
Lost and Found
Oh memset, where did you go??

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Hello, it's me!

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Why are we here?

Builtins and intrinsics are terribly fascinating and frequently misunderstood

Builtins as a vehicle of attack

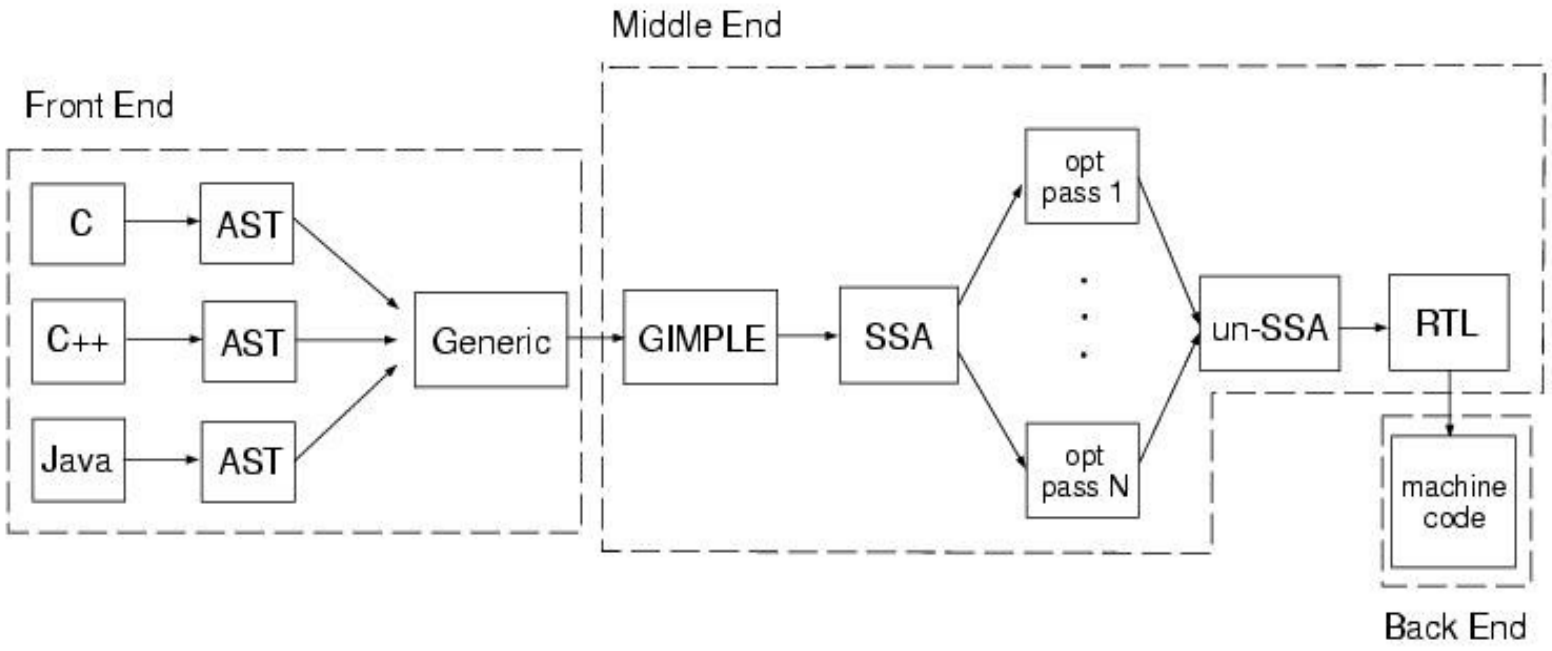
Builtins as a starting point of defense

Builtins & Intrinsics

From the docs:

- GCC provides a large number of **built-in** functions, for internal use, and for **optimization purposes of standard C library** functions
  - __builtin_puts, __builtin_alloca, __builtin_memcpy, etc. etc. etc.
- GCC **intrinsics** are built-in functions that help the developer use domain specific operations, and help the compiler **leverage machine specific functionality**
  - Vector operations, signal processing, interrupt handling, etc. etc. etc.
- Compiler can replace builtins with **custom implementation** if provided

GCC and GCC Builtins



Compiler provides its own implementation of a library function

Tailored to use case and target platform

Mostly used throughout compilation process, not by developers

Optimizing on a case by case basis, eg.:

- printf replacement
- memcpy inlining
- strlen removal
- sizeof removal

How does that look like inside?

builtins.def

builtins.h

builtins.c

xxx-builtin.def

xxxintrin.h

.. and many many more..

```
static rtx
expand_builtin_mempcpy (tree exp, rtx target)
{
  if (!validate_arglist (exp,
                         POINTER_TYPE, POINTER_TYPE, INTEGER_TYPE, VOID_TYPE))
    return NULL_RTX;

  tree dest = CALL_EXPR_ARG (exp, 0);
  tree src = CALL_EXPR_ARG (exp, 1);
  tree len = CALL_EXPR_ARG (exp, 2);

  /* Avoid expanding mempcpy into memcpy when the call is determined
     to overflow the buffer.  This also prevents the same overflow
     from being diagnosed again when expanding memcpy.  */
  if (!check_memop_sizes (exp, dest, src, len))
    return NULL_RTX;

  return expand_builtin_mempcpy_args (dest, src, len,
                                      target, exp, /*endp=*/ 1);
}
```

```
692  DEF_C99_COMPL_BUILTIN        (BUILT_IN_CTANHF, "ctanhf", BT_FN_COMPLEX_FLOAT_COMPLEX_FLOAT, ATTR_MATHFN_FPROUNDING)
693  DEF_C99_COMPL_BUILTIN        (BUILT_IN_CTANHL, "ctanhl", BT_FN_COMPLEX_LONGDOUBLE_COMPLEX_LONGDOUBLE, ATTR_MATHFN_FPROUNDING)
694  DEF_C99_COMPL_BUILTIN        (BUILT_IN_CTANL, "ctanl", BT_FN_COMPLEX_LONGDOUBLE_COMPLEX_LONGDOUBLE, ATTR_MATHFN_FPROUNDING)
695
696  /* Category: string/memory builtins.  */
697  DEF_EXT_LIB_BUILTIN    (BUILT_IN_BCMP, "bcmp", BT_FN_INT_CONST_PTR_CONST_PTR_SIZE, ATTR_PURE_NOTHROW_NONNULL_LEAF)
698  DEF_EXT_LIB_BUILTIN    (BUILT_IN_BCOPY, "bcopy", BT_FN_VOID_CONST_PTR_PTR_SIZE, ATTR_NOTHROW_NONNULL_LEAF)
699  DEF_EXT_LIB_BUILTIN    (BUILT_IN_BZERO, "bzero", BT_FN_VOID_PTR_SIZE, ATTR_NOTHROW_NONNULL_LEAF)
700  DEF_EXT_LIB_BUILTIN    (BUILT_IN_INDEX, "index", BT_FN_STRING_CONST_STRING_INT, ATTR_PURE_NOTHROW_NONNULL_LEAF)
701  DEF_LIB_BUILTIN        (BUILT_IN_MEMCHR, "memchr", BT_FN_PTR_CONST_PTR_INT_SIZE, ATTR_PURE_NOTHROW_NONNULL_LEAF)
702  DEF_LIB_BUILTIN        (BUILT_IN_MEMCMP, "memcmp", BT_FN_INT_CONST_PTR_CONST_PTR_SIZE, ATTR_PURE_NOTHROW_NONNULL_LEAF)
703  DEF_LIB_BUILTIN        (BUILT_IN_MEMCPY, "memcpy", BT_FN_PTR_PTR_CONST_PTR_SIZE, ATTR_RET1_NOTHROW_NONNULL_LEAF)
704  DEF_LIB_BUILTIN        (BUILT_IN_MEMMOVE, "memmove", BT_FN_PTR_PTR_CONST_PTR_SIZE, ATTR_RET1_NOTHROW_NONNULL_LEAF)
705  DEF_EXT_LIB_BUILTIN    (BUILT_IN_MEMPCPY, "mempcpy", BT_FN_PTR_PTR_CONST_PTR_SIZE, ATTR_RETNONNULL_NOTHROW_LEAF)
706  DEF_LIB_BUILTIN        (BUILT_IN_MEMSET, "memset", BT_FN_PTR_PTR_INT_SIZE, ATTR_RET1_NOTHROW_NONNULL_LEAF)
707  DEF_EXT_LIB_BUILTIN    (BUILT_IN_RINDEX, "rindex", BT_FN_STRING_CONST_STRING_INT, ATTR_PURE_NOTHROW_NONNULL_LEAF)
708  DEF_EXT_LIB_BUILTIN    (BUILT_IN_STPCPY, "stpcpy", BT_FN_STRING_STRING_CONST_STRING, ATTR_RETNONNULL_NOTHROW_LEAF)
709  DEF_EXT_LIB_BUILTIN    (BUILT_IN_STPNCPY, "stpncpy", BT_FN_STRING_STRING_CONST_STRING_SIZE, ATTR_RETNONNULL_NOTHROW_LEAF)
710  DEF_EXT_LIB_BUILTIN    (BUILT_IN_STRCASECMP, "strcasecmp", BT_FN_INT_CONST_STRING_CONST_STRING, ATTR_PURE_NOTHROW_NONNULL_LEAF)
711  DEF_LIB_BUILTIN        (BUILT_IN_STRCAT, "strcat", BT_FN_STRING_STRING_CONST_STRING, ATTR_RET1_NOTHROW_NONNULL_LEAF)
712  DEF_LIB_BUILTIN        (BUILT_IN_STRCHR, "strchr", BT_FN_STRING_CONST_STRING_INT, ATTR_PURE_NOTHROW_NONNULL_LEAF)
713  DEF_LIB_BUILTIN        (BUILT_IN_STRCMP, "strcmp", BT_FN_INT_CONST_STRING_CONST_STRING, ATTR_PURE_NOTHROW_NONNULL_LEAF)
```

A vast choice of functions the compiler "understands"

Builtin-spotting Opportunities

- PaX' STACKLEAK (https://pax.grsecurity.net/docs/PaXTeam-H2HC13-PaX-gcc-plugins.pdf, https://code.woboq.org/linux/linux/scripts/gcc-plugins/stackleak_plugin.c.html, https://a13xp0p0v.github.io/2018/11/04/stackleak.html)
- Kostya Serebryany's AddressSanitizer (https://github.com/google/sanitizers/wiki/AddressSanitizer, https://code.woboq.org/gcc/gcc/asan.c.html)

What can an attacker do alongside the compiler's own mechanisms?

Why are we curious about tracking builtins?

All the Passes

```
*warn_unused_result
*diagnose_omp_blocks
*diagnose_tm_blocks
tree-omplower
tree-lower
tree-tmlower
tree-ehopt
tree-eh
tree-cfg
*warn_function_return
tree-ompexp
tree-printf-return-value1
tree-wallocal
*build_cgraph_edges
*free_lang_data
ipa-visibility
ipa-chkp_versioning
ipa-chkp_ecleanup
ipa-build_ssa_passes
   tree-fixup_cfg1
   tree-ssa
   *nonnullcmp
   tree-ubsan
   *early_warn_uninitialized
   tree-nothrow
   *rebuild_cgraph_edges
ipa-chkp_passes
   tree-fixup_cfg2
   tree-chkp
   *rebuild_cgraph_edges
ipa-opt_local_passes
   tree-fixup_cfg3
   *rebuild_cgraph_edges
   tree-local-fnsummary1
   tree-einline
   tree-early_optimizations
      *remove_cgraph_callee_edges
      tree-objsz1
      tree-ccp1
      tree-forwprop1
      tree-ethread
      tree-esra
      tree-ealias
      tree-fre1
      tree-evrp
      tree-mergephi1
      tree-dse1
      tree-cddce1
      tree-eipa_sra
      tree-tailr1
      tree-switchconv
      tree-ehcleanup1
      tree-profile_estimate
      tree-local-pure-const1
      tree-fnsplit
      *strip_predict_hints
   tree-release_ssa
   *rebuild_cgraph_edges
   tree-local-fnsummary2
ipa-ipa_oacc
   ipa-pta1
   ipa-ipa_oacc_kernels
      tree-oacc_kernels
         tree-ch1
         tree-fre2
         tree-lim1
         tree-dom1
         tree-dce1
         tree-parloops1
         tree-ompexpssa1
         *rebuild_cgraph_edges
ipa-targetclone
ipa-chkp_cleanup
ipa-afdo
ipa-profile
   tree-feedback_fnsplit
ipa-free-fnsummary1
ipa-increase_alignment
ipa-tmipa
ipa-emutls
ipa-whole-program
ipa-profile_estimate
ipa-icf
ipa-devirt
ipa-cp
ipa-cdtor
ipa-hsa
ipa-fnsummary
ipa-inline
ipa-pure-const
ipa-free-fnsummary2
ipa-static-var
ipa-single-use
ipa-comdats
ipa-materialize-all-clones
ipa-pta2
ipa-simdclone
tree-fixup_cfg4
tree-ehdisp
tree-oaccdevlow
tree-ompdevlow
tree-omptargetlink
*all_optimizations
   *remove_cgraph_callee_edges
   *strip_predict_hints
   tree-ccp2
   tree-post_ipa_warn1
   tree-cunrolli
   tree-backprop
   tree-phiprop
   tree-forwprop2
   tree-objsz2
   tree-alias
   tree-retslot
   tree-fre3
   tree-mergephi2
   tree-thread1
   tree-vrp1
   tree-chkpopt
   tree-dce2
   tree-stdarg
   tree-cdce
   tree-cselim
   tree-copyprop1
   tree-ifcombine
   tree-mergephi3
   tree-phiopt1
   tree-tailr2
   tree-ch2
   tree-cplxlower1
   tree-sra
   tree-thread2
   tree-dom2
   tree-isolate-paths
   tree-phicprop1
   tree-dse2
tree-reassoc1
tree-dce3
tree-forwprop3
tree-phiopt2
tree-ccp3
tree-sincos
tree-bswap
tree-laddress
tree-lim2
tree-walloca2
tree-pre
tree-sink
tree-sancov1
tree-asan1
tree-tsan1
tree-dce4
tree-fix_loops
tree-loop
   tree-loopinit
   tree-unswitch
   tree-sccp
   tree-lsplit
   tree-unrolljam
   tree-cddce2
   tree-ivcanon
   tree-ldist
   tree-linterchange
   tree-copyprop2
   tree-graphite0
      tree-graphite
      tree-lim3
      tree-copyprop3
      tree-dce5
   tree-parloops2
   tree-ompexpssa2
   tree-ch_vect
   tree-ifcvt
   tree-vect
      tree-dce6
   tree-pcom
   tree-cunroll
   tree-slp1
   tree-aprefetch
   tree-ivopts
   tree-lim4
   tree-loopdone
tree-no_loop
   tree-slp2
tree-simduid1
tree-veclower21
tree-recip
tree-printf-return-value2
tree-reassoc2
tree-slsr
tree-split-paths
tree-tracer
tree-thread3
tree-dom3
tree-strlen
tree-thread4
tree-vrp2
tree-wrestrict
tree-phicprop2
tree-dse3
tree-cddce3
tree-forwprop4
tree-phiopt3
tree-fab1
   tree-widening_mul
   tree-store-merging
   tree-tailc
   tree-dce7
   tree-crited1
   tree-uninit1
   tree-uncprop1
   tree-local-pure-const2
*all_optimizations_g
   *remove_cgraph_callee_edges
   *strip_predict_hints
   tree-cplxlower2
   tree-veclower22
   tree-ccp4
   tree-post_ipa_warn2
   tree-objsz3
   tree-fab2
   tree-printf-return-value3
   tree-copyprop4
   tree-dce8
   tree-sancov2
   tree-asan2
   tree-tsan2
   tree-crited2
   tree-uninit2
   tree-uncprop2
   tree-local-pure-const3
*tminit
   tree-tmmark
   tree-tmmemopt
   tree-tmedge
tree-simduid2
tree-vtable-verify
tree-lower_vaarg
tree-veclower
tree-cplxlower0
tree-sancov_O0
tree-switchlower
tree-asan0
tree-tsan0
tree-sanopt
tree-ehcleanup2
tree-resx
tree-nrv
tree-optimized
*warn_function_noreturn
tree-hsagen
rtl-expand
*rest_of_compilation
   rtl-vregs
   rtl-into_cfglayout
   rtl-jump
   rtl-subreg1
   rtl-dfinit
   rtl-cse1
   rtl-fwprop1
   rtl-cprop1
   rtl-rtl_pre
   rtl-hoist
   rtl-cprop2
   rtl-store_motion
   rtl-cse_local
   rtl-ce1
   rtl-reginfo
   rtl-loop2
      rtl-loop2_init
      rtl-loop2_invariant
      rtl-loop2_unroll
      rtl-loop2_doloop
      rtl-loop2_done
   rtl-web
   rtl-cprop3
   rtl-stv1
   rtl-cse2
   rtl-dse1
   rtl-fwprop2
   rtl-auto_inc_dec
   rtl-init-regs
   rtl-ud_dce
   rtl-combine
   rtl-stv2
   rtl-ce2
   rtl-bbpart
   rtl-outof_cfglayout
   rtl-split1
   rtl-subreg2
   rtl-no-opt dfinit
   *stack_ptr_mod
   rtl-mode_sw
   rtl-asmcons
   rtl-sms
   rtl-lr_shrinkage
   rtl-sched1
   rtl-early_remat
   rtl-ira
   rtl-reload
   rtl-vzeroupper
   *all-postreload
      rtl-postreload
      rtl-gcse2
      rtl-split2
      rtl-ree
      rtl-cmpelim
      rtl-bt11
      rtl-pro_and_epilogue
      rtl-dse2
      rtl-csa
      rtl-jump2
      rtl-compgotos
      rtl-sched_fusion
      rtl-peephole2
      rtl-ce3
      rtl-rnreg
      rtl-cprop_hardreg
      rtl-rtl_dce
      rtl-bbro
      rtl-bt12
      *leaf_regs
      rtl-split4
      rtl-sched2
      *stack_regs
         rtl-split3
         rtl-stack
   *all-late_compilation
      rtl-alignments
      rtl-vartrack
      *free_cfg
      rtl-mach
      rtl-barriers
      rtl-dbr
      rtl-split5
      rtl-eh_ranges
      rtl-cet
      rtl-shorten
      rtl-nothrow
      rtl-dwarf2
      rtl-final
   rtl-dfinish
*clean_state
```

```
marion@gabrielskx:~/gcc/conference/sqlitedumps/sqlite3_O3$ ls
sqlite3.c.000i.cgraph
sqlite3.c.000i.ipa-clones
sqlite3.c.000i.type-inheritance
sqlite3.c.003t.original
sqlite3.c.004t.gimple
sqlite3.c.006t.omplower
sqlite3.c.007t.lower
sqlite3.c.010t.eh
sqlite3.c.011t.cfg
sqlite3.c.012t.ompexp
sqlite3.c.015i.visibility
sqlite3.c.018i.build_ssa_passes
sqlite3.c.019t.fixup_cfg1
sqlite3.c.020t.ssa
sqlite3.c.022t.nothrow
sqlite3.c.026i.opt_local_passes
sqlite3.c.027t.fixup_cfg3
sqlite3.c.028t.local-fnsummary1
sqlite3.c.029t.einline
sqlite3.c.030t.early_optimizations
sqlite3.c.031t.objsz1
sqlite3.c.032t.ccp1
sqlite3.c.033t.forwprop1
sqlite3.c.034t.ethread
sqlite3.c.035t.esra
sqlite3.c.036t.ealias
sqlite3.c.037t.fre1
sqlite3.c.038t.evrp
sqlite3.c.039t.mergephi1
sqlite3.c.040t.dse1
sqlite3.c.041t.cddce1
sqlite3.c.042t.eipa_sra
sqlite3.c.043t.tailr1
sqlite3.c.044t.switchconv
sqlite3.c.046t.profile_estimate
sqlite3.c.047t.local-pure-const1
sqlite3.c.048t.fnsplit
sqlite3.c.049t.release_ssa
sqlite3.c.050t.local-fnsummary2
sqlite3.c.062i.targetclone
sqlite3.c.067i.free-fnsummary1
sqlite3.c.071i.whole-program
sqlite3.c.072i.profile_estimate
sqlite3.c.073i.icf
sqlite3.c.074i.devirt
sqlite3.c.075i.cp
sqlite3.c.078i.fnsummary
sqlite3.c.079i.inline
sqlite3.c.080i.pure-const
sqlite3.c.081i.free-fnsummary2
sqlite3.c.082i.static-var
sqlite3.c.083i.single-use
sqlite3.c.084i.comdats
sqlite3.c.085i.materialize-all-clones
sqlite3.c.087i.simdclone
sqlite3.c.088t.fixup_cfg4
sqlite3.c.091t.ompdevlow
sqlite3.c.093t.ccp2
sqlite3.c.095t.cunrolli
sqlite3.c.096t.backprop
sqlite3.c.097t.phiprop
sqlite3.c.098t.forwprop2
sqlite3.c.099t.objsz2
sqlite3.c.100t.alias
sqlite3.c.101t.retslot
sqlite3.c.102t.fre3
sqlite3.c.103t.mergephi2
sqlite3.c.104t.thread1
sqlite3.c.105t.vrp1
sqlite3.c.107t.dce2
sqlite3.c.108t.stdarg
sqlite3.c.109t.cdce
sqlite3.c.110t.cselim
sqlite3.c.111t.copyprop1
sqlite3.c.112t.ifcombine
sqlite3.c.113t.mergephi3
sqlite3.c.114t.phiopt1
sqlite3.c.115t.tailr2
sqlite3.c.116t.ch2
sqlite3.c.117t.cplxlower1
sqlite3.c.118t.sra
sqlite3.c.119t.thread2
sqlite3.c.120t.dom2
sqlite3.c.121t.isolate-paths
sqlite3.c.122t.phicprop1
sqlite3.c.123t.dse2
sqlite3.c.124t.reassoc1
sqlite3.c.125t.dce3
sqlite3.c.126t.forwprop3
sqlite3.c.127t.phiopt2
sqlite3.c.128t.ccp3
sqlite3.c.129t.sincos
sqlite3.c.130t.bswap
sqlite3.c.131t.laddress
sqlite3.c.132t.lim2
sqlite3.c.134t.pre
sqlite3.c.135t.sink
sqlite3.c.139t.dce4
sqlite3.c.140t.fix_loops
sqlite3.c.141t.loop
sqlite3.c.142t.loopinit
sqlite3.c.143t.unswitch
sqlite3.c.144t.sccp
sqlite3.c.145t.lsplit
sqlite3.c.146t.unrolljam
sqlite3.c.147t.cddce2
sqlite3.c.148t.ivcanon
sqlite3.c.149t.ldist
sqlite3.c.150t.linterchange
sqlite3.c.151t.copyprop2
sqlite3.c.159t.ch_vect
sqlite3.c.160t.ifcvt
sqlite3.c.161t.vect
sqlite3.c.162t.dce6
sqlite3.c.163t.pcom
sqlite3.c.164t.cunroll
sqlite3.c.165t.slp1
sqlite3.c.167t.ivopts
sqlite3.c.168t.lim4
sqlite3.c.169t.loopdone
sqlite3.c.170t.no_loop
sqlite3.c.171t.slp2
sqlite3.c.173t.veclower21
sqlite3.c.175t.printf-return-value2
sqlite3.c.176t.reassoc2
sqlite3.c.177t.slsr
sqlite3.c.181t.dom3
sqlite3.c.182t.strlen
sqlite3.c.183t.thread4
sqlite3.c.184t.vrp2
sqlite3.c.186t.phicprop2
sqlite3.c.187t.dse3
sqlite3.c.188t.cddce3
sqlite3.c.189t.forwprop4
sqlite3.c.190t.phiopt3
sqlite3.c.191t.fab1
sqlite3.c.192t.widening_mul
sqlite3.c.193t.store-merging
sqlite3.c.194t.tailc
sqlite3.c.195t.dce7
sqlite3.c.196t.crited1
sqlite3.c.198t.uncprop1
sqlite3.c.199t.local-pure-const2
sqlite3.c.225t.switchlower
sqlite3.c.231t.nrv
sqlite3.c.232t.optimized
sqlite3.c.234r.expand
sqlite3.c.235r.vregs
sqlite3.c.236r.into_cfglayout
sqlite3.c.237r.jump
sqlite3.c.238r.subreg1
sqlite3.c.239r.dfinit
sqlite3.c.240r.cse1
sqlite3.c.241r.fwprop1
sqlite3.c.242r.cprop1
sqlite3.c.243r.pre
sqlite3.c.245r.cprop2
sqlite3.c.247r.cse_local
sqlite3.c.248r.ce1
sqlite3.c.249r.reginfo
sqlite3.c.250r.loop2
sqlite3.c.251r.loop2_init
sqlite3.c.252r.loop2_invariant
sqlite3.c.255r.loop2_done
sqlite3.c.257r.cprop3
sqlite3.c.258r.stv1
sqlite3.c.259r.dse2
sqlite3.c.263r.init-regs
sqlite3.c.264r.ud_dce
sqlite3.c.265r.combine
sqlite3.c.267r.ce2
sqlite3.c.268r.bbpart
sqlite3.c.269r.outof_cfglayout
sqlite3.c.270r.split1
sqlite3.c.271r.subreg2
sqlite3.c.273r.mode_sw
sqlite3.c.274r.asmcons
sqlite3.c.279r.ira
sqlite3.c.280r.reload
sqlite3.c.282r.postreload
sqlite3.c.283r.gcse2
sqlite3.c.284r.split2
sqlite3.c.285r.ree
sqlite3.c.286r.cmpelim
sqlite3.c.288r.pro_and_epilogue
sqlite3.c.289r.dse2
sqlite3.c.290r.csa
sqlite3.c.291r.jump2
sqlite3.c.292r.compgotos
sqlite3.c.294r.peephole2
sqlite3.c.295r.ce3
sqlite3.c.297r.cprop_hardreg
sqlite3.c.298r.rtl_dce
sqlite3.c.299r.bbro
sqlite3.c.301r.split4
sqlite3.c.302r.sched2
sqlite3.c.304r.stack
sqlite3.c.305r.alignments
sqlite3.c.306r.vartrack
sqlite3.c.307r.mach
sqlite3.c.308r.barriers
sqlite3.c.313r.shorten
sqlite3.c.314r.nothrow
sqlite3.c.315r.dwarf2
sqlite3.c.316r.final
sqlite3.c.317r.dfinish
sqlite3.c.318t.statistics
```

Compiler debug files

Relevant Concepts

1000-foot view: GIMPLE, SSA & RTL, optimization levels

10-foot view: Alice's Wonderland

998-foot view on compiler optimization

Level	CFLAG	Description
0	-O0	No optimizations enabled.
1	-O1	Optimizations are enabled that reduce code and execution time, but don't significantly increase compilation time.
2	-O2	All optimizations are enabled that reduce code and execution time, excluding those that involve a tradeoff between code size and speed.
3	-O3	Enables all optimizations at Level 2, plus those that can drastically increase code size and those that may not always improve performance.
s	-Os	Optimizes for size. Similar to Level 2, except without optimizations that could increase code size, plus additional optimizations to reduce code size.
fast	-Ofast	Optimization Level 3, plus additional optimizations that may violate the language standards.
g	-Og	Enables any optimizations that do not interfere with the debugger or significantly increase the compilation time.

```
$ gcc -Q -O2 --help=optimizers
```

shows optimizations enabled for e.g. O2

GCC recognizes O0, O1, O2, O3, Os, Ofast and Og

In detail, the number of possible optimizations is YUGE

Table: https://www.sciencedirect.com/science/article/pii/B9780128007266000124

GIMPLE – SIMPLE for GCC

The three address code representation

Target- and language independent optimization

```
# Calculate one solution to the [[quadratic equation]].
x = (-b + sqrt(b^2 - 4*a*c)) / (2*a)
```

```
t1 := b * b
t2 := 4 * a
t3 := t2 * c
t4 := t1 - t3
t5 := sqrt(t4)
t6 := 0 - b
t7 := t5 + t6
t8 := 2 * a
t9 := t7 / t8
x  := t9
```

https://en.wikipedia.org/wiki/Three-address_code

RTL – Register Transfer Language

RTL passes “implement” the machine definition

Machine definition reflects the processor ABI

Algebraic description of target instructions

Target dependent optimization, register allocation, machine code generation

```
(insn 26 25 27 2 (set (mem/c:TI (reg:DI 97) [0 MEM[(void *)&buf2]+0 S16 A128])
        (const_wide_int 0x206120736920736968742 06f6c6c6548)) "hellocompiler.c":23 -1
(nil))
```

```c
#include<stdio.h>
#include<string.h>

void main(void) {
    char name[30];
    char buf1[300], buf2[300], buf3[2000];
    char* longstring = "Hello this is a longer string to test wl
    char* moarr =   "adgweubsssssskaserjefbgggggggddddddddddddd
            "halweufhadrcfghvbfzvlhubnednfkzjesbf,hbdcv,hawevf,
            "aeknflalssodfingnlsufgnlarbngkjadfnvkjlaenrgilarrf
            "asrlgjnzndlfvnlejrkbglkzjdfbcfvkljabjerklgkbzdfkjv
            "aweednvafjgnagnkaejkjngkjaerngakej;kngak;ngkja;nb;

    int i, superlargesize = 5000;
    char superlarge[superlargesize];
    char otherlarge[superlargesize];

    memset(buf1, 0, 300);
    memset(buf2, 0, 300);

    // memcpy 1 -- 300 empty
    memcpy(buf1, buf2, 300);

    // memcpy 2 -- 13 Hello world
    memset(name, 0, 30);
    memcpy(name, "hello world!", 13);
    printf("%s\n", name);

    // memcpy 3 -- 78 long string
    memcpy(buf2, longstring, strlen(longstring));
    printf("%s\n", buf2);

    // memcpy 4 -- 600 longer string
    memcpy(buf3, moarr, strlen(moarr));
    printf("%s\n", buf3);

    // memcpy 5 -- 5000 super long string, repeating char
    for (i=0; i<superlargesize; i++) {
        superlarge[i]='x';
    }
    printf("%s\n", superlarge);

    memcpy(otherlarge, superlarge, strlen(superlarge));
    printf("%s\n", otherlarge);
}
```

hellocompiler.c

5 memcpy calls

300 byte empty buffer

13 byte hello world!

78 byte random string

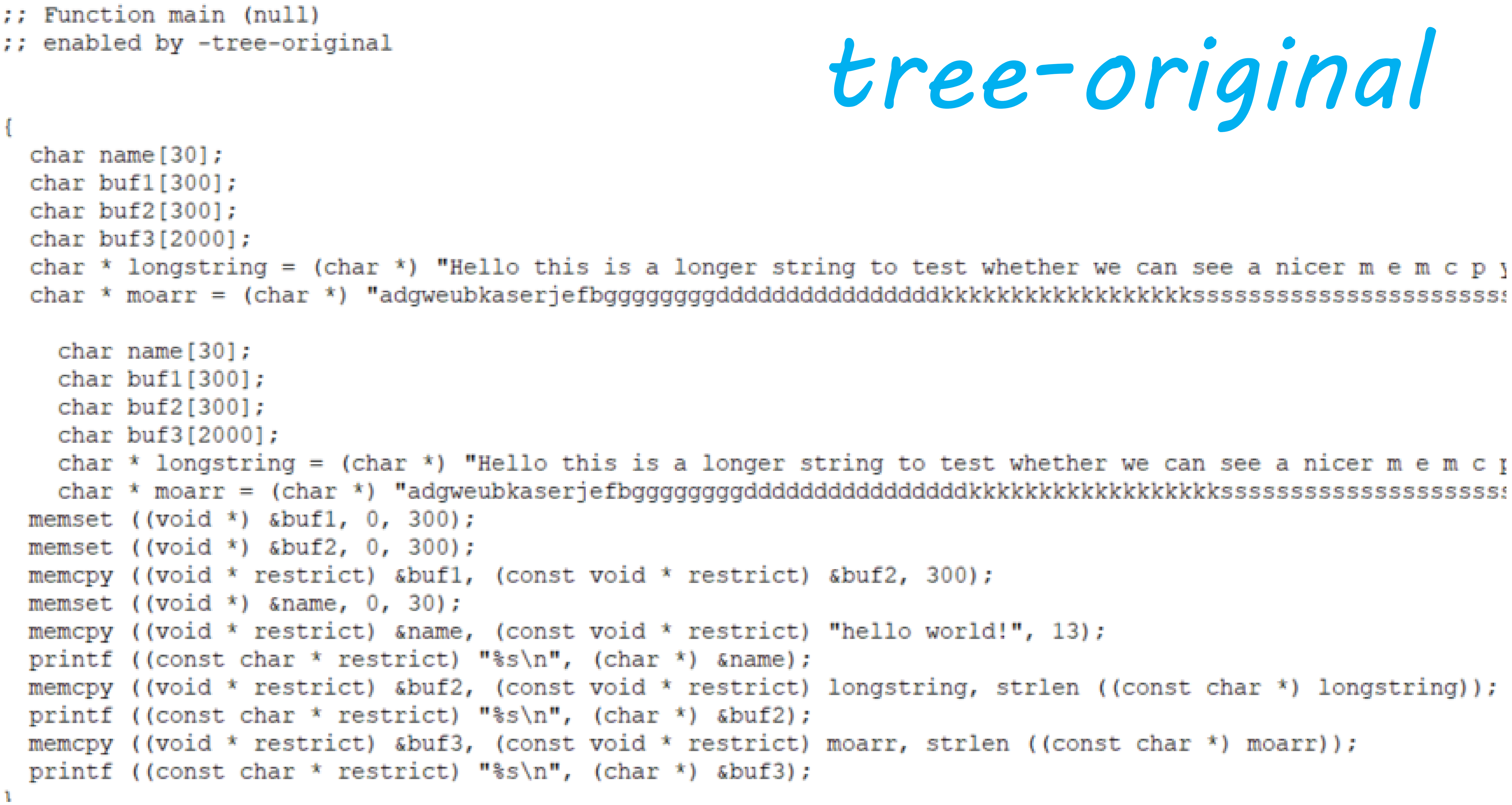
600 byte random string

5000 byte random string

Don’t forget the printfs to create dependencies!

Note: ignoring anything but “memcpy”, “memset”, etc.

tree-original



```
;; Function main (null)
;; enabled by -tree-original


{
  char name[30];
  char buf1[300];
  char buf2[300];
  char buf3[2000];
  char * longstring = (char *) "Hello this is a longer string to test whether we can see a nicer m e m c p
  char * moarr = (char *) "adgweubkaserjefbggggggggdddddddddddddddkkkkkkkkkkkkkkkkksssssssssssssssssssss

    char name[30];
    char buf1[300];
    char buf2[300];
    char buf3[2000];
    char * longstring = (char *) "Hello this is a longer string to test whether we can see a nicer m e m c
    char * moarr = (char *) "adgweubkaserjefbggggggggdddddddddddddddkkkkkkkkkkkkkkkkkssssssssssssssssss
  memset ((void *) &buf1, 0, 300);
  memset ((void *) &buf2, 0, 300);
  memcpy ((void * restrict) &buf1, (const void * restrict) &buf2, 300);
  memset ((void *) &name, 0, 30);
  memcpy ((void * restrict) &name, (const void * restrict) "hello world!", 13);
  printf ((const char * restrict) "%s\n", (char *) &name);
  memcpy ((void * restrict) &buf2, (const void * restrict) longstring, strlen ((const char *) longstring));
  printf ((const char * restrict) "%s\n", (char *) &buf2);
  memcpy ((void * restrict) &buf3, (const void * restrict) moarr, strlen ((const char *) moarr));
  printf ((const char * restrict) "%s\n", (char *) &buf3);
}
```

tree-gimple

```
main ()
{
  char name[30];
  char buf1[300];
  char buf2[300];
  char buf3[2000];
  char * longstring;
  char * moarr;

  try
    {
      longstring = "Hello this is a longer string to test whether we ca
      moarr = "adgweubkaserjefbgggggggdddddddddddddddddkkkkkkkkkkkkkkkk
      memset (&buf1, 0, 300);
      memset (&buf2, 0, 300);
      MEM[(char * {ref-all})&buf1] = MEM[(char * {ref-all})&buf2];
      memset (&name, 0, 30);
      memcpy (&name, "hello world!", 13);
      __builtin_puts (&name);
      _1 = strlen (longstring);
      memcpy (&buf2, longstring, _1);
      __builtin_puts (&buf2);
      _2 = strlen (moarr);
      memcpy (&buf3, moarr, _2);
      __builtin_puts (&buf3);
    }
  finally
    {
      name = {CLOBBER};
      buf1 = {CLOBBER};
      buf2 = {CLOBBER};
      buf3 = {CLOBBER};
    }
}
```

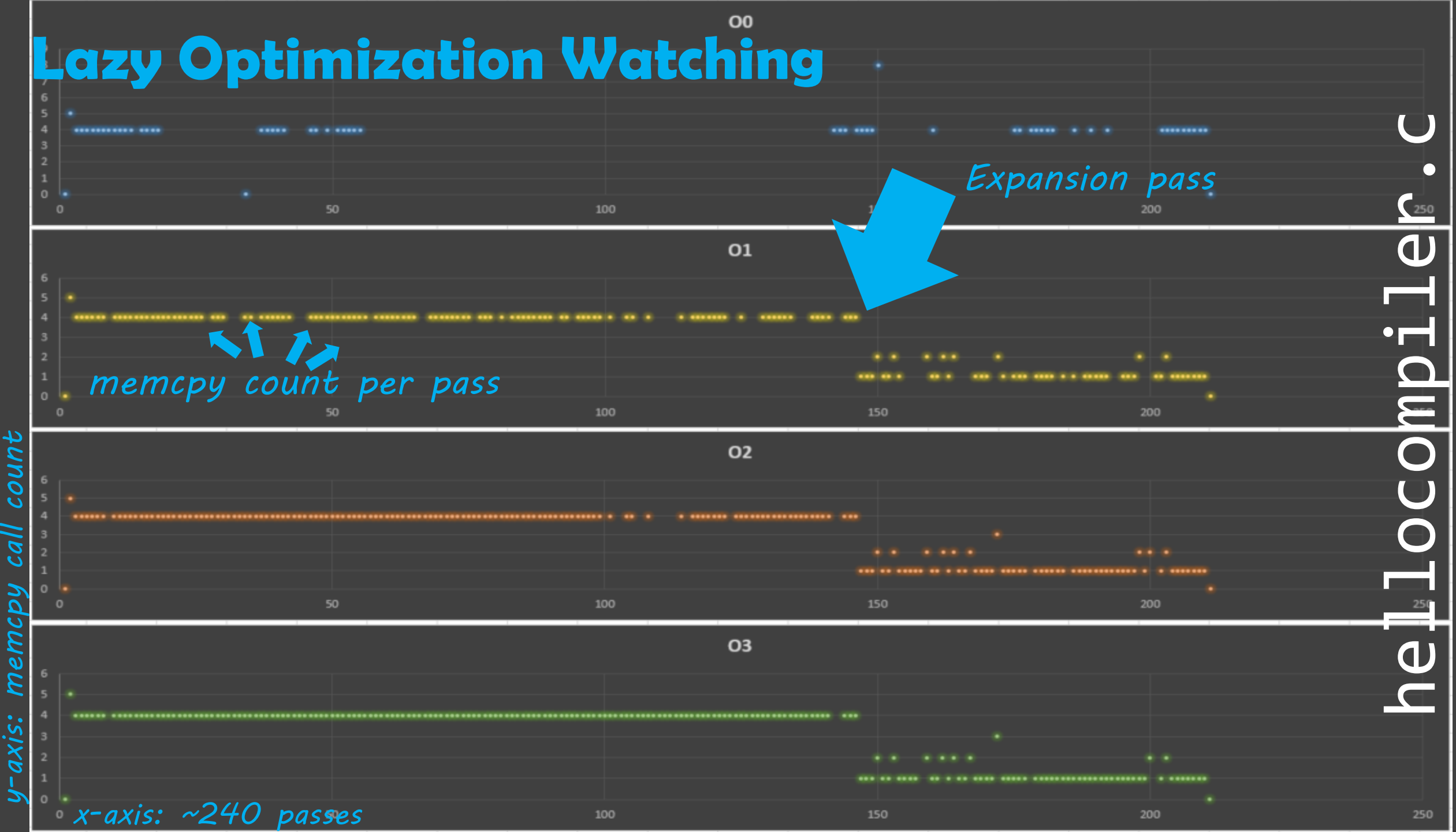
tree-optimized

```
;; Function main (main, funcdef_no=11, decl_uid=2575,
cgraph_uid=11, symbol_order=11) (executed once)

main ()
{
  char buf3[2000];
  char buf2[300];
  char name[30];

  <bb 2> [local count: 1073741825]:
  memset (&buf2, 0, 300);
  memset (&MEM[(void *)&name + 12B], 0, 18);
  memcpy (&name, "hello world!", 13);
  __builtin_puts (&name);
  memcpy (&buf2, "Hello this is a longer string to test whethe
  __builtin_puts (&buf2);
  memcpy (&buf3, "adgweubkaserjefbgggggggdddddddddddddddddkkkk
  __builtin_puts (&buf3);
  name ={v} {CLOBBER};
  buf2 ={v} {CLOBBER};
  buf3 ={v} {CLOBBER};
  return;

}
```

rtl-expand

```
(insn 26 25 27 2 (set (mem/c:TI (reg:DI 97) [0 MEM[(void *)&buf2]+0 S16 A128])
        (const_wide_int 0x206120736920736968742 06f6c6c6548)) "hellocompiler.c":23 -1
     (nil))
(insn 27 26 28 2 (set (mem/c:TI (plus:DI (reg:DI 97)
                (const_int 16 [0x10])) [0 MEM[(void *)&buf2]+16 S16 A128])
        (const_wide_int 0x6f7420676e69727473207265676e6f6c)) "hellocompiler.c":23 -1
     (nil))
(insn 28 27 29 2 (set (mem/c:TI (plus:DI (reg:DI 97)
                (const_int 32 [0x20])) [0 MEM[(void *)&buf2]+32 S16 A128])
        (const_wide_int 0x65772072656874656877207473657420)) "hellocompiler.c":23 -1
     (nil))
(insn 29 28 30 2 (set (mem/c:TI (plus:DI (reg:DI 97)
                (const_int 48 [0x30])) [0 MEM[(void *)&buf2]+48 S16 A128])
        (const_wide_int 0x726563696e206120656573206e616320)) "hellocompiler.c":23 -1
     (nil))
(insn 30 29 31 2 (set (mem/c:TI (plus:DI (reg:DI 97)
                (const_int 64 [0x40])) [0 MEM[(void *)&buf2]+64 S16 A128])
        (const_wide_int 0x697562207920702063206d2065206d20)) "hellocompiler.c":23 -1
     (nil))
(insn 31 30 32 2 (set (mem/c:SI (plus:DI (reg:DI 97)
                (const_int 80 [0x50])) [0 MEM[(void *)&buf2]+80 S4 A128])
        (const_int 1852404844 [0x6e69746c])) "hellocompiler.c":23 -1
     (nil))
(insn 32 31 33 2 (set (mem/c:HI (plus:DI (reg:DI 97)
                (const_int 84 [0x54])) [0 MEM[(void *)&buf2]+84 S2 A32])
        (const_int 8481 [0x2121])) "hellocompiler.c":23 -1
     (nil))
(insn 33 32 34 2 (set (mem/c:QI (plus:DI (reg:DI 97)
                (const_int 86 [0x56])) [0 MEM[(void *)&buf2]+86 S1 A16])
        (const_int 10 [0xa])) "hellocompiler.c":23 -1
     (nil))
(insn 34 33 35 2 (parallel [
            (set (reg:DI 98)
                (plus:DI (reg/f:DI 82 virtual-stack-vars)
                    (const_int -2304 [0xfffffffffffff700])))
            (clobber (reg:CC 17 flags))
        ]) "hellocompiler.c":24 -1
     (nil))
(insn 35 34 36 2 (set (reg:DI 5 di)
        (reg:DI 98)) "hellocompiler.c":24 -1
     (nil))
(call_insn 36 35 37 2 (set (reg:SI 0 ax)
        (call (mem:QI (symbol_ref:DI ("puts") [flags 0x41] <function_decl 0x7fb1fd6cdf00 __builtin_puts>) [0 __builtin_puts S1 A8])
            (const_int 0 [0]))) "hellocompiler.c":24 -1
     (expr_list:REG_CALL_DECL (symbol_ref:DI ("puts") [flags 0x41] <function_decl 0x7fb1fd6cdf00 __builtin_puts>)
        (nil))
    (expr_list:DI (use (reg:DI 5 di))
        (nil)))
```

Lazy Optimization Watching



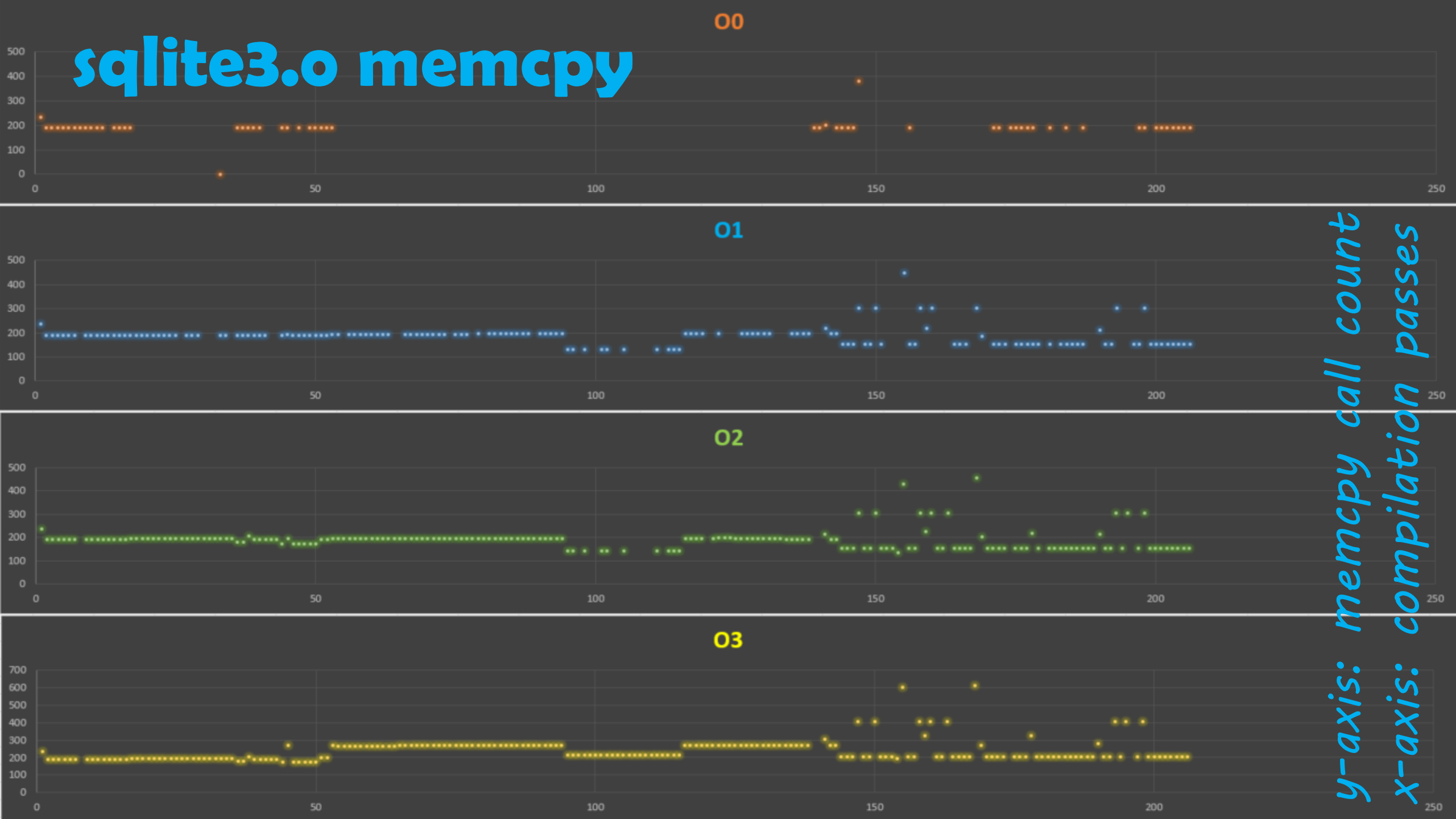
helloocompiler.c

The testbunny: Sqlite3

```
sqlite3.c
shell.c
lemon.c
mkkeywordhash.c
tclsqlite.c
```

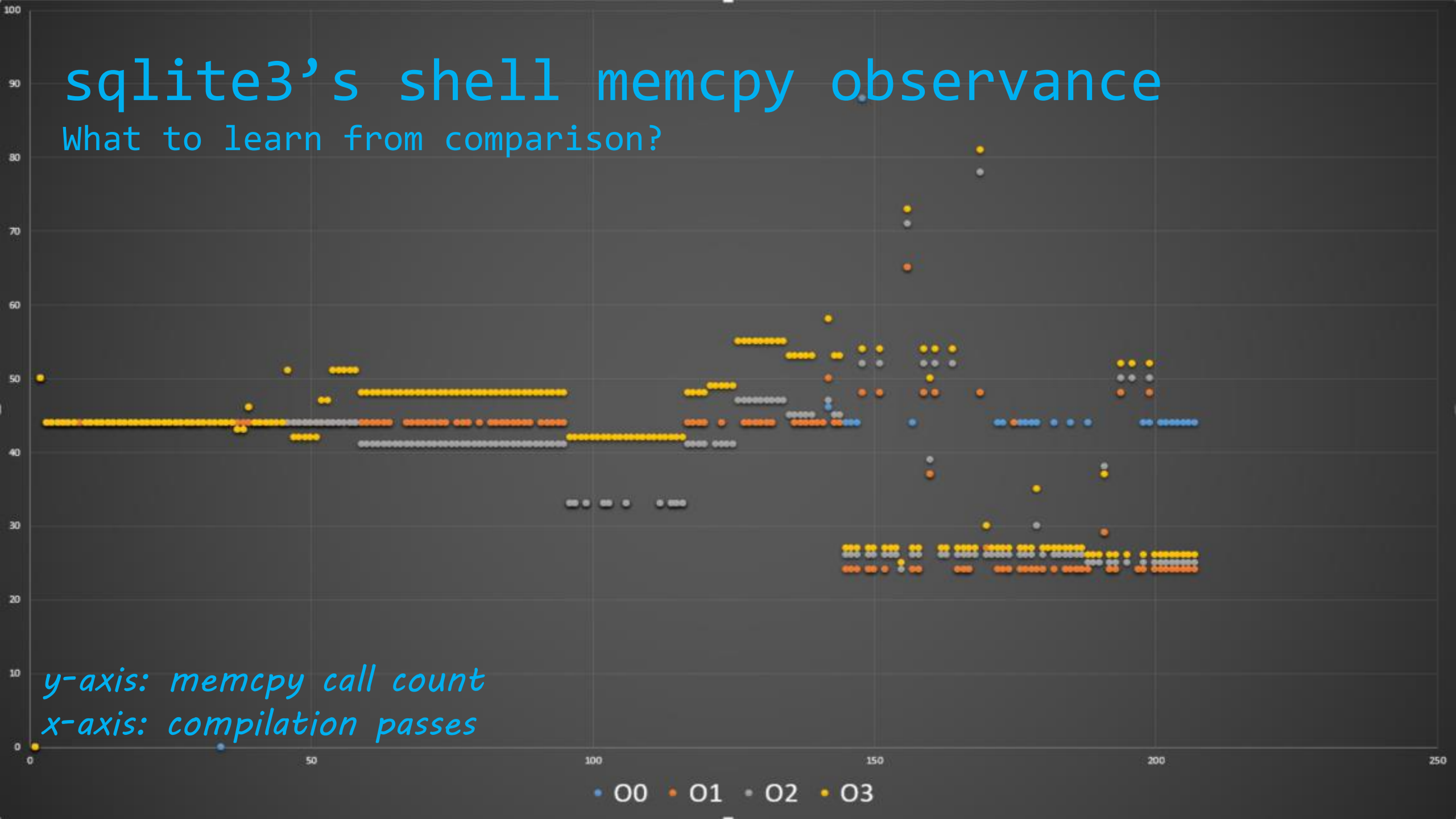
```
sqlite3 / sqlite3.o
sqlite3
lemon
mkkeywordhash
tclsqlite.o
```

sqlite3.o memcpy



sqlite3’s shell memcpy observance

What to learn from comparison?



y-axis: memcpy call count
x-axis: compilation passes

Grep for Compiler Research ^^

Fairly straight forward

Not necessarily the most accurate

Text parsing only ever gets so far:

- Code duplications for optimization purposes
- Different representations in same log file

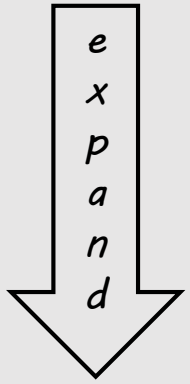
but there IS fun stuff we can do with that data...

Homemade off-by-plenty bugs

Developer controlled

Piggy-backing onto compiler behavior

```
__builtin_fun(x, y, magic_value);
```



magic_value found?
modify output

```
mov ...
mov ...
mov ...
(evil) mov dst, src
```

```c
int AUTH = 0;

int main(void)
{
    char *string1 = aligned_alloc(32, 96);
    char *string2 = "eldit934h2rkfhgppq;a3fjjdklsajieeisbnufblabghbalweglqjwebdfjhlkj"
                    "alekdgowei;anebkbirnwlekgn;qnwol";

    memcpy(string1, string2, 96);

    printf("Result %s\n", string2);

    if (AUTH != 0) {
        execl("/usr/games/xmabacus", "xmabacus", NULL);
    } else {
        printf("Nooope go away\n");
    }

    return 0;
}
```

victim variable

builtin to "fix"

magic number

DEMO TIME

Look ma, I made memcpy faster!

```
lea    rsi,[rip+0xf66]        # 2008 <_IO_stdin_used+0x
lea    rdi,[rip+0xfc7]        # 2070 <_IO_stdin_used+0x
mov    QWORD PTR [rax-0xff4],0x1

movaps XMMWORD PTR [rax],xmm0
movdqa xmm0,XMMWORD PTR [rip+0xff1]        # 20b0 <_IO_

mov    QWORD PTR [rax-0xfec],0x0

movaps XMMWORD PTR [rax+0x10],xmm0
movdqa xmm0,XMMWORD PTR [rip+0xfea]        # 20c0 <_IO_

movaps XMMWORD PTR [rax+0x20],xmm0
movdqa xmm0,XMMWORD PTR [rip+0xfee]        # 20d0 <_IO_

movaps XMMWORD PTR [rax+0x30],xmm0
movdqa xmm0,XMMWORD PTR [rip+0xff2]        # 20e0 <_IO_

movaps XMMWORD PTR [rax+0x40],xmm0
movdqa xmm0,XMMWORD PTR [rip+0xff6]        # 20f0 <_IO_

movaps XMMWORD PTR [rax+0x50],xmm0
xor    eax,eax
call   1040 <printf@plt>
mov    eax,DWORD PTR [rip+0x2f41]        # 404c <AUTH>
test   eax,eax
je     112d <main+0xad>
xor    edx,edx
lea    rsi,[rip+0xf6e]        # 2086 <_IO_stdin_used+0x
lea    rdi,[rip+0xf5c]        # 207b <_IO_stdin_used+0x
xor    eax,eax
call   1060 <execl@plt>
```

Tracking from within

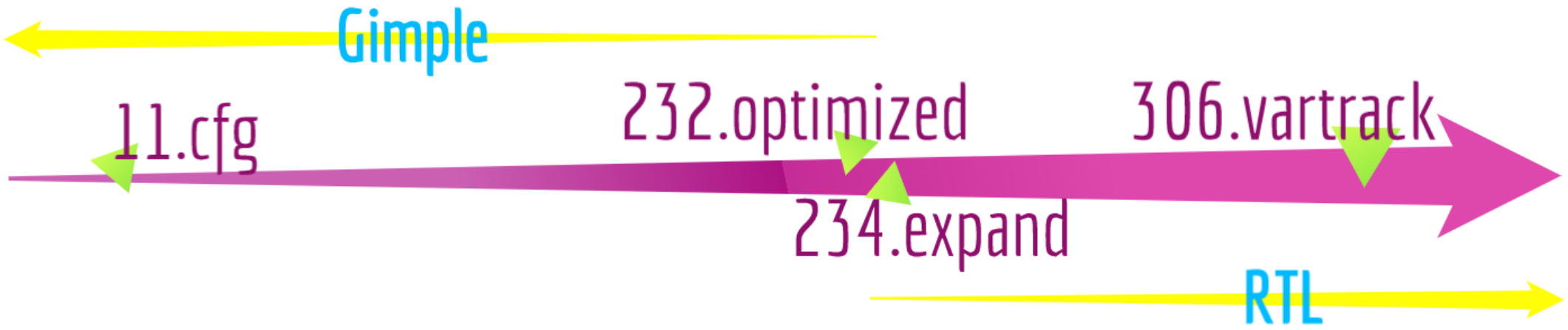
GCC's location_t available throughout compilation

Provides source file, line number, function name, etc.

Plugging into four passes to take measurements

- cfg, optimized, expand, vartrack

Two types of parsers: GIMPLE & RTL



	optsetting	binaryout	pass	token	sourcefile	linenumber
	Filter	Filter	Filter	Filter	Filter	Filter
2072	O3	sqlite3	post_expand	memcpy	shell.c	10903
2073	O3	sqlite3	post_vartrack	memcpy	shell.c	10903
2074	O3	sqlite3	post_vartrack	memcpy	shell.c	10903
2075	O3	sqlite3	post_optimized	memcpy	shell.c	9884
2076	O3	sqlite3	post_optimized	memcpy	shell.c	9885
2077	O3	sqlite3	post_optimized	memcpy	shell.c	18187
2078	O3	sqlite3	post_optimized	memcpy	shell.c	18200
2079	O3	sqlite3	post_optimized	memcpy	shell.c	18205
2080	O3	sqlite3	post_expand	memcpy	shell.c	18200
2081	O3	sqlite3	post_expand	memcpy	shell.c	18205
2082	O3	sqlite3	post_vartrack	memcpy	shell.c	18205
2083	O3	sqlite3	post_vartrack	memcpy	shell.c	18200
2084	O3	sqlite3	post_optimized	memcpy	shell.c	18426
2085	O3	sqlite3	post_optimized	memcpy	shell.c	18427
2086	O3	sqlite3	post_optimized	memcpy	shell.c	18775
2087	O3	sqlite3	post_cfg	memcpy	sqlite3.c	74941
2088	O3	sqlite3	post_cfg	memcpy	sqlite3.c	27854
2089	O3	sqlite3	post_cfg	memcpy	sqlite3.c	28229
2090	O3	sqlite3	post_cfg	memcpy	sqlite3.c	27141
2091	O3	sqlite3	post_cfg	memcpy	sqlite3.c	28283
2092	O3	sqlite3	post_cfg	memcpy	sqlite3.c	28264
2093	O3	sqlite3	post_cfg	memcpy	sqlite3.c	28305

“Big Data”

Flat dataset:

- builtin
- optimization setting
- output binary
- source file : line number

Future reseach .....

Memcpy calls in sqlite3's lemon tool

optimization

source file and line

measured passes

	source	1_post_cfg	2_post_optimized	3_post_expand	4_post_vartrack
O0	lemon.c:2644	1	1	1	1
O0	lemon.c:2659	1	1	1	1
O0	lemon.c:89	1	1	1	1
	source	1_post_cfg	2_post_optimized	3_post_expand	4_post_vartrack
O1	lemon.c:2644	1	1	0	0
O1	lemon.c:2659	1	1	1	1
O1	lemon.c:89	1	1	1	1
	source	1_post_cfg	2_post_optimized	3_post_expand	4_post_vartrack
O2	lemon.c:2644	1	1	0	0
O2	lemon.c:2659	1	1	1	1
O2	lemon.c:89	1	2	2	2
	source	1_post_cfg	2_post_optimized	3_post_expand	4_post_vartrack
O3	lemon.c:2644	1	1	0	0
O3	lemon.c:2659	1	1	1	1
O3	lemon.c:89	1	13	6	6

memcpy calls in that location

WAIT WHAT??

```
;; Function lemon_sprintf (null)
;; enabled by -tree-original


{
  struct  ap[1];
  int rc;

  # DEBUG BEGIN STMT;
    struct  ap[1];
  # DEBUG BEGIN STMT;
    int rc;
  # DEBUG BEGIN STMT;
  __builtin_va_start ((struct  *) &ap, format);
  # DEBUG BEGIN STMT;
  rc = lemon_vsprintf (str, format, (struct  *) &ap);
  # DEBUG BEGIN STMT;
  __builtin_va_end ((struct  *) &ap);
  # DEBUG BEGIN STMT;
  return rc;
}
```

Original code

lemon_sprintf(..)

inlining

lemon_vsprintf(..)

inlining / loop unrolling

lemon_addtext(..)

memcpy(..)

Location dependent actions might shift if the compiler reorders things, in case no data dependency is present

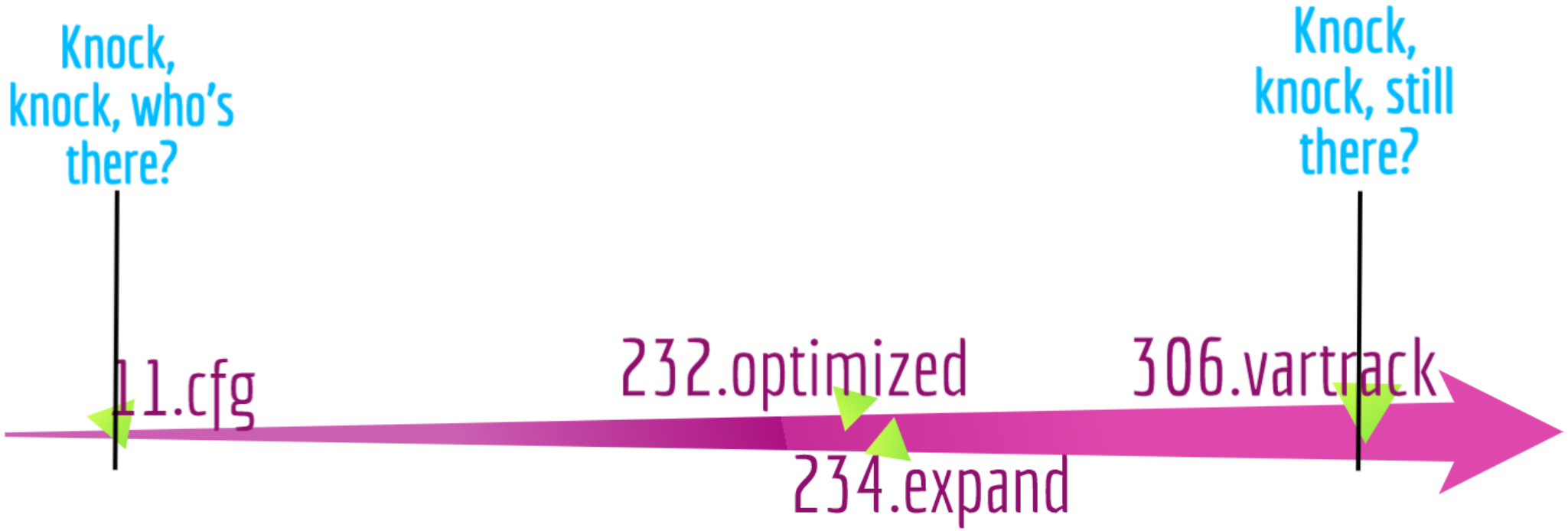
	source	1_post_cfg	2_post_optimized	3_post_expand	4_post_vartrack
O2	lemon.c:2644	1	1	0	0
O2	lemon.c:2659	1	1	1	1
O2	lemon.c:89	1	2	2	2
	source	1_post_cfg	2_post_optimized	3_post_expand	4_post_vartrack
O3	lemon.c:2644	1	1	0	0
O3	lemon.c:2659	1	1	1	1
O3	lemon.c:89	1	13	6	6

inlining

inlining + loop unrolling

But most importantly, what about the zeros?

How to know whether inlined or eliminated?



O2	sqlite3.c:168195	1	1	1	1	remains:3
O2	sqlite3.c:168366	1	1	0	0	remains:7
O2	sqlite3.c:168728	1	0	0	0	eliminated
O2	sqlite3.c:169143	1	1	0	0	remains:1
O2	sqlite3.c:169437	1	1	0	0	remains:2

memset in sqlite3.c line 168728 when compiled with -O2 disappears ...

```
168722 /*
168723 ** Malloc and Free functions
168724 */
168725 static void *fts3HashMalloc(sqlite3_int64 n){
168726   void *p = sqlite3_malloc64(n);
168727   if( p ){
168728     memset(p, 0, n);
168729   }
168730   return p;
168731 }
```

... in fact, the entire function is gone ...

```
167518 static void *fts3MallocZero(sqlite3_int64 nByte){
167519   void *pRet = sqlite3_malloc64(nByte);
167520   if( pRet ) memset(pRet, 0, nByte);
167521   return pRet;
167522 }
```

... since it had been replaced with another one O.o

The Linux Kernel Archives

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Protocol	Location
HTTP	https://www.kernel.org/pub/
GIT	https://git.kernel.org/
RSYNC	rsync://rsync.kernel.org/pub/

Latest Stable Kernel:

5.3.6

Experiments on Linux kernel 5.3.6

GCC plugin infrastructure plug n play (thx to PaX!)

Used default opt setting -O2

%%% ?

Linux kernel 5.3.6, some numbers

	memset calls via grep	memset calls in cfg	memset calls post optimized	memset calls after expand	memset calls final	Eliminated memset	Inlined memsets
Total	*19732*	12870	12476	1374	1364	434	11072
Loss			*394*	*11102*	*10*		
			% call loss since cfg	% call loss since cfg	% call loss since cfg	% memset eliminated	% memset inlined
% of cfg total			3.0614%	86.2626%	0.0777%	3.3722%	86.0295%

10717	smb2transport.o:smb2transport.c:244	1	1	0	0	2
10718	smb2transport.o:smb2transport.c:443	1	1	0	0	2
10719	smb2transport.o:smb2transport.c:444	1	1	0	0	2
10720	smb2transport.o:smb2transport.c:543	1	1	0	0	2
10721	smb2transport.o:smb2transport.c:587	1	1	0	0	10
10722	smbencrypt.o:smbencrypt.c:149	1	0	0	0	eliminated
10723	smbencrypt.o:smbencrypt.c:150	1	1	0	0	2
10724	smbencrypt.o:smbencrypt.c:151	1	1	0	0	4
10725	smbencrypt.o:smbencrypt.c:198	1	1	0	0	2
10726	smbencrypt.o:smbencrypt.c:199	1	1	0	0	4
10727	smc91c92_cs.o:smc91c92_cs.c:1552	1	1	0	0	1
10728	sme.o:etherdevice.h:240	1	1	0	0	3
10729	sme.o:sme.c:1121	1	1	0	0	4
10730	sme.o:sme.c:260	1	1	0	0	10
10731	sme.o:sme.c:369	1	1	0	0	6
10732	sme.o:sme.c:703	1	1	0	0	2
10733	sme.o:sme.c:710	1	1	0	0	2
10734	sme.o:sme.c:716	1	1	0	0	4
10735	sme.o:sme.c:929	1	1	0	0	2
10736	sme.o:sme.c:936	1	1	0	0	2
10737	sme.o:sme.c:942	1	1	0	0	1
10738	smincio_main.o:smincio_main.c:531	1	1	0	0	4

Lost memset in ./drivers/crypto/ccp/ccp-crypto-aes-cmac.c

```
static int ccp_aes_cmac_export(struct ahash_request *req, void *out)
{
    struct ccp_aes_cmac_req_ctx *rctx = ahash_request_ctx(req);
    struct ccp_aes_cmac_exp_ctx state;

    /* Don't let anything leak to 'out' */
    memset(&state, 0, sizeof(state));

    state.null_msg = rctx->null_msg;
    memcpy(state.iv, rctx->iv, sizeof(state.iv));
    state.buf_count = rctx->buf_count;
    memcpy(state.buf, rctx->buf, sizeof(state.buf));

    /* 'out' may not be aligned so memcpy from local variable */
    memcpy(out, &state, sizeof(state));

    return 0;
}
```

eliminated / implied

inlined

```
var_38          = qword ptr -38h
var_2C          = qword ptr -2Ch
var_24          = dword ptr -24h
var_20          = qword ptr -20h
var_18          = qword ptr -18h
canary          = qword ptr -10h

                call    __fentry__      ; PIC mode
                push    rbp
                mov     rbp, rsp
                sub     rsp, 30h        ; rdi - ahash_request *req
                mov     rdx, [rdi+0B0h] ; reading of request data
                mov     rcx, [rdi+0DCh]
                mov     rax, gs:28h
                mov     [rsp+38h+canary], rax
                xor     eax, eax
                mov     r9d, [rdi+0D8h]
                mov     rax, [rdi+0A8h]
                mov     r8, [rdi+0E4h]
                mov     edi, [rdi+50h]
                mov     [rsp+38h+var_2C], rdx ; space for state struct apparently held on stack
                mov     [rsp+38h+var_38+4], rax ; no sizeof, memcpy or memset calls preserved
                mov     dword ptr [rsp+38h+var_38], edi
                mov     rdx, [rsp+38h+var_38]
                mov     [rsp+38h+var_24], r9d
                mov     [rsi], rdx      ; rsi - void *out
                mov     rdx, [rsp+8]    ; memcpy(out, &state, sizeof.. inlined here
                mov     [rsp+38h+var_20], rcx
                mov     [rsi+8], rdx
                mov     rdx, [rsp+38h+var_2C+4]
                mov     [rsp+38h+var_18], r8
                mov     [rsi+10h], rdx
                mov     [rsi+18h], rcx
                mov     [rsi+20h], r8
                mov     rcx, [rsp+38h+canary]
                xor     rcx, gs:28h
                jnz     short loc_94
```

Loading of req data from first function argument

state struct occupies stack vars var_18 to var_38

inlined memcpy copying state struct data to void *out

Lost memset in smbencrypt.c

The compiler removes memset(p14..), and inlines the other two

We see the memcpy(p14, passwd,..) inlined so as passwd is copied to a stack buffer in chunks

The compiler also inlined the call to E_P16

```
int
SMBencrypt(unsigned char *passwd, const unsigned char *c8, unsigned char *p24)
{
    int rc;
    unsigned char p14[14], p16[16], p21[21];

    memset(p14, '\0', 14);
    memset(p16, '\0', 16);
    memset(p21, '\0', 21);

    memcpy(p14, passwd, 14);
    rc = E_P16(p14, p16);
    if (rc)
        return rc;

    memcpy(p21, p16, 16);
    rc = E_P24(p21, c8, p24);

    return rc;
}
```

eliminated / implied

inlined

inlined

```
static int
E_P16(unsigned char *p14, unsigned char *p16)
{
    int rc;
    unsigned char sp8[8] =
        { 0x4b, 0x47, 0x53, 0x21, 0x40, 0x23, 0x24, 0x25 };

    rc = smbhash(p16, sp8, p14);
    if (rc)
        return rc;
    rc = smbhash(p16 + 8, sp8, p14 + 7);
    return rc;
}
```

SMBEncrypt asm

```
sp8= qword ptr -5Bh
p14_1= qword ptr -53h
p14_2= dword ptr -4Bh
p14_3= word ptr -47h
p16_1= qword ptr -45h
p16_2= qword ptr -3Dh
p21_1= byte ptr -35h
p21_2= qword ptr -2Dh
p21_3= dword ptr -25h
p21_4= byte ptr -21h
cookie= qword ptr -20h

call    __fentry__      ; PIC mode
push    rbp
mov     rbp, rsp
push    r12
mov     r12, rdx
push    rbx
mov     rbx, rsi
sub     rsp, 48h
mov     rax, gs:28h
mov     [rsp+60h+cookie], rax
xor     eax, eax
mov     rax, [rdi]
lea     rdx, [rsp+60h+p14_1]
lea     rsi, [rsp+60h+sp8]
mov     [rsp+60h+p16_1], 0
mov     [rsp+60h+p14_1], rax
mov     eax, [rdi+8]
mov     [rsp+60h+p16_2], 0
mov     [rsp+60h+p14_2], eax
movzx   eax, word ptr [rdi+0Ch]
lea     rdi, [rsp+60h+p16_1]
mov     qword ptr [rsp+60h+p21_1], 0
mov     [rsp+60h+p14_3], ax
mov     rax, 252423402153474Bh
mov     [rsp+60h+p21_2], 0
mov     [rsp+60h+p21_3], 0
mov     [rsp+60h+p21_4], 0
mov     [rsp+60h+sp8], rax
call    smbhash
test    eax, eax
jz      short loc_3AF
```

p14 memset-0 omitted

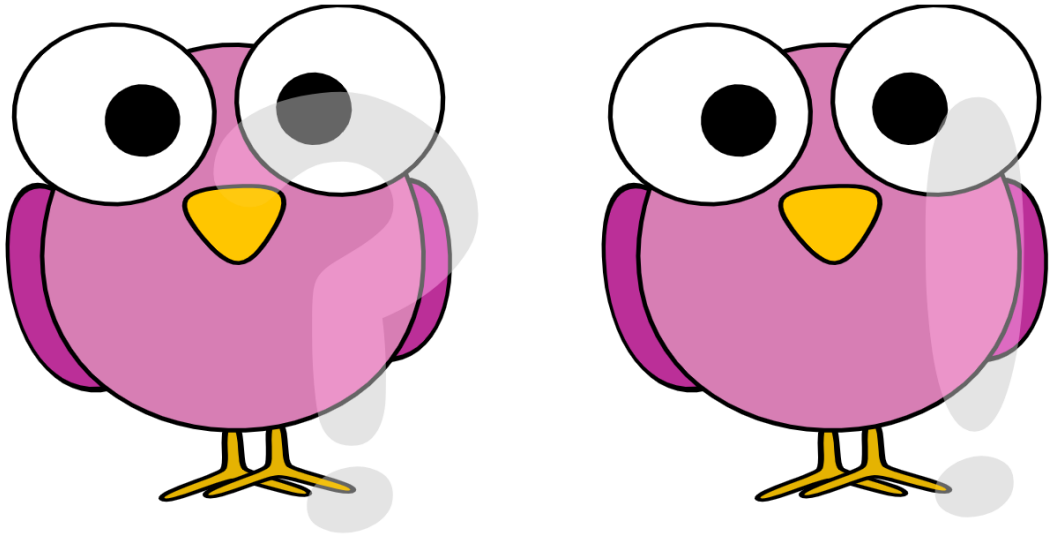
RDI holds first argument, passwd is copied to p14_1, p14_2 and p14_3

```
loc_3AF:
lea     rdx, [rsp+60h+p14_1+7]
lea     rdi, [rsp+60h+p16_2]
lea     rsi, [rsp+60h+sp8]
call    smbhash
test    eax, eax
```

- 14 bytes are copied out of the passwd buffer using mov instructions, and overwrite the given memory
- This, regardless of what the memory contained before

… and 431 other cases, but first:

- Careful tracking: wrapper functions or self-made implementations
- Understanding of application needed in order to track the right information
- Gatherable information in reality very one dimensional, much more analysis of code desireable




Thank you!