Squeezing a Go function

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What is optimizing?


Optimize at the right level


Optimize what you need when you need it
PINE
hama

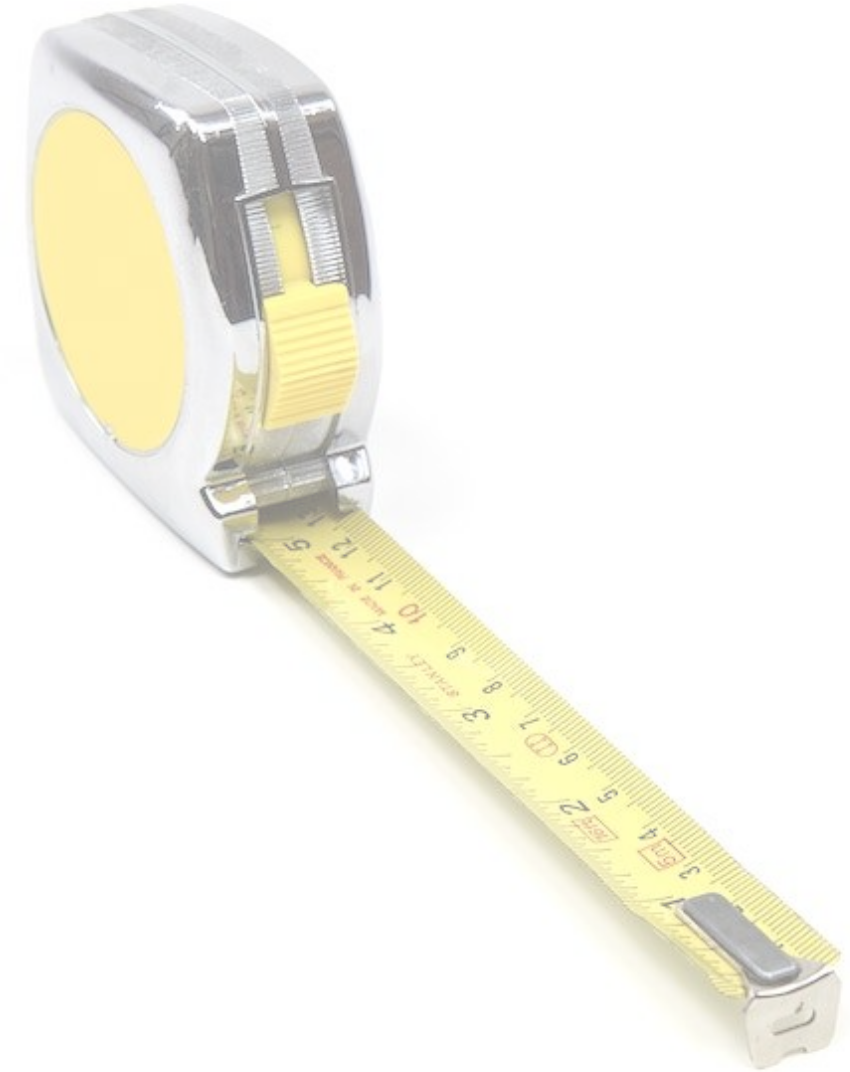
Do not guess

Measure everything

Benchmarks

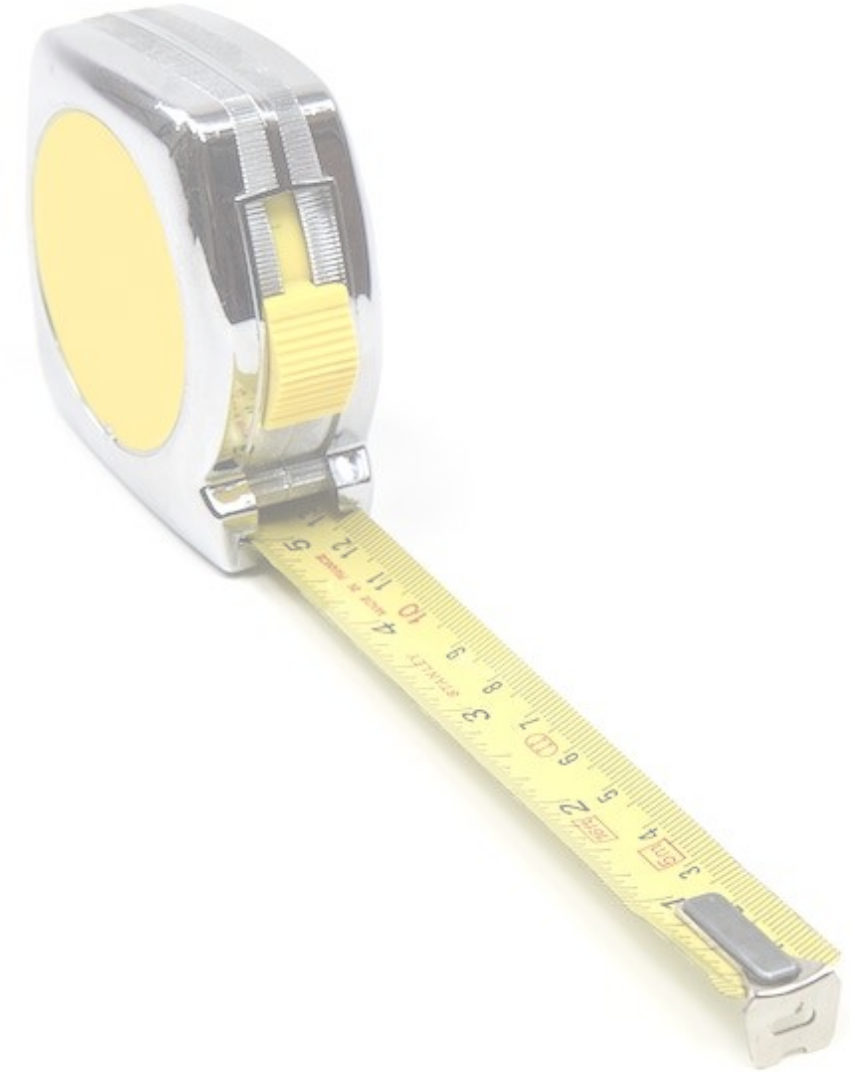
Benchmarks

```go
package main

import (
    "crypto/md5"
    "crypto/sha256"
    "testing"
)

const text = "text to get the hash"

func BenchmarkMD5Hash(b *testing.B) {
    for i := 0; i < b.N; i++ {
        _ = md5.Sum([]byte(text))
    }
}

func BenchmarkSHA256Hash(b *testing.B) {
    for i := 0; i < b.N; i++ {
        _ = sha256.Sum256([]byte(text))
    }
}
```



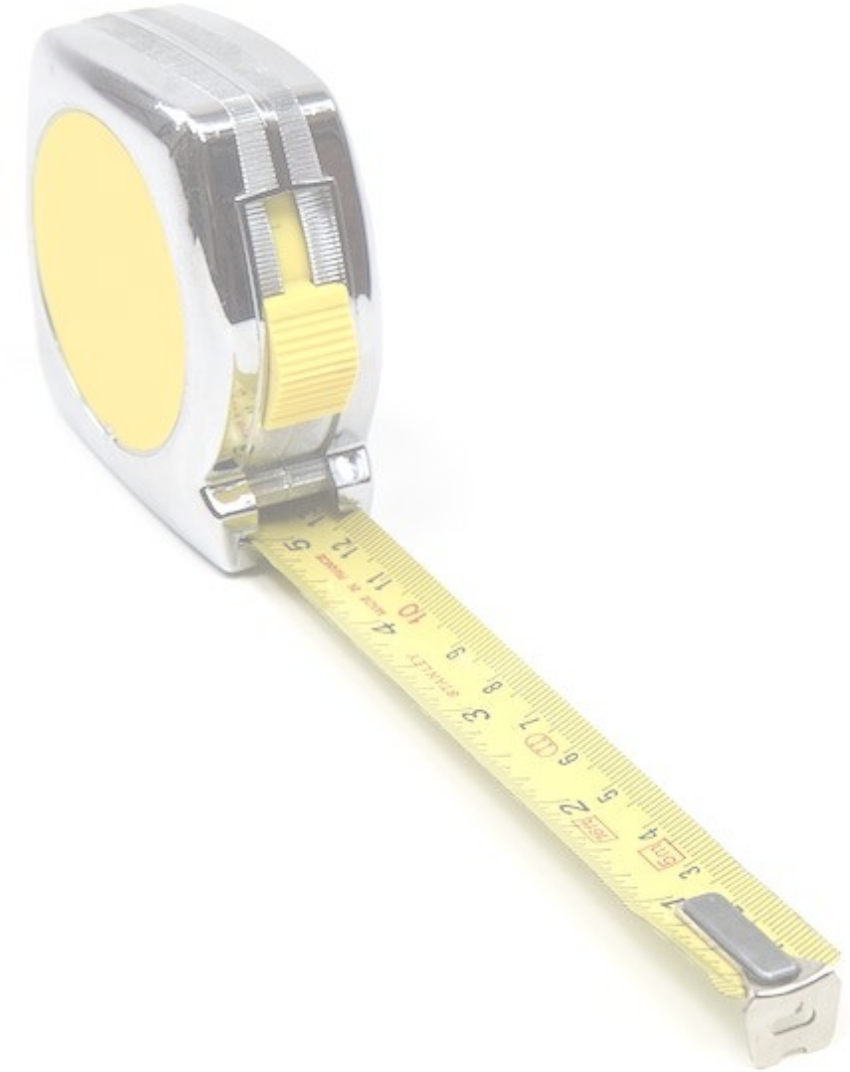
Benchmarks

```
$ go test -bench .
goos: linux
goarch: amd64
pkg: example
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkMD5Hash-12          10615232          111.5 ns/op
BenchmarkSHA256Hash-12        5326459          216.0 ns/op
PASS
ok    example    2.679s
```



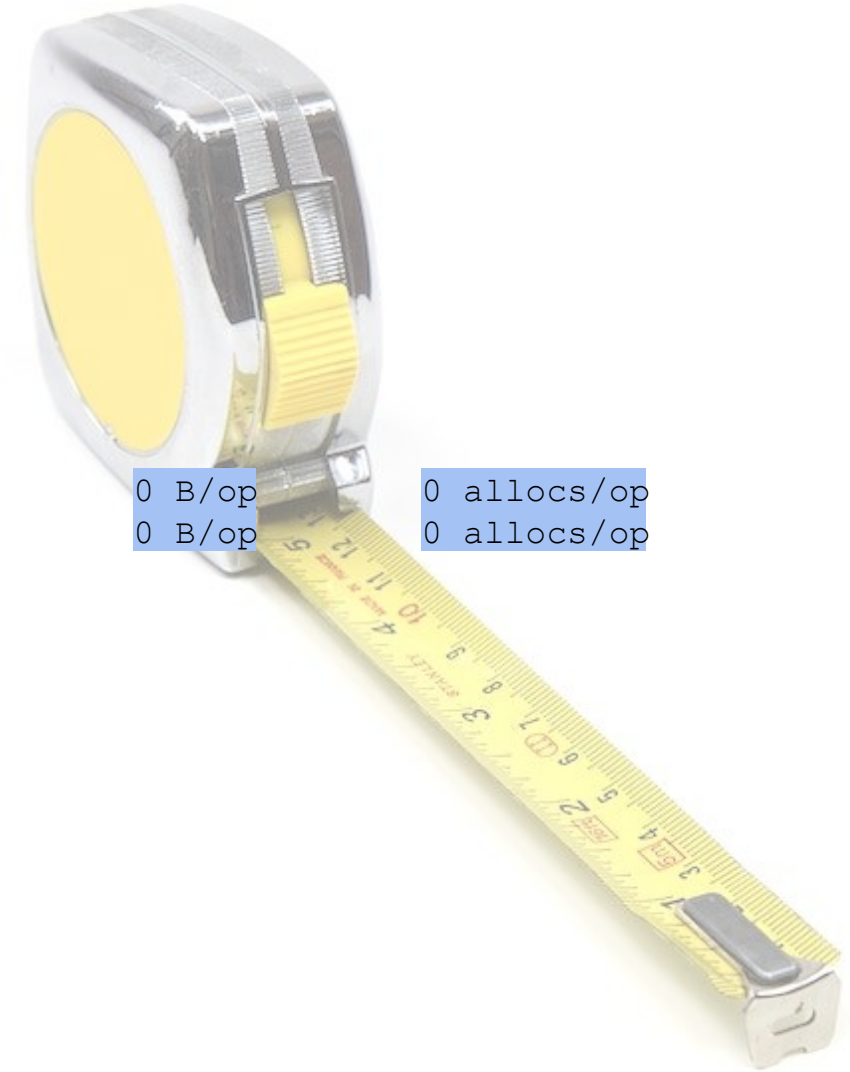
Benchmarks

```
func BenchmarkMD5Hash(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        _ = md5.Sum([]byte(text))
    }
}

func BenchmarkSHA256Hash(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        _ = sha256.Sum256([]byte(text))
    }
}
```



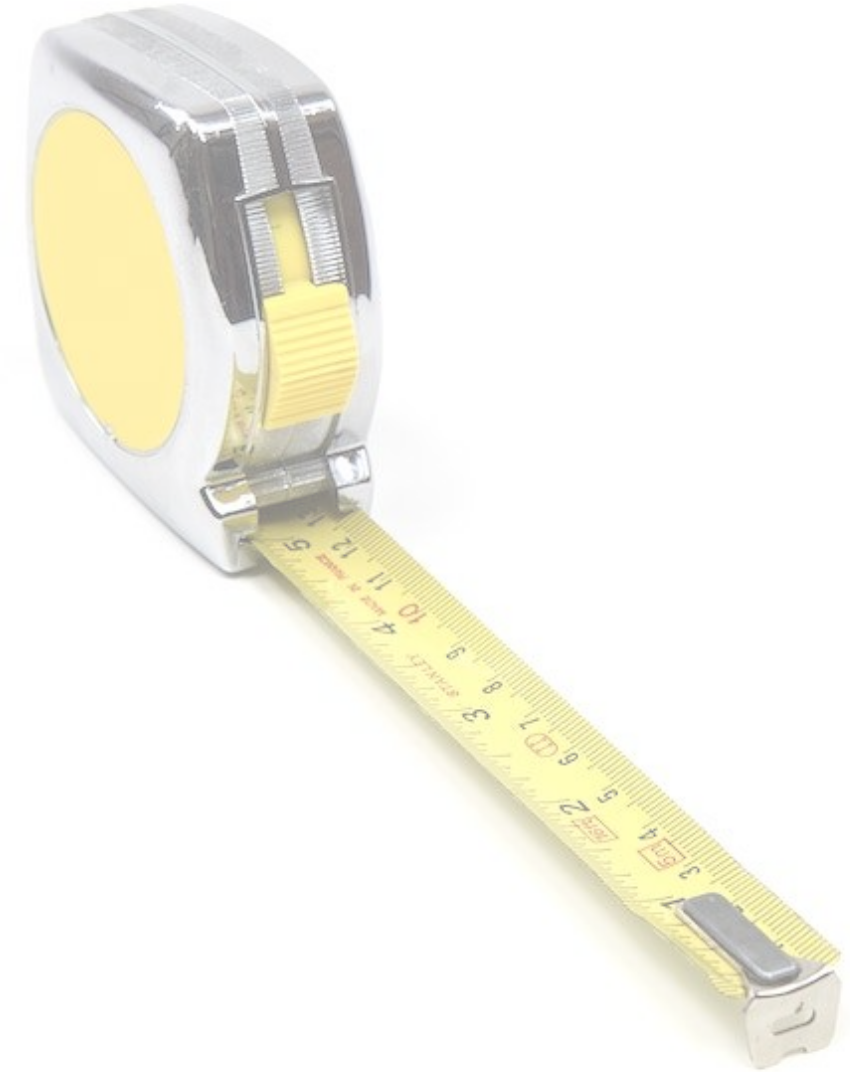
Benchmarks

```
$ go test -bench .
goos: linux
goarch: amd64
pkg: example
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkMD5Hash-12          10687831          111.5 ns/op        0 B/op        0 allocs/op
BenchmarkSHA256Hash-12        5717868          210.4 ns/op        0 B/op        0 allocs/op
PASS
ok    example    2.725s
```



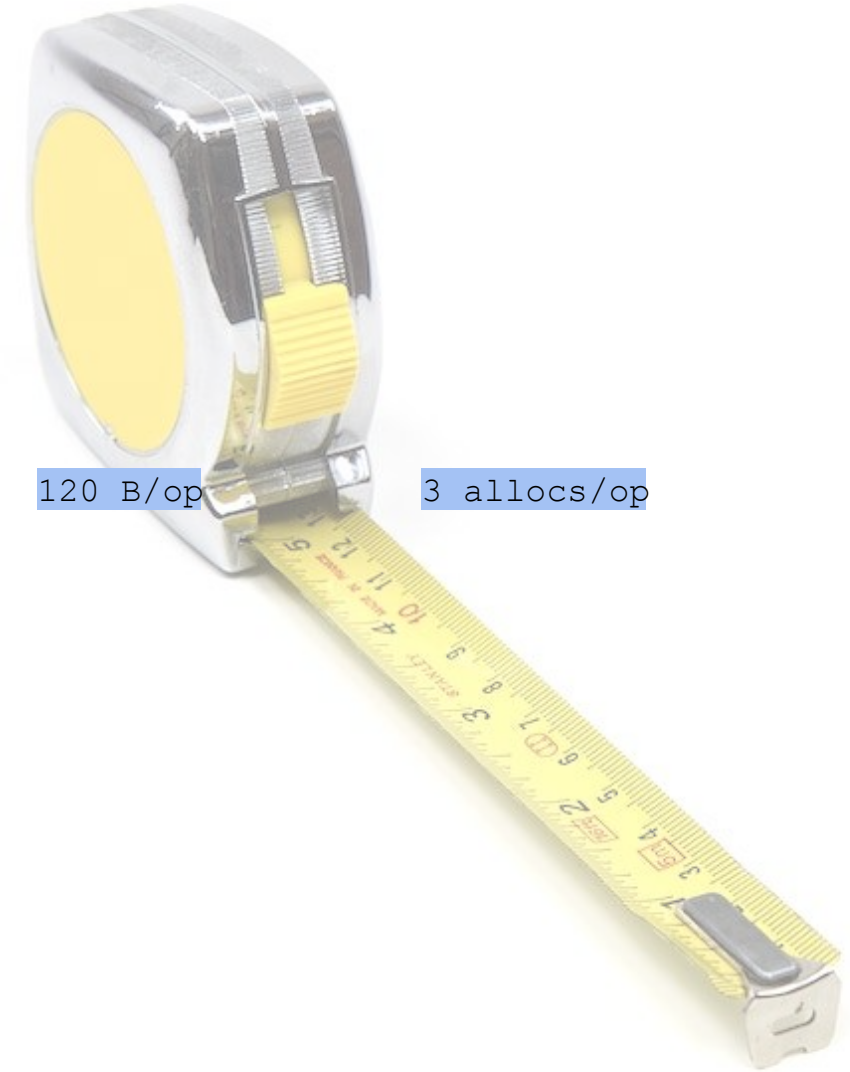
Benchmarks

```
func BenchmarkOsOpen(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        _, _ = os.Open("/proc/cpuinfo")
    }
}
```



Benchmarks

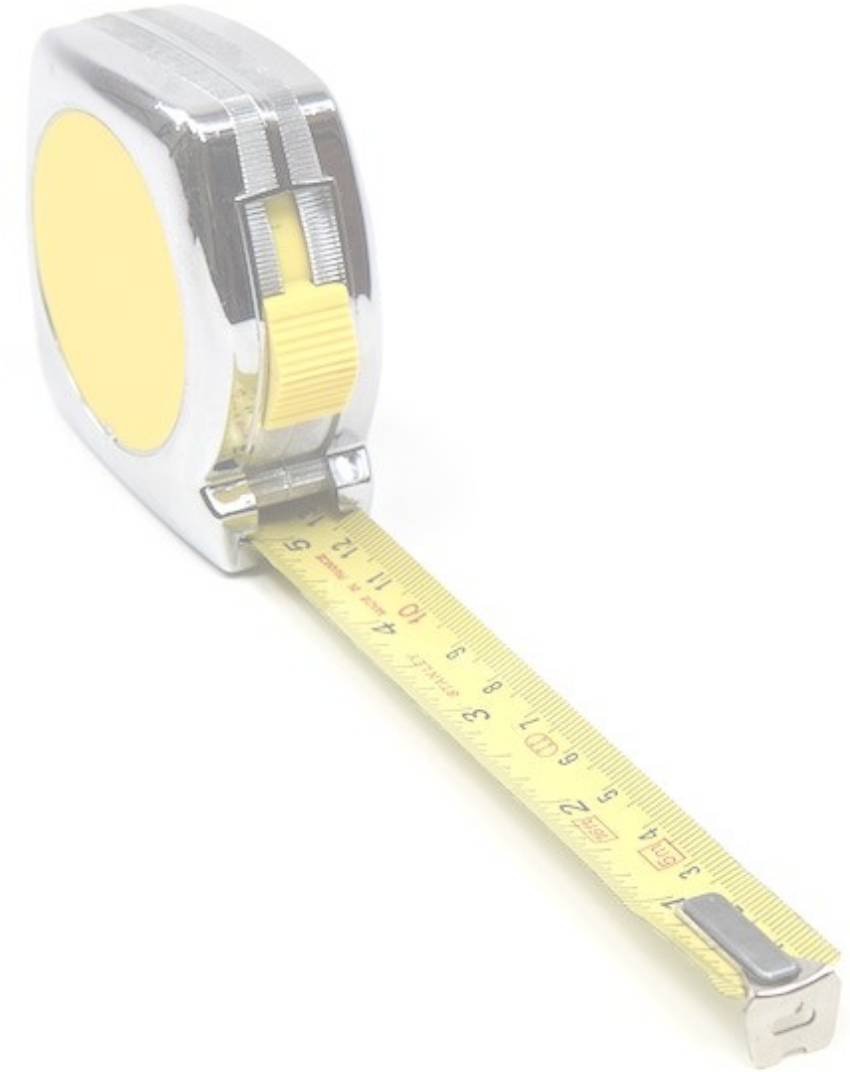
```
$ go test -bench .
goos: linux
goarch: amd64
pkg: example
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkOsOpen-12        387180          3205 ns/op         120 B/op          3 allocs/op
PASS
ok    example    2.479s
```



Profiling

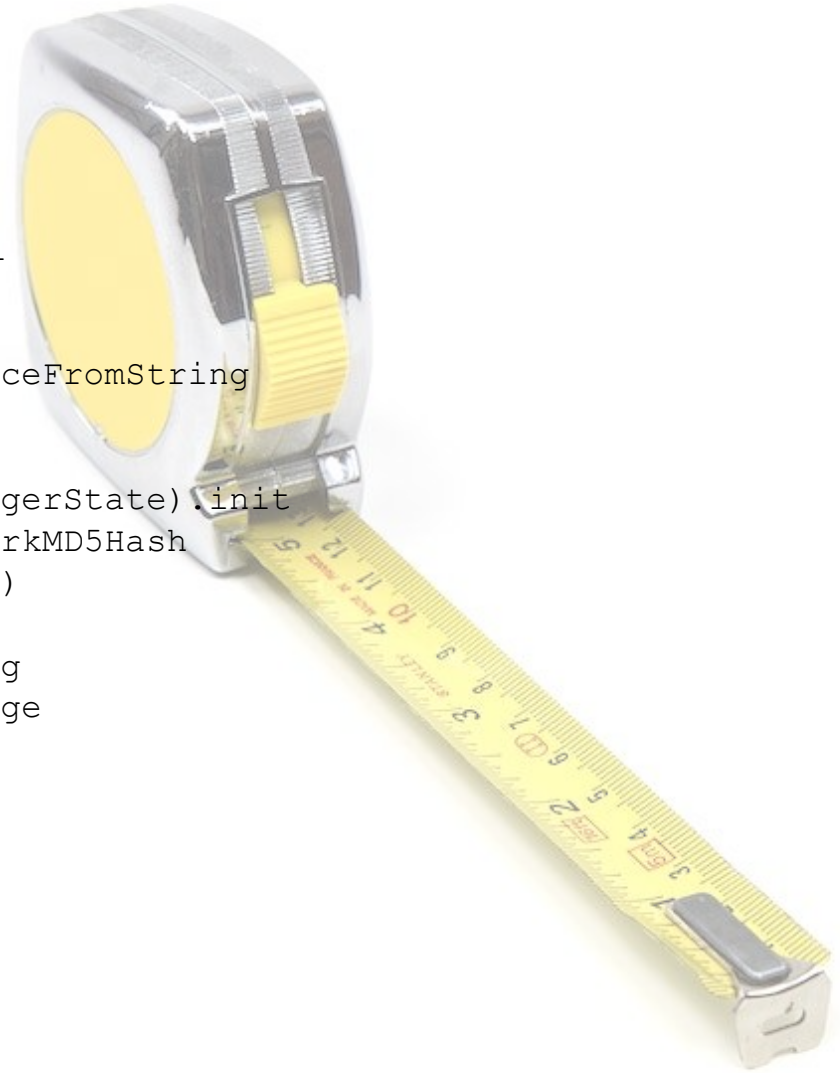
Profiling

```
func BenchmarkOsOpen(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        _, _ = os.Open("/proc/cpuinfo")
    }
}
```



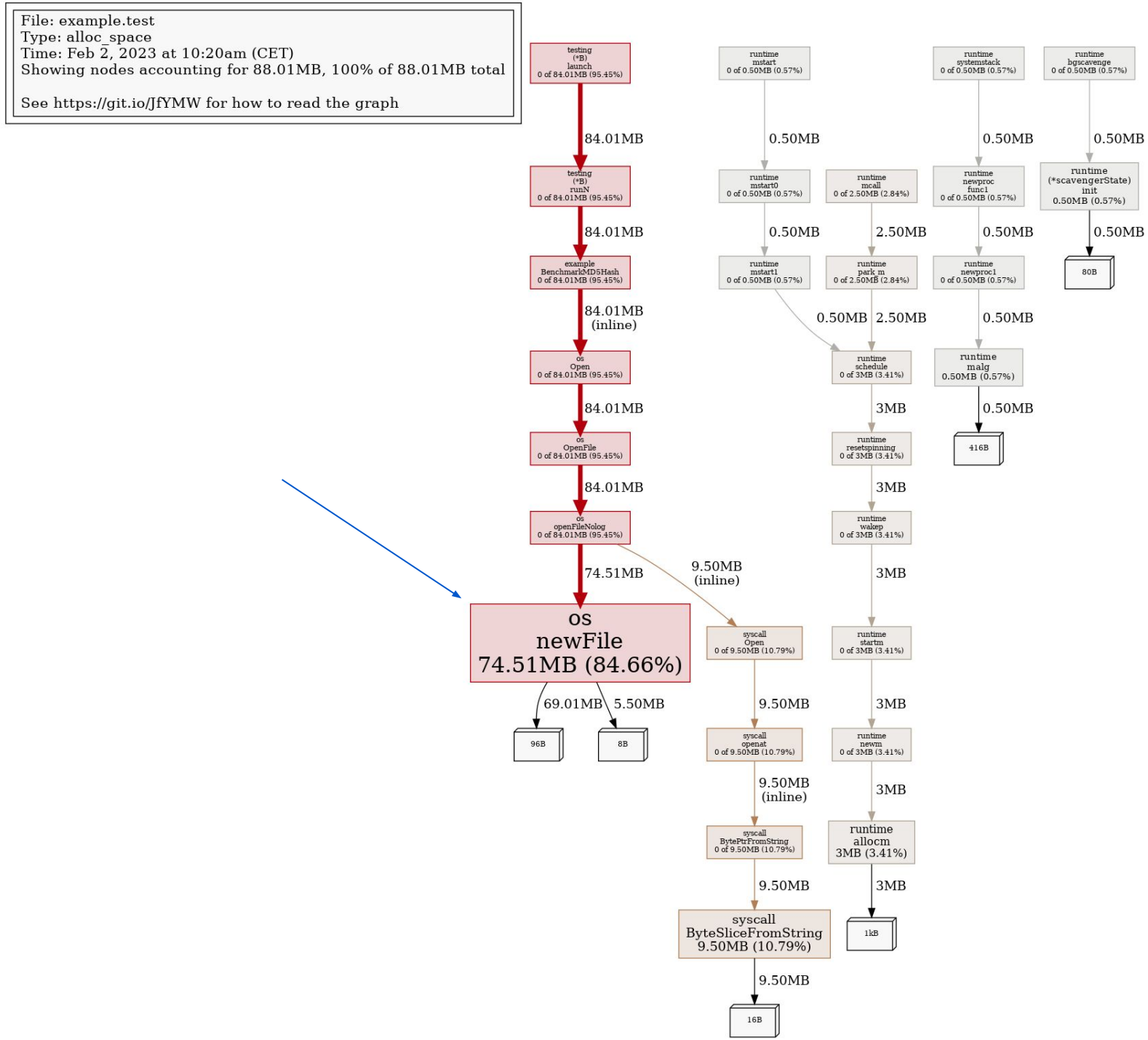
Profiling

```
$ go test -bench . -memprofile memprofile.out
$ go tool pprof -text memprofile.out
File: example.test
Type: alloc_space
Time: Feb 2, 2023 at 10:20am (CET)
Showing nodes accounting for 88.01MB, 100% of 88.01MB total
      flat  flat%   sum%        cum   cum%
   74.51MB  84.66% 84.66%  74.51MB 84.66%  os.newFile
    9.50MB  10.79% 95.45%  9.50MB  10.79%  syscall.ByteSliceFromString
       3MB  3.41%  98.86%  3MB     3.41%  runtime.allocm
    0.50MB  0.57% 99.43%   0.50MB  0.57%  runtime.malg
    0.50MB  0.57% 100%     0.50MB  0.57%  runtime.(*scavengerState).init
         0    0%   100%     84.01MB 95.45%  example.BenchmarkMD5Hash
         0    0%   100%     84.01MB 95.45%  os.Open (inline)
         0    0%   100%     84.01MB 95.45%  os.OpenFile
         0    0%   100%     84.01MB 95.45%  os.openFileNolog
         0    0%   100%     0.50MB  0.57%  runtime.bgscavenge
         0    0%   100%     2.50MB  2.84%  runtime.mcall
         0    0%   100%     0.50MB  0.57%  runtime.mstart
         0    0%   100%     0.50MB  0.57%  runtime.mstart0
         0    0%   100%     0.50MB  0.57%  runtime.mstart1
…
```



Profiling

```
$ go tool pprof -svg memprofile.out
Generating report in profile001.svg
```


File: example.test
Type: alloc_space
Time: Feb 2, 2023 at 10:20am (CET)
Showing nodes accounting for 88.01MB, 100% of 88.01MB total
See https://git.io/JfYMW for how to read the graph
testing (*B) launch 0 of 84.01MB (95.45%)
84.01MB
testing (*B) runN 0 of 84.01MB (95.45%)
84.01MB
example BenchmarkMD5Hash 0 of 84.01MB (95.45%)
84.01MB (inline)
os Open 0 of 84.01MB (95.45%)
84.01MB
os OpenFile 0 of 84.01MB (95.45%)
84.01MB
os openFileNolog 0 of 84.01MB (95.45%)
74.51MB
9.50MB (inline)
os newFile 74.51MB (84.66%)
69.01MB
5.50MB
96B
8B
syscall Open 0 of 9.50MB (10.79%)
9.50MB
syscall openat 0 of 9.50MB (10.79%)
9.50MB (inline)
syscall BytePtrFromString 0 of 9.50MB (10.79%)
9.50MB
syscall ByteSliceFromString 9.50MB (10.79%)
9.50MB
16B
runtime mstart 0 of 0.50MB (0.57%)
0.50MB
runtime mstart0 0 of 0.50MB (0.57%)
0.50MB
runtime mstart1 0 of 0.50MB (0.57%)
runtime mcall 0 of 2.50MB (2.84%)
2.50MB
runtime park_m 0 of 2.50MB (2.84%)
0.50MB
2.50MB
runtime schedule 0 of 3MB (3.41%)
3MB
runtime resetspinning 0 of 3MB (3.41%)
3MB
runtime wakep 0 of 3MB (3.41%)
3MB
runtime startm 0 of 3MB (3.41%)
3MB
runtime newm 0 of 3MB (3.41%)
3MB
runtime allocm 3MB (3.41%)
3MB
1kB
runtime systemstack 0 of 0.50MB (0.57%)
0.50MB
runtime newproc func1 0 of 0.50MB (0.57%)
0.50MB
runtime newproc1 0 of 0.50MB (0.57%)
0.50MB
runtime malg 0.50MB (0.57%)
0.50MB
416B
runtime bgscavenge 0 of 0.50MB (0.57%)
0.50MB
runtime (*scavengerState) init 0.50MB (0.57%)
0.50MB
80B

Profiling

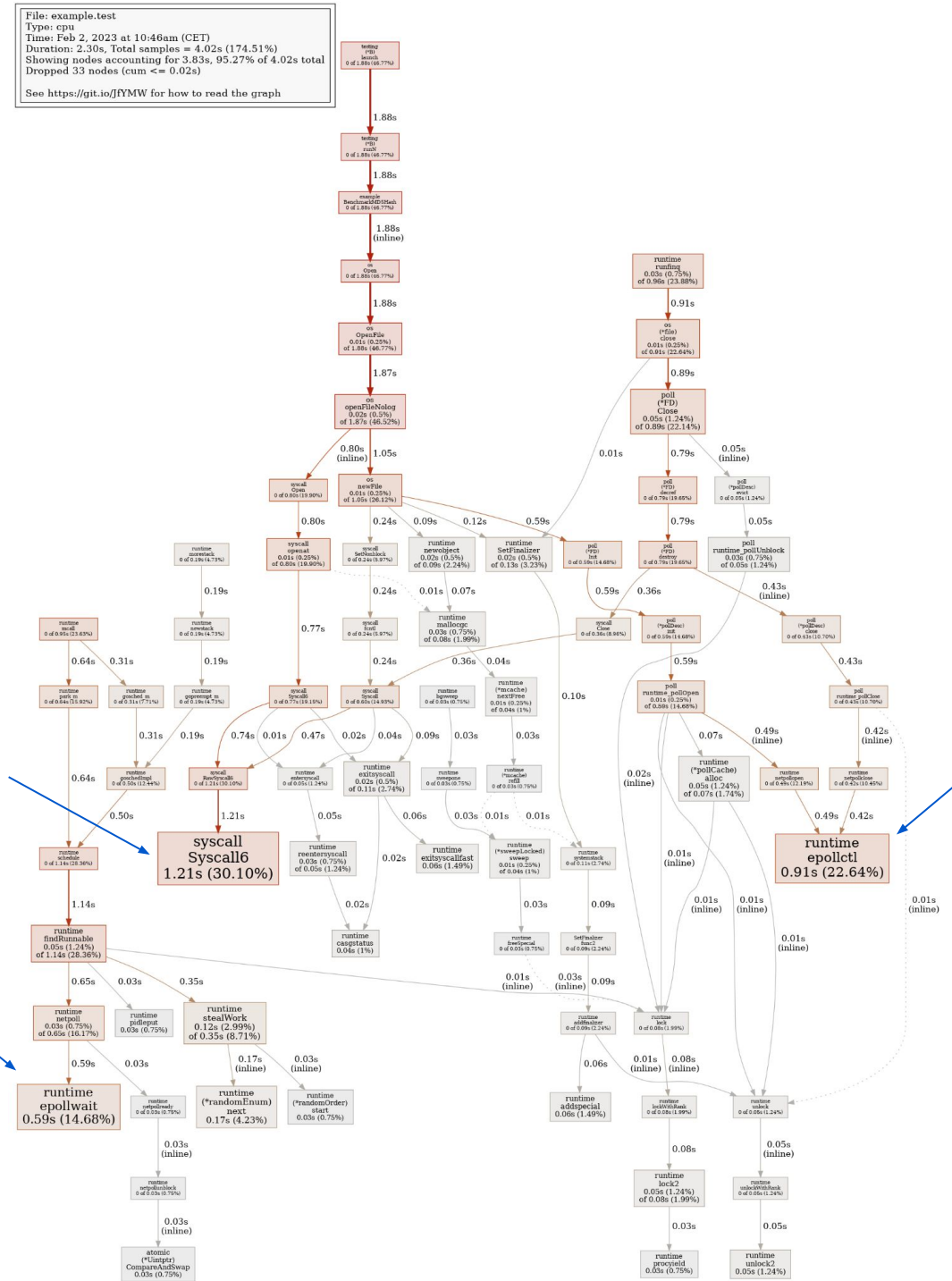
```
$ go tool pprof -list os.newFile memprofile.out
Total: 88.01MB
ROUTINE ======================== os.newFile in /usr/lib/go-1.19/src/os/file_unix.go
   74.51MB    74.51MB (flat, cum) 84.66% of Total
         .          .    122:func newFile(fd uintptr, name string, kind newFileKind) *File {
         .          .    123:    fdi := int(fd)
         .          .    124:    if fdi < 0 {
         .          .    125:      return nil
         .          .    126:    }
   74.51MB    74.51MB    127:    f := &File{&file{
         .          .    128:      pfd: poll.FD{
         .          .    129:           Sysfd:       fdi,
         .          .    130:           IsStream:    true,
         .          .    131:           ZeroReadIsEOF: true,
         .          .    132:      },
```

Profiling

```
$ go test -bench . -cpuprofile cpuprofile.out
$ go tool pprof -text cpuprofile.out
File: example.test
Type: cpu
Time: Feb 2, 2023 at 10:46am (CET)
Duration: 2.30s, Total samples = 4.02s (174.51%)
Showing nodes accounting for 3.83s, 95.27% of 4.02s total
Dropped 33 nodes (cum <= 0.02s)
      flat  flat%   sum%      cum   cum%
     1.21s 30.10% 30.10%    1.21s 30.10%  runtime/internal/syscall.Syscall6
     0.91s 22.64% 52.74%    0.91s 22.64%  runtime.epollctl
     0.59s 14.68% 67.41%    0.59s 14.68%  runtime.epollwait
     0.17s  4.23% 71.64%    0.17s  4.23%  runtime.(*randomEnum).next (inline)
     0.12s  2.99% 74.63%    0.35s  8.71%  runtime.stealWork
     0.06s  1.49% 76.12%    0.06s  1.49%  runtime.addspecial
     0.06s  1.49% 77.61%    0.06s  1.49%  runtime.exitsyscallfast
     0.05s  1.24% 78.86%    0.89s 22.14%  internal/poll.(*FD).Close
     0.05s  1.24% 80.10%    0.07s  1.74%  runtime.(*pollCache).alloc
     0.05s  1.24% 81.34%    1.14s 28.36%  runtime.findRunnable
     0.05s  1.24% 82.59%    0.08s  1.99%  runtime.lock2
     0.05s  1.24% 83.83%    0.05s  1.24%  runtime.unlock2
     0.04s     1% 84.83%    0.04s     1%  runtime.casgstatus
     0.03s  0.75% 85.57%    0.05s  1.24%  internal/poll.runtime_pollUnblock
…
```

Profiling

```
$ go tool pprof -svg cpuprofile.out
Generating report in profile002.svg
```


File: example.test
Type: cpu
Time: Feb 2, 2023 at 10:46am (CET)
Duration: 2.30s, Total samples = 4.02s (174.51%)
Showing nodes accounting for 3.83s, 95.27% of 4.02s total
Dropped 33 nodes (cum <= 0.02s)
See https://git.io/JfYMW for how to read the graph
syscall Syscall6 1.21s (30.10%)
runtime epollctl 0.91s (22.64%)
runtime epollwait 0.59s (14.68%)

Profiling

```
$ go tool pprof -list syscall.Syscall6 cpuprofile.out
Total: 4.02s
ROUTINE ======================== runtime/internal/syscall.Syscall6 in /usr/lib/go-1.19/src/runtime/internal/syscall/asm_linux_amd64.s
      1.21s       1.21s (flat, cum) 30.10% of Total
         .           .     31:    MOVQ    DI, DX  // a3
         .           .     32:    MOVQ    CX, SI  // a2
         .           .     33:    MOVQ    BX, DI  // a1
         .           .     34:    // num already in AX.
         .           .     35:    SYSCALL
      1.20s       1.20s 36:    CMPQ    AX, $0xfffffffffffff001
         .           .     37:    JLS    ok
         .           .     38:    NEGQ    AX
         .           .     39:    MOVQ    AX, CX  // errno
         .           .     40:    MOVQ    $-1, AX // r1
         .           .     41:    MOVQ    $0, BX  // r2
         .           .     42:    RET
         .           .     43:ok:
         .           .     44:    // r1 already in AX.
        10ms        10ms  45:    MOVQ    DX, BX // r2
         .           .     46:    MOVQ    $0, CX // errno
         .           .     47:    RET
ROUTINE ======================== syscall.Syscall6 in /usr/lib/go-1.19/src/syscall/syscall_linux.go
         0      770ms (flat, cum) 19.15% of Total
         .           .     85:
         .           .     86://go:uintptrkeepalive
         .           .     87://go:nosplit
         .           .     88://go:linkname Syscall6
         .           .     89:func Syscall6(trap, a1, a2, a3, a4, a5, a6 uintptr) (r1, r2 uintptr, err Errno) {
         .        10ms  90:    runtime_entersyscall()
         .       740ms 91:    r1, r2, err = RawSyscall6(trap, a1, a2, a3, a4, a5, a6)
         .        20ms  92:    runtime_exitsyscall()
         .           .     93:    return
         .           .     94:}
         .           .     95:
         .           .     96:func rawSyscallNoError(trap, a1, a2, a3 uintptr) (r1, r2 uintptr)
         .           .     97:
```

Reducing cpu usage

Reduce CPU usage

```
func find(needle string, haystack []string) int {
    result := -1
    for idx, i := range haystack {
        if i == needle {
            result = idx
        }
    }
    return result
}
```

Reduce CPU usage

```
var haystack = []string{
    "test0", "test1", "test2", "test3", "test4", "test5", "test6", "test8", "test9",
    "test10", "test11", "test12", "test13", "test14", "test15", "test16", "test18", "test19",
    "test20", "test21", "test22", "test23", "test24", "test25", "test26", "test28", "test29",
    "test30", "test31", "test32", "test33", "test34", "test35", "test36", "test38", "test39",
    "test40", "test41", "test42", "test43", "test44", "test45", "test46", "test48", "test49",
    "test50", "test51", "test52", "test53", "test54", "test55", "test56", "test58", "test59",
    "test60", "test61", "test62", "test63", "test64", "test65", "test66", "test68", "test69",
    "test70", "test71", "test72", "test73", "test74", "test75", "test76", "test78", "test79",
}

func BenchmarkFind(b *testing.B) {
    for i := 0; i < b.N; i++ {
        find("test50", haystack)
    }
}
```

Reduce CPU usage

```
goos: linux
goarch: amd64
pkg: example
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkFind-12          4147192          289.7 ns/op
PASS
ok   example  1.497s
```

Reduce CPU usage

```
func find(needle string, haystack []string) int {
    for idx, i := range haystack {
        if i == needle {
            return idx
        }
    }
    return -1
}
```

Reduce CPU usage

```
goos: linux
goarch: amd64
pkg: example
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkFind-12        7065786        172.9 ns/op
PASS
ok   example  1.396s
```

Reducing allocations

Reduce allocations

```
func sliceFunc() {
    slice := []int{}
    for x := 0; x < 1000000; x++ {
        slice = append(slice, x)
    }
}
```

Reduce allocations

```
func BenchmarkSliceFunc(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        sliceFunc()
    }
}
```

Reduce allocations

```
goos: linux
goarch: amd64
pkg: github.com/jespino/squeezing-your-go-function
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkSliceFunc-12              100    10455610 ns/op    41678303 B/op        39 allocs/op
PASS
ok   github.com/jespino/squeezing-your-go-function  1.058s
```

Reduce allocations

```
func sliceFunc() {
    slice := make([]int, 1000000)
    for x := 0; x < 1000000; x++ {
        slice[x] = x
    }
}
```

Reduce allocations

```
goos: linux
goarch: amd64
pkg: github.com/jespino/squeezing-your-go-function
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkSliceFunc-12           1417     824672 ns/op    8003596 B/op        1 allocs/op
PASS
ok   github.com/jespino/squeezing-your-go-function  1.258s
```

Reduce allocations

```
func sliceFunc2() {
    array := [1000000]int{}
    for x := 0; x < 1000000; x++ {
        array[x] = x
    }
}
```

Reduce allocations

```
goos: linux
goarch: amd64
pkg: github.com/jespino/squeezing-your-go-function
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkSliceFunc-12              4094     291574 ns/op            0 B/op          0 allocs/op
PASS
ok   github.com/jespino/squeezing-your-go-function  2.150s
```

Packing

Packing

```go
type X struct {
    a bool
    // the compiler adds 7 bytes here
    b float64
    c int32
    // the compiler adds 4 bytes here
} // Total: 24 bytes

func Packing() {
    slice := make([]X, 1000000)
    for x := 0; x < 1000000; x++ {
        slice[x] = X{}
    }
}
```

Packing

```
goos: linux
goarch: amd64
pkg: packing
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkPacking-12          453    2623811 ns/op   24002567 B/op          1 allocs/op
PASS
ok   packing  1.460s
```

Packing

```
type X struct {
    b float64
    c int32
    a bool
    // the compiler adds 3 bytes here
} // Total: 16 bytes
```

Packing

```
goos: linux
goarch: amd64
pkg: packing
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkWithGoodPacking-12           619    2036888 ns/op   16007170 B/op          1 allocs/op
PASS
ok   packing  1.461s
```

Function Inlining

Function inlining

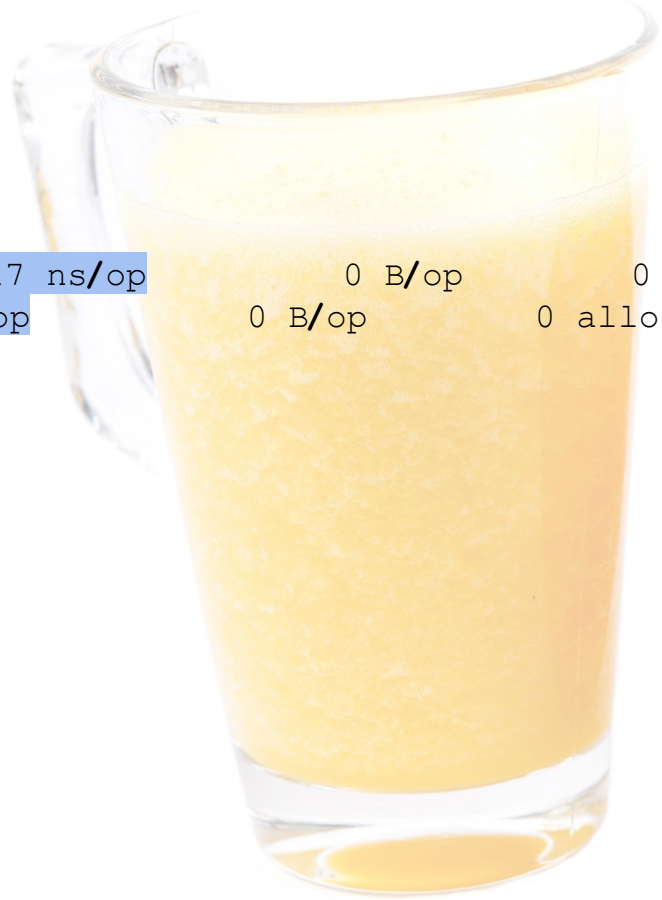
```
//go:noinline
func notInlined() int {
    return 7
}
```

Function inlining

```
func inlined() int {
    return 7
}
```

Function inlining

```
goos: linux
goarch: amd64
pkg: github.com/jespino/squeezing-your-go-function
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkInlinedFunc-12          1000000000          0.2817 ns/op          0 B/op          0 allocs/op
BenchmarkNotInlinedFunc-12       834508006           1.413 ns/op           0 B/op          0 allocs/op
PASS
ok   github.com/jespino/squeezing-your-go-function  1.642s
```



Escape Analysis

Escape analysis

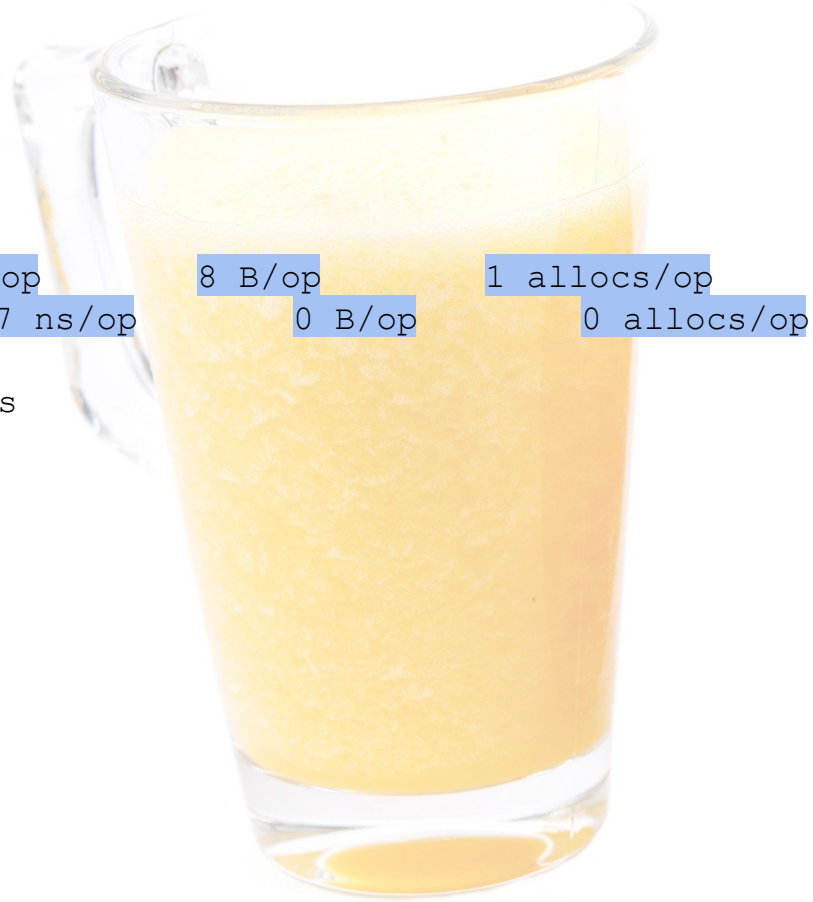
```
//go:noinline
func escaped() *int {
    val := 7
    return &val
}
```

Escape analysis

```
//go:noinline
func notEscaped() int {
    val := 7
    return val
}
```

Escape analysis

```
goos: linux
goarch: amd64
pkg: github.com/jespino/squeezing-your-go-function
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkEscaedFunc-12            74748568          13.38 ns/op        8 B/op        1 allocs/op
BenchmarkNotEscapedFunc-12        850284787             1.407 ns/op        0 B/op        0 allocs/op
PASS
ok    github.com/jespino/squeezing-your-go-function    2.360s
```



Escape Analysis and inlining

Escape analysis and function inlining

```
type Document struct {
    path []string
}

func myFunc() {
    _ = NewDocument("/proc/cpuinfo")
}

func NewDocument(path string) *Document {
    d := &Document{}
    for _, path := range filepath.SplitList(path) {
        d.path = append(d.path, path)
    }
    return d
}
```

Escape analysis and function inlining

```
goos: linux
goarch: amd64
pkg: github.com/jespino/squeezing-your-go-function
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkMyFunc-12       9090330          128.2 ns/op          56 B/op          3 allocs/op
PASS
ok    github.com/jespino/squeezing-your-go-function    2.496s
```

Escape analysis and function inlining

```
func myFunc() {
    d := NewDocument()
    d.Init("/proc/cpuinfo")
}

func NewDocument() *Document {
    return &Document{}
}

func (d *Document) Init(path string) {
    for _, path := range filepath.SplitList(path) {
        d.path = append(d.path, path)
    }
}
```

Escape analysis and function inlining

```
goos: linux
goarch: amd64
pkg: github.com/jespino/squeezing-your-go-function
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkMyFunc-12      15195864          73.23 ns/op        32 B/op        2 allocs/op
PASS
ok    github.com/jespino/squeezing-your-go-function    2.496s
```

Concurrency

Concurrency

```
func fakeIO() {
    counter := 100
    for x := 0; x < counter; x++ {
        time.Sleep(10 * time.Millisecond)
    }
}

func fakeIOParallel(goroutines int) {
    var wg sync.WaitGroup
    wg.Add(goroutines)
    counter := 100
    for x := 0; x < goroutines; x++ {
        go func(idx int) {
            defer wg.Done()
            for y := 0; y < counter; y++ {
                if y%goroutines == idx {
                    time.Sleep(10 * time.Millisecond)
                }
            }
        }(x)
    }
    wg.Wait()
}
```

Concurrency

```
func BenchmarkIOParallelOnePerJob(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        fakeIOParallel(100)
    }
}

func BenchmarkIOParallelOnePerCpu(b *testing.B) {
    b.ReportAllocs()
    cpus := runtime.NumCPU()
    for i := 0; i < b.N; i++ {
        fakeIOParallel(cpus)
    }
}

func BenchmarkIOSerial(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        fakeIO()
    }
}
```

Concurrency

```
goos: linux
goarch: amd64
pkg: concurrency
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkIOParallelOnePerJob-12           100      10599470 ns/op     15488 B/op        305 allocs/op
BenchmarkIOParallelOnePerCpu-12           12       91591538 ns/op     1648 B/op         37 allocs/op
BenchmarkIOSerial-12                      1     1014305834 ns/op      80 B/op       1 allocs/op
PASS
ok    concurrency    3.282s
```

Concurrency

```
func fakeCPU() {
    counter := 1000
    for x := 0; x < counter; x++ {
        _ = md5.Sum([]byte("test"))
    }
}

func fakeCPUParallel(goroutines int) {
    var wg sync.WaitGroup
    wg.Add(goroutines)
    counter := 1000
    for x := 0; x < goroutines; x++ {
        go func(idx int) {
            defer wg.Done()
            for y := 0; y < counter; y++ {
                if y%goroutines == idx {
                    _ = md5.Sum([]byte("test"))
                }
            }
        }(x)
    }
    wg.Wait()
}
```

Concurrency

```
func BenchmarkCPUParallelOnePerJob(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        fakeCPUParallel(1000)
    }
}

func BenchmarkCPUParallelOnePerCpu(b *testing.B) {
    b.ReportAllocs()
    cpus := runtime.NumCPU()
    for i := 0; i < b.N; i++ {
        fakeCPUParallel(cpus)
    }
}

func BenchmarkCPUSerial(b *testing.B) {
    b.ReportAllocs()
    for i := 0; i < b.N; i++ {
        fakeCPU()
    }
}
```

Concurrency

```
goos: linux
goarch: amd64
pkg: concurrency
cpu: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
BenchmarkCPUParallelOnePerJob-12          1042     1296818 ns/op      56066 B/op    2001 allocs/op
BenchmarkCPUParallelOnePerCpu-12         20469          65477 ns/op         688 B/op      25 allocs/op
BenchmarkCPUSerial-12                    10000     114459 ns/op             0 B/op       0 allocs/op
PASS
ok    concurrency    4.563s
```

Summary

References

- Efficient Go (By Bartlomiej Plotka)
- High Performance Go Workshop (By Dave Cheney)
- Go-perfbook (By Damian Gryski)
- Ultimate Go (By Ardan Labs)

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Thank you.

Mattermost