Working on LLVM/Clang for Chrome

EDAN75
8 October 2018
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Short bio

I was d04hw@efd.lth.se

Took this course in 2008

Graduated 2010, joined Google

London 2010-2013

Mountain View 2013-2017

Munich 2018-

Working on Clang/LLVM for Chrome

At the programming competition in Lund 2009 ->

Plan for this morning

1. How I ended up at Google and what I work on

   break

2. How LLVM generates code for switch statements

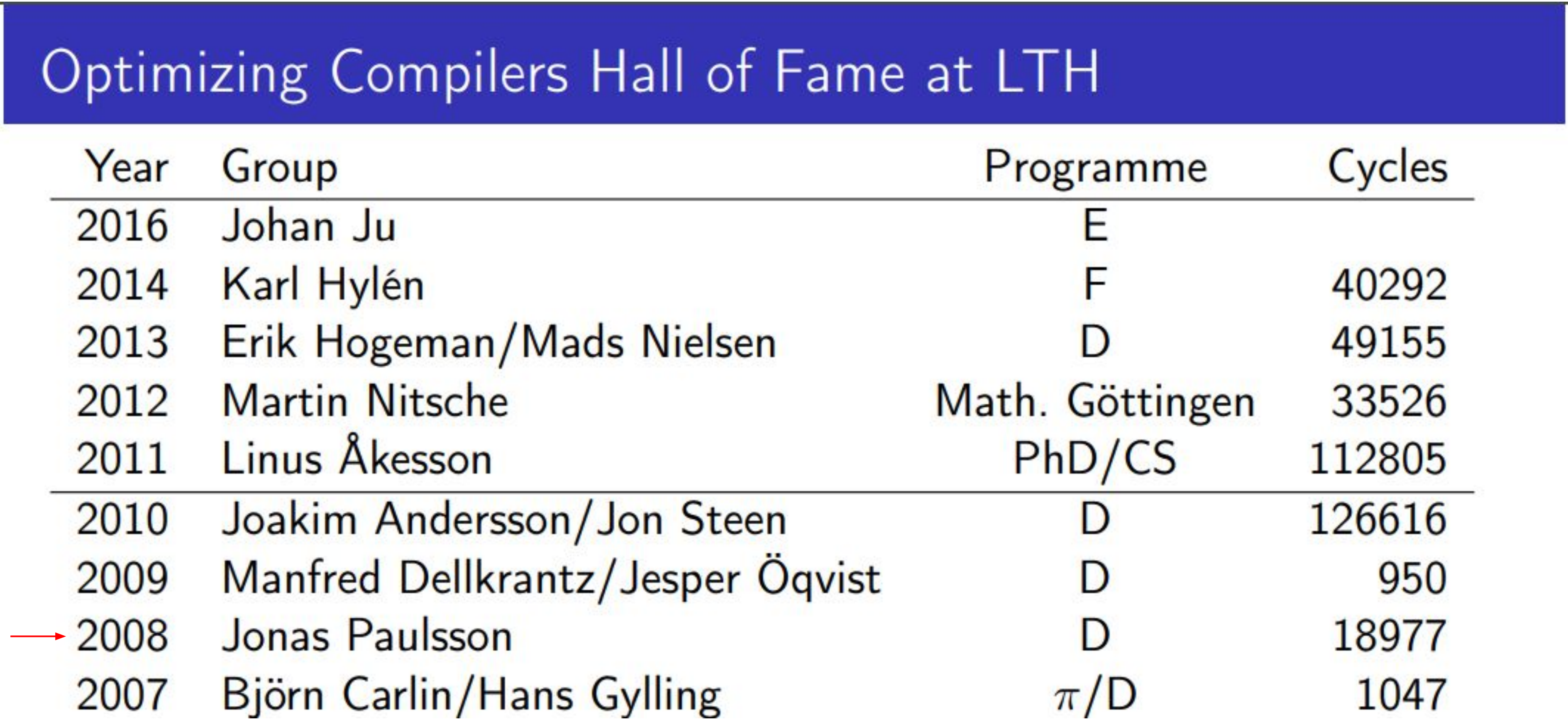
2008: Optimizing Compilers

“Every academically educated computer scientist must know how a computer functions, and must understand the ways and methods in which programs are represented and interpreted. Compilers convert program texts into internal code. Hence they constitute **the bridge between software and hardware**. “

Niklaus Wirth

Compiler Construction

2008: Optimizing Compilers



Optimizing Compilers Hall of Fame at LTH

Year	Group	Programme	Cycles
2016	Johan Ju	E	
2014	Karl Hylén	F	40292
2013	Erik Hogeman/Mads Nielsen	D	49155
2012	Martin Nitsche	Math. Göttingen	33526
2011	Linus Åkesson	PhD/CS	112805
2010	Joakim Andersson/Jon Steen	D	126616
2009	Manfred Dellkrantz/Jesper Öqvist	D	950
2008	Jonas Paulsson	D	18977
2007	Björn Carlin/Hans Gylling	π/D	1047

2009: Master’s Thesis at ARM in Lund

- They do compiler stuff and use LLVM
- Probably even more these days
- Graduation was getting closer
- Considered pursuing PhD but didn’t really have any ideas

“You should try interviewing at Google! The interviews are fun, and you get a free lunch if they bring you on-site.”

2010: Getting hired

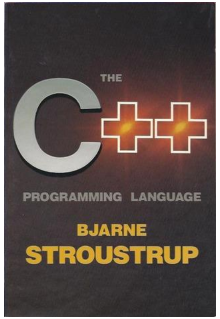
- 22 December 2009: Google phone interview
- 15 January 2010: Presented thesis
- Signed up for ENGA04
- 20 January: On-site interview in London
- 4 February: Google offer of employment
- 29 March, start date

Terminology

Chromium

+ Branding =

Chrome

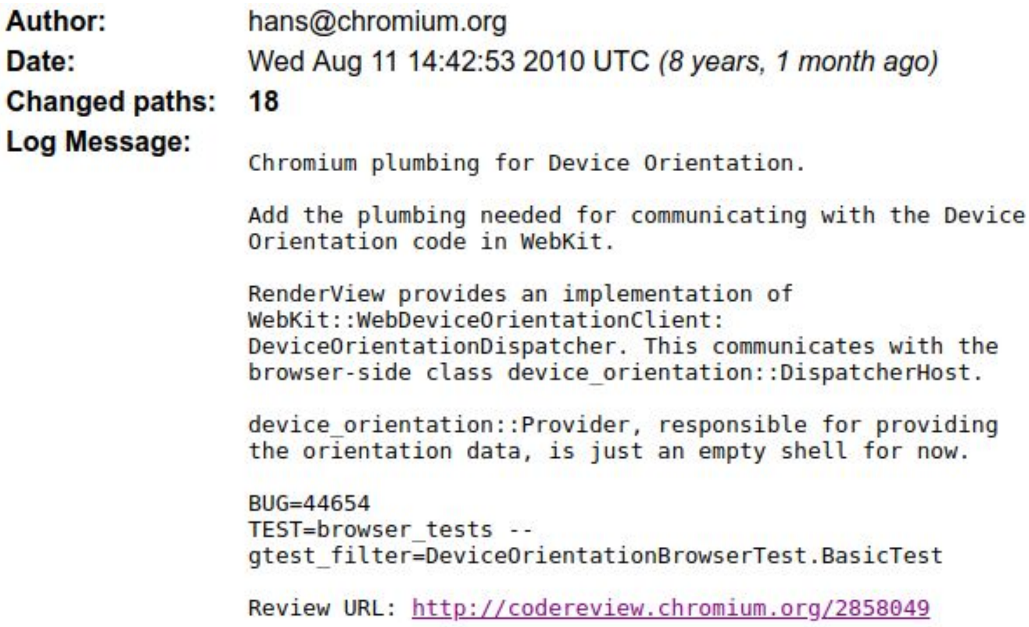


+

= Clang

Starter Project

- Various bug fixes in Chrome
- Implement DeviceOrientation events

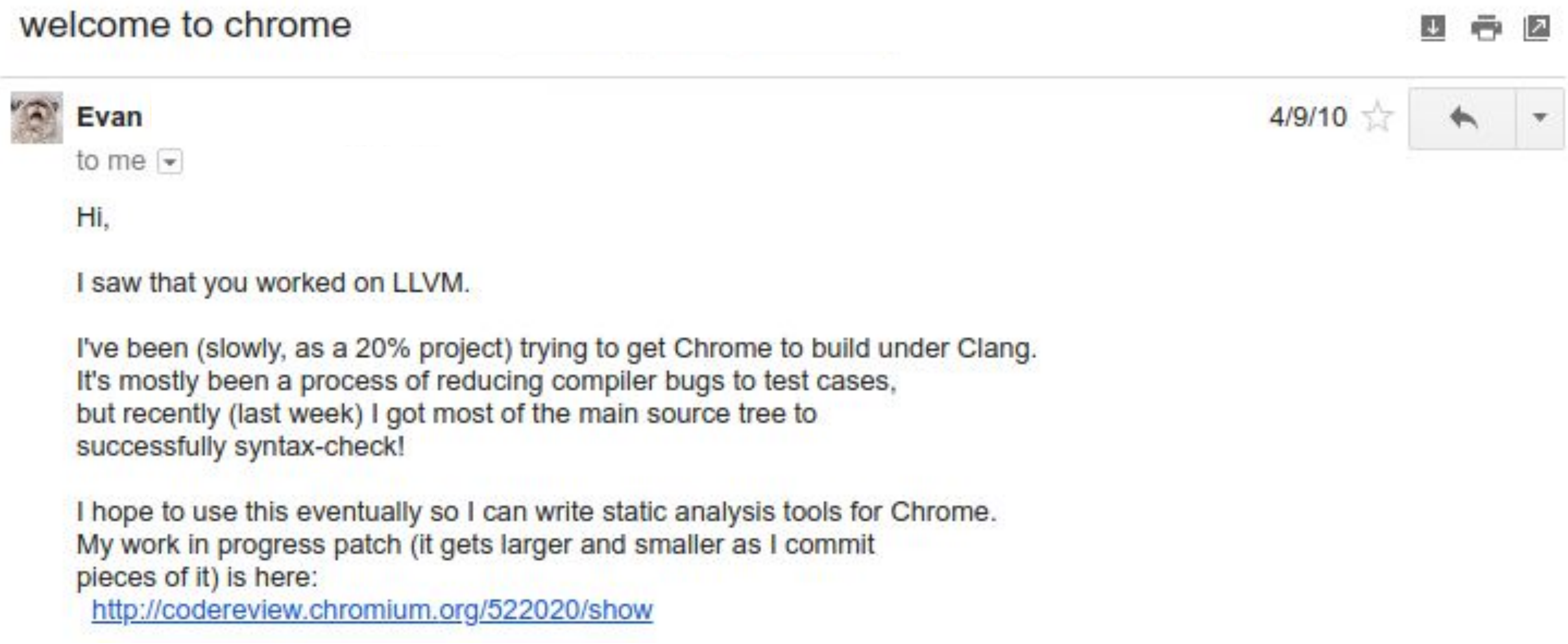


Author:	hans@chromium.org
Date:	Wed Aug 11 14:42:53 2010 UTC *(8 years, 1 month ago)*
Changed paths:	**18**

Log Message:

```
Chromium plumbing for Device Orientation.

Add the plumbing needed for communicating with the Device
Orientation code in WebKit.

RenderView provides an implementation of
WebKit::WebDeviceOrientationClient:
DeviceOrientationDispatcher. This communicates with the
browser-side class device_orientation::DispatcherHost.

device_orientation::Provider, responsible for providing
the orientation data, is just an empty shell for now.

BUG=44654
TEST=browser_tests --
gtest_filter=DeviceOrientationBrowserTest.BasicTest

Review URL: http://codereview.chromium.org/2858049
```

20% Work: Clang



welcome to chrome

Evan

to me

4/9/10

Hi,

I saw that you worked on LLVM.

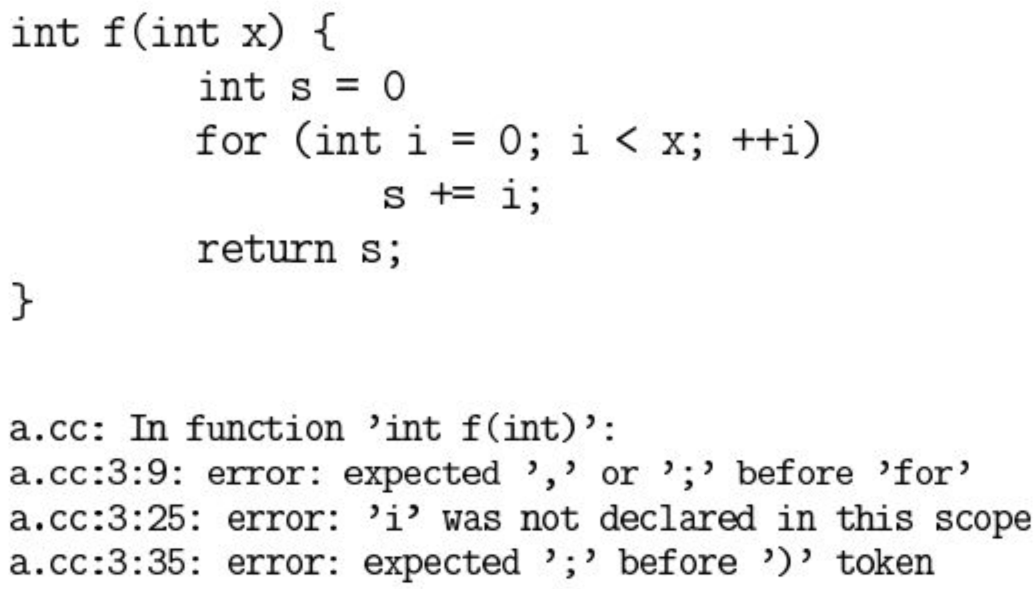
I've been (slowly, as a 20% project) trying to get Chrome to build under Clang.
It's mostly been a process of reducing compiler bugs to test cases,
but recently (last week) I got most of the main source tree to
successfully syntax-check!

I hope to use this eventually so I can write static analysis tools for Chrome.
My work in progress patch (it gets larger and smaller as I commit
pieces of it) is here:
http://codereview.chromium.org/522020/show

20% Work: Clang

- Clang was very new, we were curious
- I was excited to work on something compiler related
- Developers were very excited about better diagnostics
- It was fast
- Designed for hackability

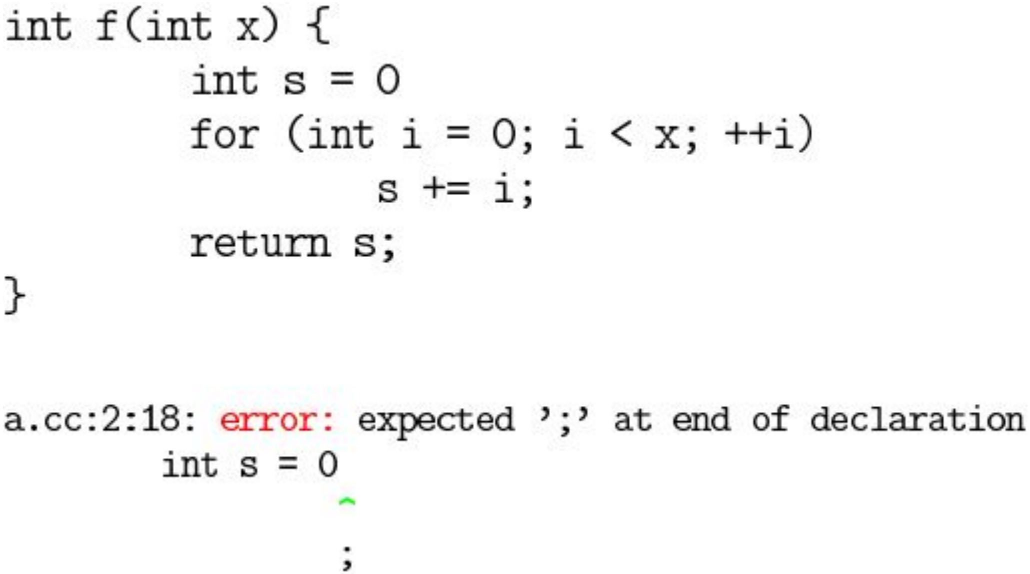
Diagnostics



```
int f(int x) {
        int s = 0
        for (int i = 0; i < x; ++i)
                s += i;
        return s;
}
```

```
a.cc: In function ’int f(int)’:
a.cc:3:9: error: expected ’,’ or ’;’ before ’for’
a.cc:3:25: error: ’i’ was not declared in this scope
a.cc:3:35: error: expected ’;’ before ’)’ token
```

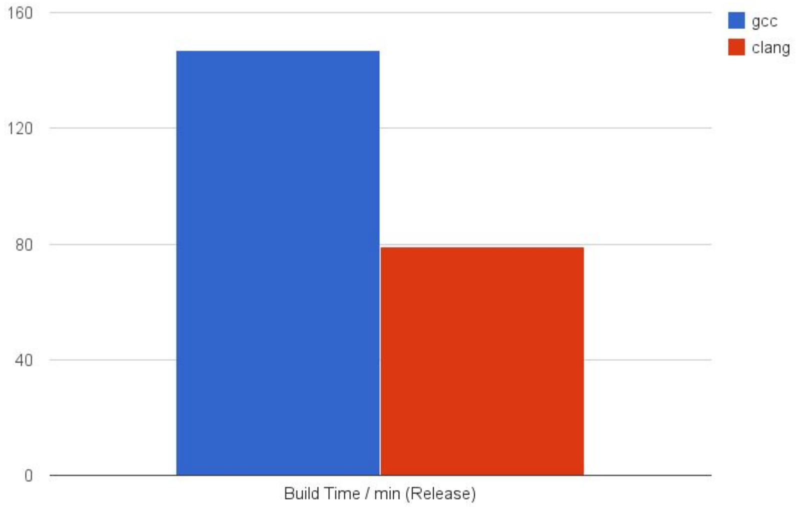
Diagnostics



```
int f(int x) {
        int s = 0
        for (int i = 0; i < x; ++i)
                s += i;
        return s;
}
```

```
a.cc:2:18: error: expected ’;’ at end of declaration
        int s = 0
                 ^
                 ;
```

Build Speed

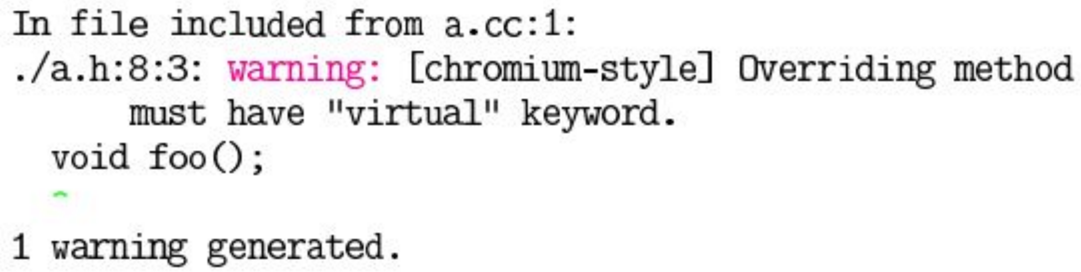


Google

Competition is good

- GCC’s diagnostics have improved a lot since then
- Build speed is more similar

Hackability



```
In file included from a.cc:1:
./a.h:8:3: warning: [chromium-style] Overriding method
      must have "virtual" keyword.
  void foo();
  ^
1 warning generated.
```

What did we have to do?

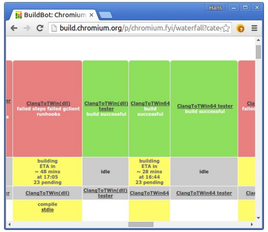
- Fix many C++ errors in Chromium
- Fix many bugs found by Clang’s warnings
- File bugs for Clang
- Fix some ourselves

- Dec 2009: First Chromium patch mentioning Clang
- Sep 2010: Linux and Mac builds work

Results

- Continuous integration with Clang on all platforms (*)
- Many developers use Clang locally
- Chrome 15 for Mac built with Clang (Oct 2011)

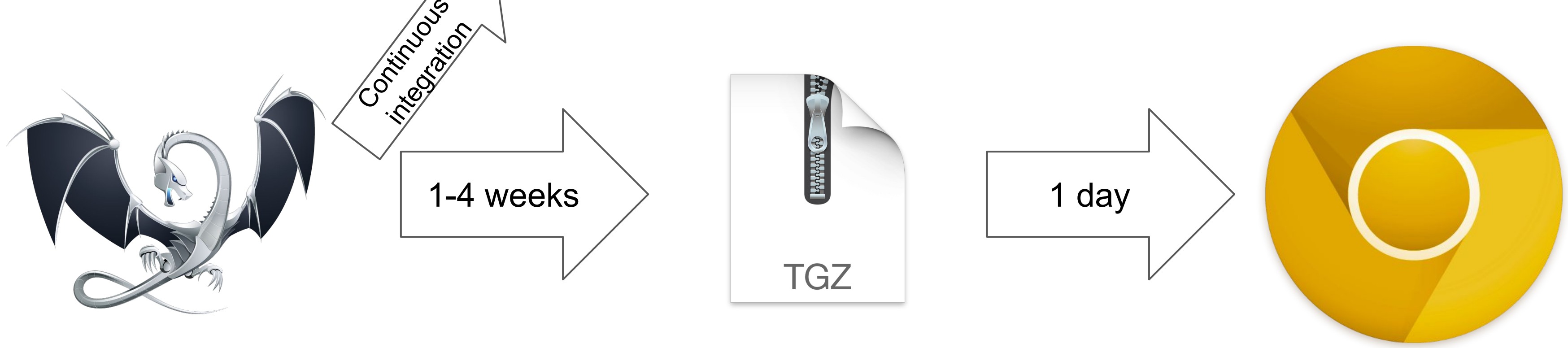
* except Windows



BuildBot: Chromium

build.chromium.org/p/chromium.fyi/waterfall?cate

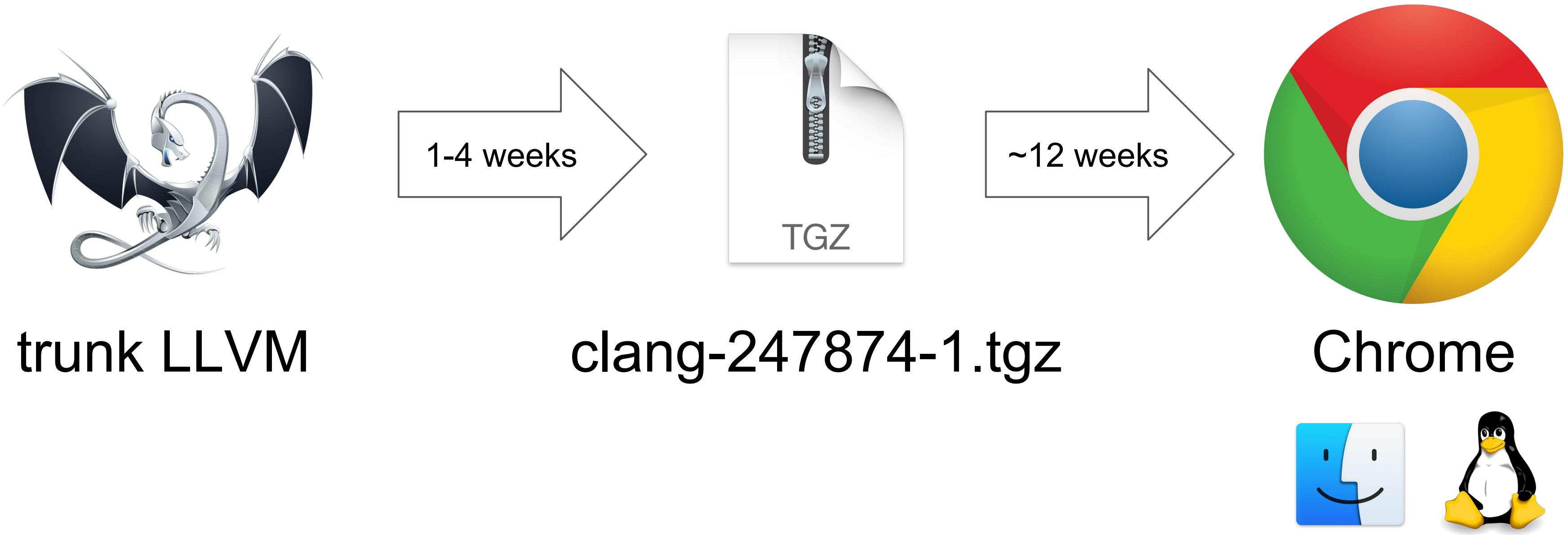
er s	ClangToTWin(dll) failed steps failed gclient runhooks	ClangToTWin(dll) tester build successful	ClangToTWin64 build successful	ClangToTWin64 tester build successful	Cla failed
	building ETA in ~ 48 mins at 17:05 23 pending	idle	building ETA in ~ 28 mins at 16:44 23 pending	idle	
er	ClangToTWin(dll)	ClangToTWin(dll) tester	ClangToTWin64	ClangToTWin64 tester	Cla
	compile stdio				



trunk LLVM

clang-247874-1.tgz

Chrome Canary



trunk LLVM

1-4 weeks

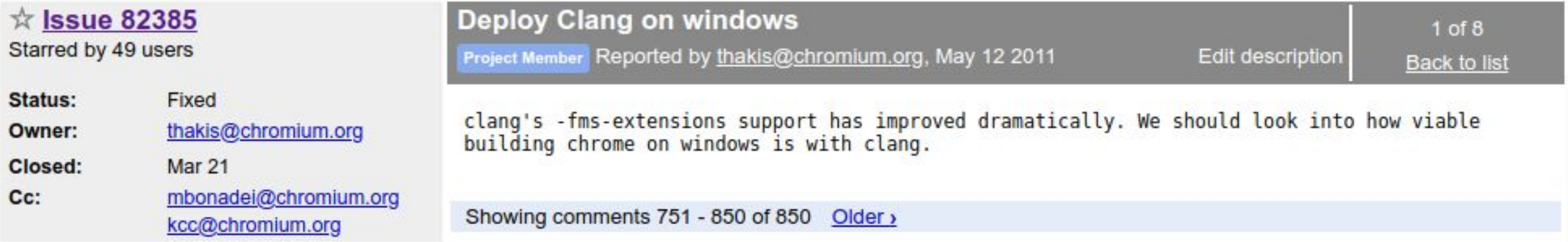
TGZ

clang-247874-1.tgz

~12 weeks

Chrome

Windows



☆ Issue 82385

Starred by 49 users

Status:	Fixed
Owner:	thakis@chromium.org
Closed:	Mar 21
Cc:	mbonadei@chromium.org kcc@chromium.org

Deploy Clang on windows

Project Member Reported by thakis@chromium.org, May 12 2011

```
clang's -fms-extensions support has improved dramatically. We should look into how viable
building chrome on windows is with clang.
```

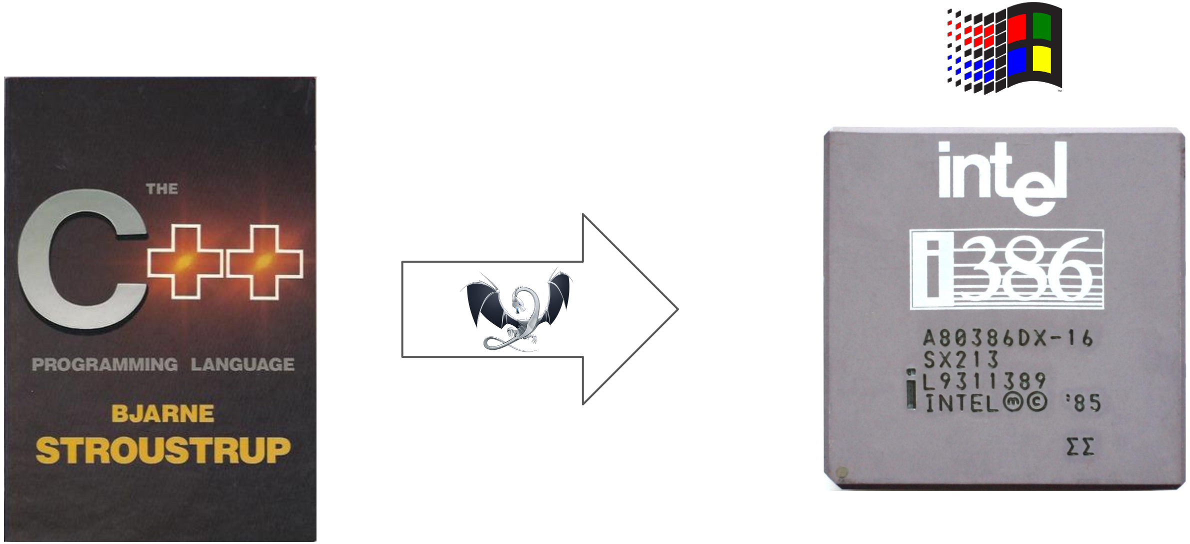
Showing comments 751 - 850 of 850 Older ›

Windows

Lots of good reasons

- Chrome’s largest desktop platform
- Running into limitations of MS Visual C++ compiler and linker
- Want to benefit from our compiler work on all platforms
- New tech: AddressSanitizer, CFI, ThinTLO, …
- Crazy ideas: cross compilation, ...

How hard could it be?



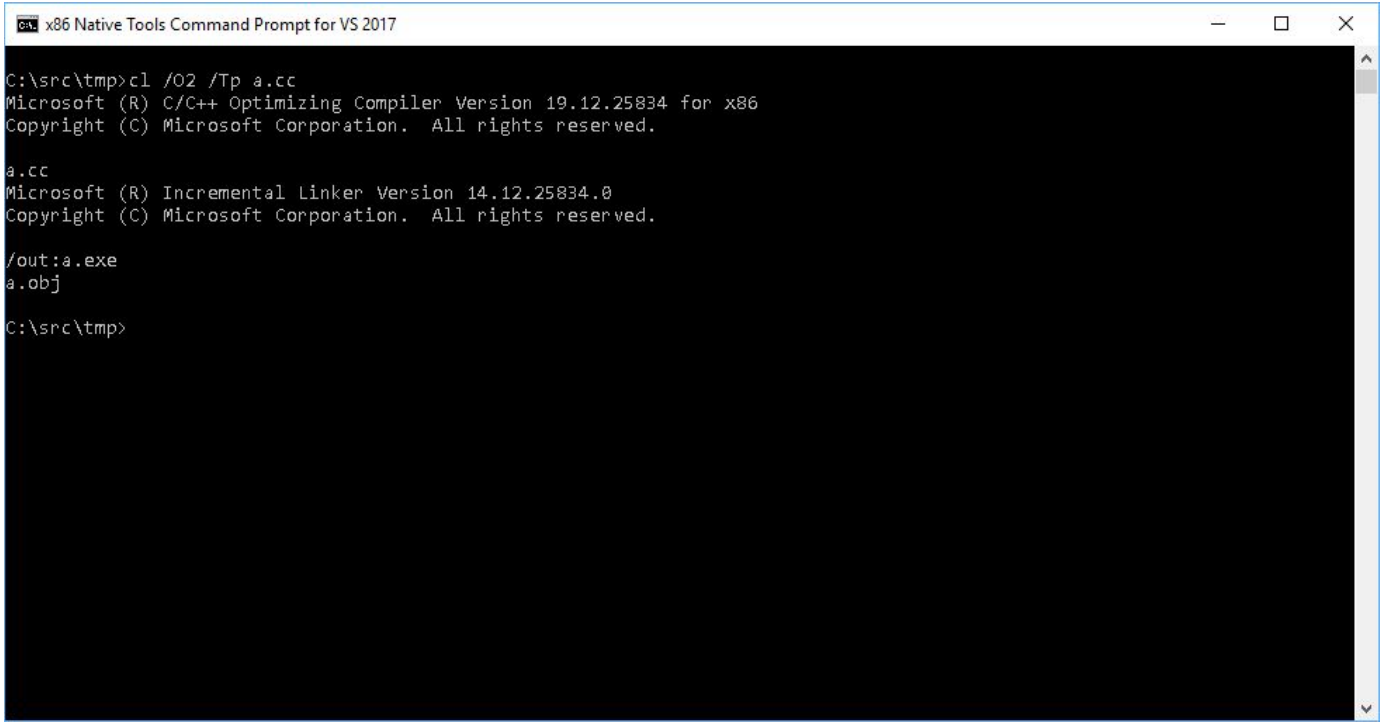
Windows Support Requirements

- Want to compile Chromium w/ Clang on Windows
- Must support compiling MS system headers
- Must be binary compatible, able to link against system libraries
- Binaries must work with existing debugging, profiling, etc. tools
- Build time, binary size and run-time performance must be on par or better
- IDE integration
- Build system integration

What about MinGW?

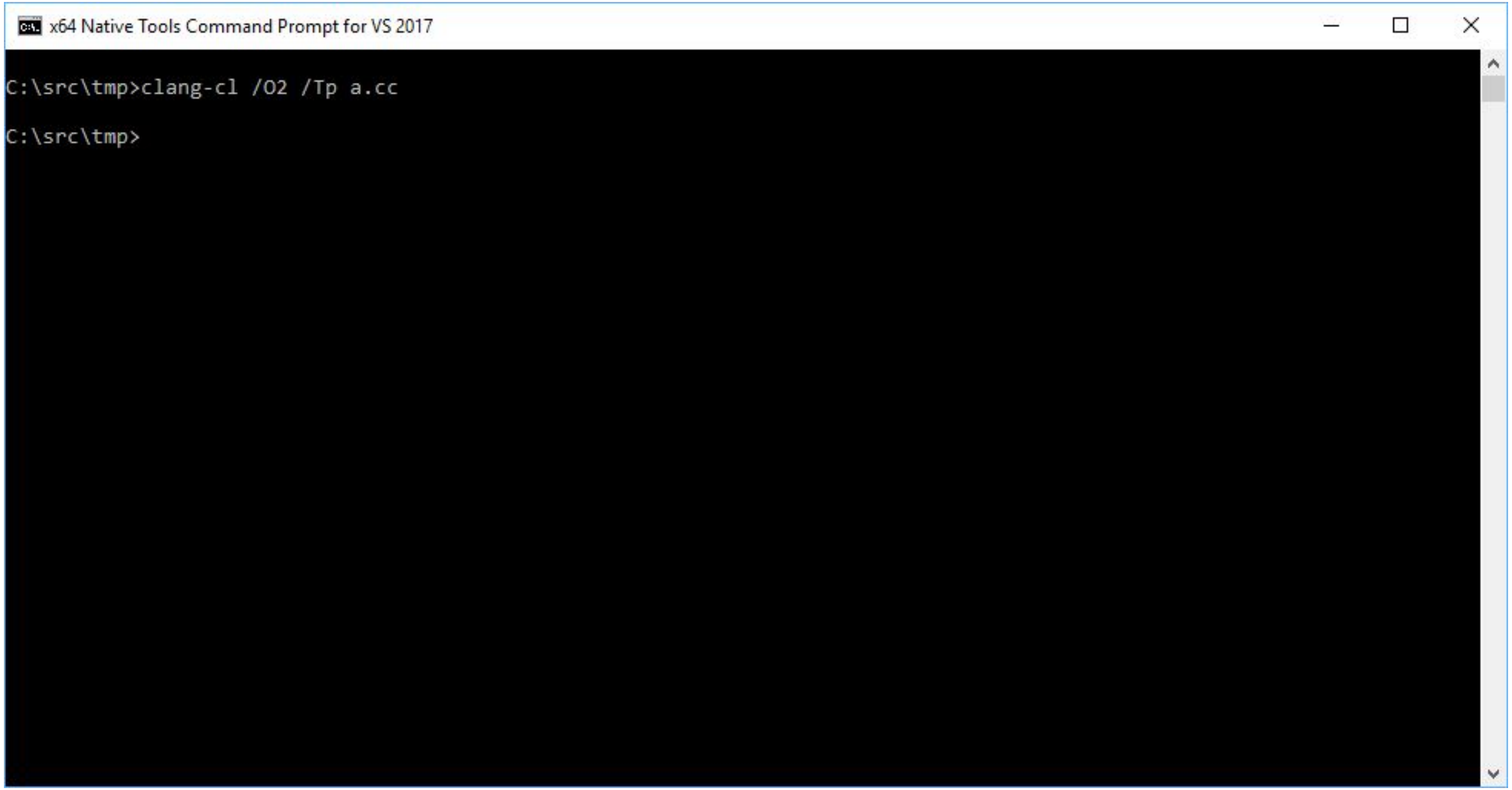
- Minimalist GNU for Windows (MinGW)
- Allows compiling Windows programs with GCC
- Not source compatible (has its own headers)
- Not binary compatible (can’t link against MSVC-built binaries)

Command-line compatibility



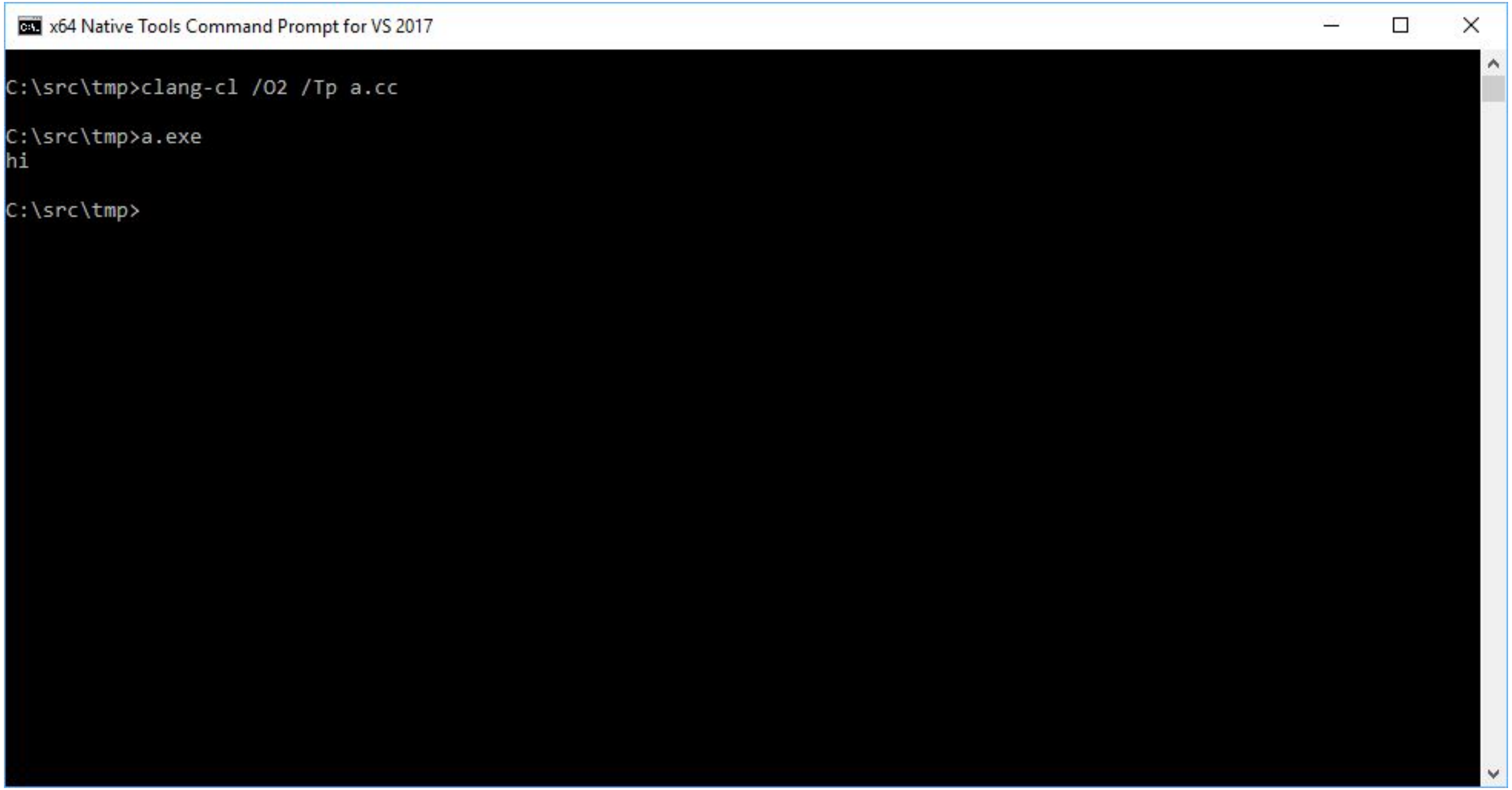
```
C:\src\tmp>cl /O2 /Tp a.cc
Microsoft (R) C/C++ Optimizing Compiler Version 19.12.25834 for x86
Copyright (C) Microsoft Corporation.  All rights reserved.

a.cc
Microsoft (R) Incremental Linker Version 14.12.25834.0
Copyright (C) Microsoft Corporation.  All rights reserved.

/out:a.exe
a.obj

C:\src\tmp>
```

Command-line compatibility



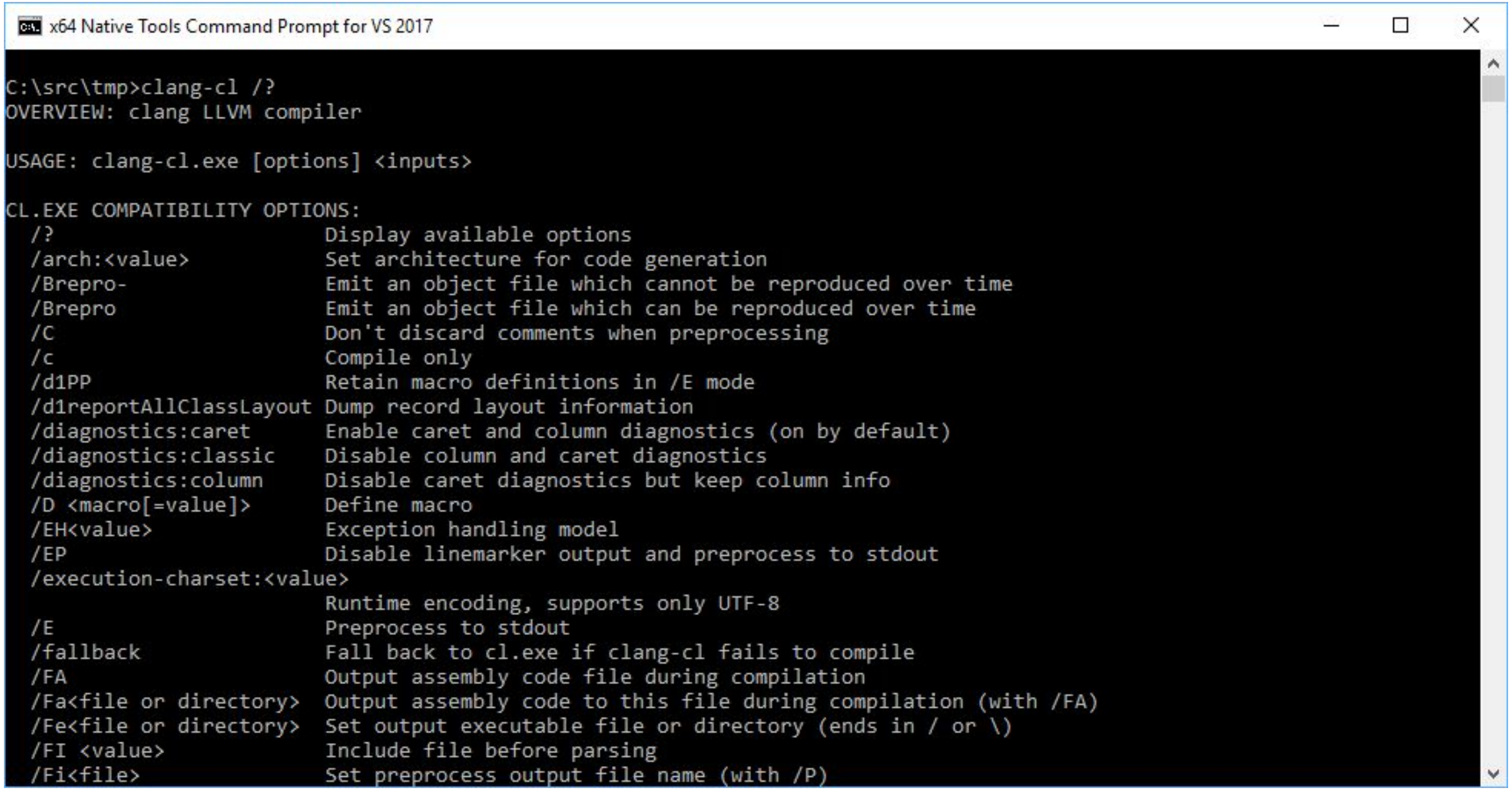
```
C:\src\tmp>clang-cl /O2 /Tp a.cc

C:\src\tmp>
```

Command-line compatibility



```
C:\src\tmp>clang-cl /O2 /Tp a.cc

C:\src\tmp>a.exe
hi

C:\src\tmp>
```

Command-line compatibility



```
C:\src\tmp>clang-cl /?
OVERVIEW: clang LLVM compiler

USAGE: clang-cl.exe [options] <inputs>

CL.EXE COMPATIBILITY OPTIONS:
  /?                      Display available options
  /arch:<value>           Set architecture for code generation
  /Brepro-                Emit an object file which cannot be reproduced over time
  /Brepro                 Emit an object file which can be reproduced over time
  /C                      Don't discard comments when preprocessing
  /c                      Compile only
  /d1PP                   Retain macro definitions in /E mode
  /d1reportAllClassLayout Dump record layout information
  /diagnostics:caret      Enable caret and column diagnostics (on by default)
  /diagnostics:classic    Disable column and caret diagnostics
  /diagnostics:column     Disable caret diagnostics but keep column info
  /D <macro[=value]>      Define macro
  /EH<value>              Exception handling model
  /EP                     Disable linemarker output and preprocess to stdout
  /execution-charset:<value>
                          Runtime encoding, supports only UTF-8
  /E                      Preprocess to stdout
  /fallback               Fall back to cl.exe if clang-cl fails to compile
  /FA                     Output assembly code file during compilation
  /Fa<file or directory>  Output assembly code to this file during compilation (with /FA)
  /Fe<file or directory>  Set output executable file or directory (ends in / or \)
  /FI <value>             Include file before parsing
  /Fi<file>               Set preprocess output file name (with /P)
```

Source Compatibility: Hyrum’s Law

With a sufficient number of users of an API [or compiler],

it does not matter what you promise in the contract:

all observable behaviors of your system

will be depended on by somebody.

(www.hyrumslaw.com)

Source Compatibility: Preprocessor Quirks

```
REM This is a comment :-]
```

Source Compatibility: Preprocessor Quirks

```
#define REM / ## /

REM This is a comment :-]
```

Source Compatibility: Two-Phase Lookup

```
template<int N> int f() { return N + a; }

int a;

void g() { f<4>(); }
```

See http://blog.llvm.org/2009/12/dreaded-two-phase-name-lookup.htm

Source Compatibility: Two-Phase Lookup

```
template<typename T, typename S = Foo> class Class;

class Foo {};

template<typename T, typename S> class Class {};
```

warning: using the undeclared type 'Foo' as a default template argument is a Microsoft extension [-Wmicrosoft-template]

It’s the little differences: Signed enums

```
enum Color { RED, BLACK };

class Node {

  Color color : 1;

};
```

Enum variables are signed on Windows

This is extra surprising in bit-fields

Don’t use enum for bitfields

Platform-specific features: dllexport

When building a DLL:

```
int __declspec(dllexport) foo() { return 42; }
```

When linking against a DLL:

```
int __declspec(dllimport) foo() { return 42; }
```

Platform-specific features: dllexport

```
struct __declspec(dllexport) Class {
  int foo() { return 42; }
};
```

Platform-specific features: dllexport

```
template <typename T> Base {
  int bar() { return 42; }
};
struct __declspec(dllexport) Class : public Base<int> {
  int foo() { return 42; }
};
```

Binary Compatibility

- Application Binary Interface (ABI)
- Defines how pieces of code interact at the binary level
- For non-Windows this is mostly well documented for C++
- For Windows it is not.

ABI basics: sizes, etc.

- `long` is always 32 bits on Windows
- `long` is 32 or 64 bits on Mac/Linux on `x86`/`x86_64`
- ...

ABI: Name Mangling

Symbols are linked together by name

```
int foo() { return 42; }
```

In C, this symbol will be called “`foo`” in the object file. (_foo on Windows)

In C++ it will be “`_Z3foov`” (Mac/Linux/...) or “`?foo@@YAHXZ`” (Windows)

ABI: Name Mangling

- Linux, Mac: Itanium C++ ABI section 5.1
- Windows: look at compiler output and figure it out

ABI: Name Mangling, Why?

In C++ many functions can have the same name:

```
int foo(int);

int foo(double);

namespace ns { int foo(); }

class C { int foo(); };
```

ABI: Name Mangling, Why?

In C++ many functions can have the same name:

```
int foo(int); // ?foo@@YAHH@Z

int foo(double); // ?foo@@YAHN@Z

namespace ns { int foo(); } // ?foo@ns@@YAHXZ

class C { int foo(); }; // ?foo@C@@QAEHXZ
```

Microsoft refers to this as “decoration” rather than “mangling”.

Name Mangling: Static Locals

```
inline void foo(bool b) {
  if (b) {
    static int x = use(&b);  // ?x@?4??foo@@YAX_N@Z@4HA
  } else {
    static int x = use(&b);  // ?x@?6??foo@@YAX_N@Z@4HA
  }
}
```

Name Mangling: Static Locals

```
inline void foo(bool b) {
  if (b) {
    static int x = use(&b);  // ?x@?4??foo@@YAX_N@Z@4HA
  }
  static int x = use(&b);    // ?x@?4??foo@@YAX_N@Z@4HA
}
a.obj : fatal error LNK1179: invalid or corrupt file
```

Fixed in Visual Studio 2015

ABI: Calling Conventions

```
struct S {
  int f(int a) { return x + a; }
  int x;
};
```

32-bit Linux/Mac: `this` and a both on the stack, return in `%EAX` (classic C-style call)

Windows: `this` in `%ECX`, a on the stack, return value in `%EAX`   (`__thiscall`)

32-bit Win also has `__stdcall`, `__fastcall`, `__vectorcall`

Record Layout

```
struct S {
  char c;
  int i;
  unsigned x : 1;
  unsigned y : 1;
};
```

```
Windows:
 0 | struct S
 0 |   char c
 4 |   int i
 8 |   unsigned int x
 8 |   unsigned int y
```

```
Linux:
 0 | struct S
 0 |   char c
 4 |   int i
 8 |   unsigned int x
 8 |   unsigned int y
```

Record Layout: Inheritance

```
struct A { int a; };

struct B { int b; };

struct C : public A,

           public B {

  int c;

};
```

```
Windows:

 0 | struct C

 0 |  struct A (base)

 0 |   int a

 4 |  struct B (base)

 4 |   int b

 8 |  int c
```

```
Linux:

0 | struct C

0 |  struct A (base)

0 |   int a

4 |  struct B (base)

4 |   int b

8 |  int c
```

Record Layout: Mysterious Padding

```
struct S {
  virtual void f();
  int i;
  double d;
};
```

```
Windows:
 0 | struct S
 0 |  (S vftable ptr)
 8 |  int i
16 |  double d
```

```
Linux:
0 | struct S
0 |  (S vtable ptr)
4 |  int i
8 |  double d
```

Virtual Functions

```
struct S {
  virtual void f();
};
void foo(S *s) {
  s->f();
}
```

```
Windows:
0 | struct S
0 |   (S vftable pointer)
VFTable for 'S' (2 entries).
0 | S RTTI
1 | void S::f()
```

```
Linux:
0 | strut S
0 |   (S vtable pointer)
Vtable for 'S' (3 entries).
0 | offset_to_top (0)
1 | S RTTI
-- (S, 0) vtable address --
2 | void S::f()
```

Pointers to Members

```
struct S {
  void f();
  int x;
};
struct T { void g(); };
struct U : public S, public T { };
typedef void (U::*UMemPtr)(void);
UMemPtr p1 = &U::f; // = { &f, 0 }
UMemPtr p2 = &U::g; // = { &g, 4 }
```

Pointers to Virtual Member Functions (Linux)

```
struct S {
  virtual void f();
  virtual void g();
};
typedef void (S::*SMemPtr)(void);
SMemPtr p1 = &S::f; // = { 1, 0 }
SMemPtr p2 = &S::g; // = { 5, 0 }
```

Pointers to Virtual Member Functions (Windows)

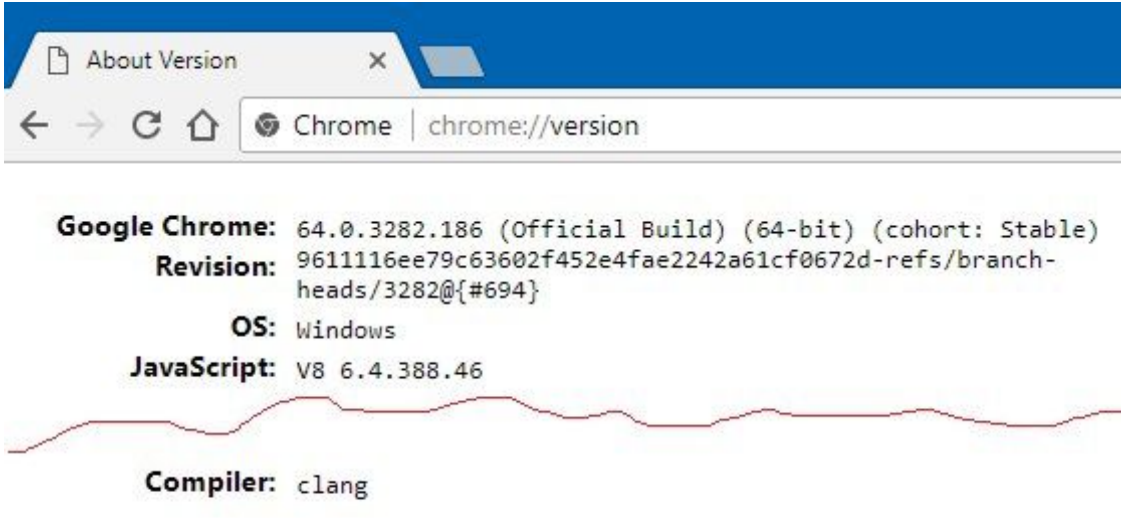
```
struct S {
  virtual void f();
};
typedef void (S::*SMemPtr)(void);
SMemPtr p1 = &S::f; // = { ??_9S$BAAE, 0 }
??_9S$BA@AE:
  ; Call 1st function in S's vftable.
  movl (%ecx), %eax
  jmp *(%eax)
```

And many other issues

- Object file format: ELF (Linux), Mach-O (Mac), COFF (Windows)
- Debug info format: DWARF (Linux, Mac), CodeView (Windows)
- Debug info container format: PDB

Results

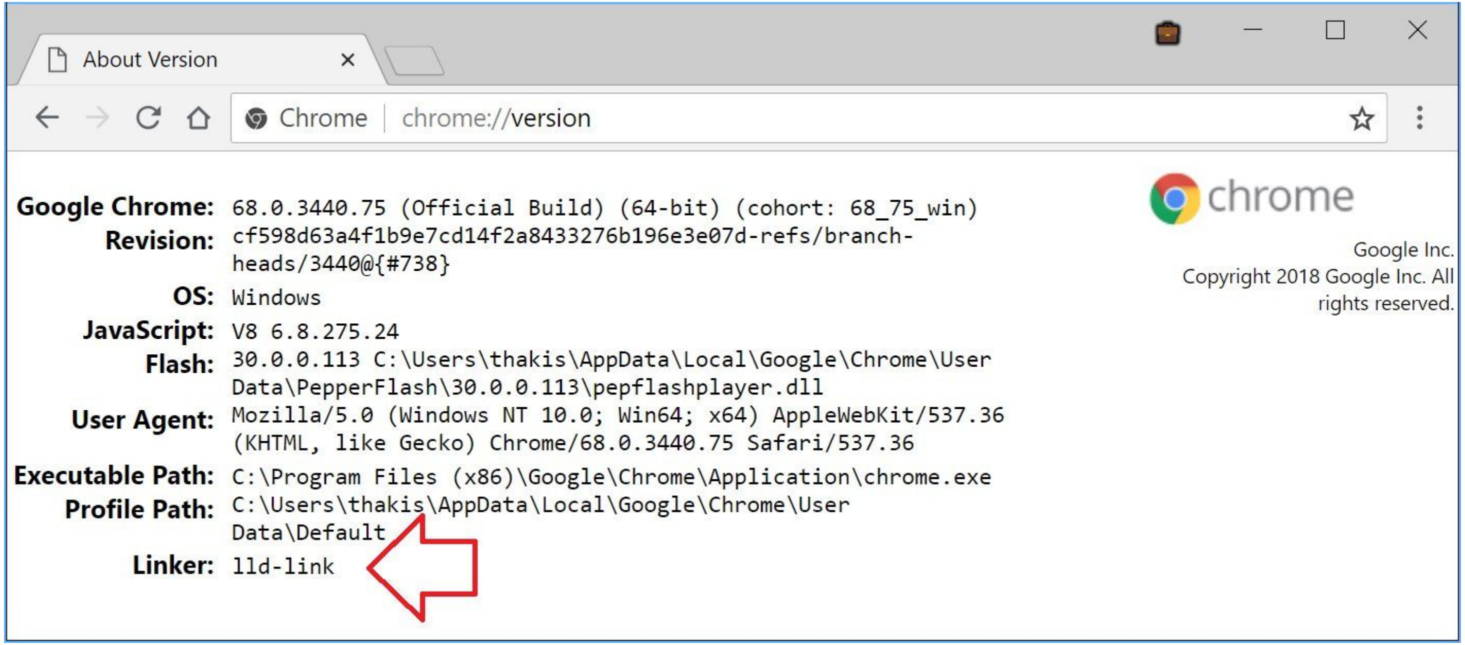
February 2018



```
Google Chrome: 64.0.3282.186 (Official Build) (64-bit) (cohort: Stable)
     Revision: 9611116ee79c63602f452e4fae2242a61cf0672d-refs/branch-
               heads/3282@{#694}
           OS: Windows
   JavaScript: V8 6.4.388.46

     Compiler: clang
```

Results

August 2018



```
     Google Chrome: 68.0.3440.75 (Official Build) (64-bit) (cohort: 68_75_win)
          Revision: cf598d63a4f1b9e7cd14f2a8433276b196e3e07d-refs/branch-
                    heads/3440@{#738}
                OS: Windows
        JavaScript: V8 6.8.275.24
             Flash: 30.0.0.113 C:\Users\thakis\AppData\Local\Google\Chrome\User
                    Data\PepperFlash\30.0.0.113\pepflashplayer.dll
        User Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36
                    (KHTML, like Gecko) Chrome/68.0.3440.75 Safari/537.36
   Executable Path: C:\Program Files (x86)\Google\Chrome\Application\chrome.exe
      Profile Path: C:\Users\thakis\AppData\Local\Google\Chrome\User
                    Data\Default
            Linker: lld-link
```

Google Inc.
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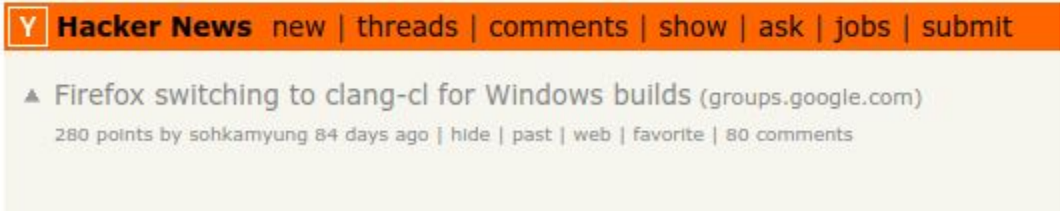
Results

It’s not just us...



Y
Hacker News new | threads | comments | show | ask | jobs | submit

Firefox switching to clang-cl for Windows builds (groups.google.com)

280 points by sohkamyung 84 days ago | hide | past | web | favorite | 80 comments

Results

- Chrome is now on a completely open-source toolchain
- We can fix and improve things ourselves!
- A new alternative for the Windows community
- Also we learned a lot about C++ internals.

Lessons

- Compilers are fun
- Practice your programming skills
- Participate in the programming competition
- …
- Be part of pushing technology forward.