Workshop on Essential Abstractions in GCC

Gray Box Probing of GCC Translation Sequence

GCC Resource Center
(www.cse.iitb.ac.in/grc)

Department of Computer Science and Engineering,
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Outline

- Overview of translation sequence in GCC
- Overview of intermediate representations
- Intermediate representations of programs across important phases

What is Gray Box Probing?

- Black Box probing:
  Examining only the input and output relationship of a system
- White Box probing:
  Examining internals of a system for a given set of inputs
- Gray Box probing:
  Examining input and output of various components/modules of a system

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What is Gray Box Probing?

Notes

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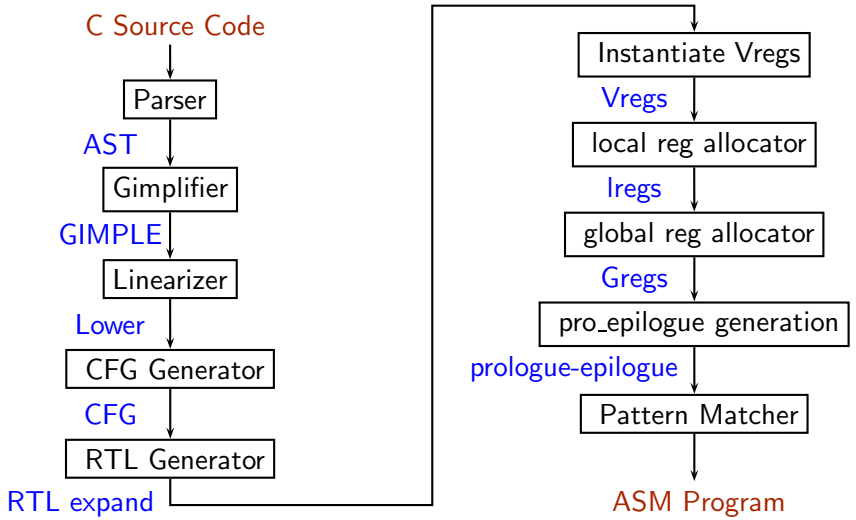
Important Phases of GCC



Lowering of abstraction!

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Important Phases of GCC

Notes

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Phases of GCC

To see output after each pass use the option
`-fdump-<ir>-<pass>`

- `<ir>`
  - `-tree-<pass>`
    - gimple
    - original
    - cfg etc.
    - Use `-all` to see all dumps
  - `-rtl-<pass>`
    - expand
    - greg
    - vreg etc
    - Use `-all` to see all dumps

Example: `gcc -fdump-tree-all -fdump-rtl-all test.c`

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Phases of GCC

Notes

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GCC Internal Representation

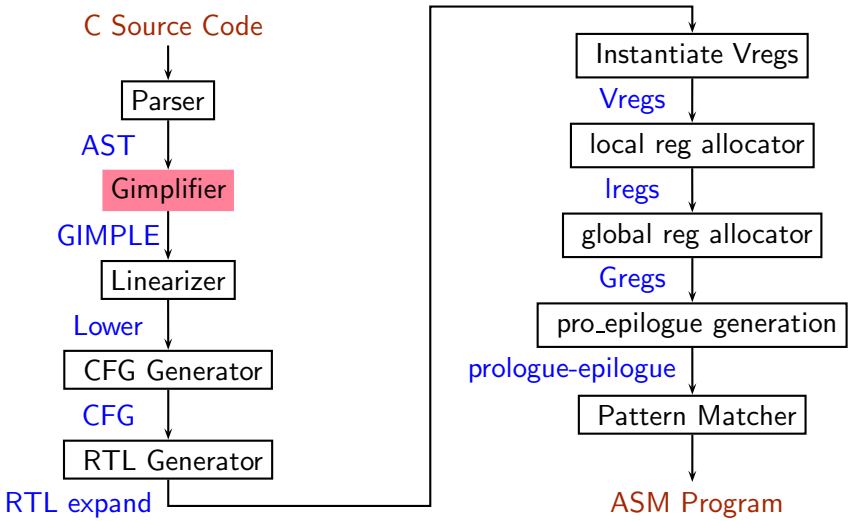
Example: test.c

```
int main()
{
    int a=2, b=3, c=4;
    while (a<=7)
    {
        a = a+1;
    }
    if (a<=12)
        a = a+b+c;
}
```

GCC Internal Representation

Notes

Important Phases of GCC



Important Phases of GCC

Notes

Gimplifier

- Three-address representation derived from GENERIC by breaking down into tuples of no more than 3 operands
- Temporaries are introduced to hold intermediate values needed to compute complex expressions.
- Control structures are explicated into conditional jumps.

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Gimplifier

Notes

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Gimple

Gimple

```
goto <D.1197>;
<D.1196>:;
a = a + 1;
<D.1197>:;
if (a <= 7)
{
      goto <D.1196>;
}
else
{
      goto <D.1198>;
}
<D.1198>:;
```

Source

```
while (a <= 7)
{
    a = a+1;
}
```

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Gimple

Notes

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Gimple

Gimple

```
if (a <= 12)
{
     D.1199 = a + b;
     a = D.1199 + c;
}
else
{
}
```

Source

```
if (a <= 12)
{
    a = a+b+c;
}
```


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Gimple

Notes

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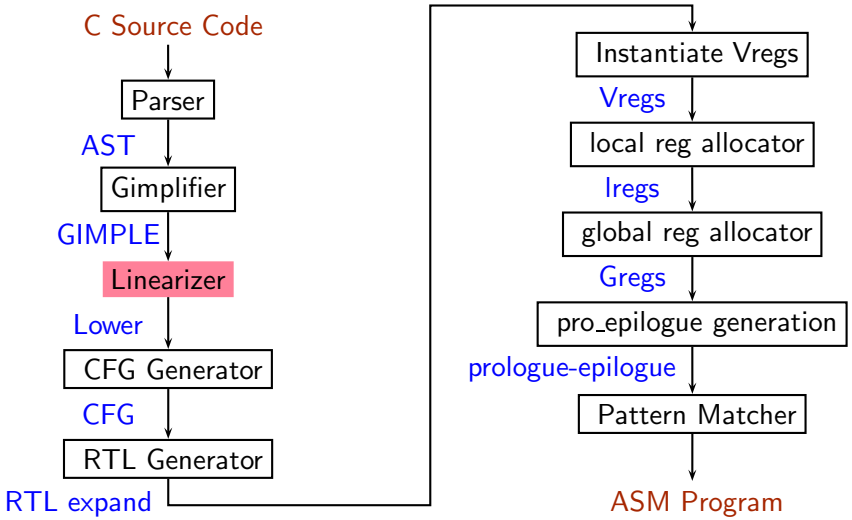
Important Phases of GCC



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Important Phases of GCC

Notes

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Gimple - Lower

Lower

```
if (a <= 12) goto <D.1200>;
else  goto <D.1201>;
<D.1200>:;
D.1199 = a + b;
a = D.1199 + c;
<D.1201>:;
return;
```

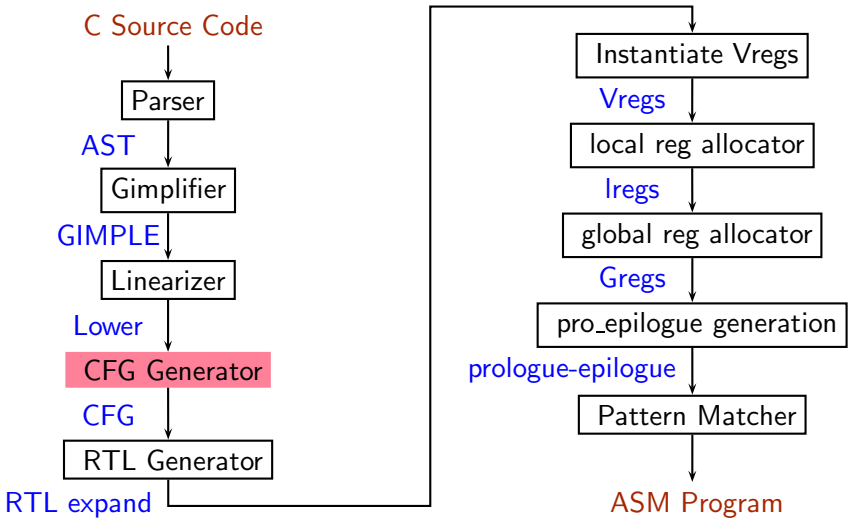
Gimple

```
if (a <= 12)
{
     D.1199 = a + b;
     a = D.1199 + c;
}
```


Gimple - Lower

Notes

Important Phases of GCC



Important Phases of GCC

Notes

Lower - CFG

CFG

```
# BLOCK 5
if (a <= 7)
    goto <bb 6>;
else
    goto <bb 7>;
# SUCC: 6 (true) 7 (false)
# BLOCK 6
D.1199 = a + b;
a = D.1199 + c;
# SUCC: 7 (fallthru)
# BLOCK 7
return;
# SUCC: EXIT
```

Lower

```
if (a <= 12) goto <D.1200>;
else  goto <D.1201>;
<D.1200>:;
D.1199 = a + b;
a = D.1199 + c;
<D.1201>:;
return;
```

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Lower - CFG

Notes

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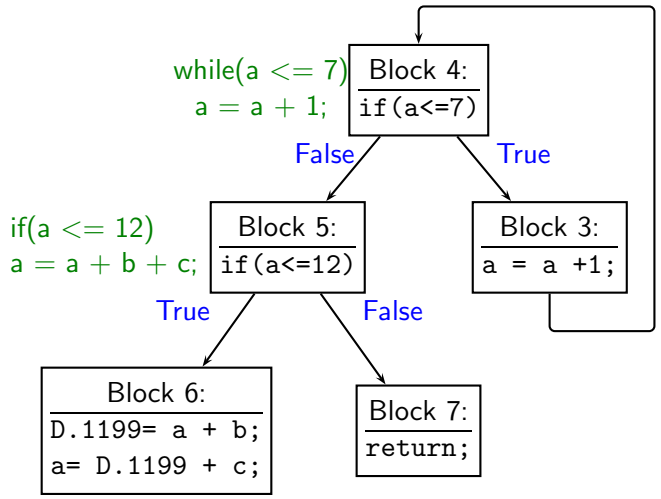
Control Flow Graph



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Control Flow Graph

Notes

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Decisions that have been taken

- Three-address representation is generated
- All high level control flow structures are made explicit.
- Source code divided into interconnected blocks of sequential statements.
- This is a convenient structure for later analysis.

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Decisions that have been taken

Notes

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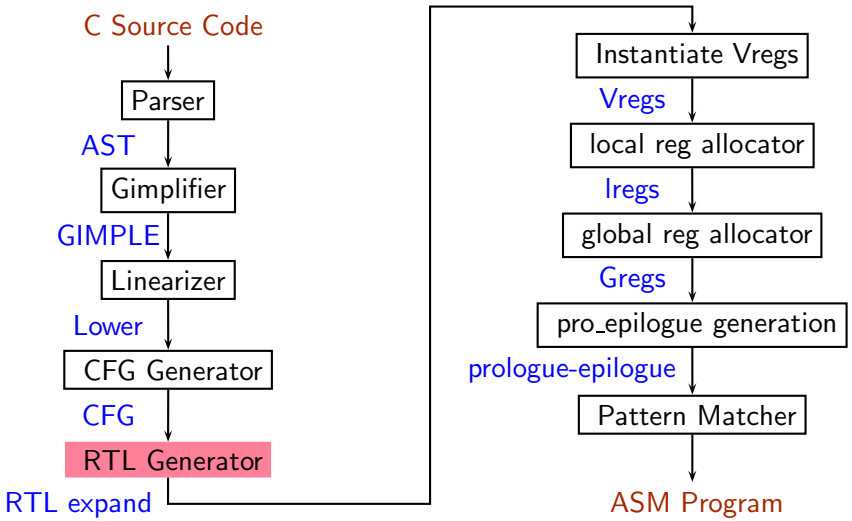
Important Phases of GCC



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Important Phases of GCC

Notes

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CFG - RTL Expand

stack($fp - 4) = stack($fp - 4) + 1
|| flags=?

```
(insn 12 11 0 test.c:6 (parallel [
   (set (mem/c/i:SI (plus:SI
            (reg/f:SI 54 virtual-stack-vars)
            (const int -4 [...])) [...])
        (plus:SI
            (mem/c/i:SI (plus:SI
                (reg/f:SI 54 virtual-stack-vars)
                (const int -4 [...])) [...])
            (const int 1 [...])))
  (clobber (reg:CC 17 flags))
  ]) -1 (nil))
```


CFG - RTL Expand

Notes

RTL in Spim

a = a + 1;

Expr:
r39=stack($fp - 4)
r40=r39+1
stack($fp - 4)=r40

```
(insn 7 6 8 test.c:6 (set (reg:SI 39)
      (mem/c/i:SI (plus:SI (reg/f:SI 33 virtual-stack-vars)
            (const_int -4 [...])) [...])) -1 (nil))
(insn 8 7 9 test.c:6 (set (reg:SI 40)
      (plus:SI (reg:SI 39)
           (const_int 1 [...]))) -1 (nil))
(insn 9 8 0 test.c:6 (set
      (mem/c/i:SI (plus:SI (reg/f:SI 33 virtual-stack-vars)
           (const_int -4 [...])) [...])
      (reg:SI 40)) -1 (nil))
```


RTL in Spim

Notes

RTL generation

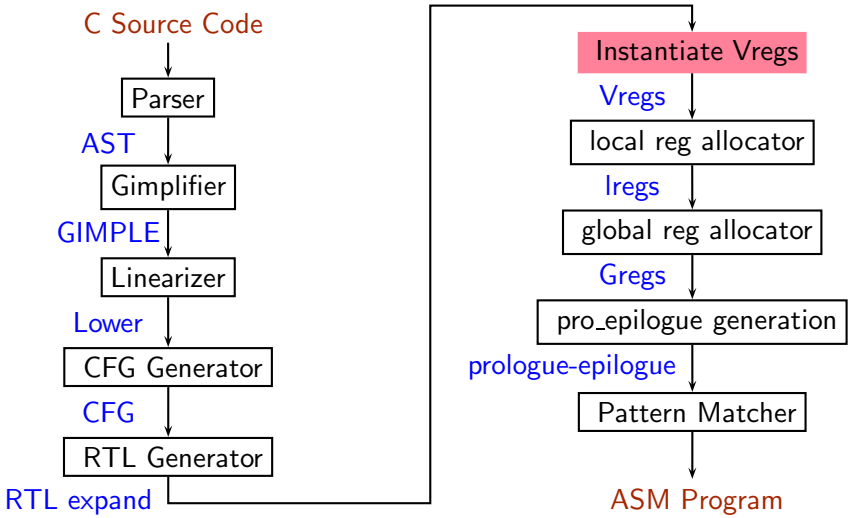
Decisions that are already taken

- A virtual stack is generated.
- RTL instruction is dependant upon architecture.
- Position of each variable is fixed with reference to frame pointer.

RTL generation

Notes

Important Phases of GCC



Important Phases of GCC

Notes

RTL Expand - Vreg

```
(insn 7 6 8 3 (set (reg:SI 39)
        (mem/c/i:SI (plus:SI (reg/f:SI 1 $at )
    (const_int -4 [...])) [...])) 4 *IITB_move_from_mem (nil))
(insn 8 7 9 3 (set (reg:SI 40)
        (plus:SI (reg:SI 39)
    (const_int 1 [...])))  12 addsi3 (nil))
(insn 9 8 18 3 (set (mem/c/i:SI (plus:SI (reg/f:SI 1 $at )
              (const_int -4 [...])) [])
        (reg:SI 40)) 5 *IITB_move_to_mem (nil))
```


RTL Expand - Vreg

Notes

Vregs generation

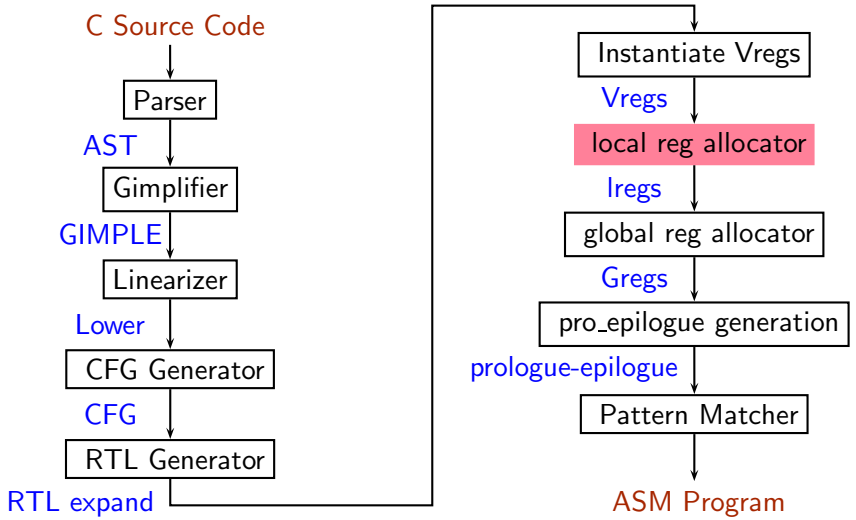
Decisions that are already taken

- Virtual stack is assigned to a hard register.
- Each insn is committed to an instruction in machine description.
- This commitment helps in scheduling, peephole, and assembly code generation.

Vregs generation

Notes

Important Phases of GCC



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Important Phases of GCC

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Vregs - Lregs

```
(insn 7 6 8 2 (set (reg:SI 39)
          (mem/c/i:SI (plus:SI (reg/f:SI 1 $at)
                           (const_int -4 [...])) [...]))
                                4 *IITB_move_from_mem (nil))
(insn 8 7 9 2 (set (reg:SI 40)
                   (plus:SI (reg:SI 39)
                            (const_int 1 [...]))) 12 addsi3
                   (expr_list:REG DEAD (reg:SI 39)(nil)))
(insn 9 8 12 2 (set
                  (mem/c/i:SI (plus:SI (reg/f:SI 1 $at)
                                  (const_int -4 [...])) [...])
                  (reg:SI 40)) 5 *IITB_move_to_mem
                 (expr_list:REG DEAD(reg:SI 40) (nil)))
```


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Vregs - Lregs

Notes

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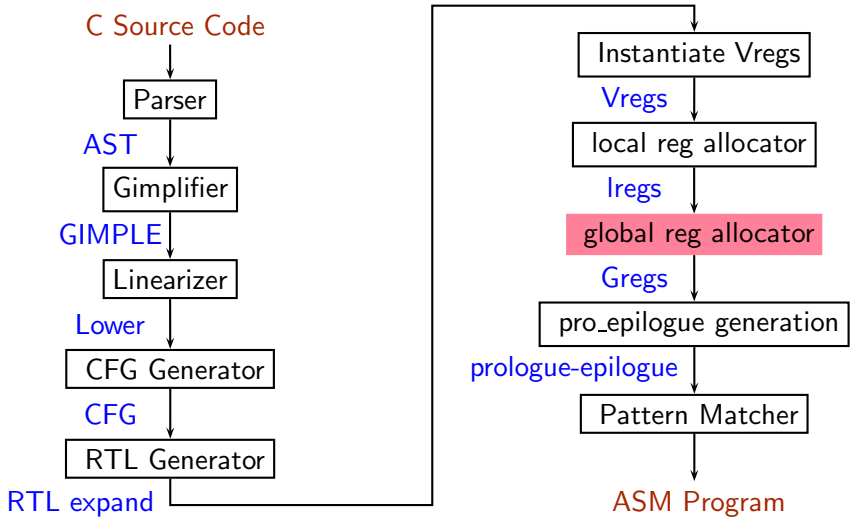
Important Phases of GCC



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Important Phases of GCC

Notes

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Lregs - Gregs

```
(insn 7 6 8 3 test.c:4 (set (reg:SI 2 $v0 [39])
          (mem/c/i:SI (plus:SI (reg/f:SI 1 $fp )
                (const_int -4 [...])) [...]))
                     4 *IITB_move_from_mem (nil))
(insn 8 7 9 3 test.c:4 (set (reg:SI $v0 [40])
          (plus:SI (reg:SI $v0 [39])
                (const_int 1 [...]))) 12 addsi3 (nil))
(insn 9 8 18 3 test.c:4 (set
                (mem/c/i:SI (plus:SI (reg/f:SI 1 $fp )
                        (const_int -4 [...])) [...])
                (reg:SI $v0 40)) 5 *IITB_move_to_mem (nil))
```

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Lregs - Gregs

Notes

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After Greg generation

Decisions that are already taken

- Local and global register are being allocated.
- Register usage has been annotated by REG_DEAD etc.

Notes

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After Greg generation
Notes
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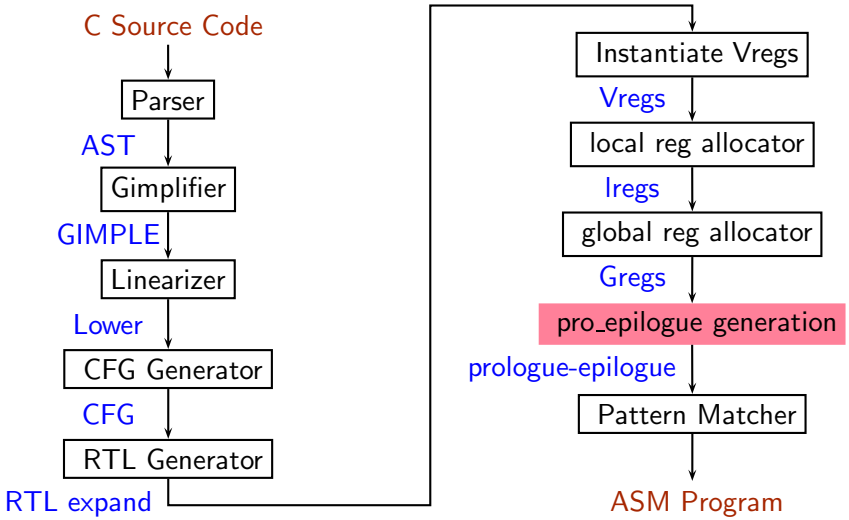
Important Phases of GCC



Notes

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Important Phases of GCC
Notes
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RTL for Function Calls in Spim

Calling function	Called function
• Allocate memory for activation records (push) • Copy arguments into stack arguments • **Call function** • Get result from stack (pop) • Deallocate memory for activation record (pop)	• Allocate memory for return value (push) • Store mandatory callee save registers (push) • Set frame pointer • Allocate local variables (push) • **Execute code** • Put result in return value space • Deallocate local variables (pop) • Load callee save registers (pop) • Return

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RTL for Function Calls in Spim

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Prologue and Epilogue

```
(insn 17 3 18 2 test.c:2
   (set (mem:SI (reg/f:SI 29 $sp) [0 S4 A8])
        (reg:SI 31 $ra)) -1 (nil))
(insn 18 17 19 2 test.c:2
   (set (mem:SI (plus:SI (reg/f:SI 29 $sp)
                   (const_int -4 [...])) [...])
      (reg/f:SI 29 $sp)) -1 (nil))
(insn 19 18 20 2 test.c:2 (set
      (mem:SI (plus:SI (reg/f:SI 29 $sp)
                  (const_int -8 [...])) [...])
      (reg/f:SI 30 $fp)) -1 (nil))
(insn 20 19 21 2 test.c:2 (set
     (reg/f:SI 30 $fp)
       (reg/f:SI 29 $sp)) -1 (nil))
(insn 21 20 22 2 test.c:2 (set
    (reg/f:SI 29 $sp)
    (plus:SI (reg/f:SI 30 $fp)
            (const_int -32 [...]))) -1 (nil))
```

```
sw $ra, 0($sp)
sw $sp, 4($sp)
sw $fp, 8($sp)
move $fp,$sp
addi $sp,$fp,32
```

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Prologue and Epilogue

Notes

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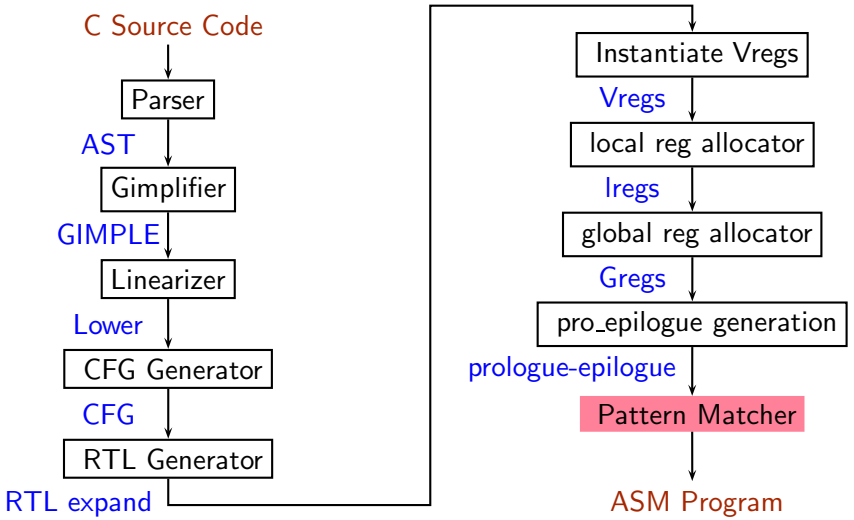
Important Phases of GCC



Important Phases of GCC

Notes

Assembly

Assembly Code for a= a + 1;

For spim	For i386

`lw $v0, -8($fp)`
`addi $v0, $v0, 1`
`sw $v0, -8($fp)`
	`addl $1, -8(%ebp)`

Assembly

Notes

Conclusion

- Source code is transformed into assembly by moving it step by step close to machine architecture.
- This transformation can be understood to a large extent by observing their inputs and output.
- Fortunately in gcc, output of all the passes can be seen using fdump.
- Complete list of dumps can be seen by doing man gcc.

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Conclusion

Notes

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