Debugging Tips and Tricks

Xcode 8 edition

Session 417

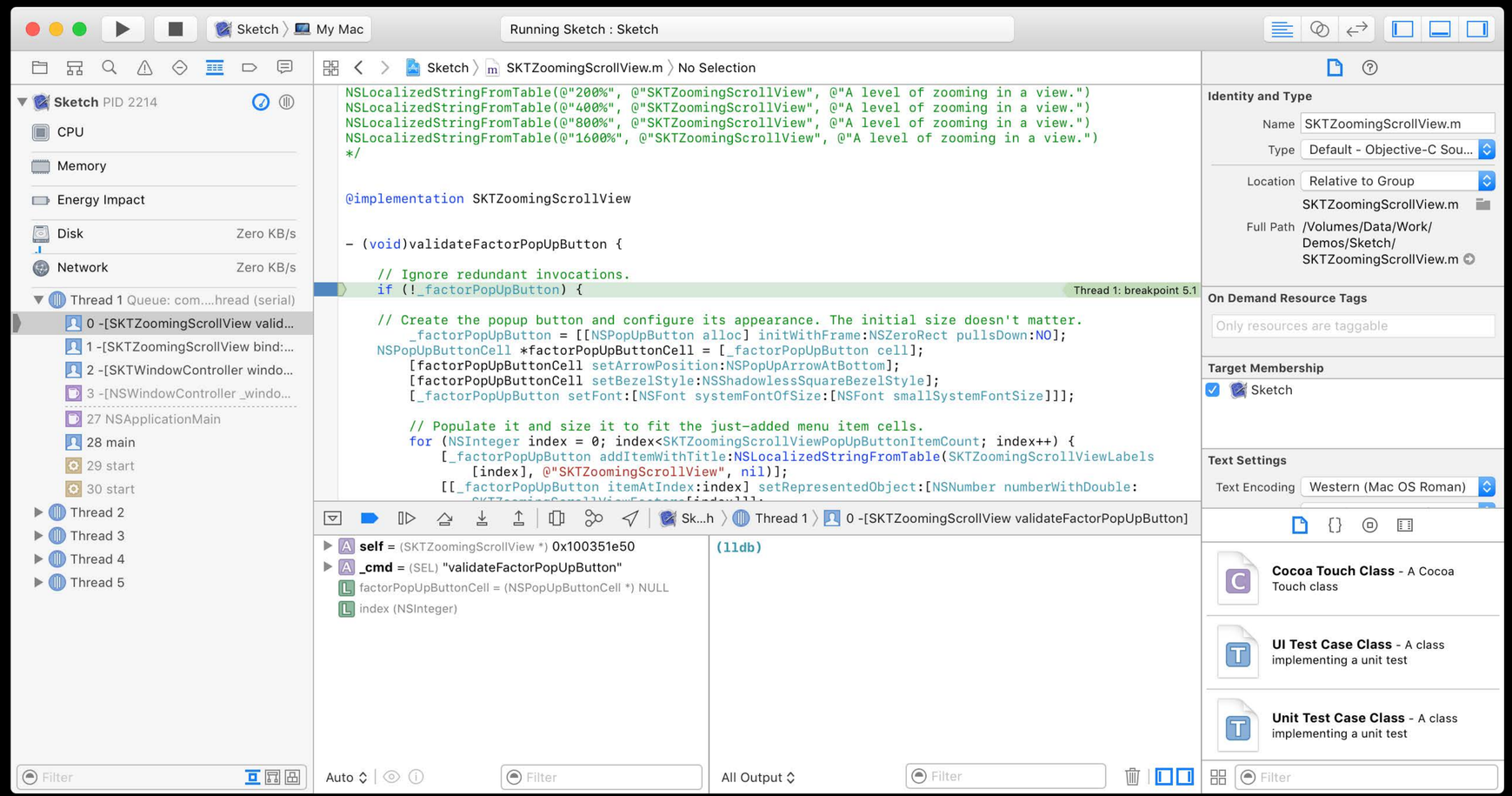
Kate Stone
Enrico Granata
Sean Callanan
Jim Ingham

LLDB is Apple's Debugger

. . . and it's everywhere you need it

LLDB in the Xcode debug console

- Xcode hosts app console + LLDB prompt



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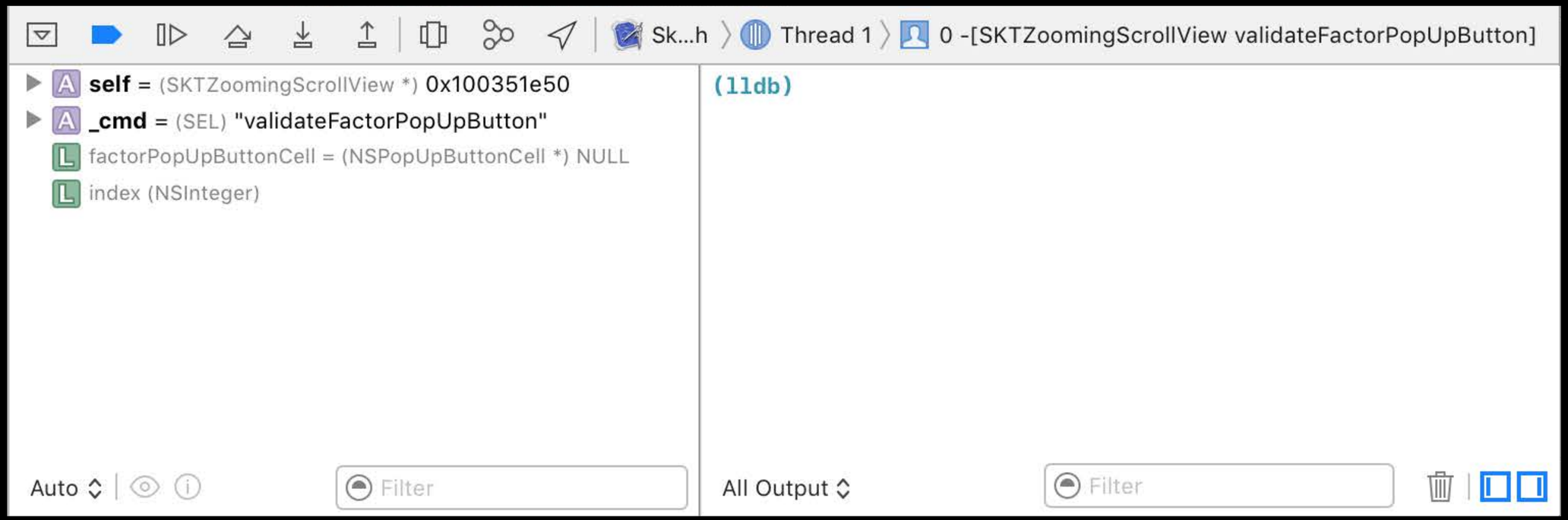

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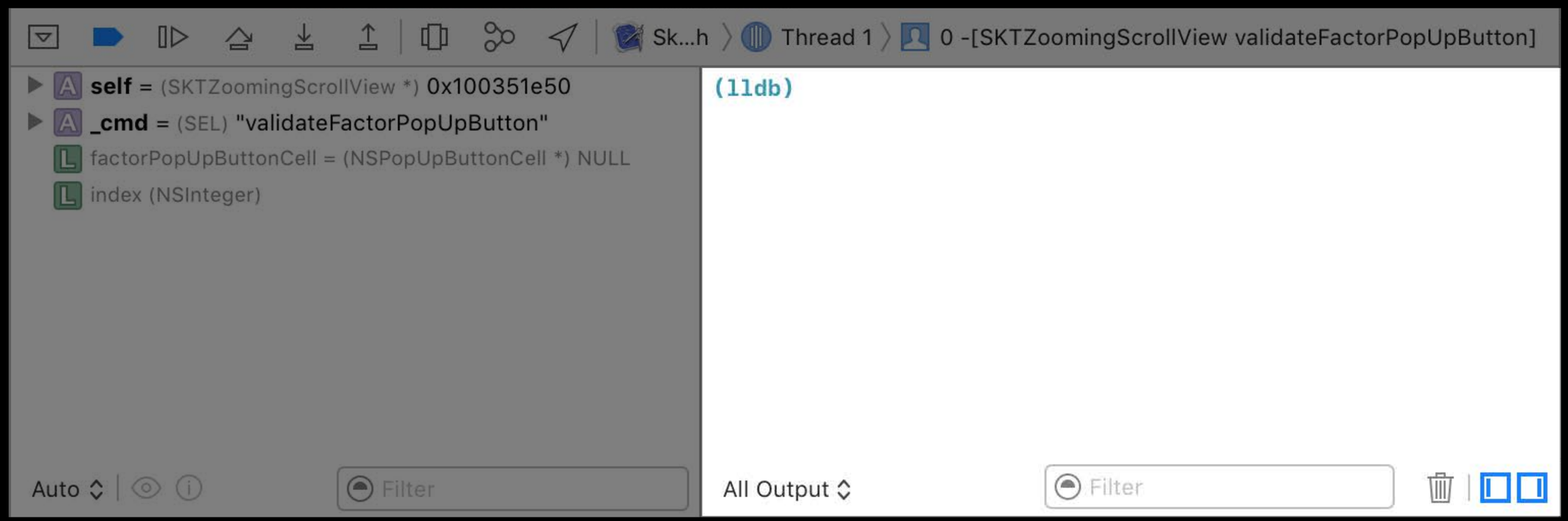

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NEW

Scheme option to use standalone terminal

Sketch 〉 My Mac

- **Build** 1 target
- **Run** Debug
- **Test** Debug
- **Profile** Release
- **Analyze** Debug
- **Archive** Release

Info | Arguments | Options | Diagnostics

Metal API Validation: Enabled

Persistent State: ☐ Launch application without state restoration

Document Versions: ☑ Allow debugging when using document Versions Browser

Working Directory: ☐ Use custom working directory:

Localization Debugging: ☐ Show non-localized strings

Application Language: System Language

Application Region: System Region

XPC Services: ☑ Debug XPC services used by this application

Queue Debugging: ☑ Enable backtrace recording

Console: ◉ Use Xcode
○ Use Terminal

Duplicate Scheme | Manage Schemes... | ☐ Shared | Close

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Scheme option to use standalone terminal

- Remainder of talk focused on LLDB commands

Visual Debugging with Xcode	Presidio	Wednesday 4:00PM
Thread Sanitizer and Static Analysis	Mission	Thursday 10:00AM

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The Swift REPL is LLDB

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The Swift REPL is LLDB

- :<command> enables any LLDB command

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```
$ swift
Welcome to Apple Swift version 3.0. Type :help for assistance.
  1>
```

```
$ swift
Welcome to Apple Swift version 3.0. Type :help for assistance.
  1> :type lookup Comparable
protocol Comparable : Equatable {
  @warn_unused_result func <(lhs: Self, rhs: Self) -> Swift.Bool
  @warn_unused_result func <=(lhs: Self, rhs: Self) -> Swift.Bool
  @warn_unused_result func >=(lhs: Self, rhs: Self) -> Swift.Bool
  @warn_unused_result func >(lhs: Self, rhs: Self) -> Swift.Bool
}
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```

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  @warn_unused_result func >(lhs: Self, rhs: Self) -> Swift.Bool
}
  1> :type lookup abs
func abs<T : SignedNumber>(_ x: T) -> T
  1>
```

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Welcome to Apple Swift version 3.0. Type :help for assistance.
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protocol Comparable : Equatable {
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  @warn_unused_result func >(lhs: Self, rhs: Self) -> Swift.Bool
}
  1> :type lookup abs
func abs<T : SignedNumber>(_ x: T) -> T
  1> :type lookup Swift
import SwiftShims
struct UnsafePointer<Pointee> : Strideable, Hashable, _Pointer {
  typealias Distance = Swift.Int
  let _rawValue: Builtin.RawPointer
  init(_ _rawValue: Builtin.RawPointer)
  init(_ from: Swift.OpaquePointer)
  …
```

```
$ swift
Welcome to Apple Swift version 3.0. Type :help for assistance.
  1>
```

```
$ swift
Welcome to Apple Swift version 3.0. Type :help for assistance.
  1> func greet() {
  2.     print("Welcome to WWDC16!")
  3. }
  4>
```

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Welcome to Apple Swift version 3.0. Type :help for assistance.
  1> func greet() {
  2.     print("Welcome to WWDC16!")
  3. }
  4> :b 2
Breakpoint 1: where = $__lldb_expr2`__lldb_expr_1.greet () -> () + 4 at repl.swift:2,
address = 0x0000000100558074
…
  4>
```

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Welcome to Apple Swift version 3.0. Type :help for assistance.
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Breakpoint 1: where = $__lldb_expr2`__lldb_expr_1.greet () -> () + 4 at repl.swift:2,
address = 0x0000000100558074
…
  4> greet()
Execution stopped at breakpoint.  Enter LLDB commands to investigate (type help for
assistance.)
…
(lldb)
```

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Welcome to Apple Swift version 3.0. Type :help for assistance.
  1> func greet() {
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Breakpoint 1: where = $__lldb_expr2`__lldb_expr_1.greet () -> () + 4 at repl.swift:2,
address = 0x0000000100558074
…
  4> greet()
Execution stopped at breakpoint.  Enter LLDB commands to investigate (type help for
assistance.)
…
(lldb) bt
* thread #1: tid = 0xd698f, 0x000000010068f064 $__lldb_expr2`greet() -> () + 4 at
repl.swift:2, queue = 'com.apple.main-thread', stop reason = breakpoint 1.1
  * frame #0: 0x000000010068f064 $__lldb_expr2`greet() -> () + 4 at repl.swift:2
    frame #1: 0x000000010068f84e $__lldb_expr4`main + 94 at repl.swift:4
    frame #2: 0x0000000100000e00 repl_swift`_mh_execute_header + 3584
    frame #3: 0x00007fffd408d285 libdyld.dylib`start + 1
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(lldb) repl
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```

LLDB as a Command-Line Tool

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- Provide a file containing LLDB commands

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lldb --source <filename>
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- Provide LLDB commands without requiring a file

```
lldb --one-line <command>
```

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lldb --source <filename>
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- Provide LLDB commands without requiring a file

```
lldb --one-line <command> -o <command2>
```

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- Provide LLDB commands without requiring a file

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- Run a series of commands and exit – unless target crashes

```
lldb --batch --source <filename>
```

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- Provide a file containing LLDB commands

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lldb --source <filename>
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- Run a series of commands and exit – unless target crashes

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while true; lldb --batch --source <filename>; done
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LLDB as a Command-Line Tool

Ideal for automating debugging tasks

- Provide a file containing LLDB commands

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lldb --source <filename>
```

- Provide LLDB commands without requiring a file

```
lldb --one-line <command> -o <command2>
```

- Run a series of commands and exit – unless target crashes

```
while true; lldb --batch --source <filename>; done
```

Review `lldb --help` for details

Xcode 8 and LLDB: Distinct Processes

NEW

… and it's completely transparent

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Multiple debugger versions supported

- Debugger selected automatically

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- Debugger selected automatically
- Swift 3 uses latest debugger
  - As does pure Objective-C and C++

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- Swift 2.3 uses Xcode 7.3.1-era debugger

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Multiple debugger versions supported

- Debugger selected automatically
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Xcode gracefully recovers when LLDB cannot

Customization and Introspection

Enrico Granata

Debugger Customization

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Customize your debugger for greater awesomeness

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Command aliases

Custom commands

Data formatters

Debugger Customization

NEW

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Command aliases

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Data formatters

Stepping actions

Command Aliases

Command Aliases

Create shorter syntax for frequent actions

Command Aliases

NEW

Create shorter syntax for frequent actions

Customize help text

```
(lldb) command alias
```

```
(lldb) command alias -h "Run a command in the UNIX shell."
```

```
(lldb) command alias -h "Run a command in the UNIX shell." --
```

```
(lldb) command alias -h "Run a command in the UNIX shell." -- shell
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```
(lldb) command alias -h "Run a command in the UNIX shell." -- shell platform shell
```

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(lldb) command alias -h "Run a command in the UNIX shell." -- shell platform shell
(lldb)
```

```
(lldb) command alias -h "Run a command in the UNIX shell." -- shell platform shell
(lldb) help shell
```

```
(lldb) command alias -h "Run a command in the UNIX shell." -- shell platform shell
(lldb) help shell
Run a command in the UNIX shell.  This command takes 'raw' input (no need to quote stuff).
…
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(lldb) command alias -h "Run a command in the UNIX shell." -- shell platform shell
(lldb) help shell
Run a command in the UNIX shell.  This command takes 'raw' input (no need to quote stuff).
…
(lldb) shell whoami
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Run a command in the UNIX shell.  This command takes 'raw' input (no need to quote stuff).
…
(lldb) shell whoami
egranata
```

Scripting LLDB in Python

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LLDB comes with a Python API

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Get started

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- Previous WWDC sessions

Debugging with LLDB	WWDC 2012
Advanced Debugging with LLDB	WWDC 2013

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Community doing amazing things

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A command to retrieve the return value of the last function call

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Only works if you `finish` your way out of a function

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Only works if you `finish` your way out of a function

- And don’t step!

```
(lldb)
```

```
(lldb) command script import ~/getreturn.py
(lldb)
```

```
(lldb) command script import ~/getreturn.py
(lldb) finish
…
Return value: (unsigned int) $0 = 2416832525
…
(lldb)
```

```
(lldb) command script import ~/getreturn.py
(lldb) finish
…
Return value: (unsigned int) $0 = 2416832525
…
(lldb) bt
```

```
    …
    frame #15: 0x00007fff81ad32c9 AE`dispatchEventAndSendReply(AEDesc const*, AEDesc*) + 39
    frame #16: 0x00007fff81ad31d5 AE`aeProcessAppleEvent + 312
    frame #17: 0x00007fff80285ae7 HIToolbox`AEProcessAppleEvent + 55
    frame #18: 0x00007fff7e9e5583 AppKit`_DPSNextEvent + 1811
    frame #19: 0x00007fff7f0eab6c AppKit`-[NSApplication(NSEvent)
_nextEventMatchingEventMask:untilDate:inMode:dequeue:] + 670
    frame #20: 0x00007fff7e9d9bf2 AppKit`-[NSApplication run] + 929
    frame #21: 0x00007fff7e9a551f AppKit`NSApplicationMain + 1237
    frame #22: 0x0000000100001462 WWDCrash`main(argc=1, argv=0x00007fff5fbff638) + 34 at
main.m:12
    frame #23: 0x00007fff94dc0285 libdyld.dylib`start + 1
    frame #24: 0x00007fff94dc0285 libdyld.dylib`start + 1
(lldb)
```

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(lldb) getreturn
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    frame #23: 0x00007fff94dc0285 libdyld.dylib`start + 1
    frame #24: 0x00007fff94dc0285 libdyld.dylib`start + 1
(lldb) getreturn
(unsigned int) $0 = 2416832525
(lldb)
```

```
class GetLatestReturnCommand:
    def __init__(self, debugger, session_dict):
        pass

    def __call__(self, debugger, command, exe_ctx, result):
        retval = exe_ctx.thread.GetStopReturnValue()
        T = retval.GetType().GetName()
        N = retval.GetName()
        V = retval.GetValue()
        S = retval.GetSummary()
        print >>result,"(%s) %s = %s" % (T, N, S if S else V if V else "")

    def get_short_help(self):
        return "Retrieve the last value returned by a function call on this thread."

def __lldb_init_module(debugger, *args):
    debugger.HandleCommand('com scr add --class command.GetLatestReturnCommand getreturn')
```

Persistent Customizations

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Save yourself from repetitive typing

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Initialization file:

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~/.lldbinit

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Xcode specific: ~/.lldbinit-Xcode

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- ~/.lldbinit
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Python at startup: use `command script import`

Data Served Three Ways

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p <expression>

po <expression>

Data Served Three Ways

- p <expression>
- po <expression>

Data Served Three Ways

- e p <expression>
- e po <expression>

- e +Full expressions

Data Served Three Ways

- e p <expression>
- e po <expression>

- e +Full expressions
  - Executed in target

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Data Served Three Ways

e p <expression>

o e po <expression>

frame variable <local-name>

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Data Served Three Ways

e p <expression>

o e po <expression>

f frame variable <local-name>

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Data Served Three Ways

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f +Extremely predictable
- Limited syntax

Data Served ~~Three~~ Ways Many

NEW

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- o e po <expression>
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Data Served ~~Three~~ Ways Many

NEW

- e p <expression>
- o e po <expression>

- f frame variable <local-name>

- e parray <count> <expression>
- o e poarray <count> <expression>

- e +Full expressions
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  - Limited syntax

Example

```
10 int main() {
11     int count = 0;
12     int* dataset = readData(count);
13     for (int i = 0; i < count; i++)          Thread 1: breakpoint 1.1
14         processElement(dataset[i]);
15     return 0;
16 }
```

Example

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```

C pointers have no notion of element count

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(lldb)
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```
(lldb) p dataset
(int *) $0 = 0x0000000100200260
(lldb)
```

```
10 int main() {
11     int count = 0;
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(lldb) p dataset
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(lldb) p dataset[0]
(int *) $1 = 0
(lldb)
```

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```
(lldb) p dataset
(int *) $0 = 0x0000000100200260
(lldb) p dataset[0]
(int *) $1 = 0
(lldb) p dataset[1]
(int) $2 = 16842769
…
```

```
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16 }
```

```
(lldb) parray 3 dataset
```

```
10 int main() {
11     int count = 0;
12     int* dataset = readData(count);
13     for (int i = 0; i < count; i++)          Thread 1: breakpoint 1.1
14         processElement(dataset[i]);
15     return 0;
16 }
```

```
(lldb) parray 3 dataset
(int *) $7 = 0x0000000100200260 {
  (int) [0] = 0
  (int) [1] = 16842769
  (int) [2] = 33685538
}
(lldb)
```

```
10 int main() {
11     int count = 0;
12     int* dataset = readData(count);
13     for (int i = 0; i < count; i++)          Thread 1: breakpoint 1.1
14         processElement(dataset[i]);
15     return 0;
16 }
```

```
10 int main() {
11     int count = 0;
12     int* dataset = readData(count);
13     for (int i = 0; i < count; i++)        Thread 1: breakpoint 1.1
14         processElement(dataset[i]);
15     return 0;
16 }
```

```
10 int main() {
11     int count = 0;
12     int* dataset = readData(count)
13     for (int i = 0; i < count; i+
14         processElement(dataset[i]);
15     return 0;
16 }
```

Thread 1: breakpoint 1.1

```
(lldb)
```

```
10 int main() {
11     int count = 0;
12     int* dataset = readData(count)
13     for (int i = 0; i < count; i++
14         processElement(dataset[i]);
15     return 0;
16 }
```

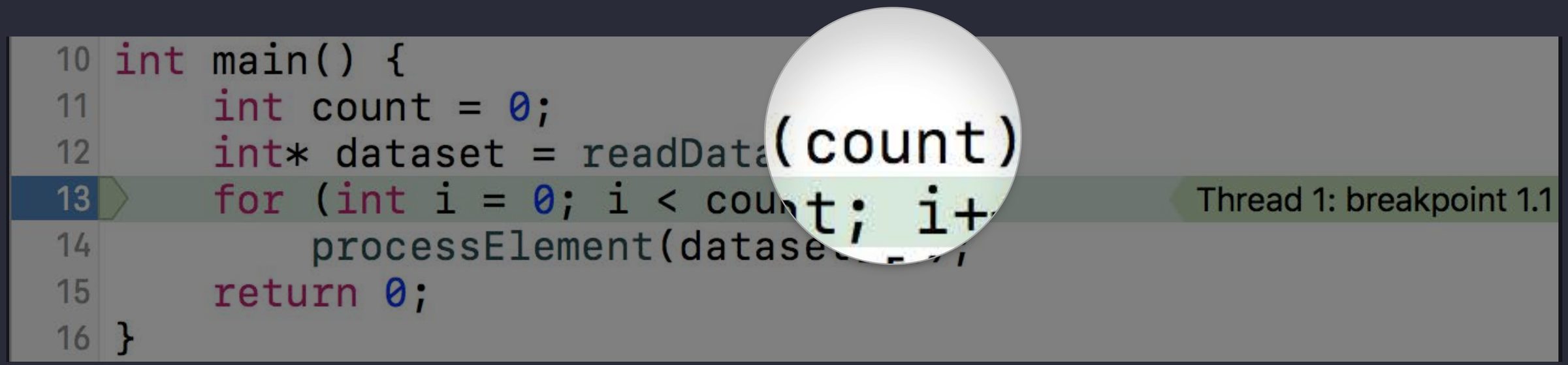
Thread 1: breakpoint 1.1

```
(lldb) parray `count` dataset
```

```
10 int main() {
11     int count = 0;
12     int* dataset = readData(count)
13     for (int i = 0; i < count; i+
14         processElement(dataset[i]);
15     return 0;
16 }
```

Thread 1: breakpoint 1.1

```
(lldb) parray `count` dataset
(int *) $8 = 0x0000000100200260 {
  (int) [0] = 0
  (int) [1] = 16842769
  (int) [2] = 33685538
  (int) [3] = 50528307
  (int) [4] = 67371076
}
(lldb)
```



```
(lldb)
```

```
(lldb) poarray `numCustomers` customers
```

```
(lldb) poarray `numCustomers` customers
{
  Kate, 1 Infinite Loop, Cupertino, CA
  Enrico, 700 Swift Street, Mountain View, CA
  Sean, SF MoMA, San Francisco, CA
  Jim, He Won’t Tell Me Blvd., Somewhere, CA
}
(lldb)
```

Exploring Memory Addresses

Exploring Memory Addresses

```
(lldb) po 0x1003183e0
Enrico, 700 Swift Street, Mountain View, CA
```

Exploring Memory Addresses

```
(lldb) po 0x1003183e0
Enrico, 700 Swift Street, Mountain View, CA
```

```
(lldb) po 0x1003183e0
4298212320
```

Exploring Memory Addresses

Exploring Memory Addresses

```
(lldb) expr -O --language objc -- 0x1003183e0
Enrico, 700 Swift Street, Mountain View, CA
```

Low-Level Debugging

Low-Level Debugging

First rule: *don't*!

Low-Level Debugging

First rule: *don't*!

Optimized code

Low-Level Debugging

First rule: *don't*!

Optimized code

Third-party code with no debug info

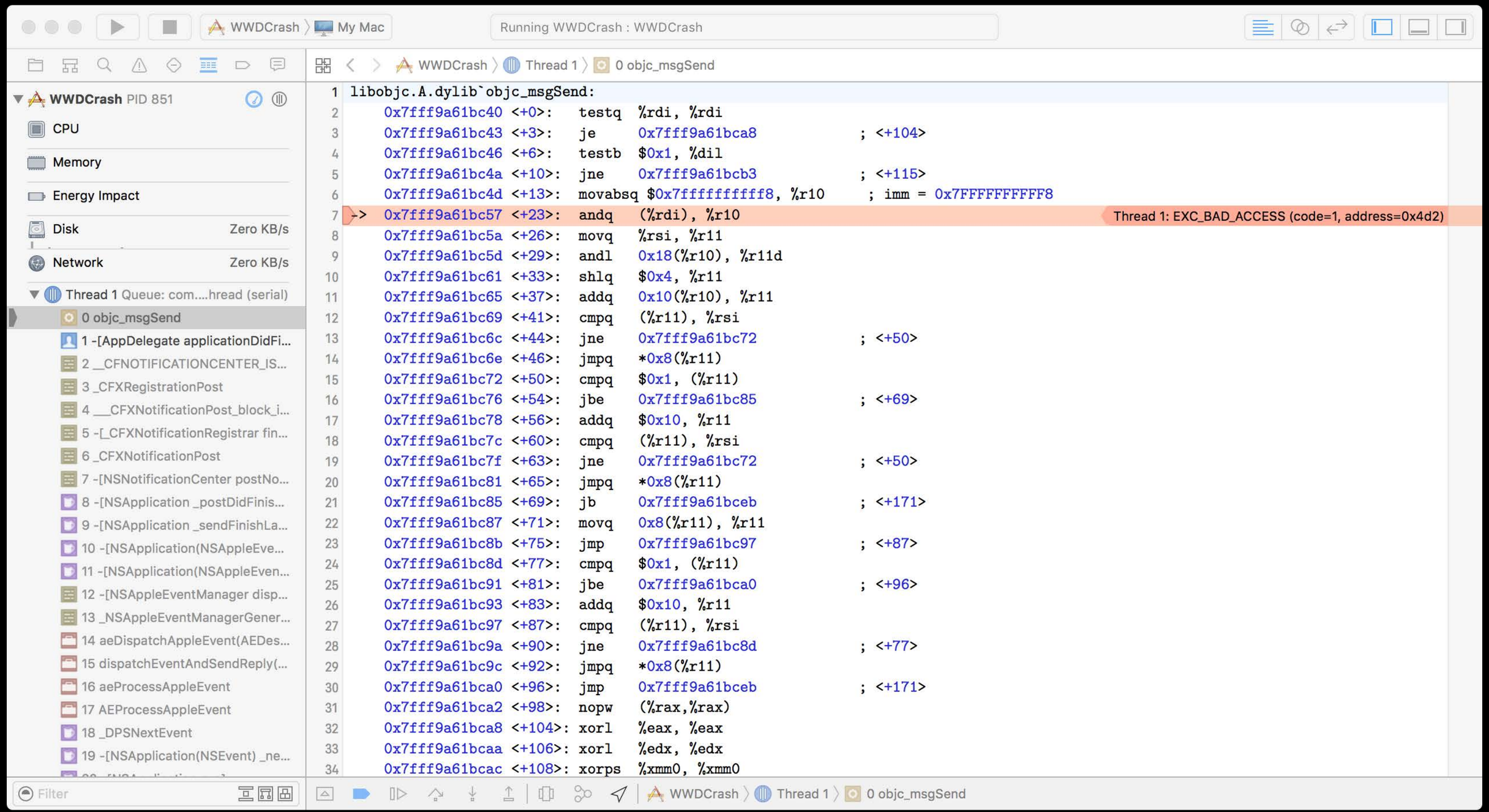
Low-Level Debugging

First rule: *don't*!

Optimized code

Third-party code with no debug info

Proceed at your own risk


WWDCrash
My Mac
Running WWDCrash : WWDCrash
WWDCrash
Thread 1
0 objc_msgSend
WWDCrash PID 851
CPU
Memory
Energy Impact
Disk
Zero KB/s
Network
Zero KB/s
Thread 1 Queue: com....hread (serial)
0 objc_msgSend
1 -[AppDelegate applicationDidFi...
2 __CFNOTIFICATIONCENTER_IS...
3 _CFXRegistrationPost
4 ___CFXNotificationPost_block_i...
5 -[_CFXNotificationRegistrar fin...
6 _CFXNotificationPost
7 -[NSNotificationCenter postNo...
8 -[NSApplication _postDidFinis...
9 -[NSApplication _sendFinishLa...
10 -[NSApplication(NSAppleEve...
11 -[NSApplication(NSAppleEven...
12 -[NSAppleEventManager disp...
13 _NSAppleEventManagerGener...
14 aeDispatchAppleEvent(AEDes...
15 dispatchEventAndSendReply(...
16 aeProcessAppleEvent
17 AEProcessAppleEvent
18 _DPSNextEvent
19 -[NSApplication(NSEvent) _ne...
Filter
1 libobjc.A.dylib`objc_msgSend:
2 0x7fff9a61bc40 <+0>: testq %rdi, %rdi
3 0x7fff9a61bc43 <+3>: je 0x7fff9a61bca8 ; <+104>
4 0x7fff9a61bc46 <+6>: testb $0x1, %dil
5 0x7fff9a61bc4a <+10>: jne 0x7fff9a61bcb3 ; <+115>
6 0x7fff9a61bc4d <+13>: movabsq $0x7fffffffffff8, %r10 ; imm = 0x7FFFFFFFFFF8
7 -> 0x7fff9a61bc57 <+23>: andq (%rdi), %r10
Thread 1: EXC_BAD_ACCESS (code=1, address=0x4d2)
8 0x7fff9a61bc5a <+26>: movq %rsi, %r11
9 0x7fff9a61bc5d <+29>: andl 0x18(%r10), %r11d
10 0x7fff9a61bc61 <+33>: shlq $0x4, %r11
11 0x7fff9a61bc65 <+37>: addq 0x10(%r10), %r11
12 0x7fff9a61bc69 <+41>: cmpq (%r11), %rsi
13 0x7fff9a61bc6c <+44>: jne 0x7fff9a61bc72 ; <+50>
14 0x7fff9a61bc6e <+46>: jmpq *0x8(%r11)
15 0x7fff9a61bc72 <+50>: cmpq $0x1, (%r11)
16 0x7fff9a61bc76 <+54>: jbe 0x7fff9a61bc85 ; <+69>
17 0x7fff9a61bc78 <+56>: addq $0x10, %r11
18 0x7fff9a61bc7c <+60>: cmpq (%r11), %rsi
19 0x7fff9a61bc7f <+63>: jne 0x7fff9a61bc72 ; <+50>
20 0x7fff9a61bc81 <+65>: jmpq *0x8(%r11)
21 0x7fff9a61bc85 <+69>: jb 0x7fff9a61bceb ; <+171>
22 0x7fff9a61bc87 <+71>: movq 0x8(%r11), %r11
23 0x7fff9a61bc8b <+75>: jmp 0x7fff9a61bc97 ; <+87>
24 0x7fff9a61bc8d <+77>: cmpq $0x1, (%r11)
25 0x7fff9a61bc91 <+81>: jbe 0x7fff9a61bca0 ; <+96>
26 0x7fff9a61bc93 <+83>: addq $0x10, %r11
27 0x7fff9a61bc97 <+87>: cmpq (%r11), %rsi
28 0x7fff9a61bc9a <+90>: jne 0x7fff9a61bc8d ; <+77>
29 0x7fff9a61bc9c <+92>: jmpq *0x8(%r11)
30 0x7fff9a61bca0 <+96>: jmp 0x7fff9a61bceb ; <+171>
31 0x7fff9a61bca2 <+98>: nopw (%rax,%rax)
32 0x7fff9a61bca8 <+104>: xorl %eax, %eax
33 0x7fff9a61bcaa <+106>: xorl %edx, %edx
34 0x7fff9a61bcac <+108>: xorps %xmm0, %xmm0
WWDCrash
Thread 1
0 objc_msgSend

Reading Registers

Read processor register values

- All registers or only a few
- Apply custom formats

```
(lldb)
```

```
(lldb) register read
```

```
(lldb) register read
General Purpose Registers:
       rax = 0x0000000000000000
       rbx = 0x0000000000000000
       rcx = 0x0000000000000000
       rdx = 0x0000000000000020
       rdi = 0x00000000000004d2
       rsi = 0x00007fff914ab7df  "stringByAppendingString:"
       rbp = 0x00007fff5fbfcf60
       rsp = 0x00007fff5fbfcf28
        r8 = 0x0000000000000010
        r9 = 0x0000000100100080
       r10 = 0x00000000ffffff00
       r11 = 0x0000000000000292
       r12 = 0x0000000000000000
       r13 = 0x00007fff5fbfcf70
       r14 = 0x0000000100096000
…
(lldb)
```

Reading Registers

Reading Registers

Arguments often passed in registers

Reading Registers

Arguments often passed in registers

Mapping given by Application Binary Interface (ABI)

Reading Registers

Arguments often passed in registers

Mapping given by Application Binary Interface (ABI)

Debugger exposes `$arg1`, `$arg2` … pseudo-registers

Reading Registers

Arguments often passed in registers

Mapping given by Application Binary Interface (ABI)

Debugger exposes `$arg1`, `$arg2` … pseudo-registers

Map one-to-one for scalar/pointer arguments

Reading Registers

Arguments often passed in registers

Mapping given by Application Binary Interface (ABI)

Debugger exposes `$arg1`, `$arg2` … pseudo-registers

- Map one-to-one for scalar/pointer arguments

Available in C-family expressions

```
int function(int some, void* thing, char more) {

 // great code

}
```

```
int function(int some, void* thing, char more) {

 // great code

}

   function(12, myBuffer, 'Q');
```

```
int function(int some, void* thing, char more) {

 // great code

}
```

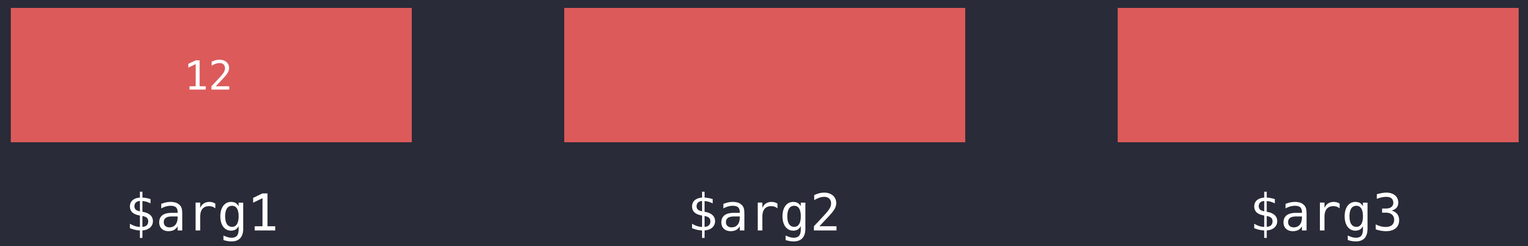
```
   function(12, myBuffer, 'Q');
```

```
int function(int some, void* thing, char more) {

 // great code

}

   function(12, myBuffer, 'Q');
```

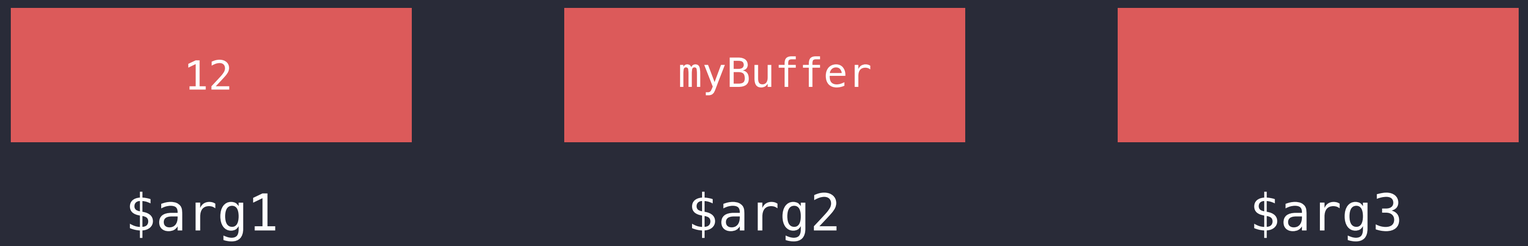


```
int function(int some, void* thing, char more) {

 // great code

}
```

```
   function(12, myBuffer, 'Q');
```

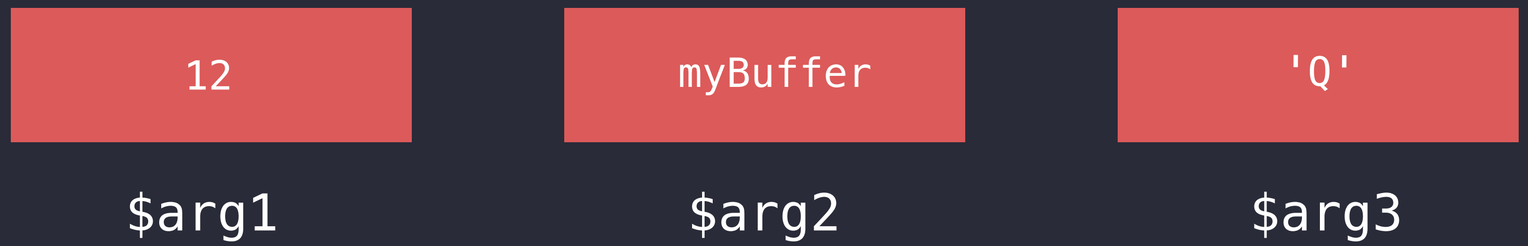


```
int function(int some, void* thing, char more) {

 // great code

}
```

```
   function(12, myBuffer, 'Q');
```



```
(lldb)
```

```
(lldb) frame select 0
frame #0: 0x00007fff8eae04d7 libobjc.A.dylib`objc_msgSend + 23
libobjc.A.dylib`objc_msgSend:
->  0x7fff8eae04d7 <+23>: andq   (%rdi), %r10
    0x7fff8eae04da <+26>: movq   %rsi, %r11
    0x7fff8eae04dd <+29>: andl   0x18(%r11), %r11d
    0x7fff8eae04e1 <+33>: shlq   $0x4, %r11
(lldb)
```

```
(lldb) frame select 0
frame #0: 0x00007fff8eae04d7 libobjc.A.dylib`objc_msgSend + 23
libobjc.A.dylib`objc_msgSend:
->  0x7fff8eae04d7 <+23>: andq   (%rdi), %r10
    0x7fff8eae04da <+26>: movq   %rsi, %r11
    0x7fff8eae04dd <+29>: andl   0x18(%r11), %r11d
    0x7fff8eae04e1 <+33>: shlq   $0x4, %r11
(lldb) register read $arg1 $arg2
     rdi = 0x00000000000004d2
     rsi = 0x00007fff914ab7df  "stringByAppendingString:"
(lldb)
```

```
(lldb) frame select 0
frame #0: 0x00007fff8eae04d7 libobjc.A.dylib`objc_msgSend + 23
libobjc.A.dylib`objc_msgSend:
->  0x7fff8eae04d7 <+23>: andq   (%rdi), %r10
    0x7fff8eae04da <+26>: movq   %rsi, %r11
    0x7fff8eae04dd <+29>: andl   0x18(%r11), %r11d
    0x7fff8eae04e1 <+33>: shlq   $0x4, %r11
(lldb) register read $arg1 $arg2
     rdi = 0x00000000000004d2
     rsi = 0x00007fff914ab7df  "stringByAppendingString:"
(lldb) memory read $arg1
error: memory read failed for 0x400
(lldb)
```

```
id objc_msgSend(id object, SEL selector, …)
```

`0x00000000000004d2`

$arg1

`stringByAppendingString:`

$arg2

```
id objc_msgSend(id object, SEL selector, …)

   objc_msgSend(                          ,                                  )
```

`0x00000000000004d2`

$arg1

`stringByAppendingString:`

$arg2

```
id objc_msgSend(id object, SEL selector, …)

   objc_msgSend(0x00000000000004d2,stringByAppendingString:)
```

`0x00000000000004d2`

$arg1

`stringByAppendingString:`

$arg2

```
id objc_msgSend(id object, SEL selector, …)

   objc_msgSend(0x00000000000004d2, stringByAppendingString:)
```

Calling selector on a bad object

`0x00000000000004d2`

$arg1

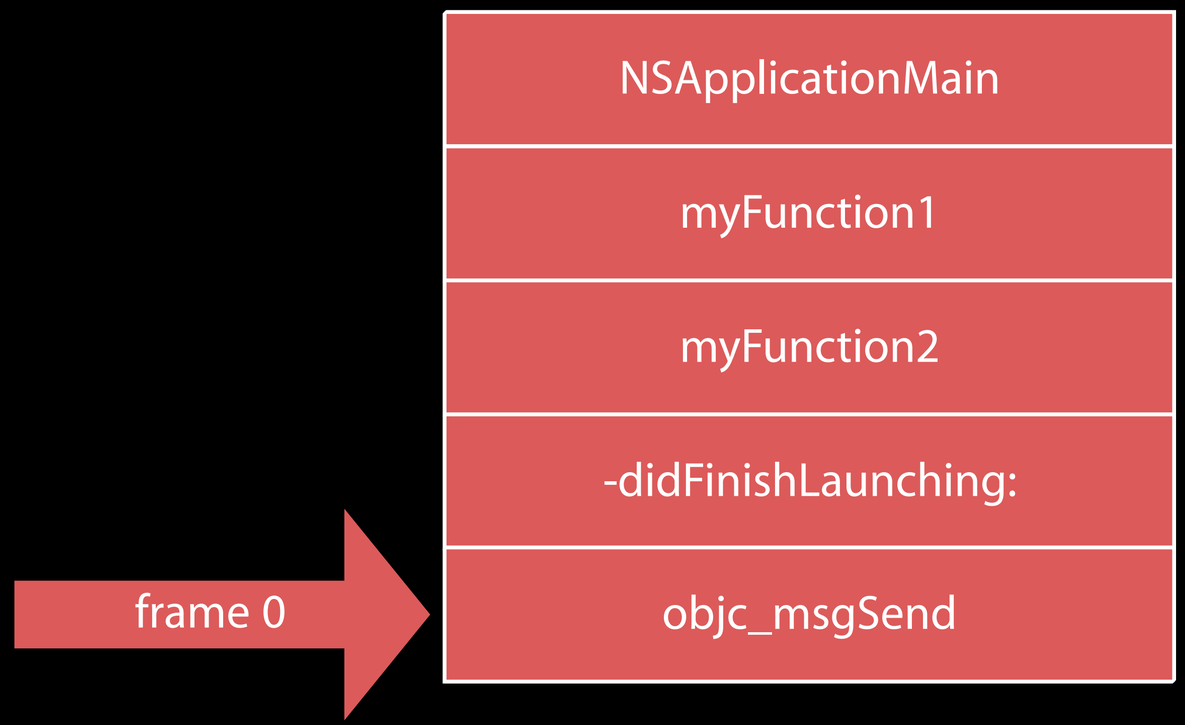
`stringByAppendingString:`

$arg2

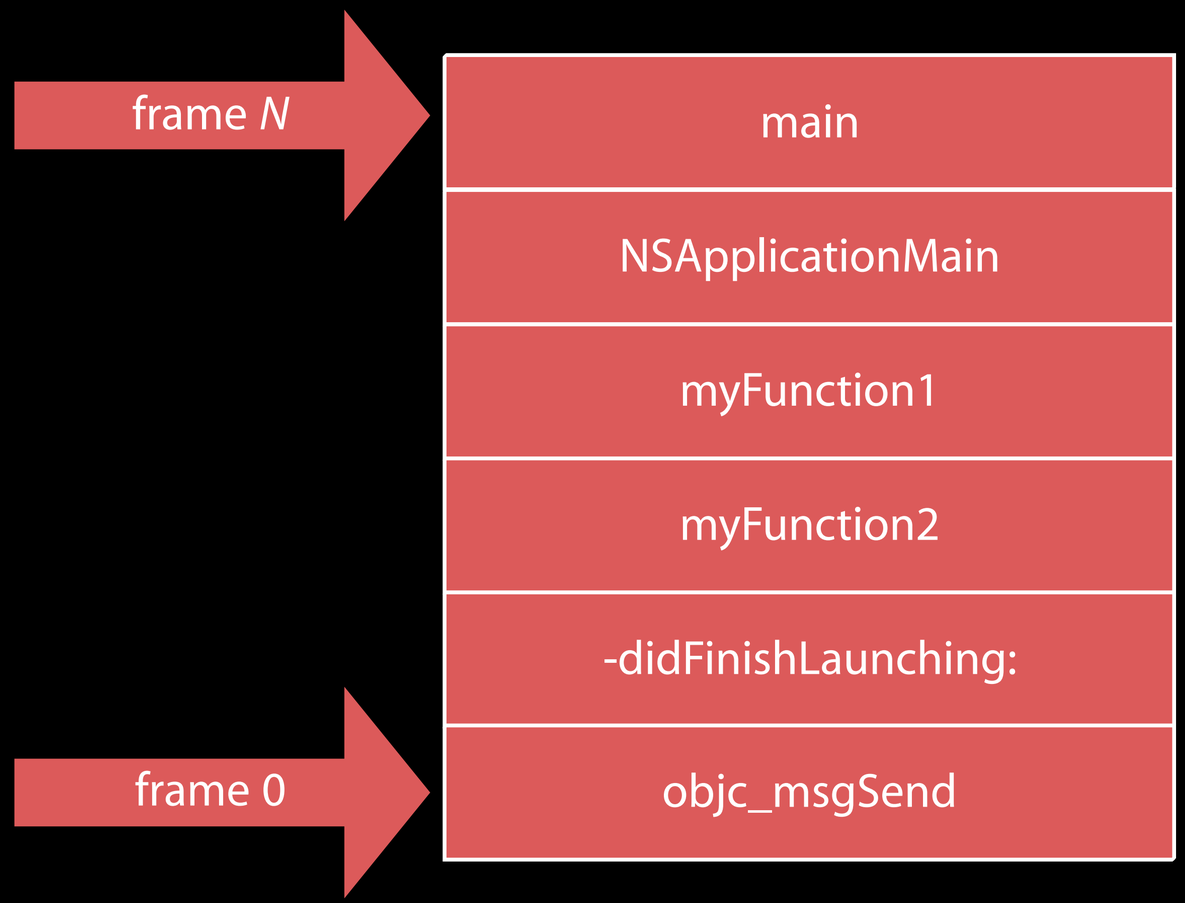
Stack Frames

Stack Frames

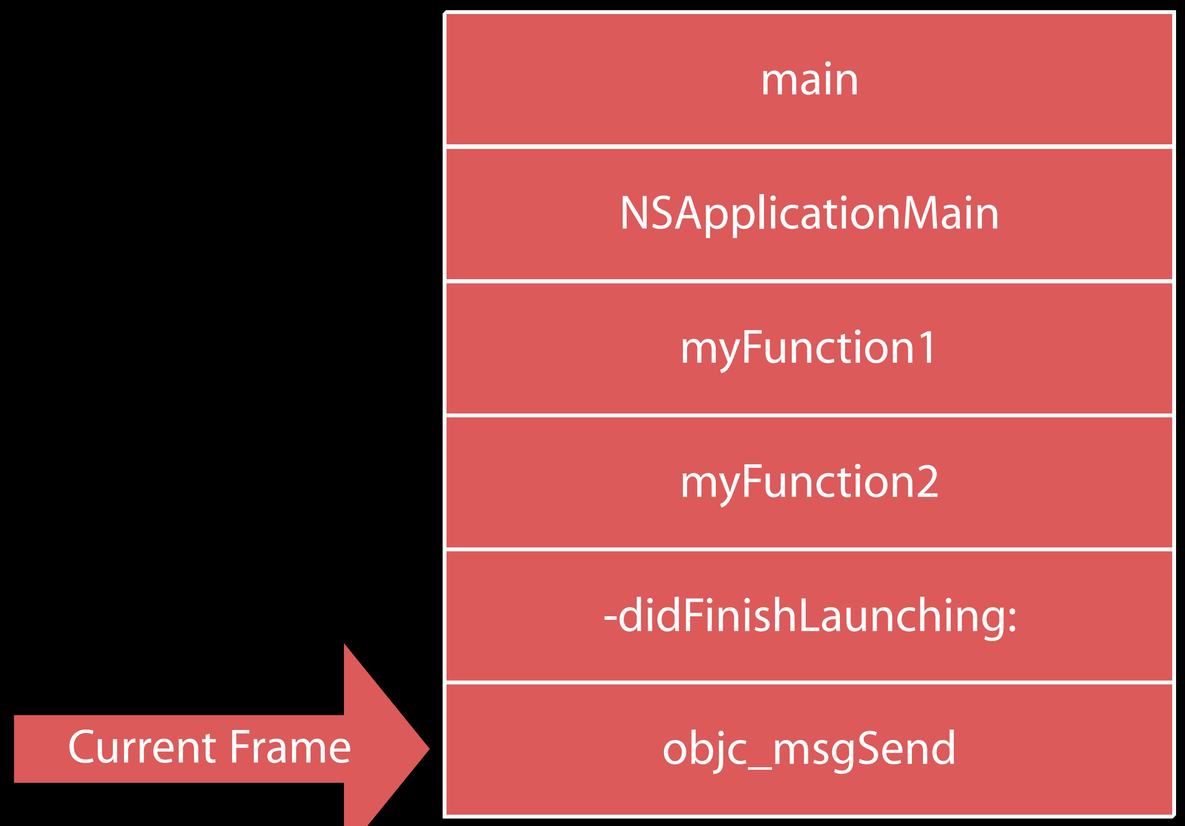
Stack Frames



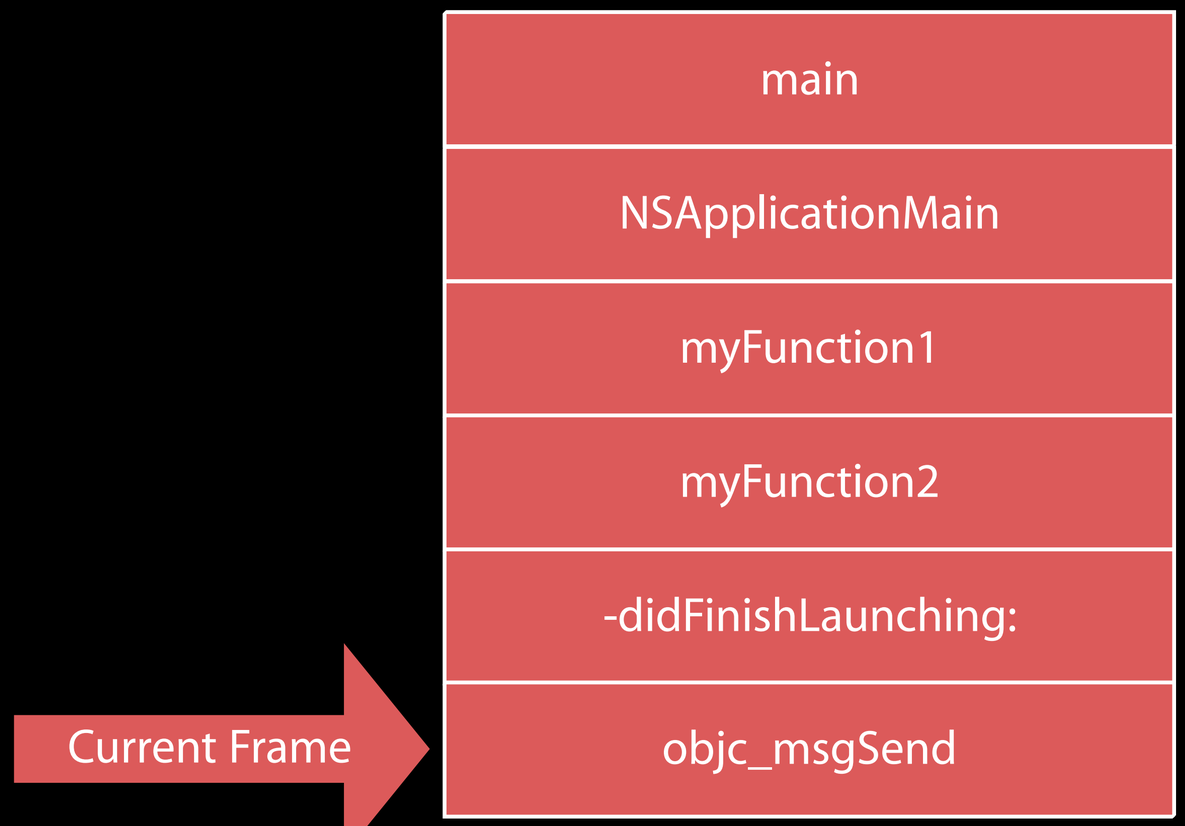
Stack Frames



Stack Frames

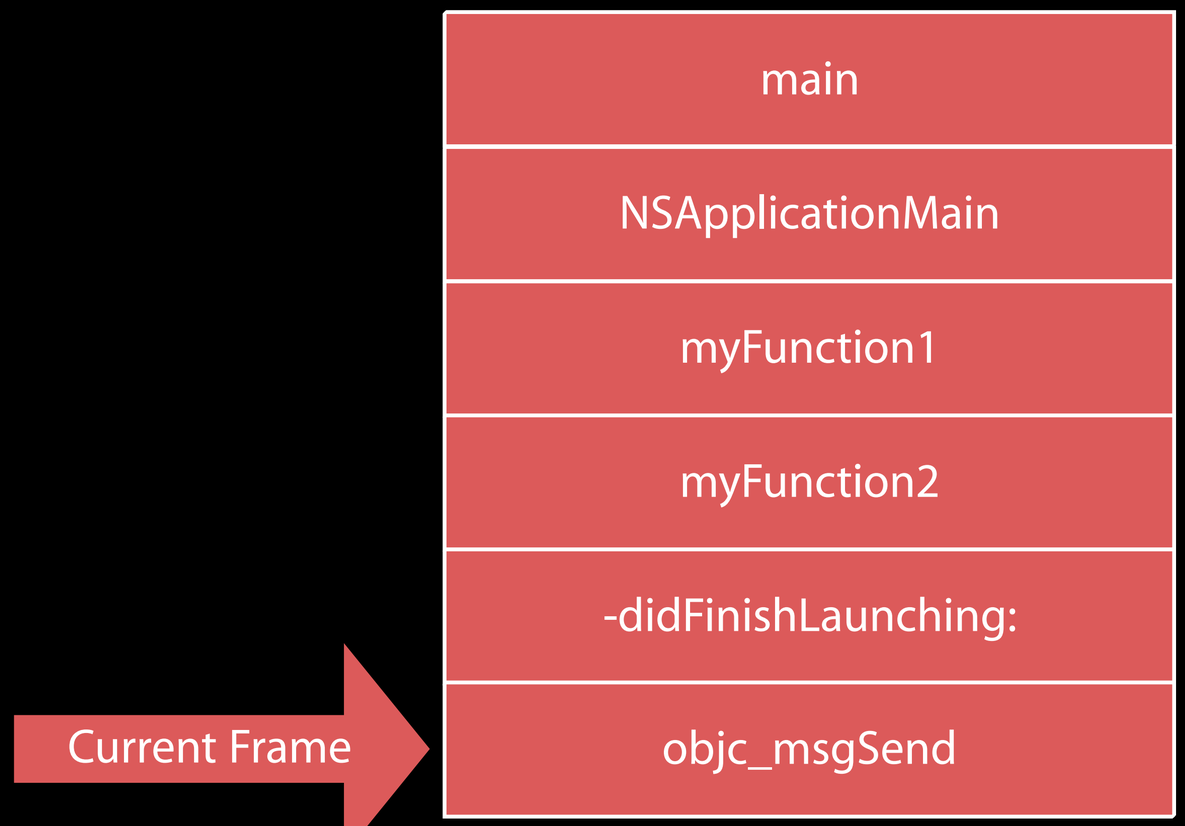


Stack Frames



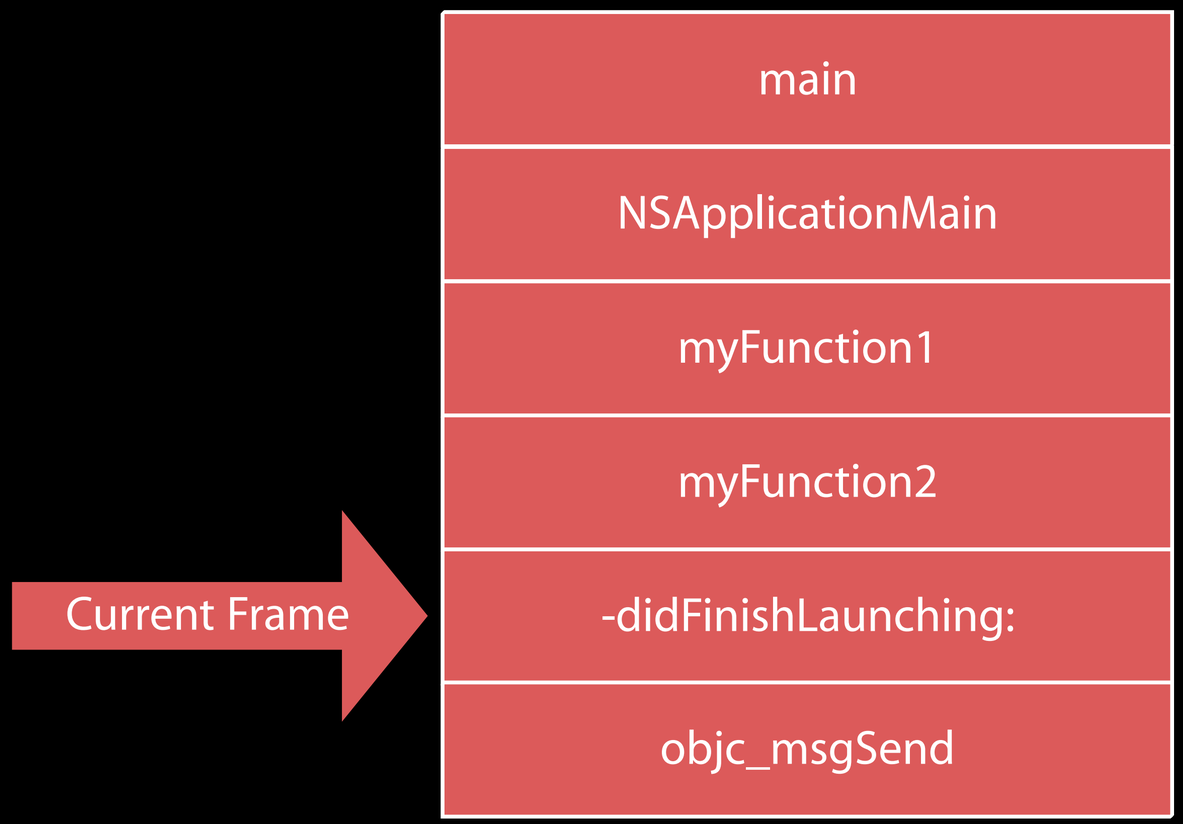

```
(lldb)
```

Stack Frames



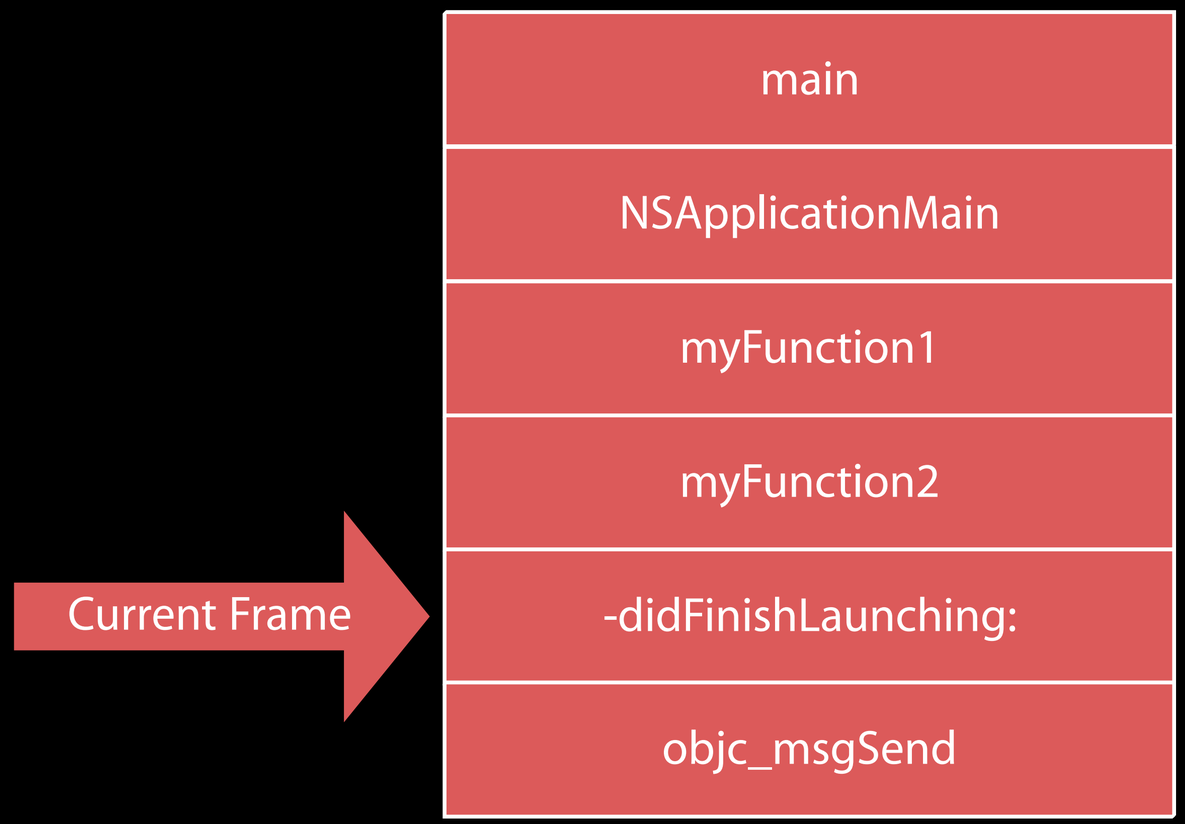

```
(lldb) up
(lldb)
```

Stack Frames

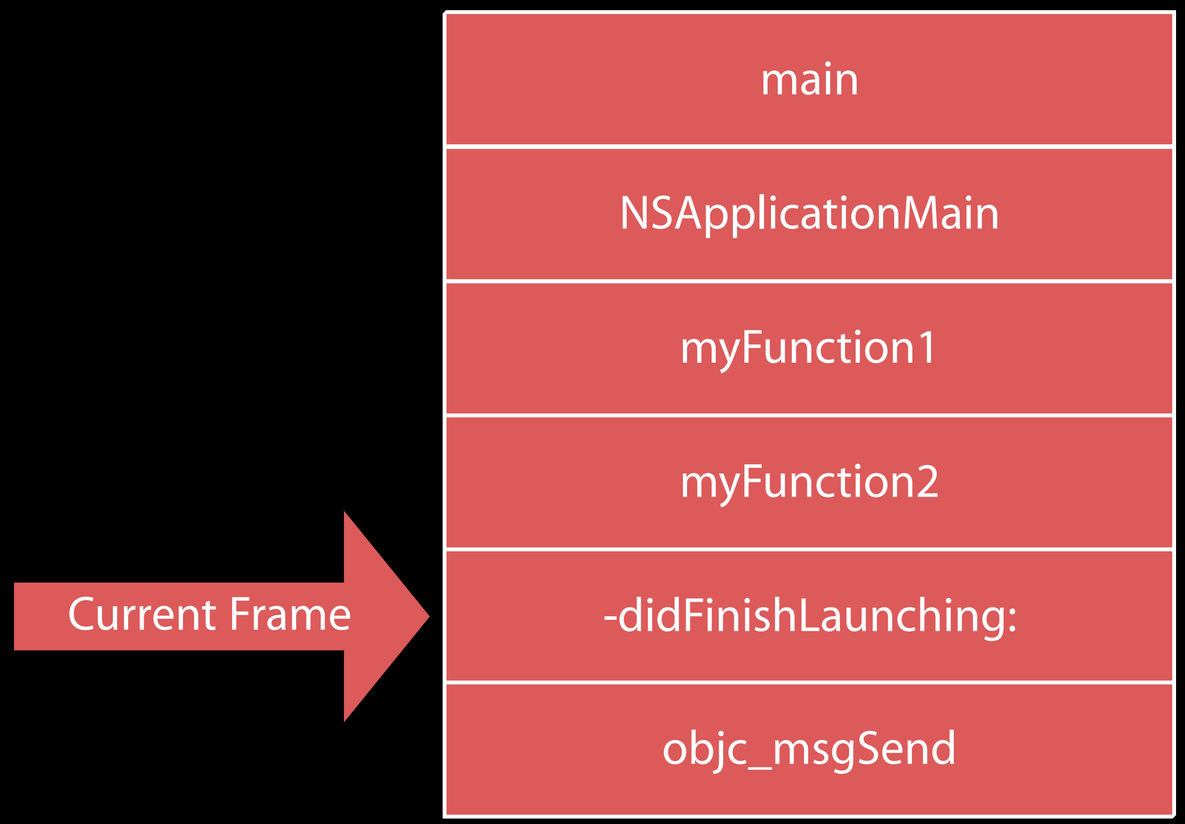



```
(lldb) up
(lldb)
```

Stack Frames

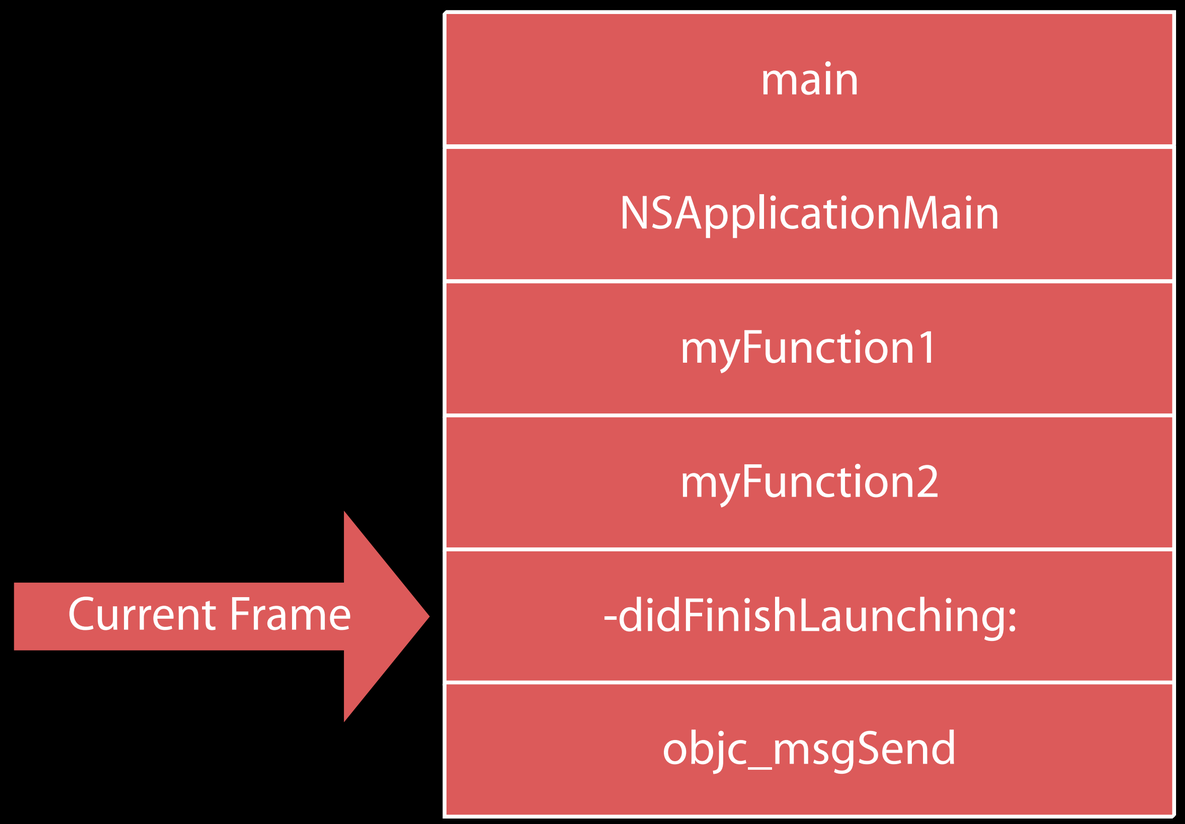


Stack Frames



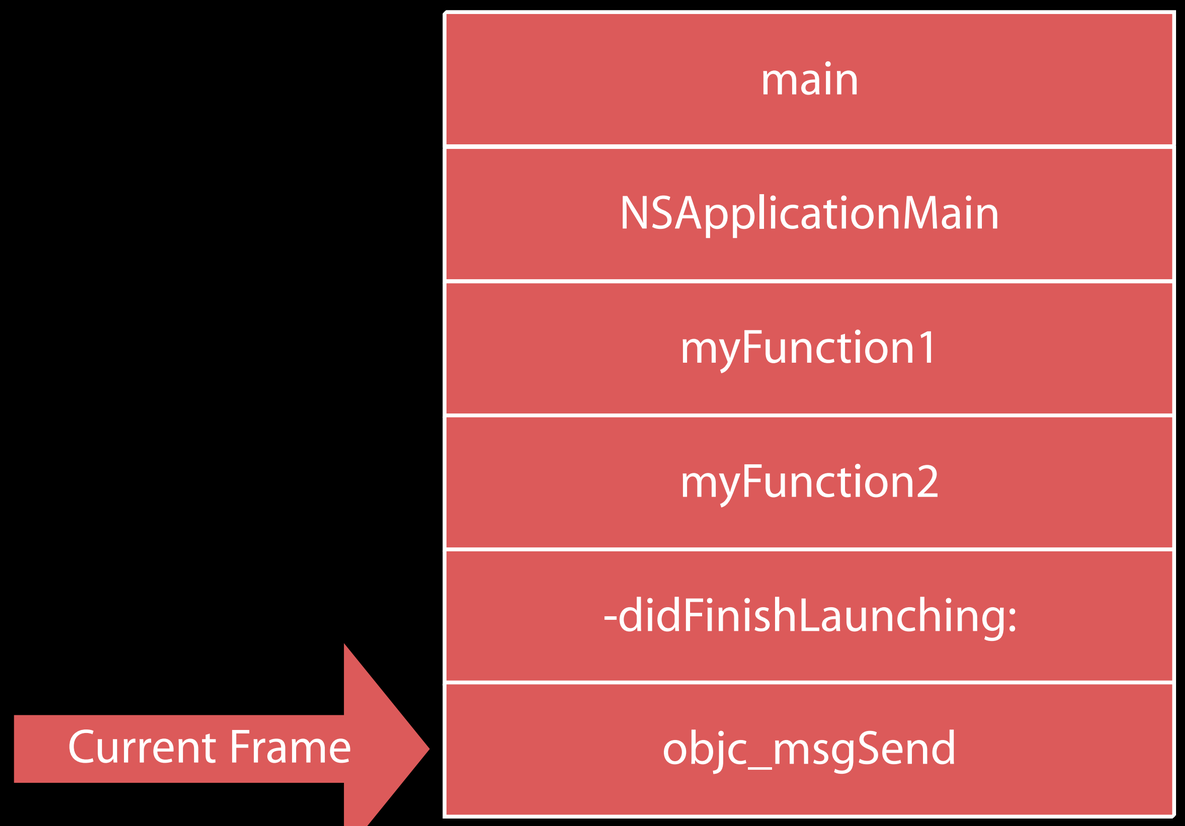

```
(lldb)
```

Stack Frames




```
(lldb) down
(lldb)
```

Stack Frames




```
(lldb) down
(lldb)
```

Disassembly

The disassemble command shows disassembled machine code

- For the current frame, an address, or a function

Disassembly

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Customize disassembly format:

- Intel vs. AT&T
- Entirely custom format (disassembly-format setting)

Disassembly

The disassemble command shows disassembled machine code

- For the current frame, an address, or a function

Customize disassembly format:

- Intel vs. AT&T
- Entirely custom format (disassembly-format setting)

Show disassembly:

- When no source or no debug info
- Always
- Never

```
(lldb)
```

```
(lldb) bt
* thread #1: tid = 0x158321, 0x00007fff8eae04d7 libobjc.A.dylib`objc_msgSend + 23, queue =
'com.apple.main-thread', stop reason = EXC_BAD_ACCESS (code=1, address=0x4d2)
  * frame #0: 0x00007fff8eae04d7 libobjc.A.dylib`objc_msgSend + 23
    frame #1: 0x0000000100000149f WWDCrash`-[AppDelegate applicationDidFinishLaunching:]
(self=0x0000000100246890, _cmd="applicationDidFinishLaunching:",
aNotification=@"NSApplicationDidFinishLaunchingNotification") + 47 at AppDelegate.m:24
…
(lldb)
```

```
(lldb) bt
* thread #1: tid = 0x158321, 0x00007fff8eae04d7 libobjc.A.dylib`objc_msgSend + 23, queue =
'com.apple.main-thread', stop reason = EXC_BAD_ACCESS (code=1, address=0x4d2)
  * frame #0: 0x00007fff8eae04d7 libobjc.A.dylib`objc_msgSend + 23
    frame #1: 0x0000000100000149f WWDCrash`-[AppDelegate applicationDidFinishLaunching:]
(self=0x0000000100246890, _cmd="applicationDidFinishLaunching:",
aNotification=@"NSApplicationDidFinishLaunchingNotification") + 47 at AppDelegate.m:24
…
(lldb)
```

```
(lldb)
```

```
(lldb) up
…
(lldb)
```

```
(lldb) up
…
(lldb) disassemble --frame
…
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend
…
(lldb)
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb)
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) ni
```

```
0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
0x100001497 <+39>: movq   %rax, %rdi
0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb)
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) reg read rax
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) reg read rax
     rax = 0x00000000000004d2
(lldb)
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) reg read rax
     rax = 0x00000000000004d2
(lldb) si
```

```
0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
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0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb)
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) si
```

```
0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
0x100001497 <+39>: movq   %rax, %rdi
0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb)
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) si
```

```
0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
0x100001497 <+39>: movq   %rax, %rdi
0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb)
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) reg read $arg1
```

```
    0x100001484 <+20>: callq  0x100001460               ; getGlobalToken
    0x100001489 <+25>: leaq   0xb90(%rip), %rdx         ; @"'magicText'"
    0x100001490 <+32>: movq   0x14a9(%rip), %rsi        ; "stringByAppendingString:"
    0x100001497 <+39>: movq   %rax, %rdi
    0x10000149a <+42>: callq  0x1000014c2               ; symbol stub for: objc_msgSend

(lldb) reg read $arg1
     rdi = 0x00000000000004d2
(lldb)
```

Low-Level Debugging

Low-Level Debugging

`getGlobalToken()` returns an invalid object

Low-Level Debugging

`getGlobalToken()` returns an invalid object

Subsequent usage causes a crash

Expression Parsing

Better and more convenient

Sean Callanan

SDK Modules in Objective-C

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");
}
```

Thread 1: breakpoint 1.1

SDK Modules in Objective-C

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");                    Thread 1: breakpoint 1.1
}
```

```
(lldb)
```

SDK Modules in Objective-C

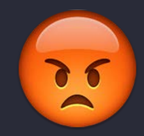
```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");   Thread 1: breakpoint 1.1
}
```

```
(lldb) p [NSApplication sharedApplication].undoManager
```

SDK Modules in Objective-C

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");   Thread 1: breakpoint 1.1
}
```

```
(lldb) p [NSApplication sharedApplication].undoManager
error: property ‘undoManager’ not found on object of type ‘id’
```



SDK Modules in Objective-C

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");
}
```

Thread 1: breakpoint 1.1

SDK Modules in Objective-C

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");   Thread 1: breakpoint 1.1
}
```

```
(lldb)
```

SDK Modules in Objective-C

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");   Thread 1: breakpoint 1.1
}
```

```
(lldb) p @import AppKit
(lldb)
```

SDK Modules in Objective-C

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");   Thread 1: breakpoint 1.1
}
```

```
(lldb) p @import AppKit 🙄
(lldb) p [NSApplication sharedApplication].undoManager
(NSUndoManager * __nullable) $1 = 0x00007fb399629cd0
```

SDK Modules in Objective-C

NEW

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");
}
```

Thread 1: breakpoint 1.1

```
(lldb) p [NSApplication sharedApplication].undoManager
(NSUndoManager * __nullable) $1 = 0x00007fb399629cd0
```

SDK Modules in Objective-C

NEW

```
@import AppKit;
void doSomeWork() {
    NSLog(@"Doing work");  Thread 1: breakpoint 1.1
}
```

```
(lldb) p [NSApplication sharedApplication].undoManager
(NSUndoManager * __nullable) $1 = 0x00007fb399629cd0
```

Controlled by

```
(lldb) settings show target.auto-import-clang-modules false
```

Reusable Code

Swift

Reusable Code

Swift

```
(lldb)
```

Reusable Code

Swift

```
(lldb) expr let a = 3; print(a)
3
(lldb)
```

Reusable Code

Swift

```
(lldb) expr let a = 3; print(a)
3

(lldb) expr a
error: <EXPR>:3:1: error: use of unresolved identifier 'a'
```

Reusable Code

Swift

```
(lldb) expr let a = 3; print(a)
3

(lldb) expr a
error: <EXPR>:3:1: error: use of unresolved identifier 'a'
```

```
func functionYouAreStoppedIn() {
    doSomeWork()                                Thread 1: breakpoint 2.1
    if (true) { let a = 3; print(a) }
}
```

Reusable Code

Swift

```
(lldb) expr let $a = 3; print($a)
3

(lldb) expr $a

(Int) $R1 = 3
```

Defining Reusable Functions

Swift

```
(lldb)
```

Defining Reusable Functions

Swift

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
```

Defining Reusable Functions

Swift

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: func $addTwoNumbers(a: Int, b: Int) -> Int {
2:   return a + b
3: }
4:

(lldb)
```

Defining Reusable Functions

Swift

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: func $addTwoNumbers(a: Int, b: Int) -> Int {
2:   return a + b
3: }
4:

(lldb) expr $addTwoNumbers(a: 2, b: 3)
(Int) $R0 = 5
```

Defining Reusable Functions

C, C++, and Objective-C

```
(lldb)
```

Defining Reusable Functions

C, C++, and Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
```

Defining Reusable Functions

C, C++, and Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: int $addTwoNumbers(int a, int b) {
2:   return a + b
3: }
4:
```

Defining Reusable Functions

C, C++, and Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: int $addTwoNumbers(int a, int b) {
2:   return a + b
3: }
4:

error: function declaration is not allowed here
error: 1 error parsing expression
```

Why Not?

Swift

Why Not?

Swift

```
func functionYouAreStoppedIn() {
  func $addTwoNumbers(…) -> Int {
  }
}
```

Why Not?

Swift

```
func functionYouAreStoppedIn() {
  func $addTwoNumbers(…) -> Int {
  }
}
```

Why Not?

Swift

```
func functionYouAreStoppedIn() {
  func $addTwoNumbers(…) -> Int {
  }
}
```

C, C++, and Objective-C

```
void functionYouAreStoppedIn() {
  int $addTwoNumbers(…) {
  }
}
```

Why Not?

Swift

```
func functionYouAreStoppedIn() {
  func $addTwoNumbers(…) -> Int {
  }
}
```

C, C++, and Objective-C

```
void functionYouAreStoppedIn() {
  int $addTwoNumbers(…) {
  }
}
```

Defining Reusable Functions

NEW

C, C++, and Objective-C

Defining Reusable Functions

NEW

C, C++, and Objective-C

```
(lldb)
```

Defining Reusable Functions

NEW

C, C++, and Objective-C

```
(lldb) expr --top-level --

Enter expressions, then terminate with an empty line to evaluate:
```

Defining Reusable Functions

NEW

C, C++, and Objective-C

```
(lldb) expr --top-level --

Enter expressions, then terminate with an empty line to evaluate:
1: int $addTwoNumbers(int a, int b) {
2:   return a + b;
3: }
4:

(lldb)
```

Defining Reusable Functions

NEW

C, C++, and Objective-C

```
(lldb) expr --top-level --

Enter expressions, then terminate with an empty line to evaluate:
1: int $addTwoNumbers(int a, int b) {
2:   return a + b;
3: }
4:

(lldb) expr $addTwoNumbers(2,3)
(Int) $R0 = 5
```

Defining Reusable Closures

Swift

Defining Reusable Closures

Swift

```
(lldb)
```

Defining Reusable Closures

Swift

```
(lldb) p let $add = { (a:Int, b:Int) in a+b }

(lldb)
```

Defining Reusable Closures

Swift

```
(lldb) p let $add = { (a:Int, b:Int) in a+b }
(lldb) p $add(s.startIndex, s.count)
(Int) $R0 = 6
```

Defining Reusable Closures

NEW

Blocks

Swift

```
(lldb) p let $add = { (a:Int, b:Int) in a+b }
(lldb) p $add(s.startIndex, s.count)
(Int) $R0 = 6
```

C, C++, and Objective-C

```
(lldb) p int (^$add)(int, int) =
         ^(int a, int b) { return a+b; }
(lldb) p $add(r.location,r.length)
(int) $0 = 4
```

Defining Reusable Closures

Blocks and lambdas

NEW

C++

```
(lldb) p auto $add = [](int a, int b)
         { return a+b; }
(lldb) p $add(a.offset,a.elements().size())
(int) $0 = 4
```

Passing Blocks to Functions

Objective-C

Passing Blocks to Functions

Objective-C

```
(lldb)
```

Passing Blocks to Functions

NEW

Objective-C

```
(lldb) p dispatch_sync(dispatch_get_global_queue(0,0),
         ^(){ printf("Hello world\n"); });

Hello world
```

Passing Blocks to Functions

Objective-C

```
(lldb) p dispatch_sync(dispatch_get_global_queue(0,0),
         ^(){ printf("Hello world\n") });
```

Passing Blocks to Functions

Objective-C

```
(lldb) p dispatch_sync(dispatch_get_global_queue(0,0),
         ^(){ printf("Hello world\n") });

error: expected ';' after expression
error: 1 error parsing expression
```

Passing Blocks to Functions

NEW

Objective-C

```
(lldb) p dispatch_sync(dispatch_get_global_queue(0,0),
         ^(){ printf("Hello world\n") });

Hello world
Fixit applied, fixed expression was:
  dispatch_sync(dispatch_get_global_queue(0,0),
       ^(){ printf("Hello world\n"); });
```

Fix-Its Work in Swift, Too!

Swift

Fix-Its Work in Swift, Too!

Swift

```
(lldb)
```

Fix-Its Work in Swift, Too!

Swift

```
(lldb) p let $myInt : Int? = 3
(lldb)
```

Fix-Its Work in Swift, Too!

Swift

```
(lldb) p let $myInt : Int? = 3
(lldb) p $myInt + 2
```

Fix-Its Work in Swift, Too!

Swift

```
(lldb) p let $myInt : Int? = 3
(lldb) p $myInt + 2

(Int) $R0 = 5
    Fixit applied, fixed expression was:
      $myInt! + 2
```

Fix-Its Work in Swift, Too!

Swift

```
(lldb) p let $myInt : Int? = 3
(lldb) p $myInt + 2

(Int) $R0 = 5
 Fixit applied, fixed expression was:
   $myInt! + 2
```

Controlled by

```
(lldb) settings set target.auto-apply-fixits false
(lldb) settings set target.notify-about-fixits false
```

Defining Reusable Types

Swift

Defining Reusable Types

Swift

```
(lldb)
```

Defining Reusable Types

Swift

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
```

Defining Reusable Types

Swift

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: class $MyClass {
2:   let m_a: Int
3:   init(a: Int) { m_a = a }
4: }

(lldb)
```

Defining Reusable Types

Swift

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: class $MyClass {
2:   let m_a: Int
3:   init(a: Int) { m_a = a }
4: }

(lldb) expr $MyClass(a:1)
($MyClass) $R0 = 0x00000001010023e0 (m_a = 1)
```

Defining Reusable Types

C++

```
(lldb)
```

Defining Reusable Types

C++

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
```

Defining Reusable Types

C++

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: class $MyClass {
2:   int m_a;
3:   $MyClass(int a) : m_a(a) { }
4: }

(lldb)
```

Defining Reusable Types

C++

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: class $MyClass {
2:   int m_a;
3:   $MyClass(int a) : m_a(a) { }
4: }

(lldb) expr $MyClass(1)
($MyClass) $0 = (m_a = 1)
```

Example

User-defined predicates

Objective-C

```
(lldb)
```

Example

User-defined predicates

Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
```

Example

User-defined predicates

Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: NSPredicate *$p =
2:   [NSPredicate predicateWithBlock:
3:     ^(NSString *str, NSDictionary *bind) {
4:       return [str containsString:@"error"]; }]
```

Example

User-defined predicates

Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: NSPredicate *$p =
2:   [NSPredicate predicateWithBlock:
3:     ^(NSString *str, NSDictionary *bind) {
4:       return [str containsString:@"error"]; }]
```

Example

User-defined predicates

Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: NSPredicate *$p =
2:   [NSPredicate predicateWithBlock:
3:     ^(NSString *str, NSDictionary *bind) {
4:       return [str containsString:@"error"]; }]

(lldb)
```

Example

User-defined predicates

Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: NSPredicate *$p =
2:   [NSPredicate predicateWithBlock:
3:     ^(NSString *str, NSDictionary *bind) {
4:       return [str containsString:@"error"]; }]

(lldb) po [messages filteredArrayUsingPredicate:$p]
```

Example

User-defined predicates

Objective-C

```
(lldb) expr

Enter expressions, then terminate with an empty line to evaluate:
1: NSPredicate *$p =
2:   [NSPredicate predicateWithBlock:
3:     ^(NSString *str, NSDictionary *bind) {
4:       return [str containsString:@"error"]; }]

(lldb) po [messages filteredArrayUsingPredicate:$p]
<__NSSingleObjectArrayI 0x100307f90>(
error parsing JSON
)
```

Breakpoints and Troubleshooting

Jim Ingham

Breakpoints

Breakpoints

Simple notion:

Breakpoints

Simple notion:

- Breakpoints stop your program

Breakpoints

Simple notion:

- Breakpoints stop your program

LLDB's view:

Breakpoints

Simple notion:

- Breakpoints stop your program

LLDB's view:

- Breakpoints are searches for places to stop

Breakpoints

Simple notion:

- Breakpoints stop your program

LLDB's view:

- Breakpoints are searches for places to stop
- Breakpoints specify search criteria

Breakpoints

Simple notion:

- Breakpoints stop your program

LLDB's view:

- Breakpoints are searches for places to stop
- Breakpoints specify search criteria
- Search hits are *actual* places to stop: "Breakpoint Locations"

Xcode's Breakpoints

Xcode's Breakpoints

Xcode breakpoints *are* LLDB breakpoints

Xcode's Breakpoints

Xcode breakpoints *are* LLDB breakpoints

Created from editor gutter; LLDB does:

```
(lldb)
```

Xcode's Breakpoints

Xcode breakpoints *are* LLDB breakpoints

Created from editor gutter; LLDB does:

```
(lldb) break set --line 36 --file GreatCode.swift
```

Xcode's Breakpoints

Xcode breakpoints *are* LLDB breakpoints

Created from editor gutter; LLDB does:

```
(lldb) break set --line 36 --file GreatCode.swift
```

Symbolic breakpoint; LLDB does:

```
(lldb)
```

Xcode's Breakpoints

Xcode breakpoints *are* LLDB breakpoints

Created from editor gutter; LLDB does:

```
(lldb) break set --line 36 --file GreatCode.swift
```

Symbolic breakpoint; LLDB does:

```
(lldb) break set --name Foo
```

Multiple Locations

When and why?

Multiple Locations

When and why?

All breakpoints are searches

Multiple Locations

When and why?

All breakpoints are searches

Multiple results are always possible

Multiple Locations

When and why?

All breakpoints are searches

Multiple results are always possible

Let's see some examples

Multiple Locations

When and why?

All breakpoints are searches

Multiple results are always possible

Let's see some examples

- First for symbolic breakpoints:

```
(lldb)
```

```
(lldb) break set --name main
Breakpoint 1: 19 locations.
(lldb)
```

```
(lldb) break set --name main

Breakpoint 1: 19 locations.

(lldb) break list 1

1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]

…
```

```
(lldb) break set --name main

Breakpoint 1: 19 locations.

(lldb) break list 1

1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]

…
```

--name breakpoints use loose matching

```
(lldb) break set --name main

Breakpoint 1: 19 locations.

(lldb) break list 1

1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]

…

(lldb)
```

```
(lldb) break set --name main

Breakpoint 1: 19 locations.

(lldb) break list 1

1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]

…

(lldb) break set --fullname main
```

Try a full-name breakpoint

```
(lldb) break set --name main
Breakpoint 1: 19 locations.
(lldb) break list 1
1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]
…
(lldb) break set --fullname main
Breakpoint 2: 2 locations.
(lldb)
```

```
(lldb) break set --name main
Breakpoint 1: 19 locations.
(lldb) break list 1
1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]
…
(lldb) break set --fullname main
Breakpoint 2: 2 locations.
(lldb) break list 2
2: name = 'main', locations = 2
  2.1: where = Sketch`main + 55 at SKTMain.m:17
  2.2: where = libpcap.A.dylib`main
```

```
(lldb) break set --name main
Breakpoint 1: 19 locations.
(lldb) break list 1
1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]
…
(lldb) break set --fullname main
Breakpoint 2: 2 locations.
(lldb) break list 2
2: name = 'main', locations = 2
  2.1: where = Sketch`main + 55 at SKTMain.m:17
  2.2: where = libpcap.A.dylib`main
```

Two shared libraries with the same symbol

```
(lldb) break set --name main
Breakpoint 1: 19 locations.
(lldb) break list 1
1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]
…
(lldb) break set --fullname main
Breakpoint 2: 2 locations.
(lldb) break list 2
2: name = 'main', locations = 2
  2.1: where = Sketch`main + 55 at SKTMain.m:17
  2.2: where = libpcap.A.dylib`main
(lldb)
```

```
(lldb) break set --name main
Breakpoint 1: 19 locations.
(lldb) break list 1
1: name = 'main', locations = 19
  1.1: where = Sketch`main + 55 at SKTMain.m:17
  1.2: where = Foundation`-[NSThread main]
  1.3: where = Foundation`-[NSBlockOperation main]
…
(lldb) break set --fullname main
Breakpoint 2: 2 locations.
(lldb) break list 2
2: name = 'main', locations = 2
  2.1: where = Sketch`main + 55 at SKTMain.m:17
  2.2: where = libpcap.A.dylib`main
(lldb) break set --fullname main --shlib Sketch
Breakpoint 3: where = Sketch`main + 55 at SKTMain.m:17, address = 0x0000000100018fe7
```

Multiple Locations

When and why?

Multiple Locations

When and why?

Example with file and line breakpoint locations:

```
(lldb)
```

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
   13            print ("Main's closure did something.")
   14        }
(lldb)
```

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
   13            print ("Main's closure did something.")
   14        }
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```

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
   13            print ("Main's closure did something.")
   14        }
(lldb) break set --line 12 --file Example.swift
Breakpoint 1: 2 locations.
(lldb)
```

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
   13            print ("Main's closure did something.")
   14        }
(lldb) break set --line 12 --file Example.swift
Breakpoint 1: 2 locations.
(lldb) break list 1
1: file = '/tmp/Example.swift', line = 12, exact_match = 0, locations = 2
  1.1: where = Example`Example.callIt () -> () + 25 at Example.swift:12, ...
  1.2: where = Example`Example.(callIt () -> ()).(closure #1) + 15 at Example.swift:13, ...
```

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
   13            print ("Main's closure did something.")
   14        }
(lldb) break set --line 12 --file Example.swift
Breakpoint 1: 2 locations.
(lldb) break list 1
1: file = '/tmp/Example.swift', line = 12, exact_match = 0, locations = 2
  1.1: where = Example`Example.callIt () -> () + 25 at Example.swift:12, ...
  1.2: where = Example`Example.(callIt () -> ()).(closure #1) + 15 at Example.swift:13, ...
```

This is the closure function

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
   13            print ("Main's closure did something.")
   14        }
(lldb) break set --line 12 --file Example.swift
Breakpoint 1: 2 locations.
(lldb) break list 1
1: file = '/tmp/Example.swift', line = 12, exact_match = 0, locations = 2
  1.1: where = Example`Example.callIt () -> () + 25 at Example.swift:12, ...
  1.2: where = Example`Example.(callIt () -> ()).(closure #1) + 15 at Example.swift:13, ...
```

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
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(lldb) break set --line 12 --file Example.swift
Breakpoint 1: 2 locations.
(lldb) break list 1
1: file = '/tmp/Example.swift', line = 12, exact_match = 0, locations = 2
  1.1: where = Example`Example.callIt () -> () + 25 at Example.swift:12, ...
  1.2: where = Example`Example.(callIt () -> ()).(closure #1) + 15 at Example.swift:13, ...
```

This is the contribution to the containing function

```
(lldb) source list --line 12
   10    func callIt ()
   11    {
   12        my_object.useClosure() {() -> Void in
   13            print ("Main's closure did something.")
   14        }
(lldb) break set --line 12 --file Example.swift
Breakpoint 1: 2 locations.
(lldb) break list 1
1: file = '/tmp/Example.swift', line = 12, exact_match = 0, locations = 2
  1.1: where = Example`Example.callIt () -> () + 25 at Example.swift:12, ...
  1.2: where = Example`Example.(callIt () -> ()).(closure #1) + 15 at Example.swift:13, ...
```

Breakpoint Set Command

Breakpoint Set Command

`breakpoint set` command form:

```
(lldb)
```

Breakpoint Set Command

`breakpoint set` command form:

```
(lldb) break set --<Type> <Value> --<OtherOptions>
```

Breakpoint Set Command

`breakpoint set` command form:

```
(lldb) break set --<Type> <Value> --<OtherOptions>
```

Type option:

Breakpoint Set Command

`breakpoint set` command form:

```
(lldb) break set --<Type> <Value> --<OtherOptions>
```

Type option:

- Sets the kind of search you are doing (file and line, symbol name, etc.)

Breakpoint Set Command

`breakpoint set` command form:

```
(lldb) break set --<Type> <Value> --<OtherOptions>
```

Type option:

- Sets the kind of search you are doing (file and line, symbol name, etc.)
- Value is the data for the search

Breakpoint Set Command

`breakpoint set` command form:

```
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```

Type option:

- Sets the kind of search you are doing (file and line, symbol name, etc.)
- Value is the data for the search

Other options:

Breakpoint Set Command

`breakpoint set` command form:

```
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```

Type option:

- Sets the kind of search you are doing (file and line, symbol name, etc.)
- Value is the data for the search

Other options:

- Ignore count, condition, and so on

Breakpoint Set Command

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- Specify whether to break, not where…

Breakpoint Set Command

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```

Type option:

- Sets the kind of search you are doing (file and line, symbol name, etc.)
- Value is the data for the search

Other options:

- Ignore count, condition, and so on
- Specify whether to break, not where…
- Can be modified after the fact

Breakpoint Locations

Where to stop

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Each breakpoint location is a single search result

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- Unique address where program execution may halt

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  - Written separated by a dot

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Where to stop

Each breakpoint location is a single search result

- Unique address where program execution may halt
- Specified by breakpoint and location numbers:
  - Written separated by a dot
  - 1.1, 2.2...

Options for Breakpoints and Locations

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Breakpoints and locations take the same generic options

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Options for Breakpoints and Locations

Breakpoints and locations take the same generic options

- Conditions, commands, and so on

Location options override breakpoint options

Disabling the breakpoint deactivates all locations

- Locations can be disabled individually
- Disabled locations stay disabled when disabling/enabling breakpoint

More Powerful Breakpoint Types

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How to search for places to stop?

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How to search for places to stop?

LLDB offers two spaces to search:

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LLDB offers two spaces to search:

- Both use *regular expressions* to express search patterns

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LLDB offers two spaces to search:

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- Function name searches:

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- Source text searches:

More Powerful Breakpoint Types

How to search for places to stop?

LLDB offers two spaces to search:

- Both use *regular expressions* to express search patterns
- Function name searches:

  `--func-regex` (or `-r`)
- Source text searches:

  `--source-pattern-regexp` (or `-p`)

Pattern Matching for Function Names

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Example problems:

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- Stop on all methods implemented by a class

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```
(lldb)
```

Pattern Matching for Function Names

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- Stop on all methods implemented by a class
- But not parent or subclasses
  - Swift:

```
(lldb) break set -r "\.ClassName\..*"
```

Pattern Matching for Function Names

Example problems:

- Stop on all methods implemented by a class
- But not parent or subclasses
  - Swift:

```
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```

  - Objective-C:

```
(lldb)
```

Pattern Matching for Function Names

Example problems:

- Stop on all methods implemented by a class
- But not parent or subclasses
  - Swift:

```
(lldb) break set -r "\.ClassName\..*"
```

  - Objective-C:

```
(lldb) break set -r "\[ClassName \.*\]"
```

Pattern Matching for Function Names

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Example problems:

Pattern Matching for Function Names

Example problems:

- Stop on all functions in a given module:

```
(lldb)
```

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Example problems:

- Stop on all functions in a given module:

```
(lldb) break set -r ".*" --shlib MyModule
```

Pattern Matching for Function Names

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- Stop on all functions in a given module:

```
(lldb) break set -r ".*" --shlib MyModule
```

  - Use with breakpoint commands to trace execution

Pattern Matching for Function Names

Example problems:

- Stop on all functions in a given module:

```
(lldb) break set -r ".*" --shlib MyModule
```

  - Use with breakpoint commands to trace execution
  - This will slow down execution

Pattern Matching for Function Names

Example problems:

- Stop on all functions in a given module:

```
(lldb) break set -r ".*" --shlib MyModule
```

- Use with breakpoint commands to trace execution
- This will slow down execution
- Disable locations as you hit them

Pattern Matching in Source

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Some constructs are obvious in source

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But hard to identify in generated code

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```
->someField
```

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Some constructs are obvious in source

But hard to identify in generated code

- Use of MACROS
- Very specific usages:
  - Places where you get a particular field from a pointer:

```
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```

You can also use it to make your own markers:

Pattern Matching in Source

Some constructs are obvious in source

But hard to identify in generated code

- Use of MACROS
- Very specific usages:
  - Places where you get a particular field from a pointer:

```
->someField
```

You can also use it to make your own markers:

```
// Break here
```

Pattern Matching in Source

Command format:

Pattern Matching in Source

Command format:

```
(lldb)
```

Pattern Matching in Source

Command format:

```
(lldb) break set --source-regexp "// Break here" -f main.swift
```

Pattern Matching in Source

Command format:

```
(lldb) break set --source-regexp "// Break here" -f main.swift
```

Patterns in code can mark useful spots to stop

Pattern Matching in Source

Command format:

```
(lldb) break set --source-regexp "// Break here" -f main.swift
```

`-f` specifies files to search for matches

Pattern Matching in Source

Pattern Matching in Source

Example problem:

Pattern Matching in Source

Example problem:

- In a complex function that can return from many places

Pattern Matching in Source

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- In a complex function that can return from many places
- Stop whenever it returns null

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`--source-regexp-function` (or `-X`) limits search to a function

Pattern Matching in Source

Example problem:

- In a complex function that can return from many places
- Stop whenever it returns null
  - `--source-regexp-function` (or `-X`) limits search to a function

```
(lldb) break set -p "return *nullptr" -X Foo::StateMachine -f Foo.cpp
```

Additional Breakpoint Options

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Specify the language for a breakpoint

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- Use the `--language` (or `-L`) option to `break set`

Additional Breakpoint Options

Specify the language for a breakpoint

- Use the `--language` (or `-L`) option to `break set`
- Useful in mixed Swift/Objective-C projects

Additional Breakpoint Options

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Restricting a breakpoint to a specific thread:

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- By thread id:

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```
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```

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- By thread id:

```
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```
--thread-name (or -T)
```

Additional Breakpoint Options

Restricting a breakpoint to a specific thread:

- By thread id:

```
--thread-id (or -t)
```

- By name for threads named by `pthread_setname_np()`:

```
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```

- To threads servicing a particular named queue:

Additional Breakpoint Options

Restricting a breakpoint to a specific thread:

- By thread id:

```
--thread-id (or -t)
```

- By name for threads named by `pthread_setname_np()`:

```
--thread-name (or -T)
```

- To threads servicing a particular named queue:

```
--queue-name (or -q)
```

Applying Options to Existing Breakpoints

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Options can be set/modified on extant breakpoints

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Can modify Xcode breakpoints as well

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Command is `break modify`

```
(lldb) break modify -T ImportantThreads 1 2.1 4.1-4.5 7-10
```

Applying Options to Existing Breakpoints

Options can be set/modified on extant breakpoints

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Command is `break modify`

- Specify breakpoints, breakpoint locations, or ranges of either

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(lldb) break modify -T ImportantThreads 1 2.1 4.1-4.5 7-10
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Applying Options to Existing Breakpoints

Options can be set/modified on extant breakpoints

Can modify Xcode breakpoints as well

Command is `break modify`

- Specify breakpoints, breakpoint locations, or ranges of either
- Defaults to last set breakpoint when none specified

```
(lldb) break modify -T ImportantThreads 1 2.1 4.1-4.5 7-10
```

Storing Complex Breakpoints

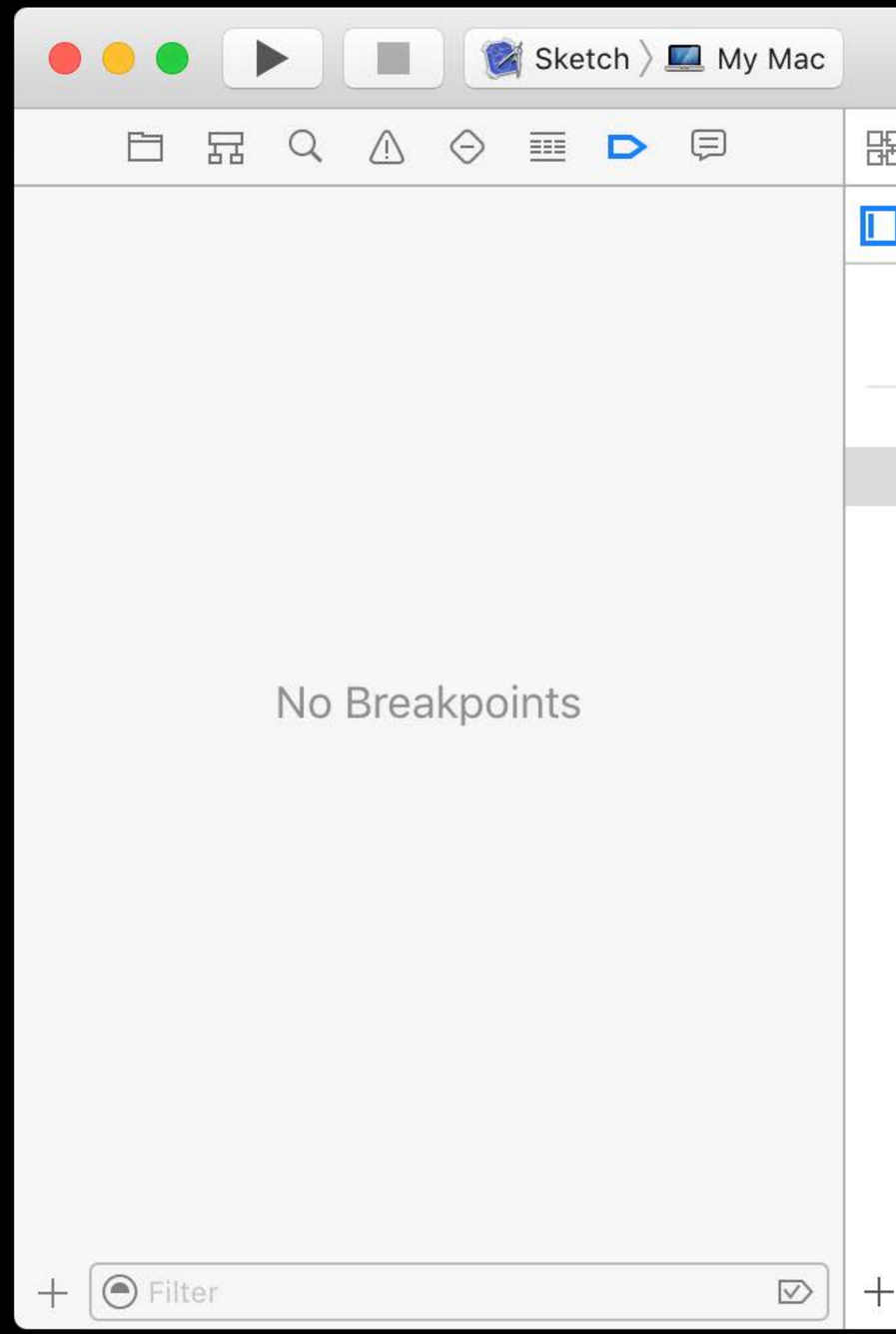
Storing Complex Breakpoints

Xcode only persists breakpoints set through the UI

Storing Complex Breakpoints

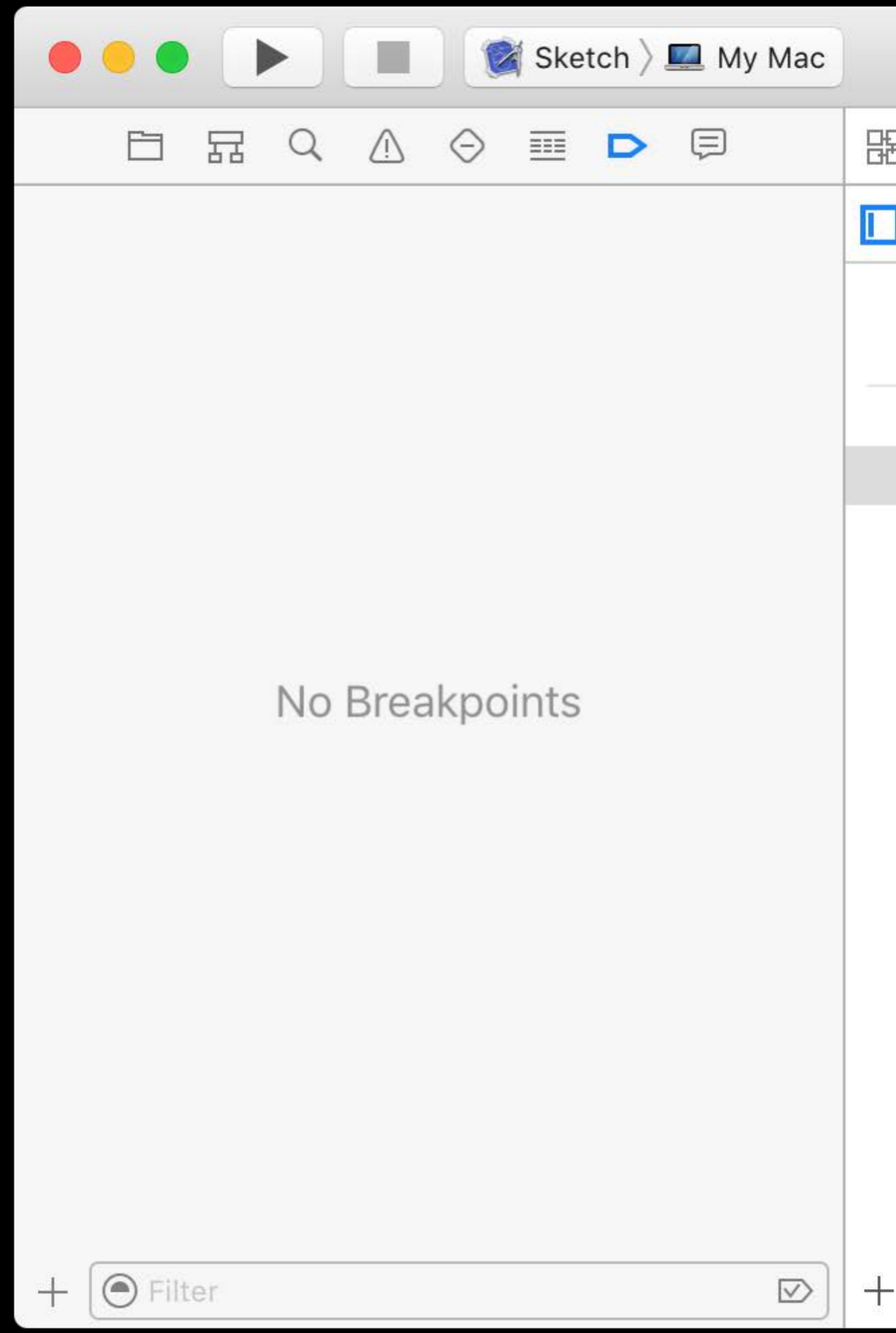
Xcode only persists breakpoints set through the UI

- For breakpoints in *all* projects, set in ~/.lldbinit


Sketch
My Mac
No Breakpoints
Filter

Storing Breakpoints in a Project

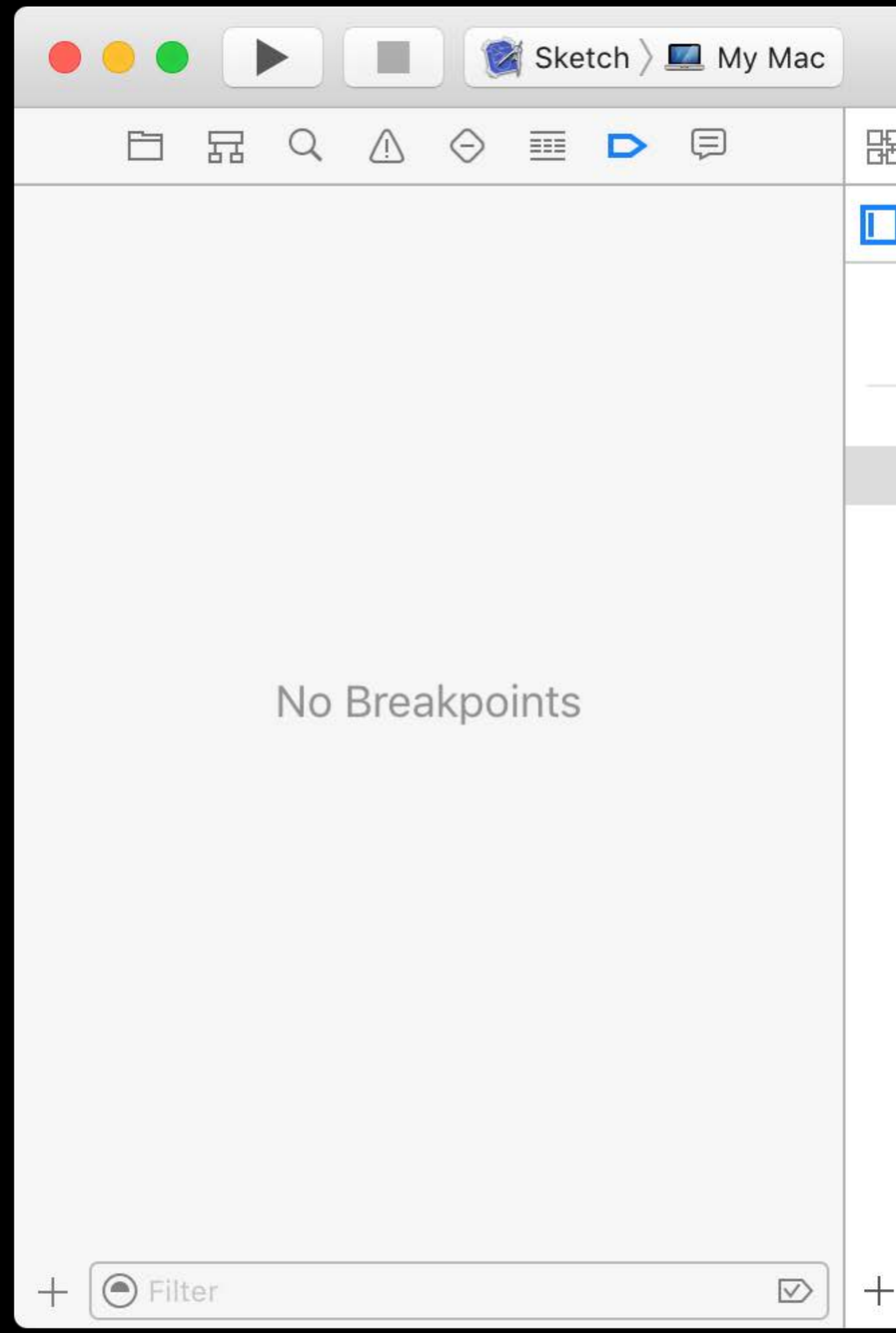
Make a breakpoint Xcode will store



Storing Breakpoints in a Project

Make a breakpoint Xcode will store

Something hit early on



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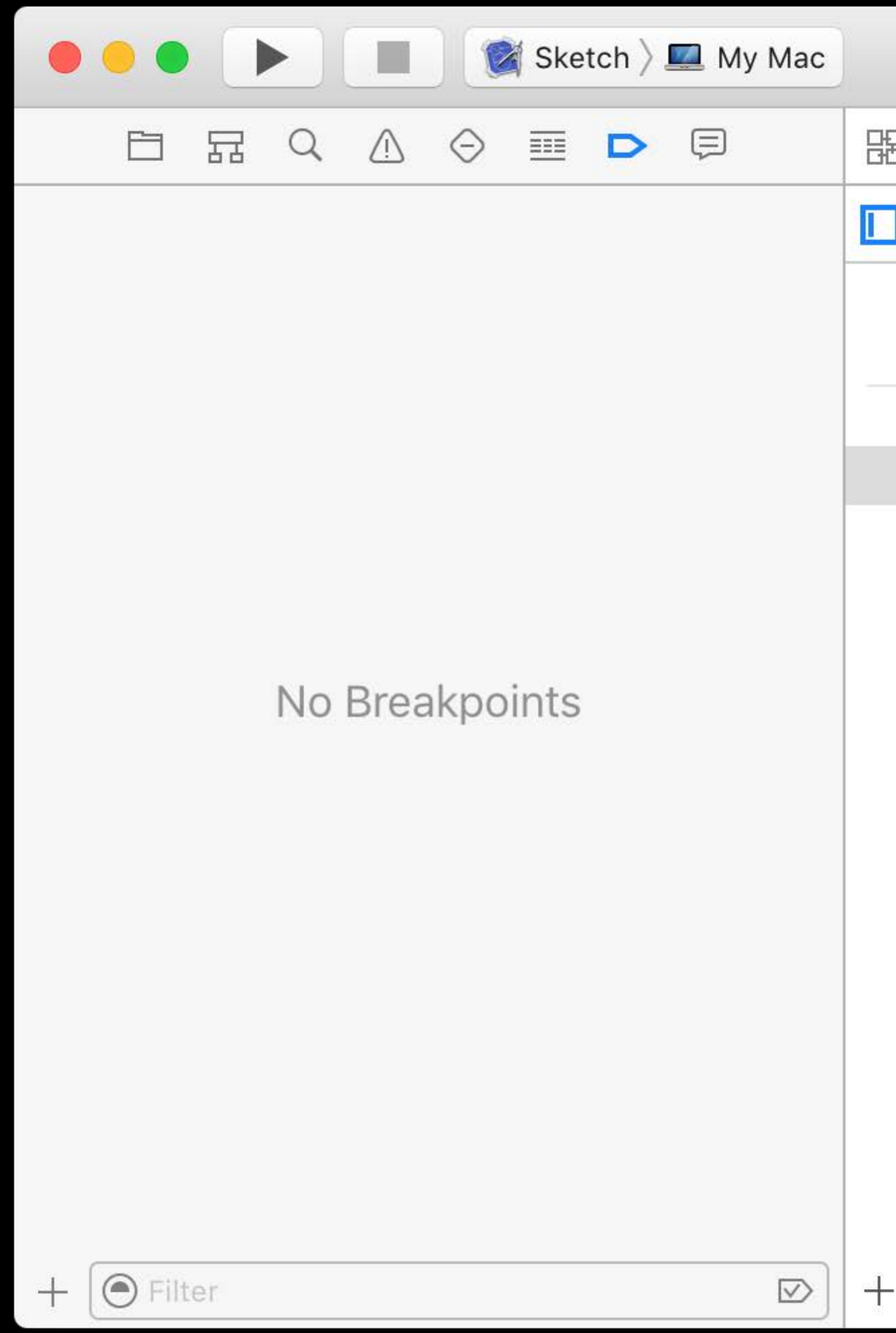
Add your breakpoints as commands



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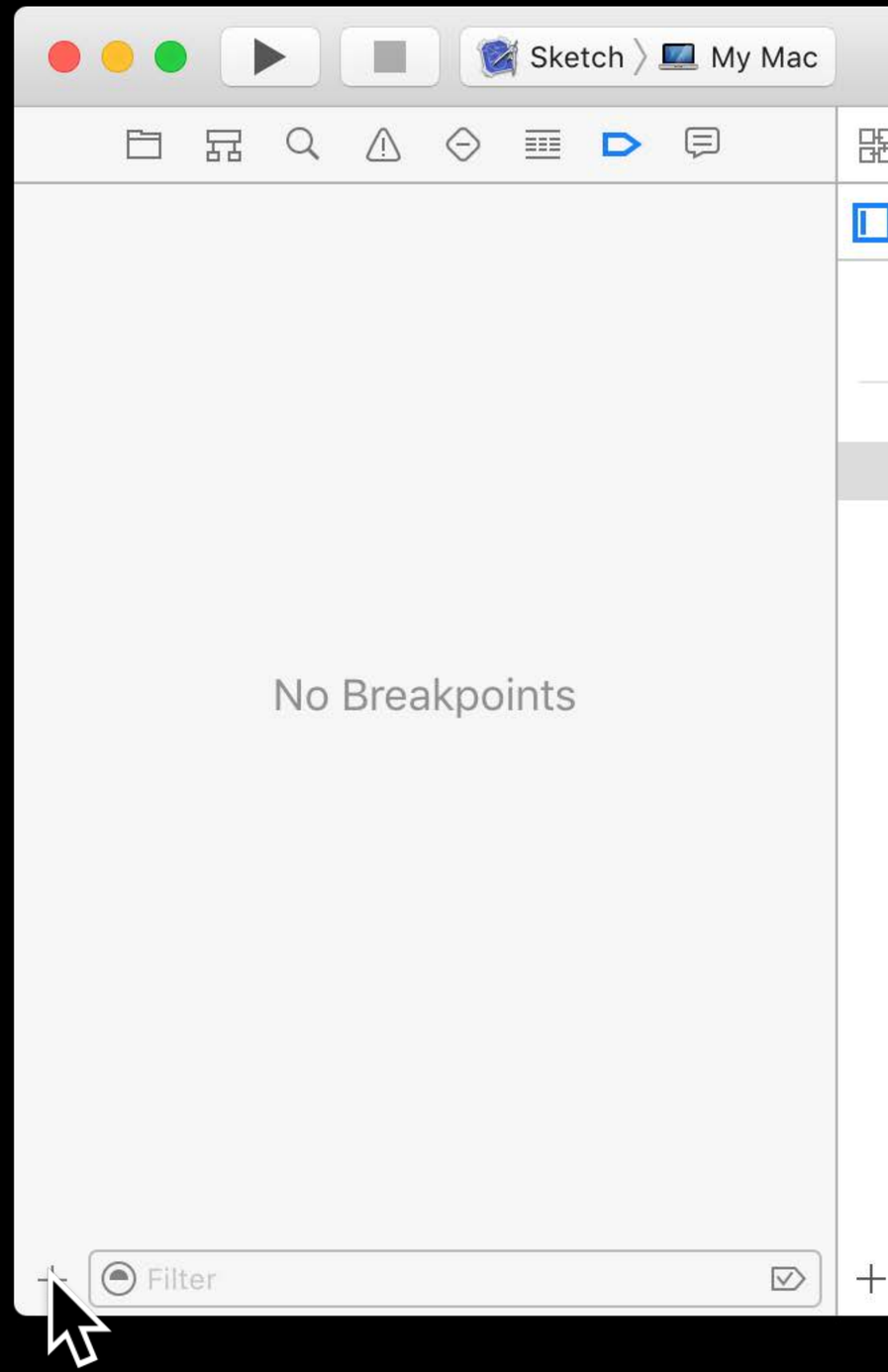

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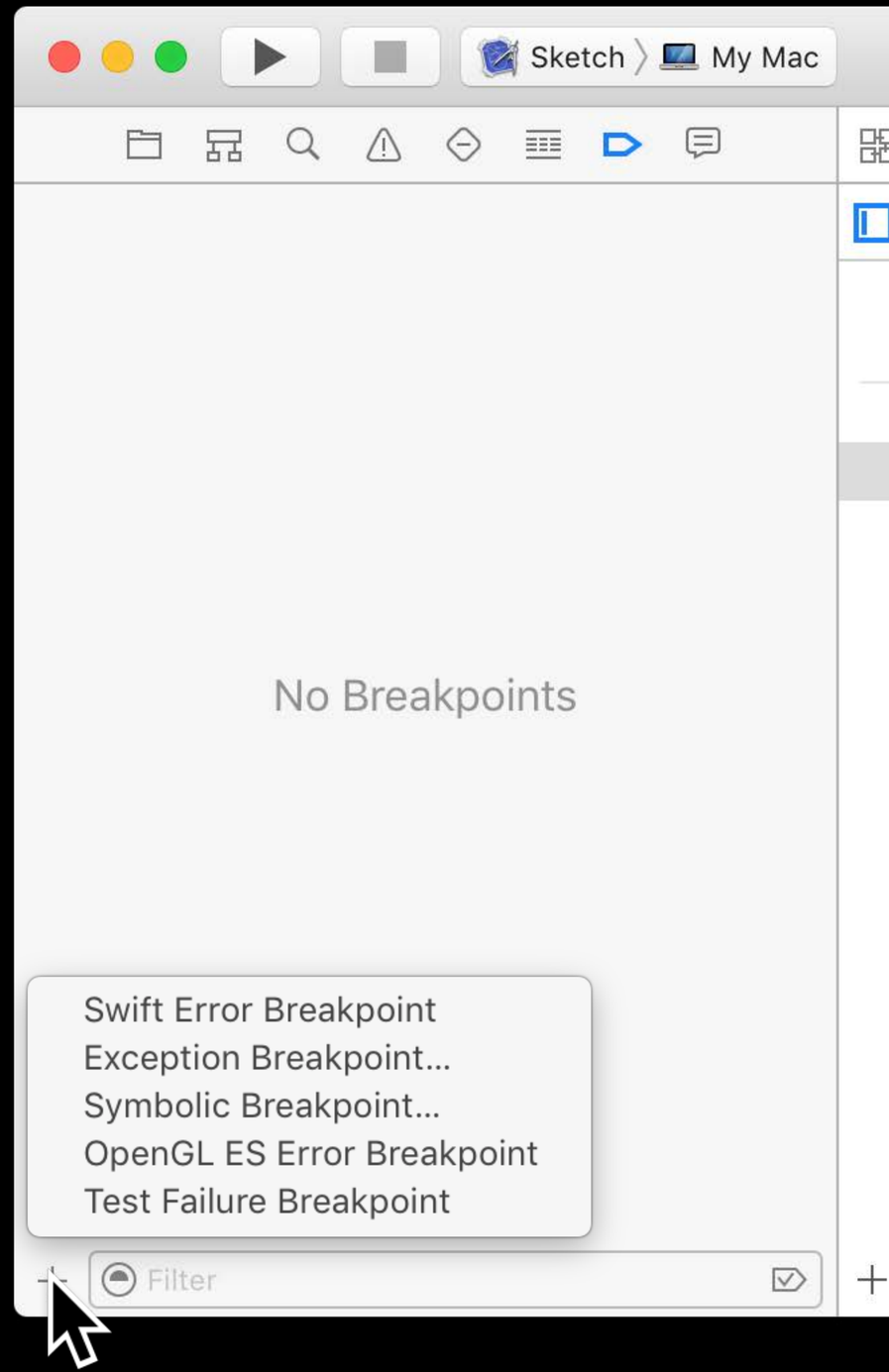
Make a breakpoint Xcode will store

Something hit early on

Add your breakpoints as commands



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Make a breakpoint Xcode will store

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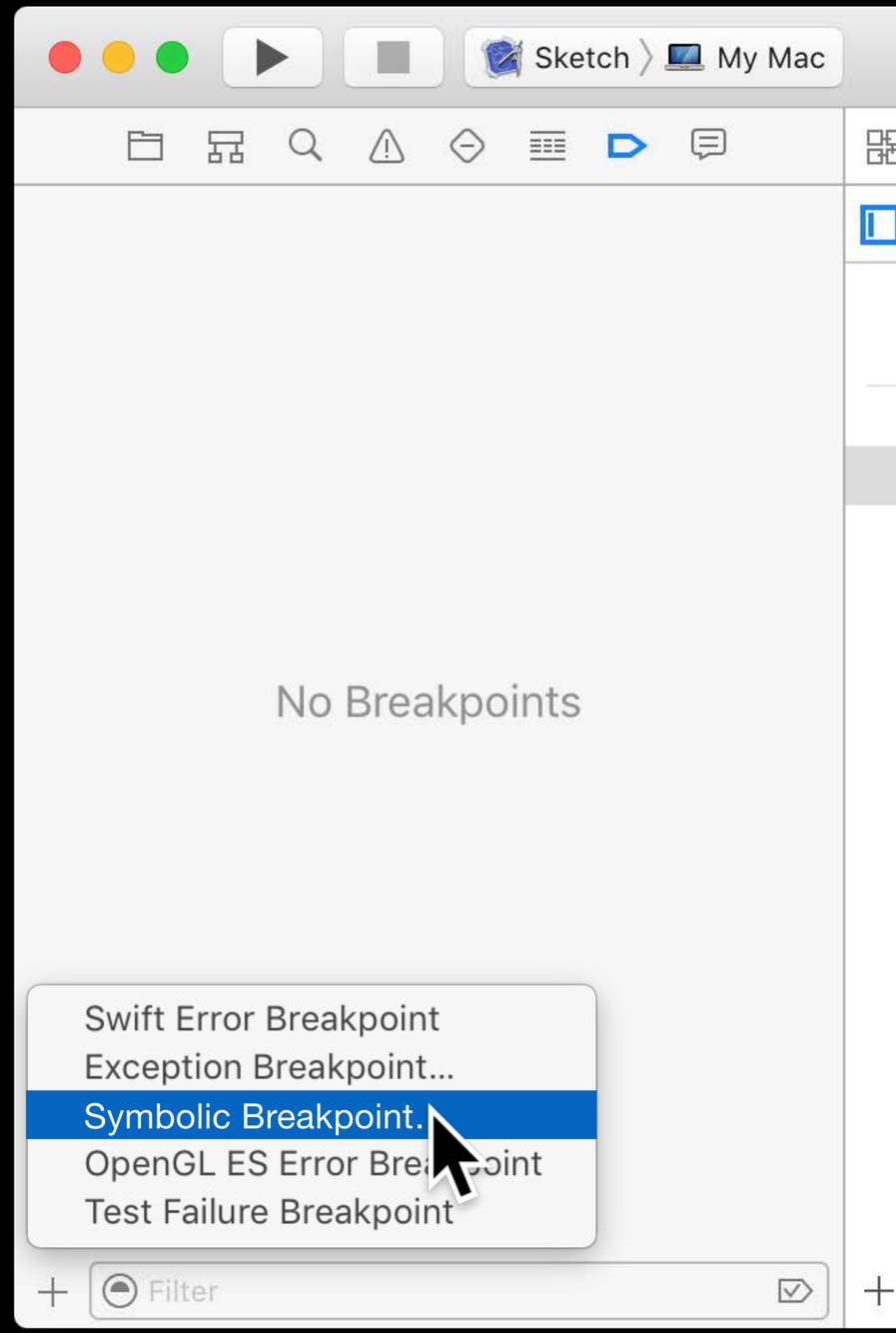
Add your breakpoints as commands



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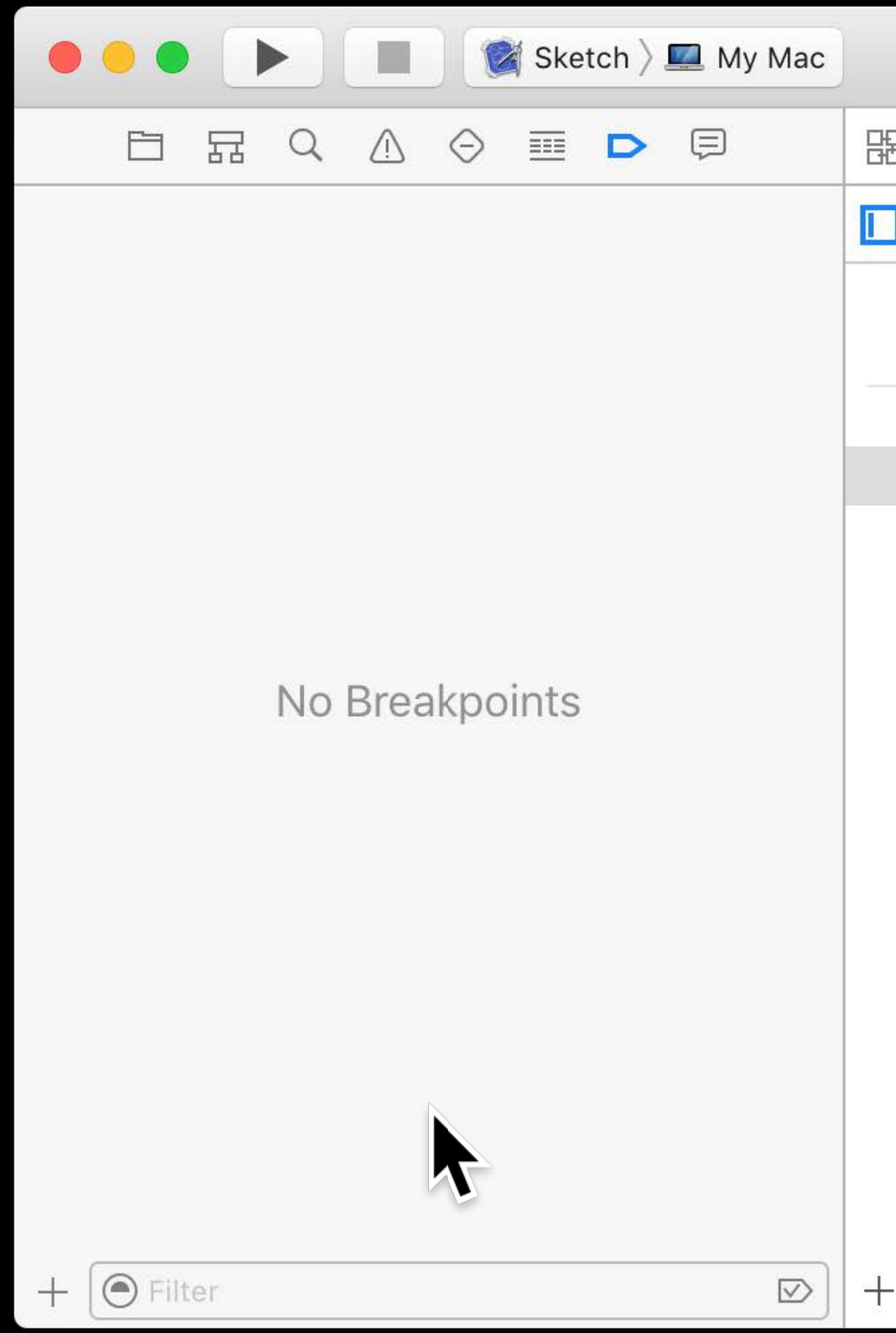

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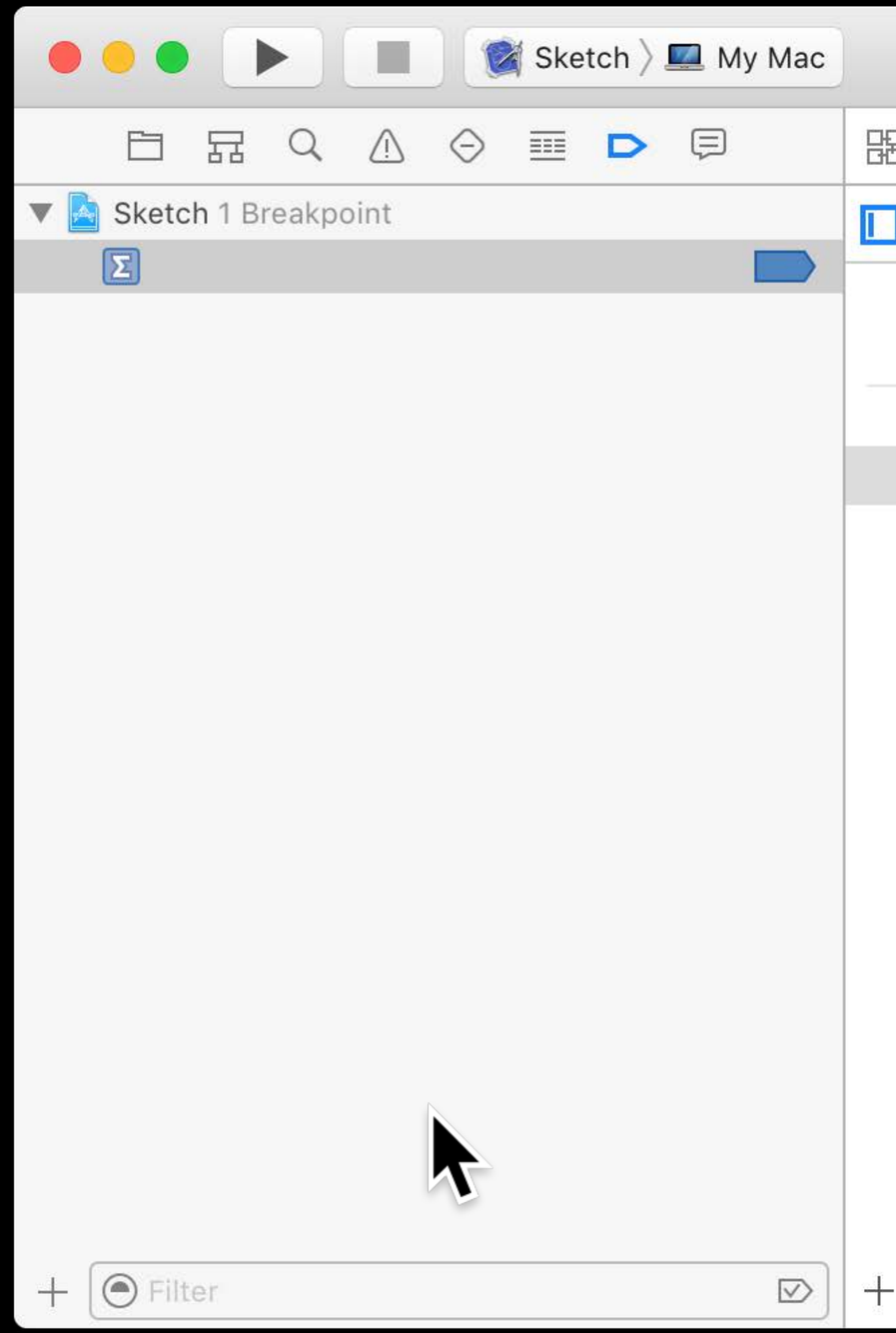
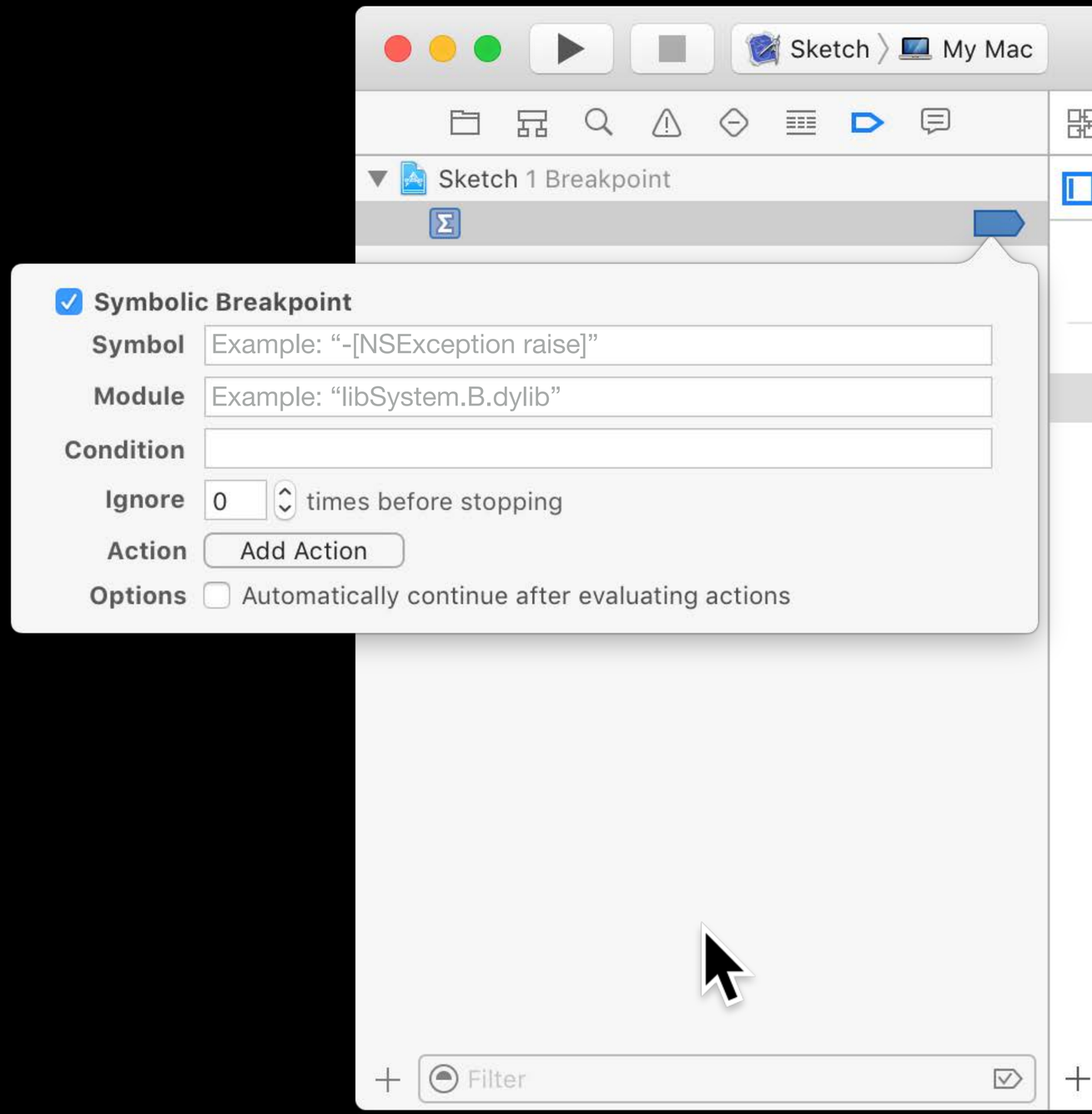


Storing Breakpoints in a Project

Make a breakpoint Xcode will store

Something hit early on

Add your breakpoints as commands



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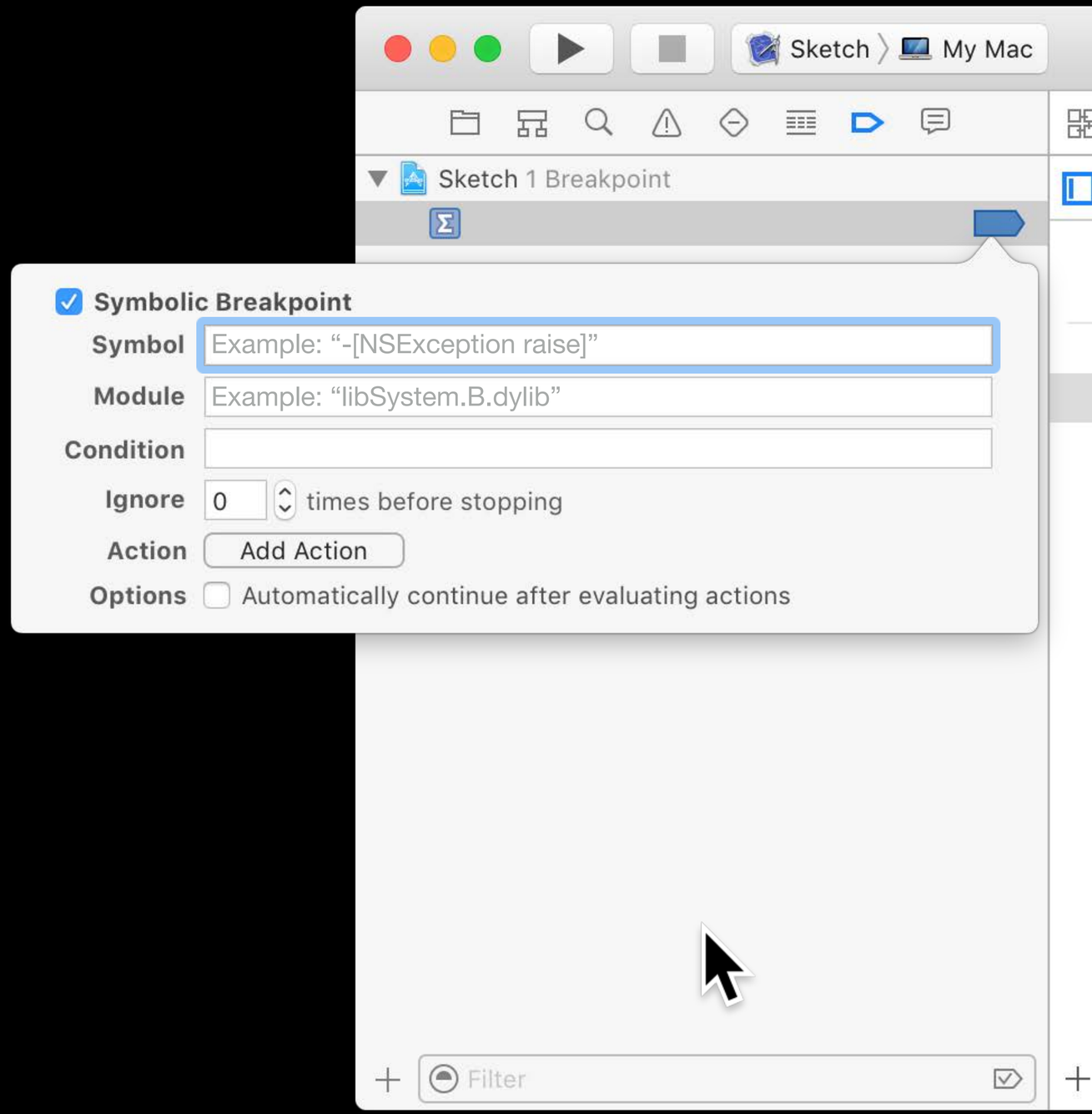

Storing Breakpoints in a Project

Make a breakpoint Xcode will store

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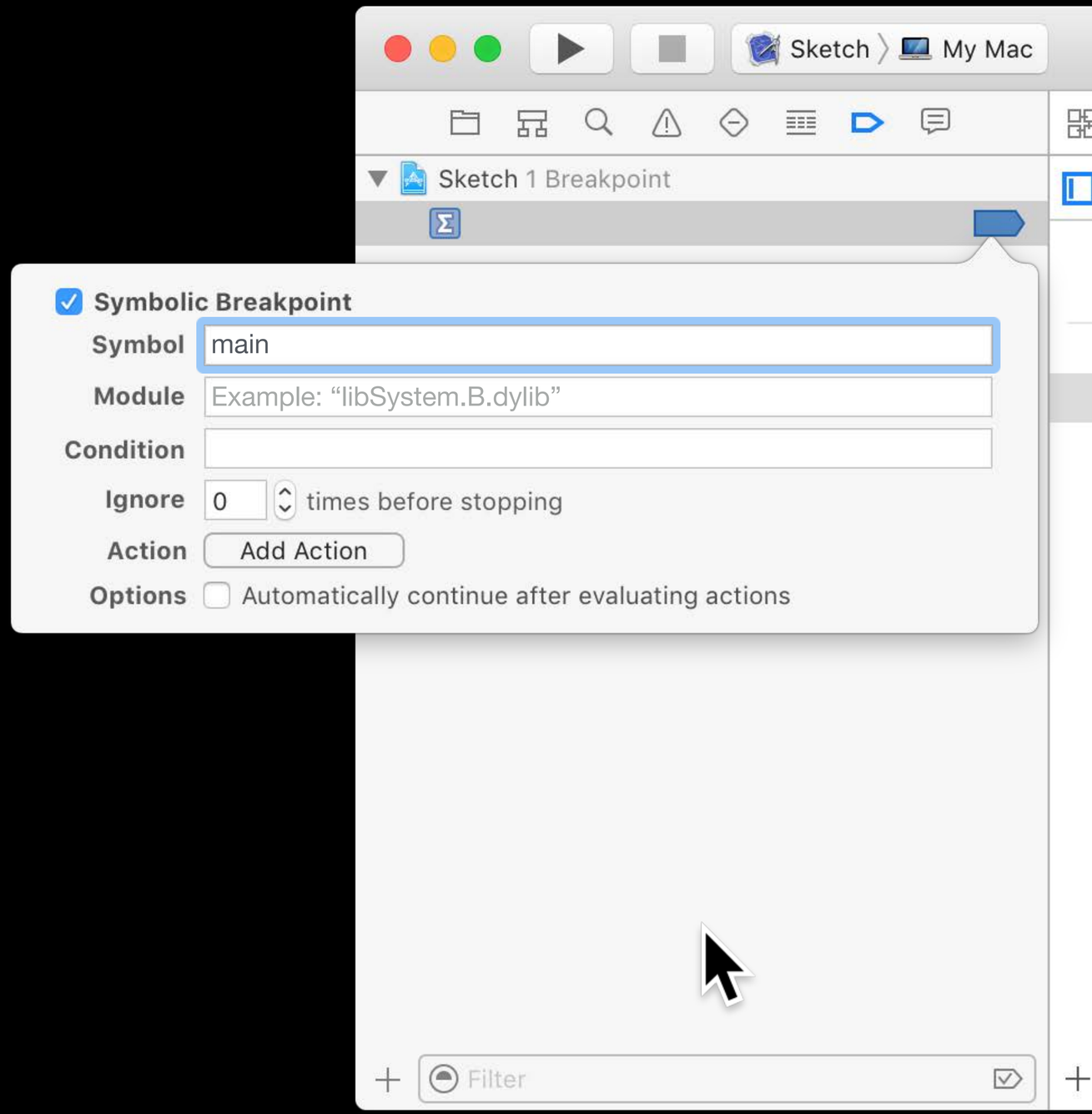
Add your breakpoints as commands



Storing Breakpoints in a Project

Make a breakpoint Xcode will store

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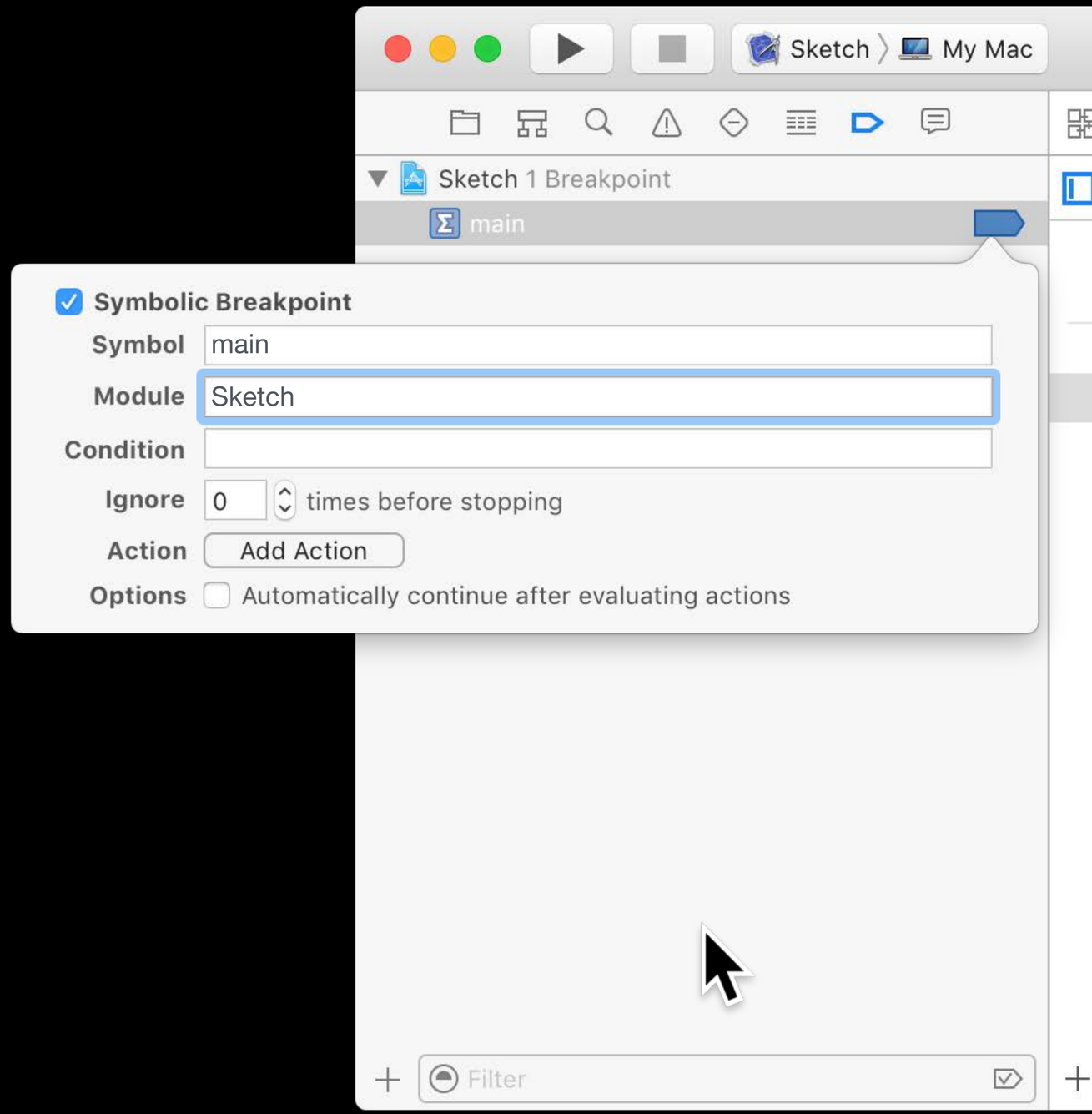
Add your breakpoints as commands



Storing Breakpoints in a Project

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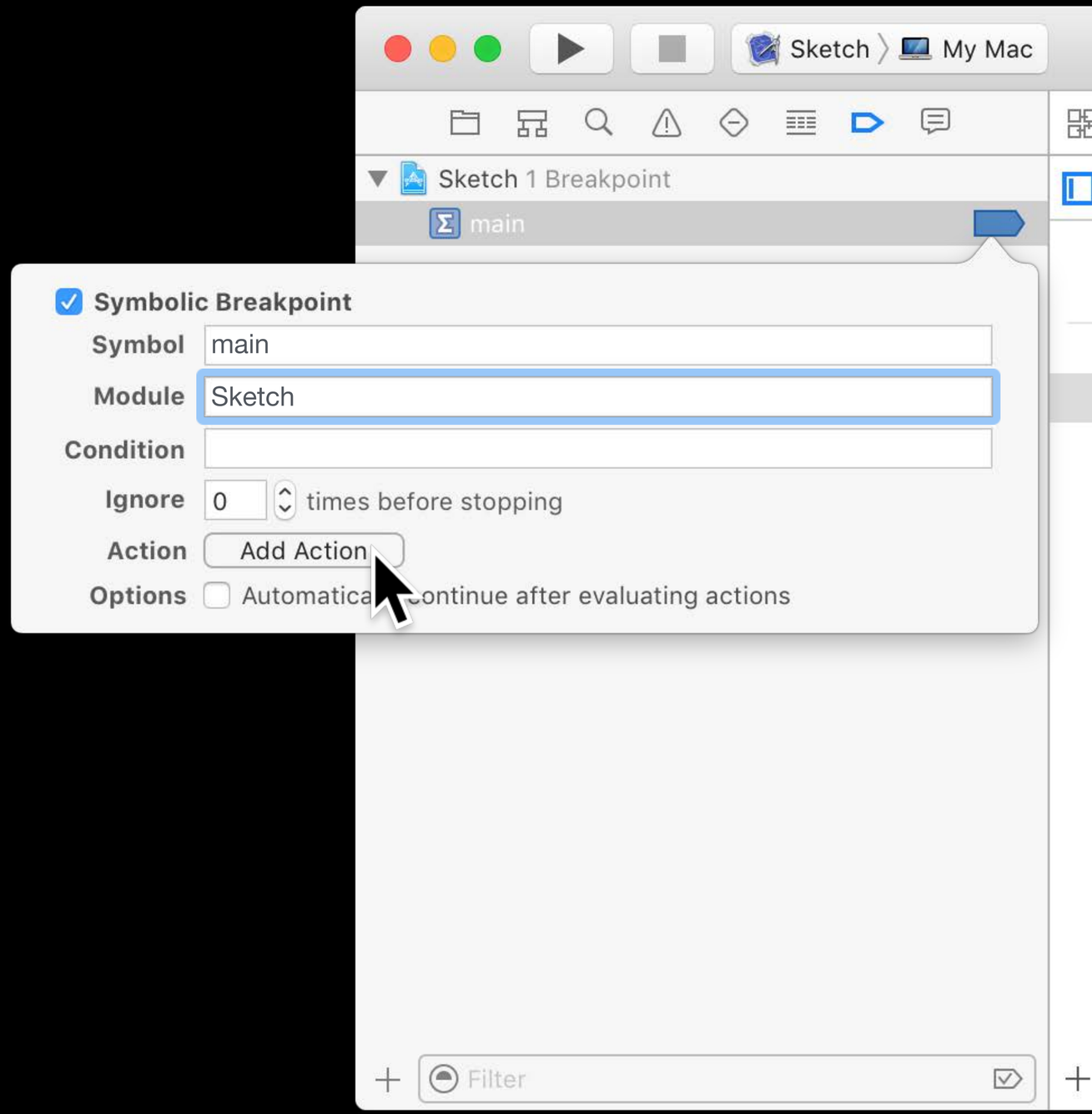
Add your breakpoints as commands



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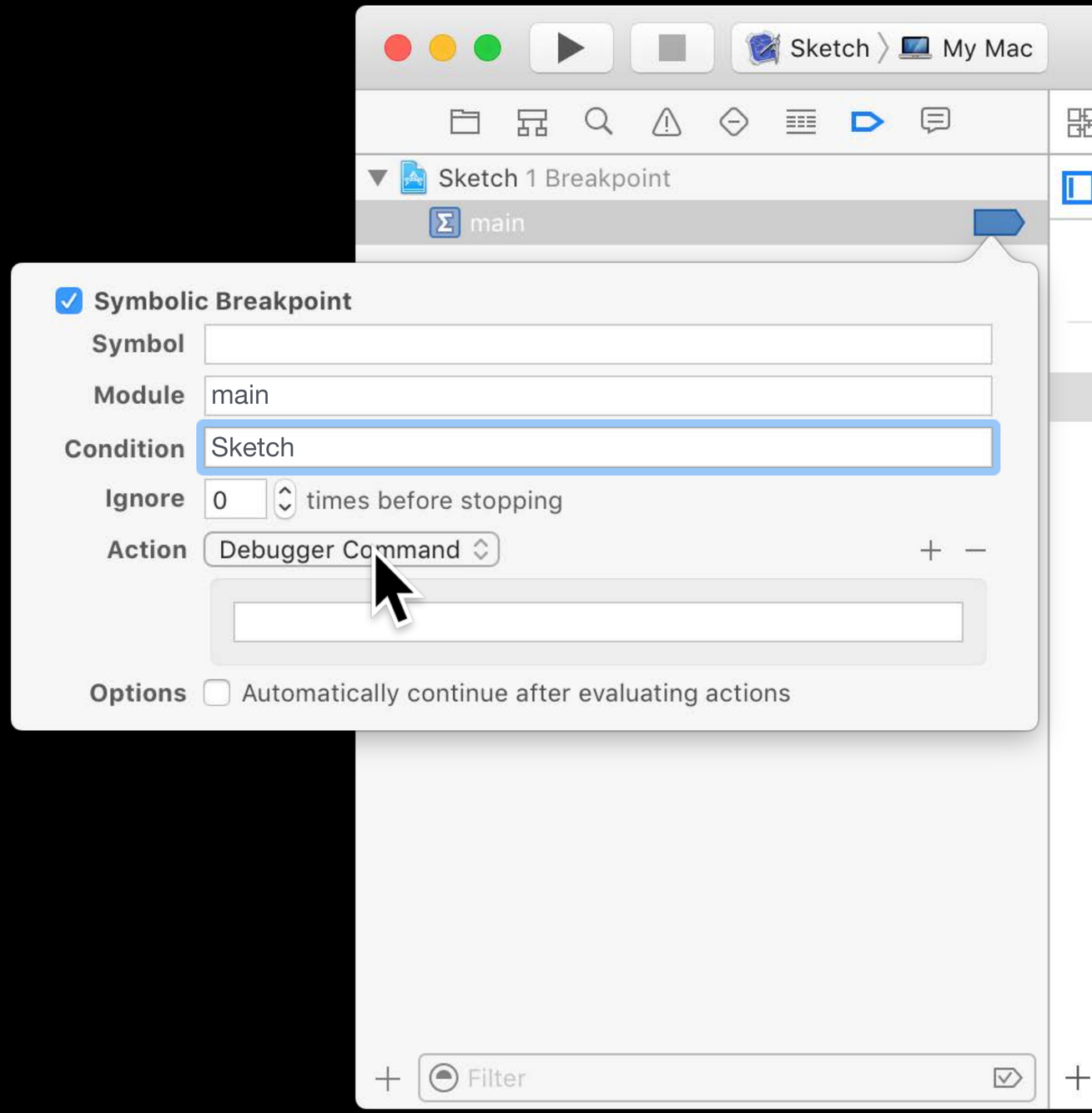
Make a breakpoint Xcode will store

Something hit early on

Add your breakpoints as commands



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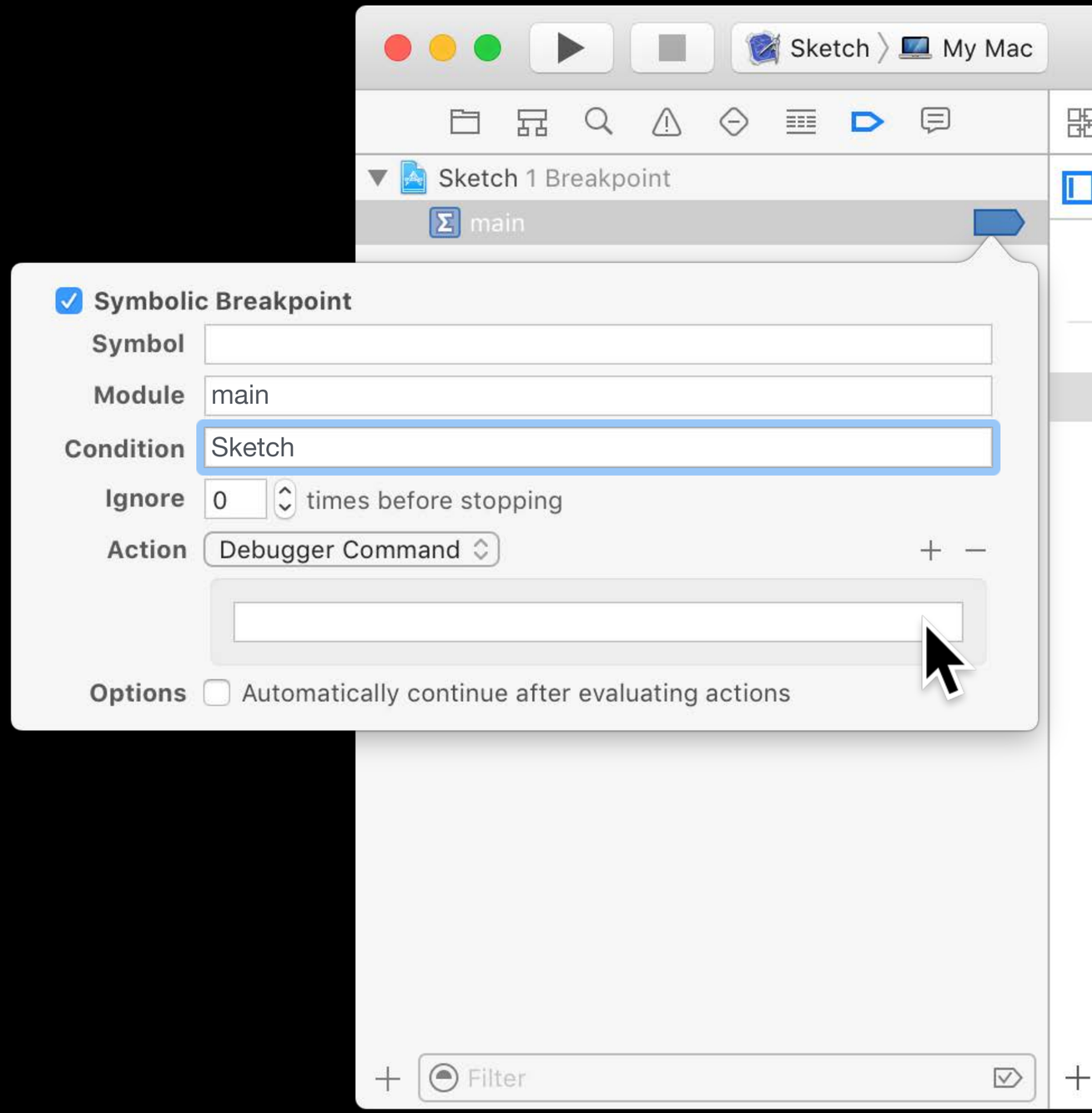
Make a breakpoint Xcode will store

Something hit early on

Add your breakpoints as commands

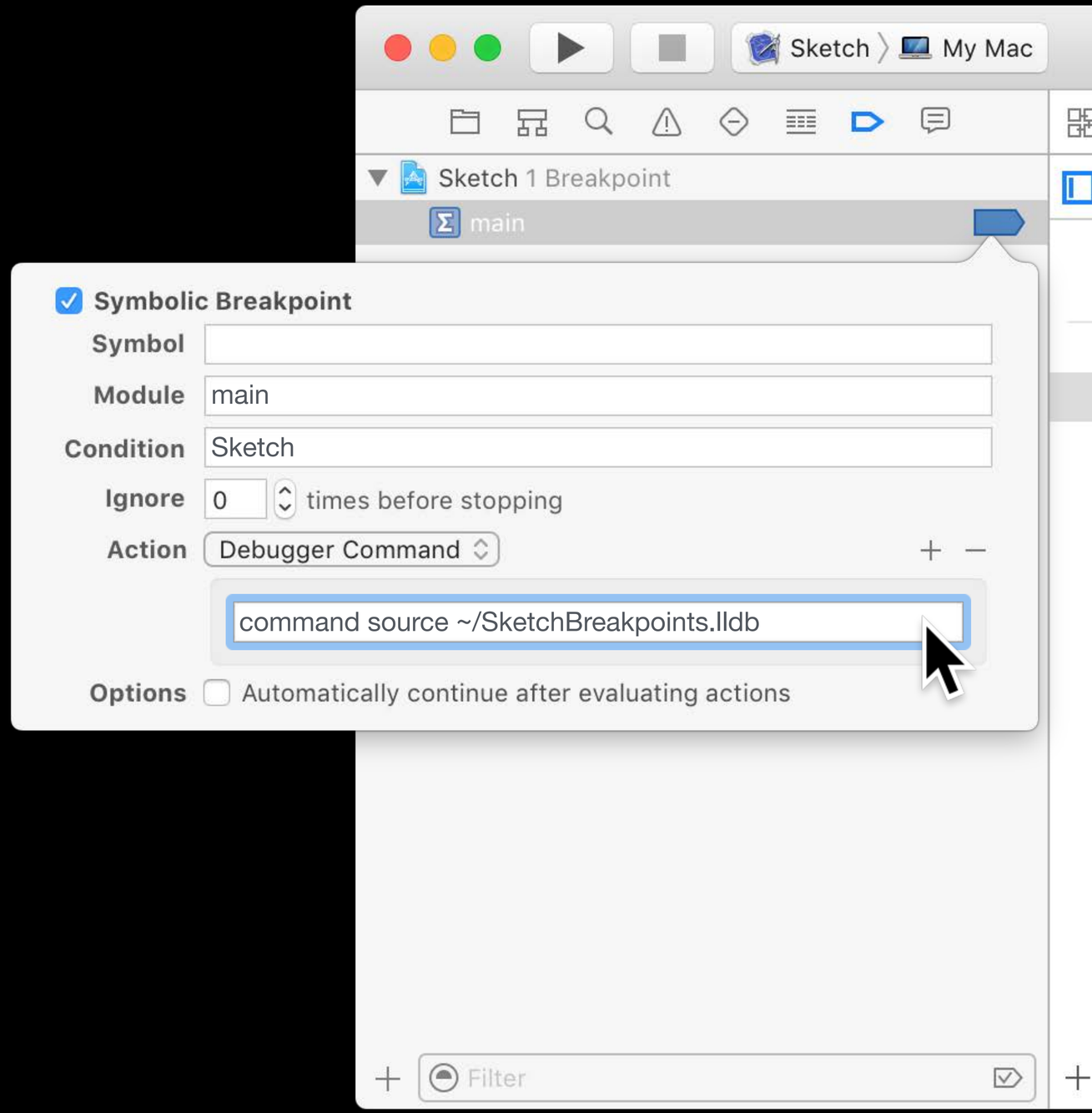


Storing Breakpoints in a Project

Make a breakpoint Xcode will store

Something hit early on

Add your breakpoints as commands

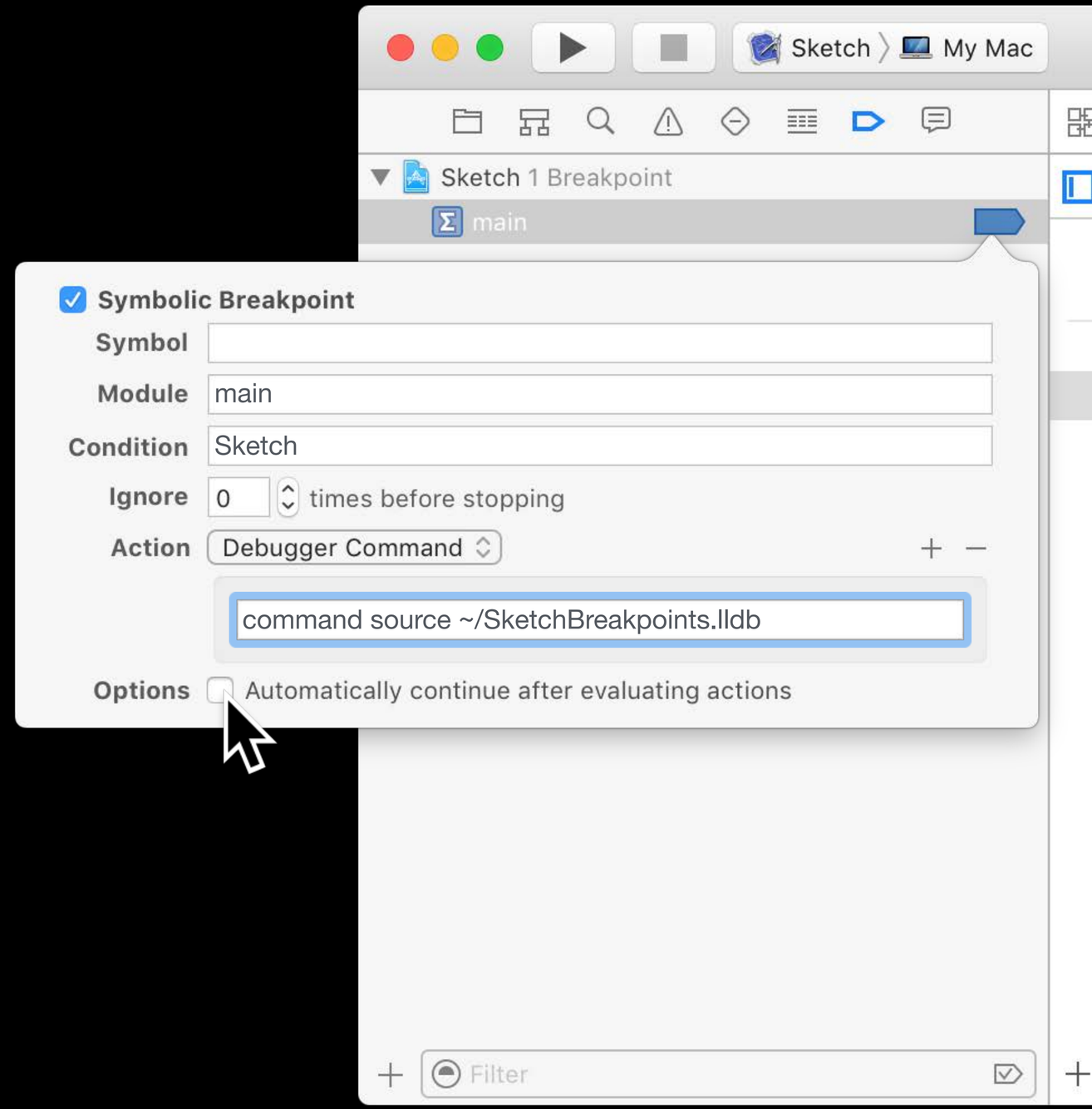


Storing Breakpoints in a Project

Make a breakpoint Xcode will store

Something hit early on

Add your breakpoints as commands



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Make a breakpoint Xcode will store

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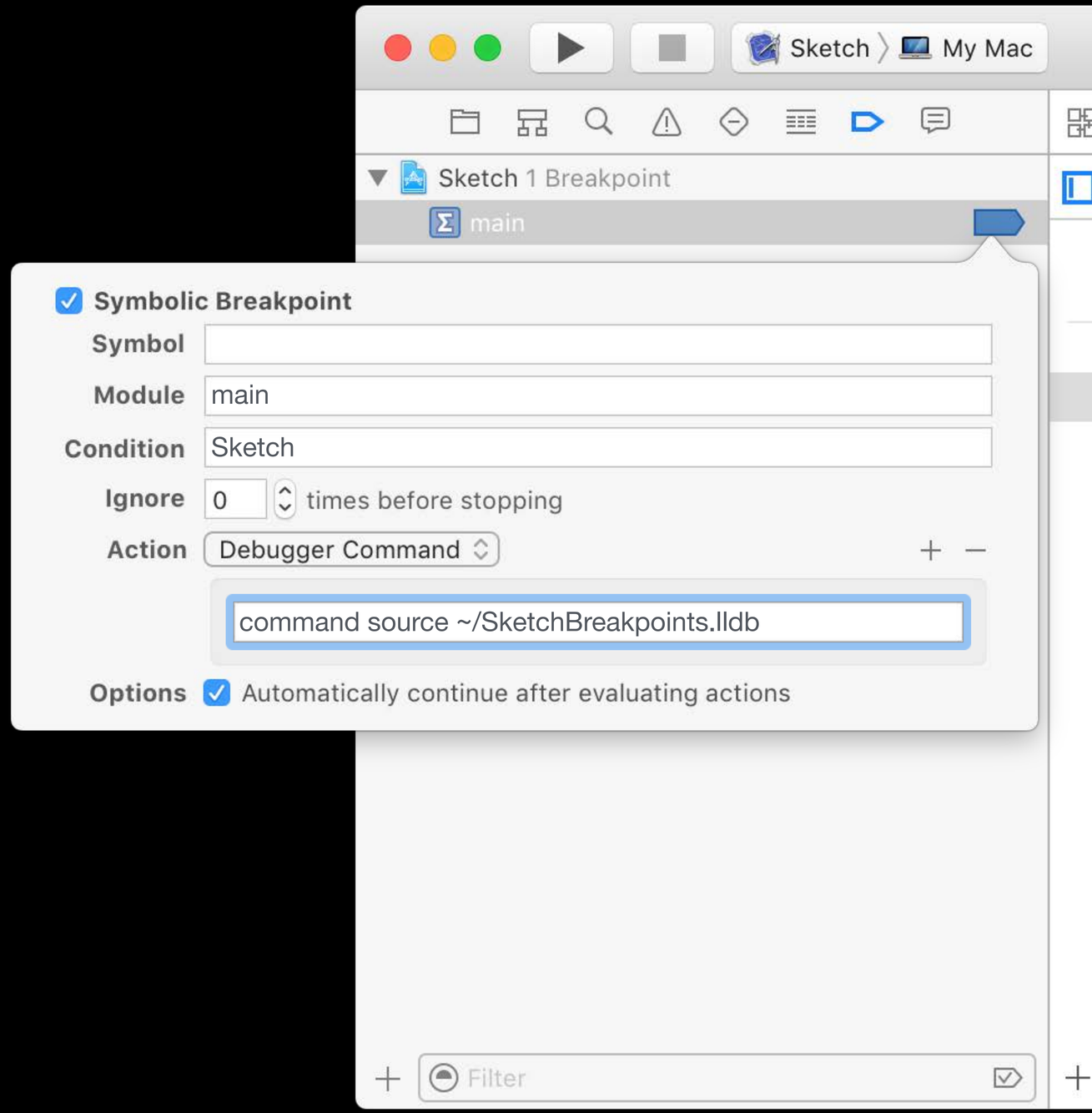
Add your breakpoints as commands



Stepping

Targeted Stepping in Complex Situations

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In modern languages, many simple expressions are actually function calls

Targeted Stepping in Complex Situations

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Often not interesting to step through...

Targeted Stepping in Complex Situations

In modern languages, many simple expressions are actually function calls

Often not interesting to step through...

This is a common scenario:

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35   main () -> Void
   36   {
   37       let my_cp = ComputedProperties()
-> 38       doSomething(my_cp.computed_ivar_1,
   39                   my_cp.computed_ivar_2,
   40                   my_cp.computed_ivar_3)
   41   }
(lldb)
```

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35    main () -> Void
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   37        let my_cp = ComputedProperties()
-> 38        doSomething(my_cp.computed_ivar_1,
   39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
(lldb)
```

I want to stop in **`doSomething`**

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35    main () -> Void
   36    {
   37        let my_cp = ComputedProperties()
-> 38        doSomething(my_cp.computed_ivar_1,
   39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
(lldb) step
Process 5108 stopped
* thread #1: tid = 0xaa0a3, function: stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int , stop reason = step in
    frame #0: 0x00000001000010fd stepping`stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int at stepping.swift:5
   2    {
   3        var computed_ivar_1 : Int {
   4            get {
-> 5               return 10
   6            }
   7        }
   8        var computed_ivar_2 : Int {
(lldb)
```

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35    main () -> Void
   36    {
   37        let my_cp = ComputedProperties()
-> 38        doSomething(my_cp.computed_ivar_1,
   39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
(lldb) step
Process 5108 stopped
* thread #1: tid = 0xaa0a3, function: stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int , stop reason = step in
    frame #0: 0x00000001000010fd stepping`stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int at stepping.swift:5
   2     {
   3         var computed_ivar_1 : Int {
   4             get {
-> 5                 return 10
   6             }
   7         }
   8         var computed_ivar_2 : Int {
(lldb)
```

Instead I stopped in an accessor

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35    main () -> Void
   36    {
   37        let my_cp = ComputedProperties()
-> 38        doSomething(my_cp.computed_ivar_1,
   39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
(lldb) step
Process 5108 stopped
* thread #1: tid = 0xaa0a3, function: stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int , stop reason = step in
    frame #0: 0x00000001000010fd stepping`stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int at stepping.swift:5
   2    {
   3        var computed_ivar_1 : Int {
   4            get {
-> 5               return 10
   6            }
   7        }
   8        var computed_ivar_2 : Int {
(lldb)
```

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
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   37        let my_cp = ComputedProperties()
-> 38        doSomething(my_cp.computed_ivar_1,
   39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
(lldb) step
Process 5108 stopped
* thread #1: tid = 0xaa0a3, function: stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int , stop reason = step in
    frame #0: 0x00000001000010fd stepping`stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int at stepping.swift:5
   2    {
   3        var computed_ivar_1 : Int {
   4            get {
-> 5               return 10
   6            }
   7        }
   8        var computed_ivar_2 : Int {
(lldb) finish
...
(lldb)
```

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35    main () -> Void
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   41    }
(lldb) step
Process 5108 stopped
* thread #1: tid = 0xaa0a3, function: stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int , stop reason = step in
    frame #0: 0x00000001000010fd stepping`stepping.ComputedProperties.computed_ivar_1.getter :
Swift.Int at stepping.swift:5
   2    {
   3        var computed_ivar_1 : Int {
   4            get {
-> 5               return 10
   6            }
   7        }
   8        var computed_ivar_2 : Int {
(lldb) finish
...
(lldb) step
...
```

Targeted Stepping in Complex Situations

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Step into `doSomething` without stopping in accessors?

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Use the step command's `--step-in-target` option:

```
(lldb)
```

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Use the step command's `--step-in-target` option:

```
(lldb) step --step-in-target doSomething
```

Targeted Stepping in Complex Situations

Step into `doSomething` without stopping in accessors?

Use the step command's `--step-in-target` option:

```
(lldb) step --step-in-target doSomething
```

That *almost* works in this case:

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35   main () -> Void
   36   {
   37       let my_cp = ComputedProperties()
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   39                   my_cp.computed_ivar_2,
   40                   my_cp.computed_ivar_3)
   41   }
(lldb)
```

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35    main () -> Void
   36    {
   37        let my_cp = ComputedProperties()
-> 38        doSomething(my_cp.computed_ivar_1,
   39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
(lldb) step --step-in-target doSomething
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = step in
    frame #0: 0x000000010000117a stepping`stepping.main () -> () at stepping.swift:39
   36    {
   37        let my_cp = ComputedProperties()
   38        doSomething(my_cp.computed_ivar_1,
-> 39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
   42
```

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35    main () -> Void
   36    {
   37        let my_cp = ComputedProperties()
-> 38        doSomething(my_cp.computed_ivar_1,
   39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
(lldb) step --step-in-target doSomething
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = step in
    frame #0: 0x000000010000117a stepping`stepping.main () -> () at stepping.swift:39
   36    {
   37        let my_cp = ComputedProperties()
   38        doSomething(my_cp.computed_ivar_1,
-> 39                    my_cp.computed_ivar_2,
   40                    my_cp.computed_ivar_3)
   41    }
   42
```

Well, at least I didn't end up in the accessor

Targeted Stepping in Complex Situations

Targeted Stepping in Complex Situations

Stepping is by source line

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This call spans multiple lines...

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Specify the end line number:

```
(lldb)
```

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Stepping is by source line

This call spans multiple lines...

Specify the end line number:

```
(lldb) step -t doSomething --end-linenumber 40
```

Targeted Stepping in Complex Situations

Stepping is by source line

This call spans multiple lines...

Specify the end line number:

```
(lldb) step -t doSomething --end-linenumber 40
```

Easier: use the special token `block`

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Stepping is by source line

This call spans multiple lines...

Specify the end line number:

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(lldb) step -t doSomething --end-linenumber 40
```

Easier: use the special token `block`

- Step with a safeguard around the current semantic block

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Stepping is by source line

This call spans multiple lines...

Specify the end line number:

```
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- Step with a safeguard around the current semantic block

There's even an alias for this:

Targeted Stepping in Complex Situations

Stepping is by source line

This call spans multiple lines...

Specify the end line number:

```
(lldb) step -t doSomething --end-linenumber 40
```

Easier: use the special token `block`

- Step with a safeguard around the current semantic block

There's even an alias for this:

`sif` stands for step into function

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35   main () -> Void
   36   {
   37       let my_cp = ComputedProperties()
-> 38       doSomething(my_cp.computed_ivar_1,
   39                   my_cp.computed_ivar_2,
   40                   my_cp.computed_ivar_3)
   41   }
(lldb)
```

```
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.main () -> () , stop reason = breakpoint 1.1
    frame #0: 0x0000000100001165 stepping`stepping.main () -> () at stepping.swift:38
   35   main () -> Void
   36   {
   37       let my_cp = ComputedProperties()
-> 38       doSomething(my_cp.computed_ivar_1,
   39                   my_cp.computed_ivar_2,
   40                   my_cp.computed_ivar_3)
   41   }
(lldb) sif doSomething
Process 4971 stopped
* thread #1: tid = 0x1c8535, function: stepping.doSomething (Swift.Int, Swift.Int, Swift.Int) ->
Swift.Int , stop reason = step in
    frame #0: 0x00000001000011c0 stepping`stepping.doSomething (Swift.Int, Swift.Int, Swift.Int) ->
Swift.Int at stepping.swift:31
   28   func
   29   doSomething(_ one : Int, _ two: Int, _ three: Int) -> Int
   30   {
-> 31       return one + two + three
   32   }
   33
   34   func
```

Troubleshooting

What Binaries Were Loaded?

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Sometimes you need to see exactly what binaries you are running

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- I have built Release and Debug; which am I using now?

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- I have a dSYM, is it getting read in?

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Sometimes you need to see exactly what binaries you are running

- I have built Release and Debug; which am I using now?
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The command to query the binaries in your program is:

```
(lldb)
```

What Binaries Were Loaded?

Sometimes you need to see exactly what binaries you are running

- I have built Release and Debug; which am I using now?
- I have a dSYM, is it getting read in?

The command to query the binaries in your program is:

```
(lldb) image list [<ModuleName>]
```

What Binaries Were Loaded?

Sometimes you need to see exactly what binaries you are running

- I have built Release and Debug; which am I using now?
- I have a dSYM, is it getting read in?

The command to query the binaries in your program is:

- With no arguments, lists all binaries

```
(lldb) image list [<ModuleName>]
```

```
(lldb)
```

```
(lldb) image list Example
[  0] C9F4C7B9-7A81-3428-A1D3-A454B3A3C472 0x0000000100000000 /private/tmp/Example/build/Debug/
Example.app/Contents/MacOS/Example
      /private/tmp/Example/build/Debug/Example.app.dSYM/Contents/Resources/DWARF/Example
```

```
(lldb) image list Example
[  0] C9F4C7B9-7A81-3428-A1D3-A454B3A3C472 0x0000000100000000 /private/tmp/Example/build/Debug/
Example.app/Contents/MacOS/Example
      /private/tmp/Example/build/Debug/Example.app.dSYM/Contents/Resources/DWARF/Example
```

This is the path to the binary

```
(lldb) image list Example
[  0] C9F4C7B9-7A81-3428-A1D3-A454B3A3C472 0x0000000100000000 /private/tmp/Example/build/Debug/
Example.app/Contents/MacOS/Example
      /private/tmp/Example/build/Debug/Example.app.dSYM/Contents/Resources/DWARF/Example
```

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[  0] C9F4C7B9-7A81-3428-A1D3-A454B3A3C472 0x0000000100000000 /private/tmp/Example/build/Debug/
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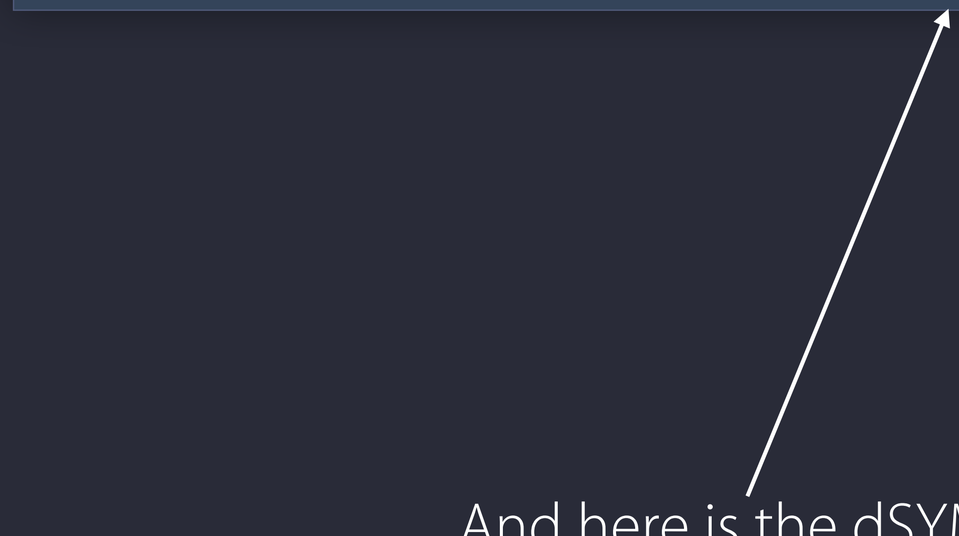
      /private/tmp/Example/build/Debug/Example.app.dSYM/Contents/Resources/DWARF/Example
```

```
(lldb) image list Example
[  0] C9F4C7B9-7A81-3428-A1D3-A454B3A3C472 0x0000000100000000 /private/tmp/Example/build/Debug/
Example.app/Contents/MacOS/Example
      /private/tmp/Example/build/Debug/Example.app.dSYM/Contents/Resources/DWARF/Example
```



And here is the dSYM

Swift Debug Information

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In Swift, the debugger reads type information directly from the Swift module

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TL;DR?

Swift Debug Information

In Swift, the debugger reads type information directly from the Swift module

- Ensures greater fidelity – good!
- Ties the debugger to the compiler that built the module

The binding between Objective-C modules and Swift is required by the debugger

- LLDB has to reconstruct the Objective-C modules as originally built

TL;DR?

- All Swift code with debug info needs to have been built locally

Optimized Code Debugging

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Enrico's Rule of Optimized Code Debugging:

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- Don't do it if you don't have to

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Optimized Code Debugging

Enrico's Rule of Optimized Code Debugging:

- Don't do it if you don't have to

Corollary to Enrico's Rule of Optimized Code Debugging:

- Most people who do it do it by accident

Optimized Code Debugging

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```
Func was compiled with optimization - stepping may behave oddly; variables may not be available.
```

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- Compiler flag `-gmodules`
- Can speed up compile times

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- Deleted the module cache? Rebuild before debugging

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More than source-level debugging

- Rich tools for exploring running code

More Information

https://developer.apple.com/wwdc16/417

Related Sessions

Visual Debugging with Xcode	Presidio	Wednesday 4:00PM
Thread Sanitizer and Static Analysis	Mission	Thursday 10:00AM
Debugging with LLDB	WWDC 2012	
Advanced Debugging with LLDB	WWDC 2013	

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