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# Free RISC-V Systems
## Benefits and Status of QEMU

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# What is QEMU?

## Emulator

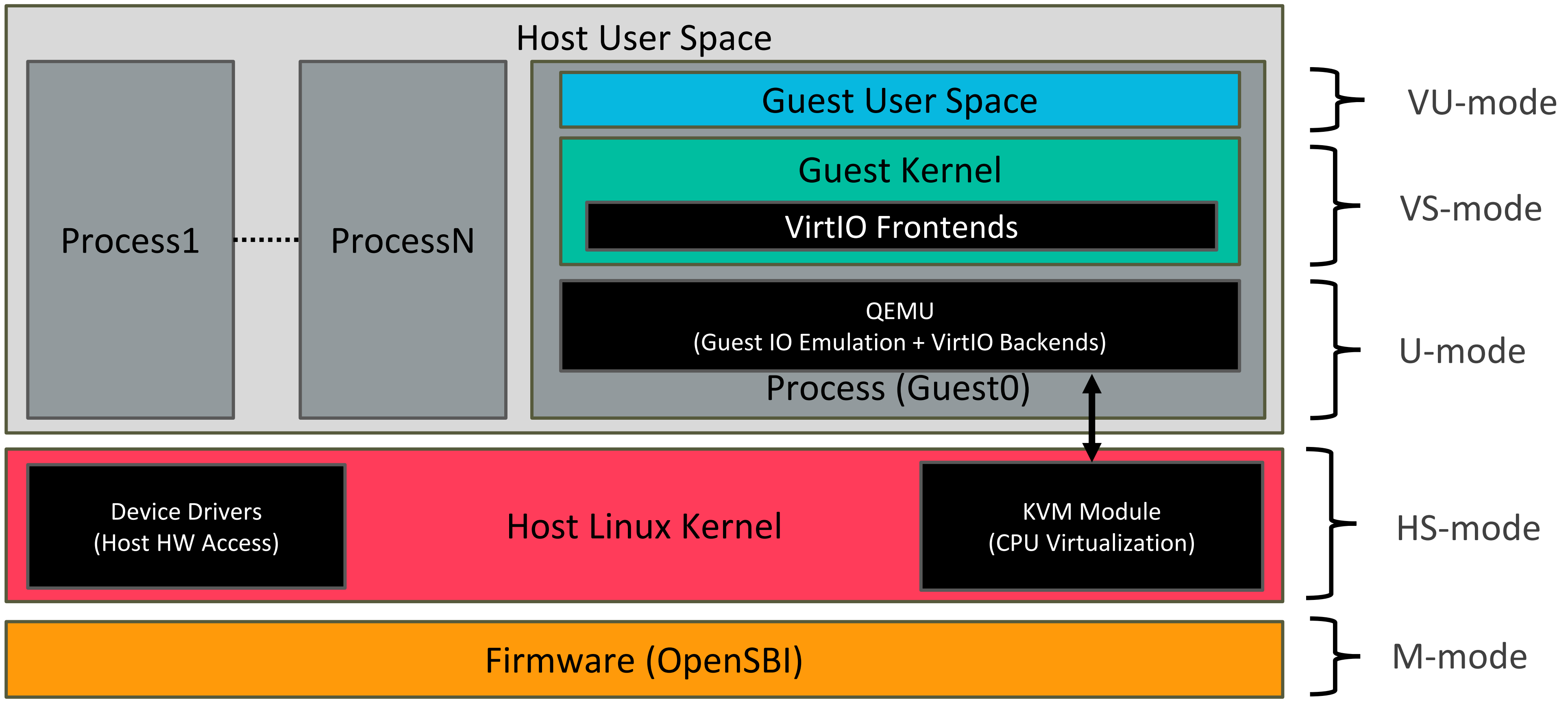
- QEMU is a very quick open source (mostly GPLv2) emulator and hypervisor
- It is not cycle accurate, but it is functionally accurate
- It uses the Tiny Code Generator (TCG) to translate different guest architecture instructions to host executable code
  - Supports full system (softMMU) emulation
  - Also supports just Linux/BSD user space translation
- Open source project, not written or maintained by a single company

Benoît Canet – wiki.qemu.org/Logo CC BY-SA

# What is QEMU?

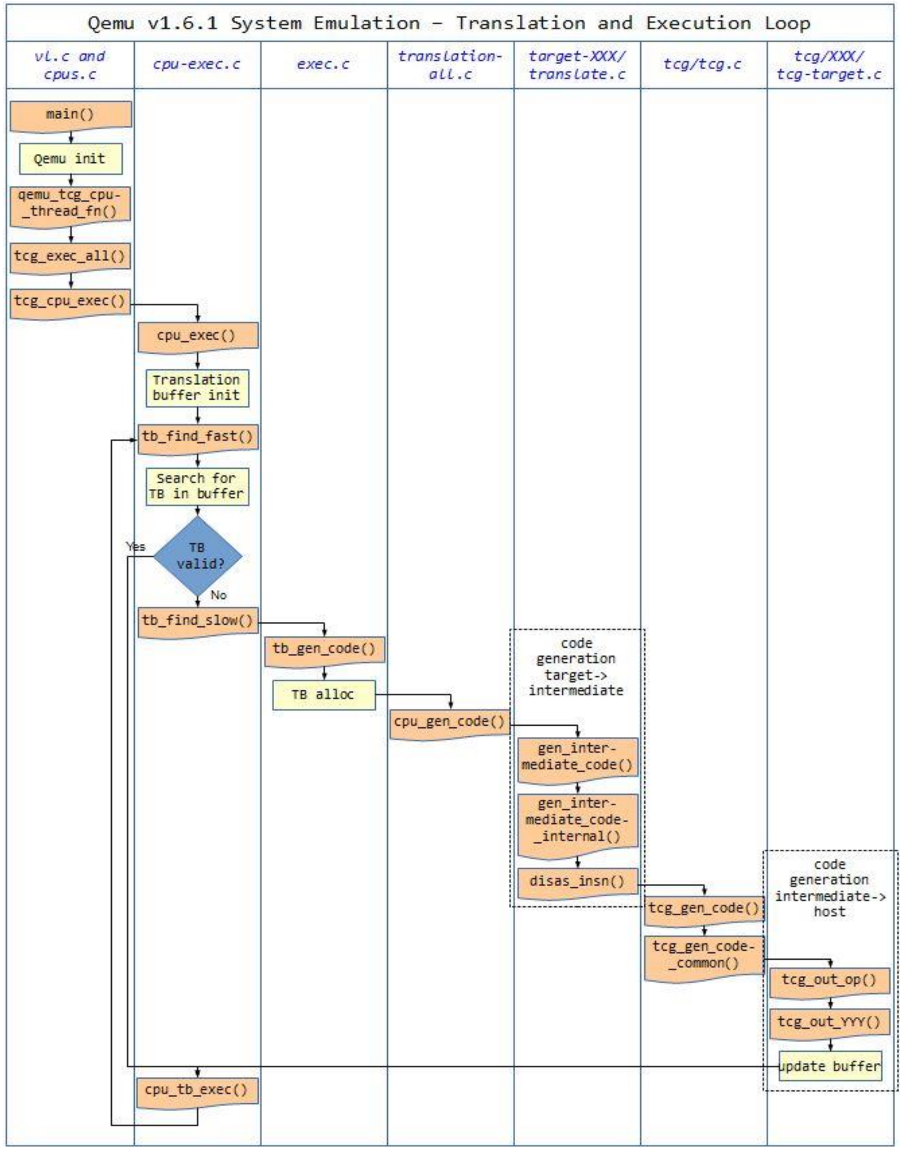
## Hypervisor

O.T.S.U. – KVM Logo CC BY-SA



# Basics of Tiny Code Generator (TCG)

- TCG began as a backend for a C compiler
- TCG can convert TCG ops to target (host) instructions
  - It also performs some optimisations and liveness analysis to improve performance
- TCG will combine blocks of guest code into a TB blocks
  - The end of a block occurs when a branch/jump instruction is encounted
- TCG currently natively supports these targets (hosts)
  - AArch64, ARMv7, x86, AMD64, MIPS, PPC, PPC64, S390, Sparc and RISC-V

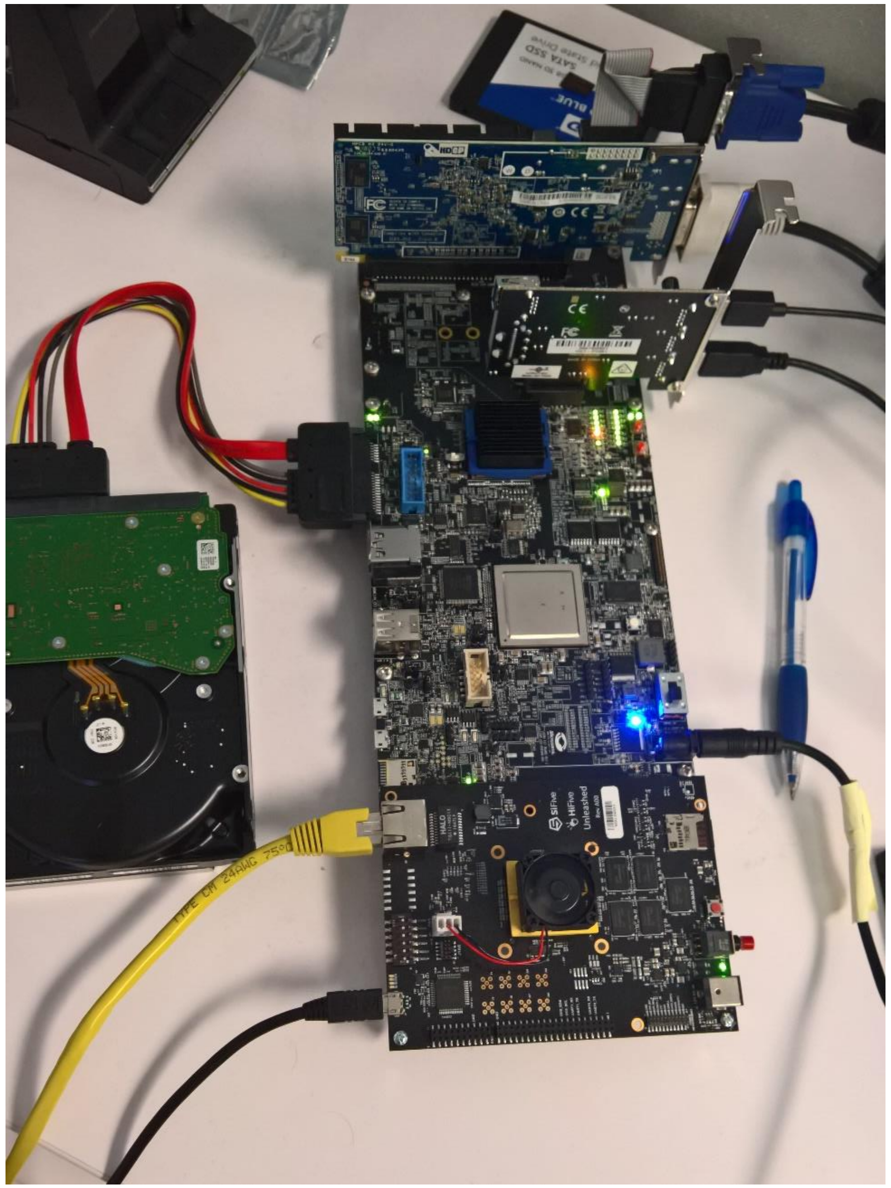


VividD - https://stackoverflow.com/questions/20675226/qemu-code-flow-instruction-cache-and-tcg

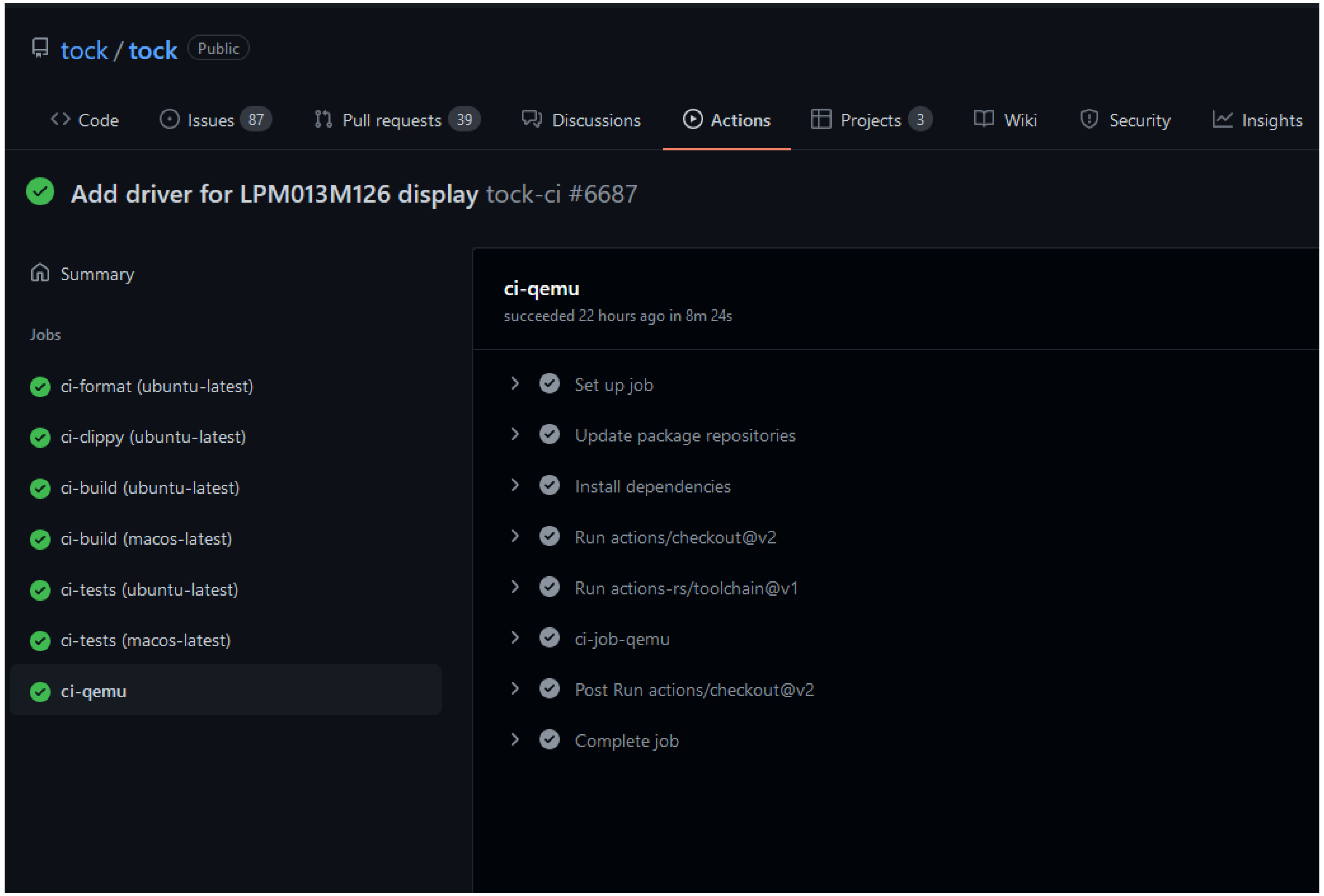
## Benefits of QEMU

## Free Hardware

- QEMU is faster than FPGAs and completely customisable
- QEMU is available on all major distros



# Tock for OpenTitan CI


tock / tock Public

Code | Issues 87 | Pull requests 39 | Discussions | Actions | Projects 3 | Wiki | Security | Insights

Add driver for LPM013M126 display tock-ci #6687

Summary

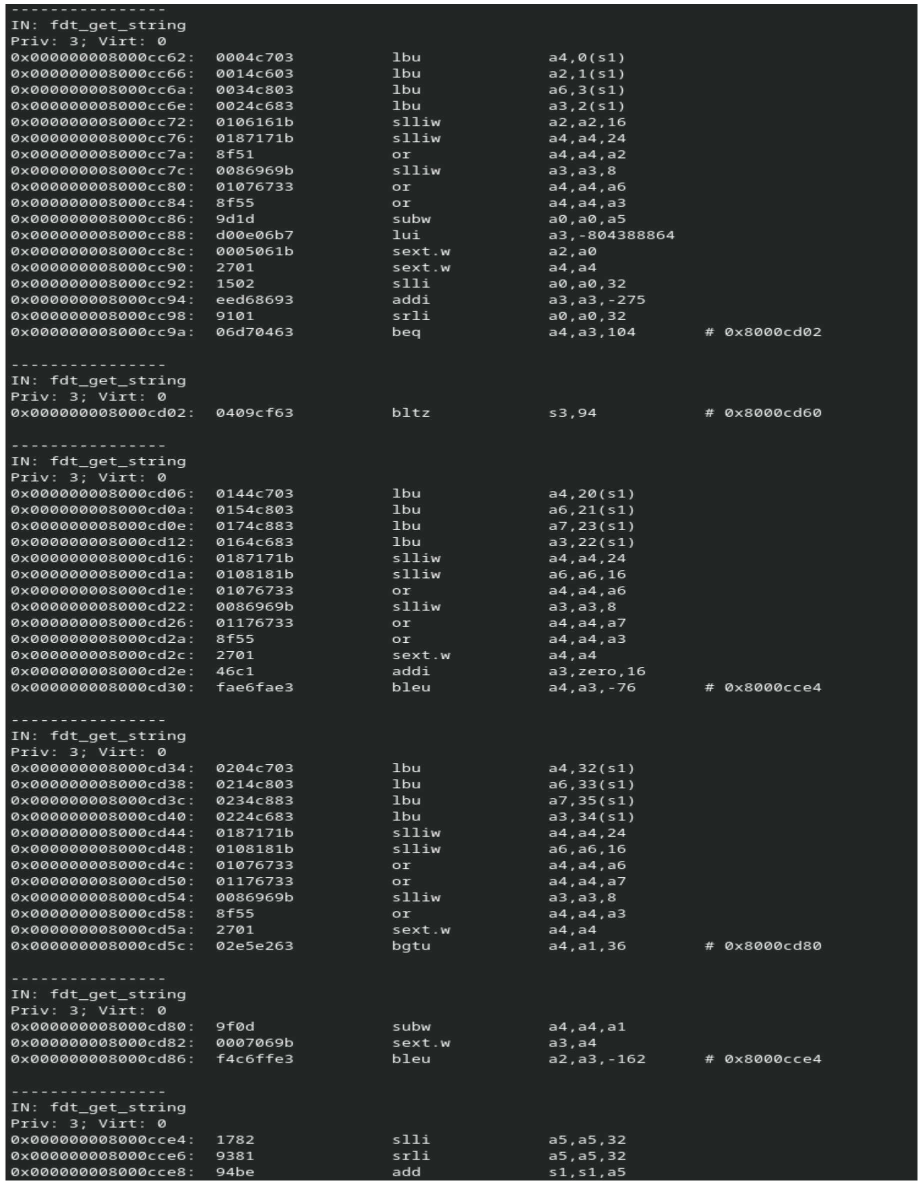
Jobs

- ✓ ci-format (ubuntu-latest)
- ✓ ci-clippy (ubuntu-latest)
- ✓ ci-build (ubuntu-latest)
- ✓ ci-build (macos-latest)
- ✓ ci-tests (ubuntu-latest)
- ✓ ci-tests (macos-latest)
- ✓ ci-qemu

ci-qemu
succeeded 22 hours ago in 8m 24s

- ✓ Set up job
- ✓ Update package repositories
- ✓ Install dependencies
- ✓ Run actions/checkout@v2
- ✓ Run actions-rs/toolchain@v1
- ✓ ci-job-qemu
- ✓ Post Run actions/checkout@v2
- ✓ Complete job

# Using QEMU to Develop Extensions



```
----------------
IN: fdt_get_string
Priv: 3; Virt: 0
0x000000008000cc62:  0004c703          lbu             a4,0(s1)
0x000000008000cc66:  0014c603          lbu             a2,1(s1)
0x000000008000cc6a:  0034c803          lbu             a6,3(s1)
0x000000008000cc6e:  0024c683          lbu             a3,2(s1)
0x000000008000cc72:  0106161b          slliw           a2,a2,16
0x000000008000cc76:  0187171b          slliw           a4,a4,24
0x000000008000cc7a:  8f51              or              a4,a4,a2
0x000000008000cc7c:  0086969b          slliw           a3,a3,8
0x000000008000cc80:  01076733          or              a4,a4,a6
0x000000008000cc84:  8f55              or              a4,a4,a3
0x000000008000cc86:  9d1d              subw            a0,a0,a5
0x000000008000cc88:  d00e06b7          lui             a3,-804388864
0x000000008000cc8c:  0005061b          sext.w          a2,a0
0x000000008000cc90:  2701              sext.w          a4,a4
0x000000008000cc92:  1502              slli            a0,a0,32
0x000000008000cc94:  eed68693          addi            a3,a3,-275
0x000000008000cc98:  9101              srli            a0,a0,32
0x000000008000cc9a:  06d70463          beq             a4,a3,104       # 0x8000cd02

----------------
IN: fdt_get_string
Priv: 3; Virt: 0
0x000000008000cd02:  0409cf63          bltz            s3,94           # 0x8000cd60

----------------
IN: fdt_get_string
Priv: 3; Virt: 0
0x000000008000cd06:  0144c703          lbu             a4,20(s1)
0x000000008000cd0a:  0154c803          lbu             a6,21(s1)
0x000000008000cd0e:  0174c883          lbu             a7,23(s1)
0x000000008000cd12:  0164c683          lbu             a3,22(s1)
0x000000008000cd16:  0187171b          slliw           a4,a4,24
0x000000008000cd1a:  0108181b          slliw           a6,a6,16
0x000000008000cd1e:  01076733          or              a4,a4,a6
0x000000008000cd22:  0086969b          slliw           a3,a3,8
0x000000008000cd26:  01176733          or              a4,a4,a7
0x000000008000cd2a:  8f55              or              a4,a4,a3
0x000000008000cd2c:  2701              sext.w          a4,a4
0x000000008000cd2e:  46c1              addi            a3,zero,16
0x000000008000cd30:  fae6fae3          bleu            a4,a3,-76       # 0x8000cce4

----------------
IN: fdt_get_string
Priv: 3; Virt: 0
0x000000008000cd34:  0204c703          lbu             a4,32(s1)
0x000000008000cd38:  0214c803          lbu             a6,33(s1)
0x000000008000cd3c:  0234c883          lbu             a7,35(s1)
0x000000008000cd40:  0224c683          lbu             a3,34(s1)
0x000000008000cd44:  0187171b          slliw           a4,a4,24
0x000000008000cd48:  0108181b          slliw           a6,a6,16
0x000000008000cd4c:  01076733          or              a4,a4,a6
0x000000008000cd50:  01176733          or              a4,a4,a7
0x000000008000cd54:  0086969b          slliw           a3,a3,8
0x000000008000cd58:  8f55              or              a4,a4,a3
0x000000008000cd5a:  2701              sext.w          a4,a4
0x000000008000cd5c:  02e5e263          bgtu            a4,a1,36        # 0x8000cd80

----------------
IN: fdt_get_string
Priv: 3; Virt: 0
0x000000008000cd80:  9f0d              subw            a4,a4,a1
0x000000008000cd82:  0007069b          sext.w          a3,a4
0x000000008000cd86:  f4c6ffe3          bleu            a2,a3,-162      # 0x8000cce4

----------------
IN: fdt_get_string
Priv: 3; Virt: 0
0x000000008000cce4:  1782              slli            a5,a5,32
0x000000008000cce6:  9381              srli            a5,a5,32
0x000000008000cce8:  94be              add             s1,s1,a5
```

- QEMU is a valuable tool in prototyping extensions
  - It's much quicker to add features to QEMU then hardware or full system simulators
  - QEMU is also very quick at running, allowing quick turn around times for tests
- QEMU can dump guest instructions as they are generated
  - Running QEMU with the `-d in_asm` command line argument outputs the generated input instructions

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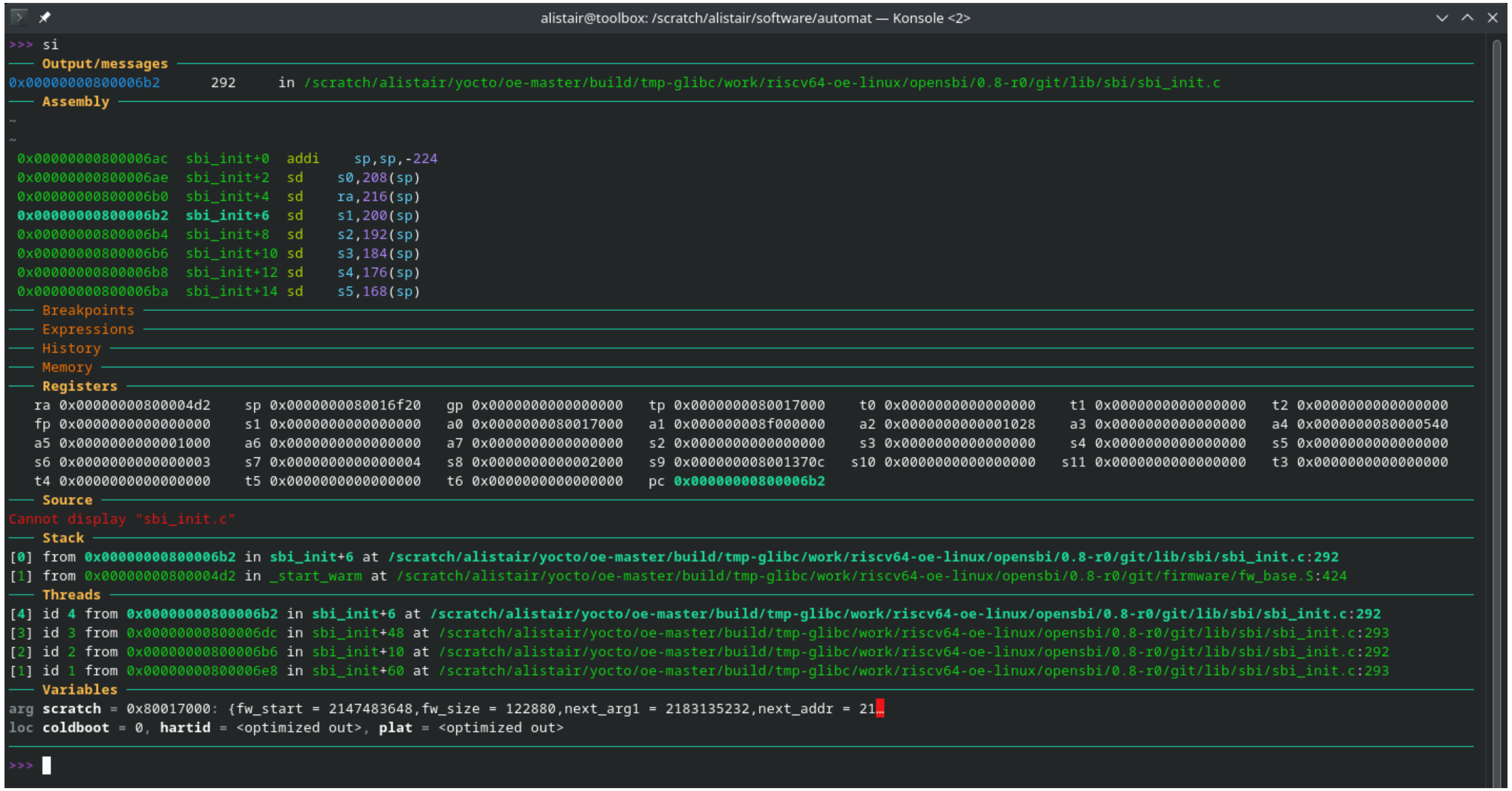
# Debugging with QEMU


alistair@toolbox: /scratch/alistair/software/automat — Konsole <2>

```
>>> si
─── Output/messages ────────────────────────────────────────────────────────────
0x00000000800006b2      292     in /scratch/alistair/yocto/oe-master/build/tmp-glibc/work/riscv64-oe-linux/opensbi/0.8-r0/git/lib/sbi/sbi_init.c
─── Assembly ───────────────────────────────────────────────────────────────────
~
~
 0x00000000800006ac  sbi_init+0  addi    sp,sp,-224
 0x00000000800006ae  sbi_init+2  sd    s0,208(sp)
 0x00000000800006b0  sbi_init+4  sd    ra,216(sp)
 0x00000000800006b2  sbi_init+6  sd    s1,200(sp)
 0x00000000800006b4  sbi_init+8  sd    s2,192(sp)
 0x00000000800006b6  sbi_init+10 sd    s3,184(sp)
 0x00000000800006b8  sbi_init+12 sd    s4,176(sp)
 0x00000000800006ba  sbi_init+14 sd    s5,168(sp)
─── Breakpoints ────────────────────────────────────────────────────────────────
─── Expressions ────────────────────────────────────────────────────────────────
─── History ────────────────────────────────────────────────────────────────────
─── Memory ─────────────────────────────────────────────────────────────────────
─── Registers ──────────────────────────────────────────────────────────────────
   ra 0x00000000800004d2    sp 0x0000000080016f20   gp 0x0000000000000000   tp 0x0000000080017000    t0 0x0000000000000000    t1 0x0000000000000000   t2 0x0000000000000000
   fp 0x0000000000000000    s1 0x0000000000000000   a0 0x0000000080017000   a1 0x000000008f000000    a2 0x0000000000001028    a3 0x0000000000000000   a4 0x0000000080000540
   a5 0x0000000000001000    a6 0x0000000000000000   a7 0x0000000000000000   s2 0x0000000000000000    s3 0x0000000000000000    s4 0x0000000000000000   s5 0x0000000000000000
   s6 0x0000000000000003    s7 0x0000000000000004   s8 0x0000000000002000   s9 0x000000008001370c   s10 0x0000000000000000   s11 0x0000000000000000   t3 0x0000000000000000
   t4 0x0000000000000000    t5 0x0000000000000000   t6 0x0000000000000000   pc 0x00000000800006b2
─── Source ─────────────────────────────────────────────────────────────────────
Cannot display "sbi_init.c"
─── Stack ──────────────────────────────────────────────────────────────────────
[0] from 0x00000000800006b2 in sbi_init+6 at /scratch/alistair/yocto/oe-master/build/tmp-glibc/work/riscv64-oe-linux/opensbi/0.8-r0/git/lib/sbi/sbi_init.c:292
[1] from 0x00000000800004d2 in _start_warm at /scratch/alistair/yocto/oe-master/build/tmp-glibc/work/riscv64-oe-linux/opensbi/0.8-r0/git/firmware/fw_base.S:424
─── Threads ────────────────────────────────────────────────────────────────────
[4] id 4 from 0x00000000800006b2 in sbi_init+6 at /scratch/alistair/yocto/oe-master/build/tmp-glibc/work/riscv64-oe-linux/opensbi/0.8-r0/git/lib/sbi/sbi_init.c:292
[3] id 3 from 0x00000000800006dc in sbi_init+48 at /scratch/alistair/yocto/oe-master/build/tmp-glibc/work/riscv64-oe-linux/opensbi/0.8-r0/git/lib/sbi/sbi_init.c:293
[2] id 2 from 0x00000000800006b6 in sbi_init+10 at /scratch/alistair/yocto/oe-master/build/tmp-glibc/work/riscv64-oe-linux/opensbi/0.8-r0/git/lib/sbi/sbi_init.c:292
[1] id 1 from 0x00000000800006e8 in sbi_init+60 at /scratch/alistair/yocto/oe-master/build/tmp-glibc/work/riscv64-oe-linux/opensbi/0.8-r0/git/lib/sbi/sbi_init.c:293
─── Variables ──────────────────────────────────────────────────────────────────
arg scratch = 0x80017000: {fw_start = 2147483648,fw_size = 122880,next_arg1 = 2183135232,next_addr = 21…
loc coldboot = 0, hartid = <optimized out>, plat = <optimized out>
────────────────────────────────────────────────────────────────────────────────
>>> 
```

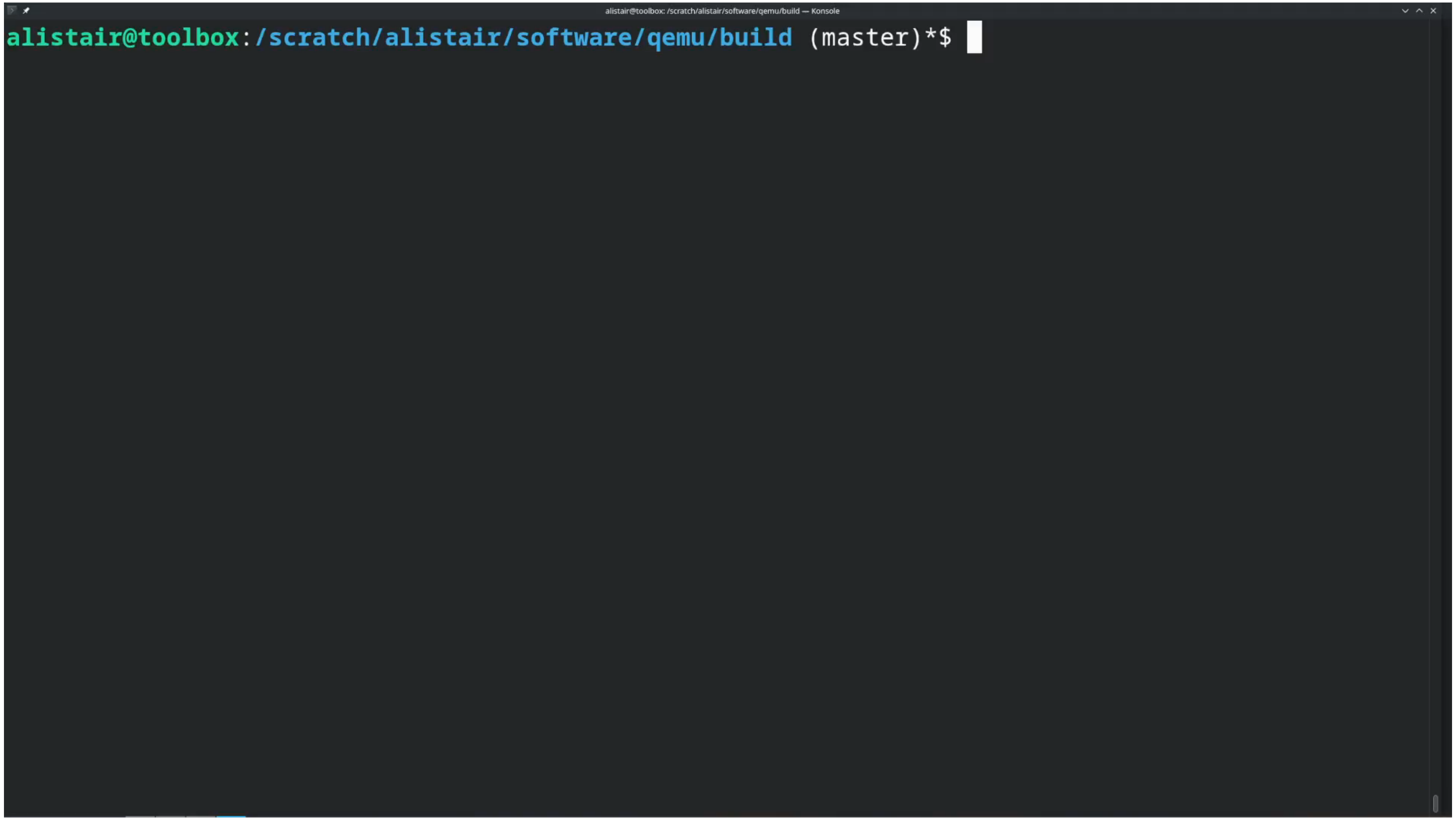
## QEMU Status

# Current Mainline QEMU Status

- QEMU supports these extensions:
  - I, E, G, M, A, F, D, C, S, U, V, H, Counters, Zifencei, Zicsr, Zfh, Zfhmin, Zve32f, Zve64f, MMU, PMP, debug, svinval, svnapot, svpbmt, Zba Zbb, Zbc, Zbs, Zdinx, Zfinx, Zhinx, Zhinxmin, J, ePMP and AIA
- Patches on list for
  - IOMMU, crypto extensions and more
- Vendor extensions
  - XVentanacondOps
- 32/64/128-bit CPUs
- Contributions from: Western Digital, SiFive, C-Sky, Windriver, ISCAS and many others
- Getting started information available at: https://wiki.qemu.org/Documentation/Platforms/RISCV

# RISC-V KVM on QEMU

## QEMU supports KVM on RISC-V systems



alistair@toolbox: /scratch/alistair/software/qemu/build — Konsole

```
alistair@toolbox:/scratch/alistair/software/qemu/build (master)*$
```

# Vector Extension Demo

alistair@toolbox: /scratch/alistair/software/qemu/build — Konsole

```
alistair@toolbox:/scratch/alistair/software/qemu/build (master)*$ 
```

# Vendor Extensions in QEMU

- Adding new instructions
  1. Add a .decode file
     - An easy-to-read decoder file that defines the instructions
  2. Write TCG C implementation in trans_*.c.inc file
     - This contains assembly like implementation for instructions
  3. Wire up new files, add CPU config property and expose it to users
- Adding new CSRs still a work in progress
- Follow toolchain conventions
  – https://github.com/riscv-non-isa/riscv-toolchain-conventions/pull/17

## How to get involved

- Contribute code to the QEMU mailing list
  - https://wiki.qemu.org/Contribute/MailingLists
- Help review and test extensions you are interested in

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