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Getting Started with LLVM
The TL;DR Version

Diana Picus

Please read the docs!

http://llvm.org/docs/

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What This Talk Is About

- ~~The LLVM IR(s)~~
- ~~The LLVM codebase~~

- The LLVM community
- Committing patches
- LLVM developer tools
- Writing tests for LLVM

- More discussions: Grand Peninsula C, Wednesday 4PM

Interacting with the Community

- Mailing lists
  - $PROJECT-dev
    - Try to keep an eye on the discussions here
  - $PROJECT-commits
    - Use mail filters
    - Start reviewing patches

$PROJECT ∈ { llvm, cfe, … }

Interacting with the Community

- Mailing lists
- IRC
  - #llvm on oftc
  - #llvm-build

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Interacting with the Community

- Mailing lists
- IRC
- Dev meetings
  - US LLVM
  - EuroLLVM
  - Devrooms and workshops at other conferences
  - YouTube channel
    https://www.youtube.com/channel/UCv2_41bSAa5Y_8BacJUZfjQ

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Interacting with the Community

- Mailing lists
- IRC
- Dev meetings
- Socials
  - https://www.meetup.com/pro/llvm/

Interacting with the Community

- Mailing lists
- IRC
- Dev meetings
- Socials
- Bugzilla
  - https://bugs.llvm.org/

Interacting with the Community

- Mailing lists
- IRC
- Dev meetings
- Socials
- Bugzilla
- Code of conduct
  - https://llvm.org/docs/CodeOfConduct.html

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Submitting a Patch

- https://llvm.org/docs/DeveloperPolicy.html

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Submitting a Patch

- https://llvm.org/docs/DeveloperPolicy.html
- Make sure your patch is based on trunk
- Keep it small
  - Submit unrelated changes as separate patches
  - Try to break your patch into logical chunks

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Submitting a Patch

- https://llvm.org/docs/DeveloperPolicy.html
- Make sure your patch is based on trunk
- Keep it small
- Please have tests!
  - Or mark your patch as NFC

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Submitting a Patch

- https://llvm.org/docs/DeveloperPolicy.html
- Make sure your patch is based on trunk
- Keep it small
- Please have tests!
- Have a descriptive summary
  - Short and catchy title
  - Why is your patch needed?
  - How does your patch work?

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Submitting a Patch

- https://llvm.org/docs/DeveloperPolicy.html
- Make sure your patch is based on trunk
- Keep it small
- Please have tests!
- Have a descriptive summary
- Please follow the coding style
  - clang/tools/clang-format/git-clang-format or clang-format-diff.py
  - Only catches formatting issues, try to internalize the rest
  - https://llvm.org/docs/CodingStandards.html
  - https://llvm.org/docs/ProgrammersManual.html

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Phabricator

- https://llvm.org/docs/Phabricator.html
- Web interface or Arcanist

Phabricator

- https://llvm.org/docs/Phabricator.html
- Web interface or Arcanist
- Full context
  - git diff -U99999 or equivalent

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Phabricator

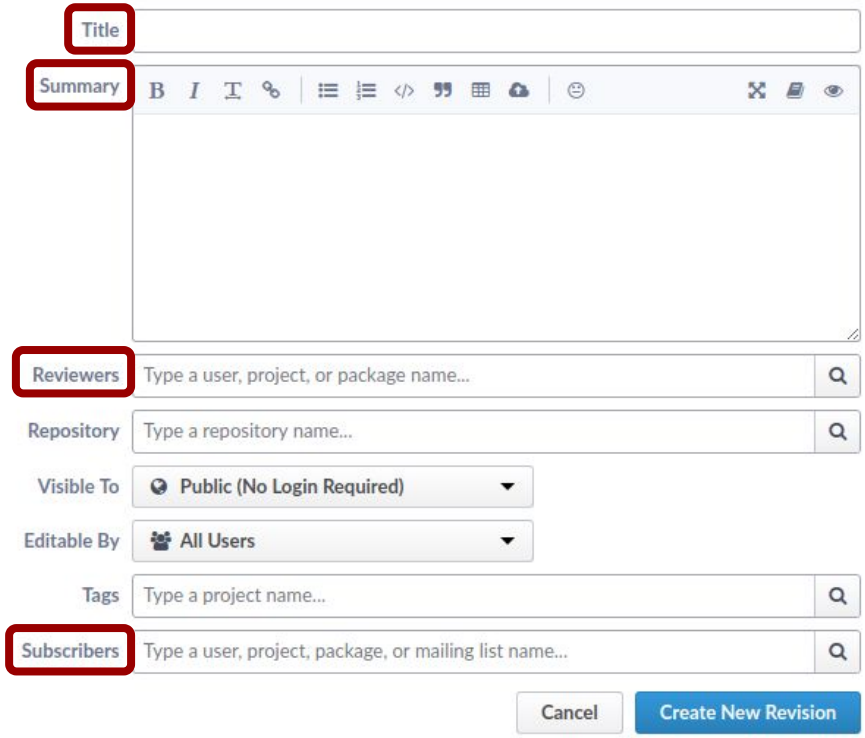
- https://llvm.org/docs/Phabricator.html
- Web interface or Arcanist
- Full context
- Subscribers
  - $PROJECT-commits
  - Please refrain from adding $PROJECT-dev

Phabricator

- https://llvm.org/docs/Phabricator.html
- Web interface or Arcanist
- Full context
- Subscribers
- Reviewers
  - git blame
  - CODE_OWNERS.txt

Phabricator

- https://llvm.org/docs/Phabricator.html
- Web interface or Arcanist
- Full context
- Subscribers
- Reviewers



Start with this!

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Phabricator

- https://llvm.org/docs/Phabricator.html
- Web interface or Arcanist
- Full context
- Subscribers
- Reviewers
- Ping / rebase ~ once/week

Committing a Patch

- Patches need to be accepted
  - When at least one person has accepted a patch, it can be committed
  - Patches can still be reviewed after commit
  - Please address any follow-up comments

Committing a Patch

- Patches need to be accepted
- Committing a patch
  - If you don’t have commit access, ask the person that approved the patch to commit for you
  - After 2-3 patches you can ask for commit access

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Committing a Patch

- Patches need to be accepted
- Committing a patch
- Last line of summary - link to Phabricator review
  - Differential Revision: https://reviews.llvm.org/D01234
  - If you forget to add that, close the Phabricator review manually

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Committing a Patch

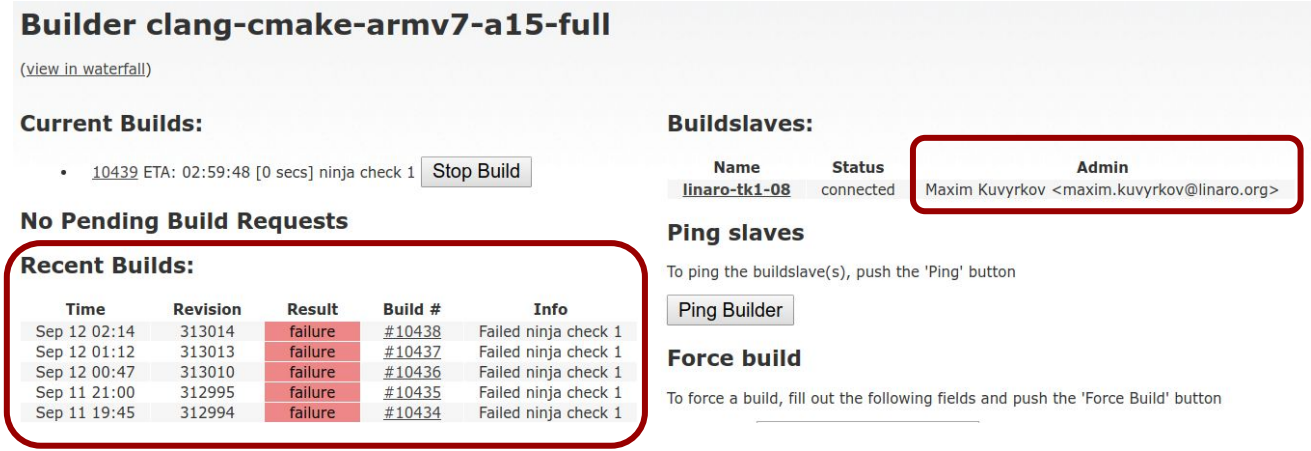
- Patches need to be accepted
- Committing a patch
- Last line of summary - link to Phabricator review
- Please keep an eye on the buildbots

Buildbots

- Different platforms and configurations
  - Hardware, OS, compiler
  - Projects added (compiler-rt, lld, test-suite)
  - Bootstrap / selfhost
- 2-3h for 70-80% of the buildbots
- Blame emails
- IRC chat bots
- Console
  - http://lab.llvm.org:8011/console

Dealing with failures

- Revision ranges
- Ask if unsure!
- Top priority: appeasing the bots
  - Fix or **revert**
  - **Don't be afraid to revert :)**
  - Always mention which revision you're fixing/reverting/reapplying



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Releases

- 2 major releases / year
- 1-2 minor releases in between
- Avoid disruptive changes around the release branch point


UPlanFL N
4x/0.13
∞/– /FN26.5

Developer Tools

- Not for production use!
- There are several of them
- We'll only cover opt, llc, FileCheck
- https://llvm.org/docs/CommandGuide/
  - -help or -help-hidden is often more useful

opt

- Interfaces with the middle-end

- Can use the old (default) pass manager or the new one
- This talk will focus on the old pass manager interface

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Running passes

```
opt -mem2reg -simplify-cfg in.bc -o out.bc
                                 -S -o out.ll
                                 -S -o -

opt -O0 in.ll -S -o out.ll
    -O1
    -O2
    -O3
    -Os
    -Oz

opt -inline -O1 -instcombine in.ll -o out.bc
```

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What Is Run

```
opt -sroa -debug-pass=Structure in.ll [...]

  Pass Arguments: -targetlibinfo -tti -targetpassconfig
                  -assumption-cache-tracker -domtree -sroa
                  -verify -write-bitcode (or -print-module)
  Target Library Information
  Target Transform Information
  Target Pass Configuration
  Assumption Cache Tracker
    ModulePass Manager
      FunctionPass Manager
        Dominator Tree Construction
        SROA
        Module Verifier
      Bitcode Writer (or Print Module IR)
```

What Is Run

```
opt -O3 -debug-pass=Arguments in.ll [...]
   vs
clang -O3 -mllvm -debug-pass=Arguments [...]
```


Debug dumps

```
opt -O3 -debug-only=licm [...]

  LICM hoisting to for.body.lr.ph:
   %1 = load i32, i32* %x, align 4
  LICM hoisting to for.body.lr.ph:
   %wide.trip.count = zext i32 %n to i64
```

http://llvm.org/docs/ProgrammersManual.html#the-debug-macro-and-debug-option

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IR dumps

```
opt -O3 -print-before=loop-vectorize [...]
opt -O3 -print-after=loop-vectorize [...]
```

```
*** IR Dump After Loop Vectorization ***
; Function Attrs: norecurse nounwind readonly
define i32 @f(i32 %x) local_unnamed_addr #0 {
entry:
  %x.addr = alloca i32, align 4
  [...]
}
```

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IR dumps

```
opt -O3 -print-before-all
        -filter-print-funcs=f [...]
opt -O3 -print-after-all [...]
```

```
*** IR Dump After Loop Vectorization ***
; Function Attrs: norecurse nounwind readonly
define i32 @f(i32 %x) local_unnamed_addr #0 {
entry:
  [...]
}
*** IR Dump After Canonicalize natural loops ***
; Function Attrs: norecurse nounwind readonly
define i32 @f(i32 %x) local_unnamed_addr #0 {
entry:
  [...]
}
```

Other Features

- Statistics

  http://llvm.org/docs/ProgrammersManual.html#the-statistic-class-stats-option
  - opt -stats [...]
- Debug counters

  http://llvm.org/docs/ProgrammersManual.html#adding-debug-counters-to-aid-in-debugging-your-code
  - opt --debug-counter=my-counter-skip=1,my-counter-count=3 [...]
- Dot graphs

  http://llvm.org/docs/ProgrammersManual.html#viewing-graphs-while-debugging-code
  - opt -dot-cfg [...] & related flags
  - Function::viewGraph() from a debugger
- Timers http://llvm.org/doxygen/classllvm_1_1Timer.html
  - opt -time-passes [...]

llc

- Interfaces with the backend

- Some of the flags from opt still work
  - E.g. -debug-pass, -debug-only, -print-after-all etc
- Running passes is slightly different
  - `llc -run-pass=machine-scheduler [...]`
- `Partial pipelines`
  - `llc -O3 -stop-before=machine-scheduler [...]`
  - `llc -O3 -start-after=machine-scheduler [...]`
- Caveat: not all passes are registered

Case Study: Instruction selection

- Global ISel - new, still in development
  - Organized as passes, very llc friendly
- DAG ISel - old, default framework
  - Uses its own representation, different from IR and MIR (SelectionDAG)
  - Has some internal steps, but they are not proper passes
    - => special debug flags
  - All the info: llc -debug-only=isel
  - SelectionDAGs after various steps:
    - -view-dag-combine1-dags
    - -view-legalize-types-dags
    - -view-legalize-dags
    - -view-dag-combine2-dags
    - -view-dag-combine-lt-dags
    - -view-isel-dags
    - -view-sched-dags
    - -view-sunit-dags
    - Can be filtered by basic block with -filter-view-dags
  - See SelectionDAGISel::CodeGenAndEmitDAG

Beware of the Flags!

- https://llvm.org/docs/CommandLine.html
- Decentralized system for adding flags
  - Each implementation file can add its own custom flags
- Flags may be accepted but (silently) ignored
  - clang -mllvm -stop-before=machine-scheduler 👍 Actually stops
  - clang -mllvm -stop-before=loop-vectorize 👎 Doesn't stop


Testing LLVM

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Testing LLVM

- https://llvm.org/docs/TestingGuide.html
- Regression tests
  - check-all
  - Should be run before every commit (on a Release build)
  - New functionality => new regression test

Testing LLVM

- https://llvm.org/docs/TestingGuide.html
- Regression tests
- Test-suite
  - Separate repo
  - Lots of applications for testing correctness
  - Some benchmarks
  - Can skip for simple commits

Regression tests

- $PROJECT/unittests
  - Use these for testing APIs
  - Google Test and Google Mock
  - Target for all tests: check-$PROJECT-unit
  - Targets for specific tests: grep for add_$PROJECT_unittest

$PROJECT ∈ { llvm, clang, … }

Regression tests

- $PROJECT/unittests
- $PROJECT/test
  - Use these for everything else
  - opt, llc, llvm-mc etc
  - FileCheck
  - Target for all tests: check-$PROJECT
  - Target for specific tests: check-path-to-test-in-lowercase
    - llvm/test/Transforms/EarlyCSE/AArch64/*.ll
    - check-llvm-transforms-earlycse-aarch64
  - Can also run one test or all tests in one directory with LIT
    - llvm-lit llvm/test/Transforms/EarlyCSE/AArch64/intrinsics.ll
    - llvm-lit llvm/test/Transforms/EarlyCSE

$PROJECT ∈ { llvm, clang, … }

Adding an IR Test

- The easy way: Copy and modify an existing test
  - ...but not a very old one
- The long way:
  - Step 1: Get a clean IR module
  - Step 2: Add RUN lines
  - Step 3: Add CHECK lines

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Adding an IR Test

- The long way: Get a starting point in plain C

```
void f(int *x, int *y,
       int * restrict z, int n) {
  for (int i = 0; i < n; i++)
    z[i] = x[i] + y[i];
}
```

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Adding an IR Test

`clang -O0 -S -emit-llvm vect.c -o vect.ll`

```
; ModuleID = 'vect.c'
source_filename = "vect.c"
target datalayout = "e-m:e-i8:8:32-i16:16:32-i64:64-i128:128-n32
target triple = "aarch64--linux"

; Function Attrs: noinline nounwind optnone
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) #0 {
entry:
  %x.addr = alloca i32*, align 8
  %y.addr = alloca i32*, align 8
  ret void
}

attributes #0 = { noinline nounwind optnone "correctly-rounded-div

!llvm.module.flags = !{!0}
!llvm.ident = !{!1}

!0 = !{i32 1, !"wchar_size", i32 4}
!1 = !{!"clang version 6.0.0 "}
```

Adding an IR Test

```
clang -O0 -S -emit-llvm vect.c -o vect.ll
```

```
; ModuleID = 'vect.c'
source_filename = "vect.c"
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!llvm.module.flags = !{!0}
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```

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Adding an IR Test

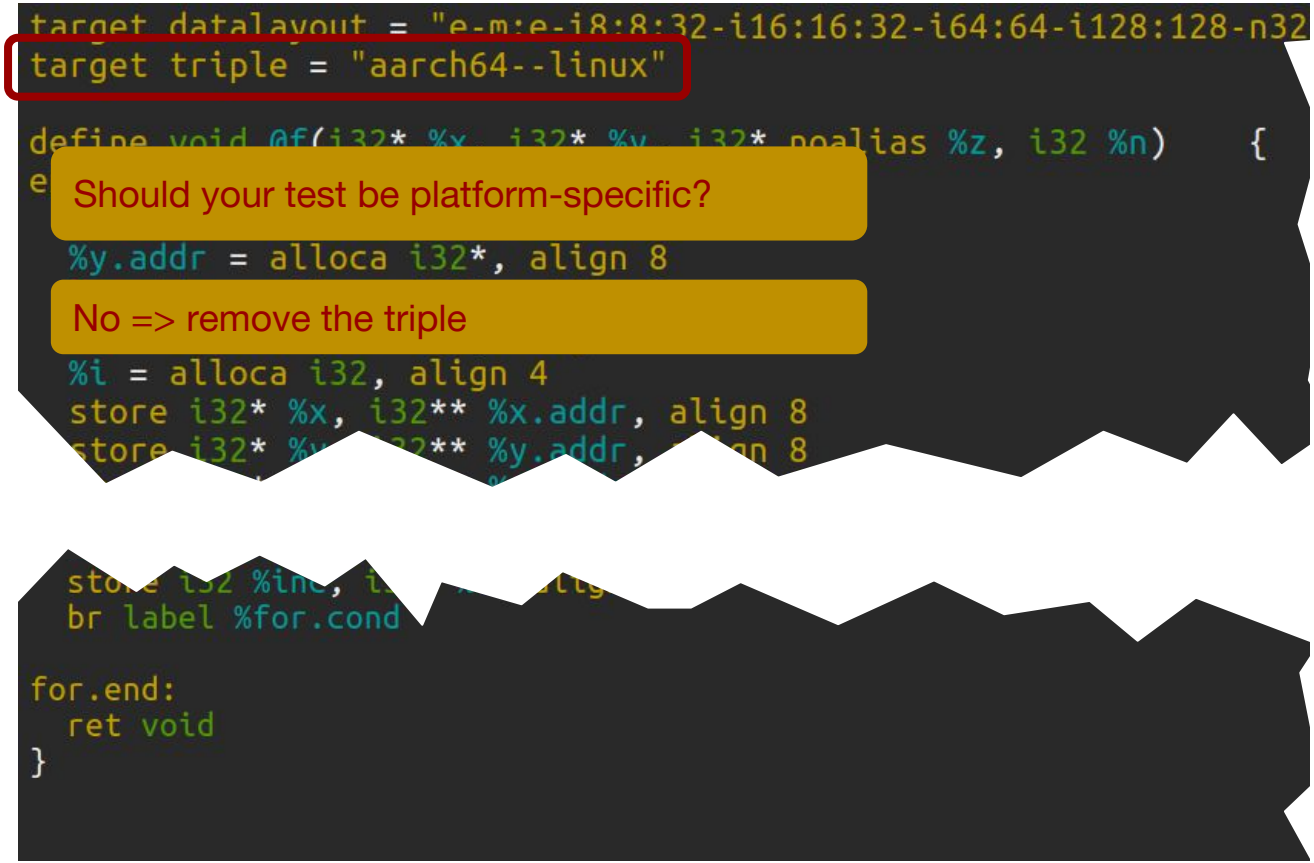
```
target datalayout = "e-m:e-i8:8:32-i16:16:32-i64:64-i128:128-n32
target triple = "aarch64--linux"

define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) #0 {
entry:
  %x.addr = alloca i32*, align 8
  %y.addr = alloca i32*, align 8
  %z.addr = alloca i32*, align 8
  %n.addr = alloca i32, align 4
  %i = alloca i32, align 4
  store i32* %x, i32** %x.addr, align 8
  store i32* %y, i32** %y.addr, align 8
```

```
  br label %for.cond

for.end:
  ret void
}

attributes #0 = { noinline nounwind optnone "correctly-rounded-divid
```

!!!

Adding an IR Test

Adding an IR Test



Adding an IR Test

Should your test be platform-specific?

Yes => put the test in a target dir
E.g. test/Transforms/LoopVectorize/**AArch64**
If you have to create the dir, make sure you copy and update a **lit.local.cfg** file

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Adding an IR Test

```
target datalayout = "e-m:e-i8:8:32-i16:16:32-i64:64-i128:128-n32
target triple = "aarch64--linux"

d                                                    ias %z, i32 %n)    {
e
  %y.addr = alloca i32*, align 8
  %z.addr = alloca i32*, align 8
  %n.addr = alloca i32, align 4
  %i = alloca i32, align 4
  store i32* %x, i32** %x.addr, align 8
  store i32* %                 32** %y.addr,          n 8
```

Should your test care about type alignments, native type sizes, endianness?

```
  br label %for.cond

for.end:
  ret void
}
```

Adding an IR Test

```
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n)    {
entry:
  %x.addr = alloca i32*, align 8
  %y.addr = alloca i32*, align 8
  %z.addr = alloca i32*, align 8
  %n.addr = alloca i32, align 4
  %i = alloca i32, align 4
  store i32* %x, i32** %x.addr, align 8
  store i32* %y, i32** %y.addr, align 8
  store i32* %z, i32** %z.addr, align 8
```

opt can clean these up for you

```
for.inc:
  %10 = load i32, i32* %i, align 4
  %inc = add nsw i32 %10, 1
  store i32 %inc, i32* %i, align 4
  br label %for.cond

for.end:
  ret void
}
```

Adding an IR Test

`opt -mem2reg vect.ll -S -o vect.ll`

```
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
entry:
  br label %for.cond

for.cond:
  %i.0 = phi i32 [ 0, %e
  %cmp = icmp slt i32 %i.
  br i1 %cmp, label %for

for.body:
  %idxprom = sext i32 %i
  %arrayidx = getelement
  %0 = load i32, i32* %arrayidx, align 4
  %idxprom1 = sext i32 %i.0 to i64
  %arrayidx2 = getelementptr inbounds i32, i32* %y, i64 %idxprom1
  %1 = load i32, i32* %arrayidx2, align 4
  %add = add nsw i32 %0, %1
  %idxprom3 = sext i32 %i.0 to i64
  %arrayidx4 =
```

Nice and clean.
You may still want to run other passes to further canonicalize / clean up the code.
E.g. -loop-rotate, -simplifycfg, -instcombine

Alternatively, you can use -print-before on a -O3 run, or edit the file manually.
Run -verify on it before proceeding to make sure the IR is well formed.

Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
entr
  %c
  br i1 %cmp1, label %for.body.lr.ph, label %for.end

for.body.lr.ph:
  br label %for.body

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
  %idxprom1 = sext i32 %i.02 to i64
  %arrayidx2 = getelementptr inbounds i32, i32* %y, i64 %idxprom1
  %1 = load i32, i32* %arrayidx2, align 4
  %add = add nsw i32 %0, %1
  %idxprom3 = sext i32 %i.02 to i64
  %arrayidx4 = getelementptr inbounds i32, i32* %z, i64 %idxprom3
  store i32 %add, i32* %arrayidx4, align 4
```

Add one or more RUN lines

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Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
ent
                                                  label %for.end
fo

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
  %idxprom1 = sext i32 %i.02 to i64
  %arrayidx2 = getelementptr inbounds i32, i32* %y, i64 %idxprom1
  %1 = load i32, i32* %arrayidx2, align 4
  %add = add nsw i32 %0, %1
  %idxprom3 = sext i32 %i.02 to i64
  %arrayidx4 = getelementptr inbounds i32, i32* %z, i64 %idxprom3
  store i32 %add, i32* %arrayidx4, align 4
```

%s = the current file
%t = a temporary file (won't conflict with temporaries for other tests)

See docs for other substitutions

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Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
entry
  %ci
  br                                    r.ph, label %for.end

for.body.lr.ph:
  br label %for.body

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
  %idxprom1 = sext i32 %i.02 to i64
  %arrayidx2 = getelementptr inbounds i32, i32* %y, i64 %idxprom1
  %1 = load i32, i32* %arrayidx2, align 4
  %add = add nsw i32 %0, %1
  %idxprom3 = sext i32 %i.02 to i64
  %arrayidx4 = getelementptr inbounds i32, i32* %z, i64 %idxprom3
  store i32 %add, i32* %arrayidx4, align 4
```

Feeds the input through stdin
=> no path in the ModuleID
=> fewer spurious matches

Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;      | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
;      | FileCheck %s --check-prefixes=CHECK,WIDTH8
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
; CHECK-LABEL: @f
entry:
  %cmp1 = icmp slt i32 0, %
  br i1 %cmp1, label %for.body.lr.ph, label %for.end

for.body.lr.ph:
  br label %for.body

  ; WIDTH4: [[NMODVF:%.*]] = urem i32 %n, 4
  ; WIDTH8: [[NMODVF:%.*]] = urem i32 %n, 8
  ; CHECK: {{%.*}} = sub i32 %n, [[NMODVF]]

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
```

This is what actually checks the results.

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Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH8
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
; CHECK-LABEL:
entry:
  %cmp1 = ic
  br i1 %cmp1, label %for.body.lr.ph, label %for.end

for.body.lr.ph:
  br label %for.body

  ; WIDTH4: [[NMODVF:%.*]] = urem i32 %n, 4
  ; WIDTH8: [[NMODVF:%.*]] = urem i32 %n, 8
  ; CHECK: {{%.*}} = sub i32 %n, [[NMODVF]]

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
```

grep-like tool adapted to LLVM's testing needs

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Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH8
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
  br i1 %cmp1, label %for.body.lr.ph, label %for.end

for.body.lr.ph:
  br label %for.body

  ; WIDTH4: [[NMODVF:%.*]] = urem i32 %n, 4
  ; WIDTH8: [[NMODVF:%.*]] = urem i32 %n, 8
  ; CHECK: {{%.*}} = sub i32 %n, [[NMODVF]]

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
```

Read the test output from stdin

Read the test reference output from the current file

Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
```

```
vector.ph:
  %n.mod.vf = urem i32 %n, 4
  %n.vec = sub i32 %n, %n.mod.vf
  br label %vector.body
```

Expected output for a vector width of 4

```
  br

; WIDTH4: [[NMODVF:%.*]] = urem i32 %n, 4
; WIDTH8: [[NMODVF:%.*]] = urem i32 %n, 8
; CHECK: {{%.*}} = sub i32 %n, [[NMODVF]]

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
```

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Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
```

```
vector.ph:
  %n.mod.vf = urem i32 %n, 4
  %n.vec = sub i32 %n, %n.mod.vf
  br label %vector.body
```

Expected output for a vector width of 4

Actual name relevant for the test
=> Should be used in the checks

```
  br

  ; WIDTH4: [[NMODVF:%.*]] = urem i32 %n, 4
  ; WIDTH8: [[NMODVF:%.*]] = urem i32 %n, 8
  ; CHECK: {{%.*}} = sub i32 %n, [[NMODVF]]

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
```

Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
```

```
vector.ph:
  %n.mod.vf = urem i32 %n, 4
  %n.vec = sub i32 %n, %n.mod.vf
```

Expected output for a vector width of 4

Actual name **not** relevant for the test
=> Better to use a regex

```
; WIDTH4: [[NMODVF:%.*]] = urem i32 %n, 4
; WIDTH8: [[NMODVF:%.*]] = urem i32 %n, 8
; CHECK: {{%.*}} = sub i32 %n, [[NMODVF]]

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
```

Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;       | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
```

```
vector.ph:
  %n.mod.vf = urem i32 %n, 4
  %n.vec = sub i32 %n, %n.mod.vf
  br label %vector.body
```

Expected output for a vector width of 4

```
  br

  ; WIDTH4: [[NM                    i32 %n, 4
  ; WIDTH8: [[NM                    i32 %n, 8
  ; CHECK: {{%.*}} = sub i32 %n, [[NMODVF]]

for.body:
  %i.02 = ph                                  %inc, %for.inc ]
  %idxprom =
  %arrayidx                                   * %x, i64 %idxprom
  %0 = load i32                 * %arrayidx, align 4
```

Unnamed regex

Alternative check if we don't care about the assignment:
; CHECK: sub i32 %n, [[NMODVF]]

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Adding an IR Test

```
; RUN: opt < %s -S -loop-vectorize -force-vector-width=4 \
;      | FileCheck %s --check-prefixes=CHECK,WIDTH4
; RUN: opt < %s -S -loop-vectorize -force-vector-width=8 \
;      | FileCheck %s --check-prefixes=CHECK,WIDTH8
define void @f(i32* %x, i32* %y, i32* noalias %z, i32 %n) {
; CHECK-LABEL: @f
entry:
  %cm
  br                                          %for.end

for.b
  br label %for.body

  ; W
  ; W
  ; C

for.body:
  %i.02 = phi i32 [ 0, %for.body.lr.ph ], [ %inc, %for.inc ]
  %idxprom = sext i32 %i.02 to i64
  %arrayidx = getelementptr inbounds i32, i32* %x, i64 %idxprom
  %0 = load i32, i32* %arrayidx, align 4
```

Helps avoid spurious matches by dividing the file into blocks. Check lines can only match output in the current block.

Protip: Don't name your functions @f :) Label names should only match in one place in the test output. Pick something suggestive (test-vect-add, test-noalias).

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Other FileCheck Features

- https://llvm.org/docs/CommandGuide/FileCheck.html
- CHECK-NEXT
- CHECK-SAME
- CHECK-DAG

Other LIT Features

- https://llvm.org/docs/CommandGuide/lit.html
- LIT_USE_INTERNAL_SHELL
  - Makes it easier to know which RUN line in a test failed
- REQUIRES, UNSUPPORTED, XFAIL

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Adding an MIR Test

- Same principles apply
- Fortunately, you can use -stop-before/after from clang
  - clang -mllvm -stop-before=expand-isel-pseudos -o test.mir [...]
- Unfortunately, that will produce A LOT of output

Adding an MIR Test

- Same principles apply
- Fortunately, you can use -stop-before/after from clang
  - clang -mllvm -stop-before=expand-isel-pseudos -o test.mir [...]
- Unfortunately, that will produce A LOT of output
- IR part
  - In some cases you may be able to remove the whole IR section
  - Otherwise, clean up as you would for opt
  - Replace function bodies with { ret void }

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Adding an MIR Test

- Same principles apply
- Fortunately, you can use -stop-before/after from clang
  - clang -mllvm -stop-before=expand-isel-pseudos -o test.mir [...]
- Unfortunately, that will produce A LOT of output
- IR part
- MIR part
  - Remove any irrelevant function properties
    - alignment? exposesReturnsTwice? frameInfo? fixedStack? etc etc
  - Remove basic block successors (if irrelevant)
    - successors: %bb.6.middle(0x04000000), %bb.5.vector.body(0x7c000000)

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Adding an MIR Test

- Same principles apply
- Fortunately, you can use -stop-before/after from clang
  - clang -mllvm -stop-before=expand-isel-pseudos -o test.mir [...]
- Unfortunately, that will produce A LOT of output
- IR part
- MIR part
- llc caveat
  - Unlike opt, llc produces an output file by default
  - That file will remain in the test directory
  - Next test run => spurious test without RUN lines => buildbot failure
  - Avoid by redirecting the output to stdout, /dev/null or %t

One Last Thing about Debugging...

- Many objects in LLVM have a dump() method
- You can use this in a debugger or as part of your debug dumps

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Thank You

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