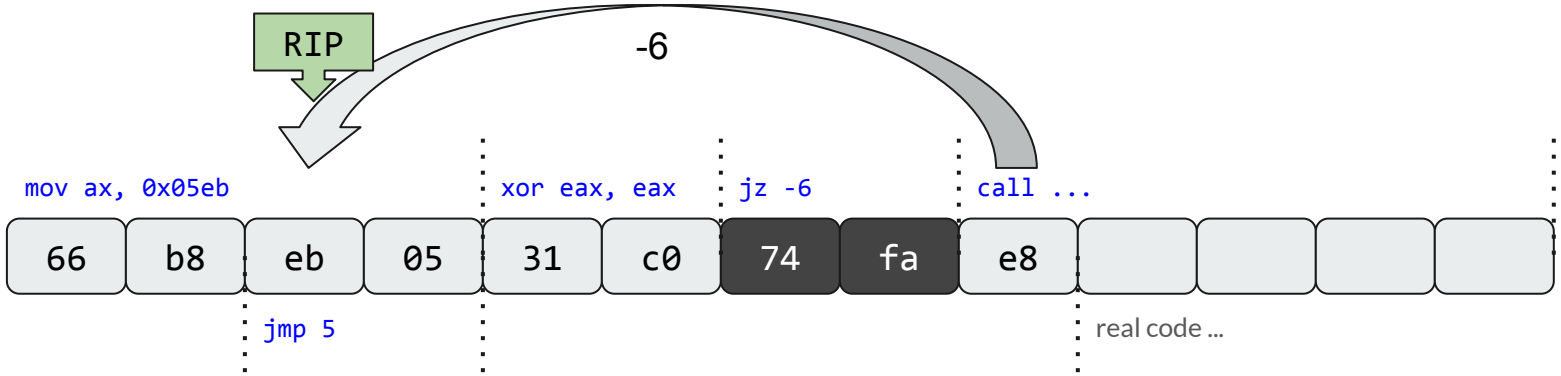
Things can get arbitrarily complex



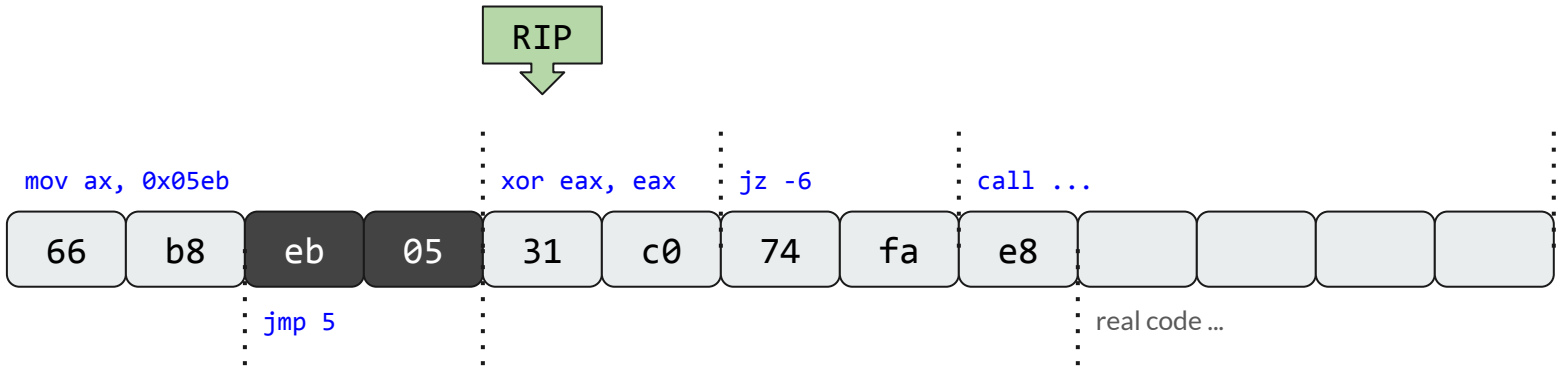
Things can get arbitrarily complex



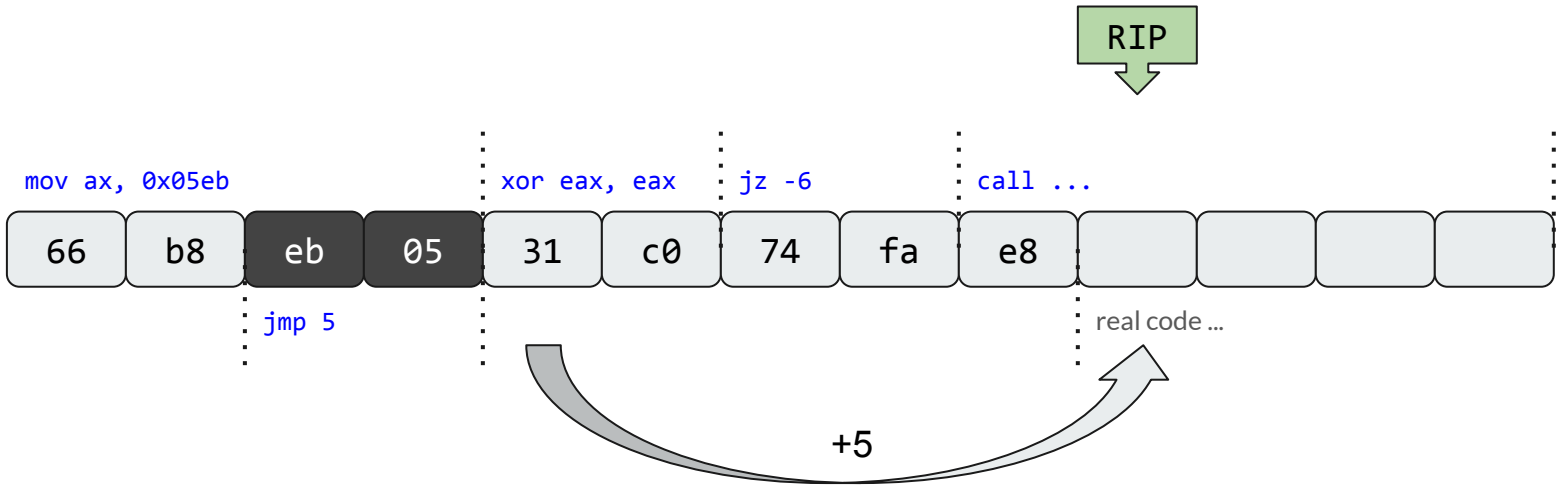
Things can get arbitrarily complex



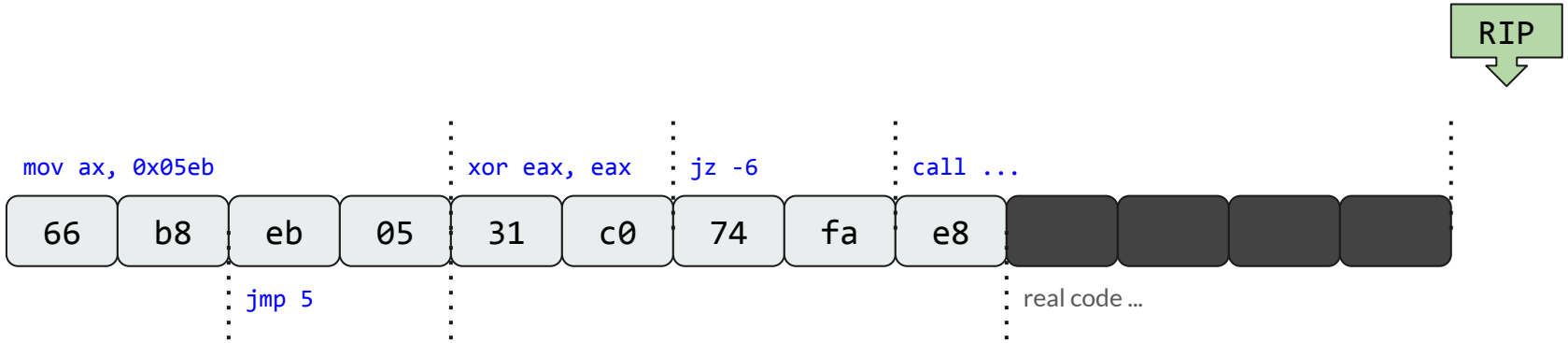
Things can get arbitrarily complex



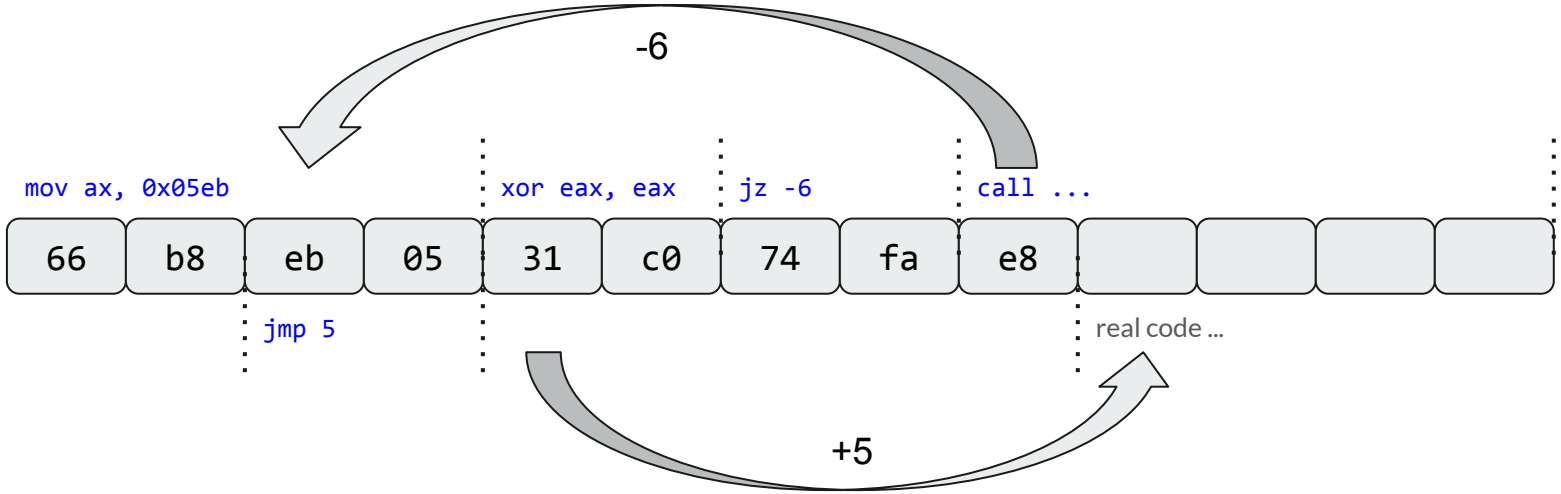
Things can get arbitrarily complex



Things can get arbitrarily complex

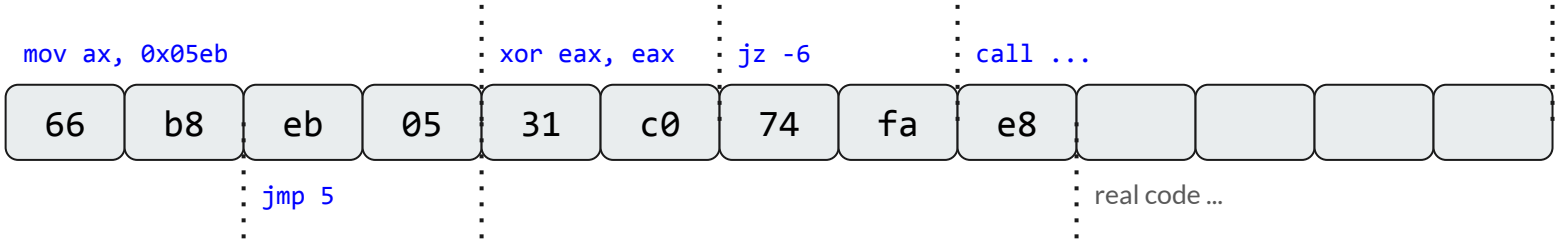


Things can get arbitrarily complex



It's pretty easy to code

```
        global _start, start

start:
_start:
        mov ax, 0x05eb
        xor eax, eax
        db 0x74, 0xfa, 0xe8
        ; hidden code begins here
        mov rdi, 22
        mov rax, 60
        syscall
        hlt
```



Things can get pretty nasty

- You don't actually *have* to honor the calling conventions. You can just pretend to.
- The stack is just unprotected memory. You can write to it.
- The instruction pointer is just another register. You can modify it directly.
- Push and jump! Push and return!
- … and lots of other stuff.

Next time:
Threaded disassembly