



# The Updated Status of RISC-V SW

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**2019 RISC-V Workshop Taiwan**



The main contributor to the RISC-V software eco-system



# GNU Toolchain

■ **bintuils 2.32 (Released at 2019/2/2)**

■ **GCC 9 (Expected release at 2019/4E)**

- RV32E
- Interrupt attribute
- ELF Attribute support

```
void __attribute__((interrupt))  
foo (void)  
{  
}
```

```
.attribute arch, "rv32i2p0_m2p0_a2p0_f2p0_d2p0_c2p0"  
.attribute unaligned_access, 0  
.attribute stack_align, 16
```





# ELF Attribute

## ■ Record more info into object file.

- Arch info, stack alignment or version of privilege spec.
- Disassembler: "How can I interpret the ELF correctly?"
- Linker: "Can I link those ELF objects?"
- Loader: "Can I load the ELF objects and make them run?"

## ■ More detail:

- [https://groups.google.com/a/groups.riscv.org/d/msg/sw-dev/KbywJrTczdQ/5CNB\\_63BAgAJ](https://groups.google.com/a/groups.riscv.org/d/msg/sw-dev/KbywJrTczdQ/5CNB_63BAgAJ)
- <https://github.com/riscv/riscv-elf-psabi-doc/pull/71>  
.attribute arch, "rv32i2p0\_m2p0\_a2p0\_f2p0\_d2p0\_c2p0"  
.attribute unaligned\_access, 0  
.attribute stack\_align, 16



# Debugger

## ■ GDB

- Software single step
- Linux/FreeBSD support

## ■ OpenOCD

- Upstreamed!





# Glibc

- **glibc 2.27 (2018/2) included RV64 support.**
- **RV32 supporting.**
  - Contributed by Andes.
  - Ready to upstream!
    - ◆ Waiting Y2038 patches for Linux kernel
  - Expect to be upstreamed this year.
  - Latest stable branch:
    - ◆ <https://github.com/riscv/riscv-glibc/tree/riscv-glibc-2.29>



# LLVM

## ■ LLVM

- RV32IMAFDC & RV64IMAFDC Code gen.
- Missing hard-float calling convention.
  - ◆ Expected to be completed this year.

## ■ LLD

- Contributed by Andes.
- Faster and smaller implementation than GNU's linker.
- RISC-V support is included in LLD 8!



# RISC-V System Software Status

- Linux
- u-Boot
- FreeRTOS
- Arduino



# Linux Kernel Verifications



## ■ Investigating the results of LTP

- Stress tests to find more problems to be fixed
- Current status
  - ◆ LTP-20180316
    - Total Tests: 1983
    - Total Skipped Tests: 586
    - Total Failures: 95
    - Kernel Version: 4.17.0-00232-geeac8377bba0
    - Machine Architecture: riscv64
    - Hostname: Andes

## ■ Fix the kernel hang issue in lock torture tests when **CONFIG\_PREEMPT=y**

- Merged to mainline
- <https://lkml.org/lkml/2019/1/3/7>

# Linux Kernel Tools

## ■ Ftrace support

- For developers to debug
- Support dynamic ftrace
- Merged to mainline
- <https://lkml.org/lkml/2018/1/18/477>

## ■ Perf support

- For developers to evaluate the bottleneck of the whole system
- Merged to mainline
- Will be talked at 10:00 this morning
- <https://lkml.org/lkml/2018/4/2/171>

# Linux kernel Power Management

## ■ Suspend2ram support

- Able to be suspended by sysfs commands and wakeup by RTC and uart interrupt

## ■ PowerBrake support

- Able to reduce power consumption through sysfs commands to reduce performance

```
~ # uname -a
Linux Andes 4.17.0-00249-ge0fb0f3ff87-dirty #33 SMP PREEMPT Tue Feb 26 17:46:38 CST 2019 riscv64 GNU/Linux
~ # cat /proc/cpuinfo
hart      : 0
isa       : rv64i2p0m2p0a2p0f2p0d2p0c2p0xv5-0p0
mmu       : sv39

hart      : 1
isa       : rv64i2p0m2p0a2p0f2p0d2p0c2p0xv5-0p0
mmu       : sv39
```

Andes RV64 cores

```
~ # cat /sys/power/state
freeze standby mem
~ # echo enabled > /sys/devices/platform/f0300000.serial/tty/tty50/power/wakeup
~ # echo mem > /sys/power/state
PM: suspend entry (deep)
PM: Syncing filesystems ... done.
Freezing user space processes ... (elapsed 0.010 seconds) done.
OOM killer disabled.
Freezing remaining freezable tasks ... (elapsed 0.010 seconds) done.
Suspending console(s) (use no_console_suspend to debug)
dDisabling non-boot CPUs ...
CPU1: shutdown
Enabling non-boot CPUs ...
CPU: online
cache: parent cpu1 should not be sleeping
CPU1 is up
OOM killer enabled
Restarting tasks ... done.
sh: write error: Invalid argument
~ # dPM: suspend exit
```

Suspend2ram

```
-sh: d: not found
~ # ls
root
```

Wakeup by uart

```
/mnt/riscv/mount_d # uname -a
Linux Andes 4.17.0-00250-gd63b2bcc59af-dirty #54 SMP PREEMPT Mon Mar 4 10:41:02 CS
/mnt/riscv/mount_d # cat /proc/cpuinfo
hart      : 0
isa       : rv64i2p0m2p0a2p0f2p0d2p0c2p0xv5-0p0
mmu       : sv39

hart      : 1
isa       : rv64i2p0m2p0a2p0f2p0d2p0c2p0xv5-0p0
mmu       : sv39
```

```
/mnt/riscv/mount_d # cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_governor
powersave
/mnt/riscv/mount_d # cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_available_governors
performance powersave
```

PowerBrake

```
/mnt/riscv/mount_d # cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_cur_freq
60000
/mnt/riscv/mount_d # echo 10 > /sys/devices/system/cpu/cpu0/cpufreq/scaling_min_freq
/mnt/riscv/mount_d # echo 100 > /sys/devices/system/cpu/cpu0/cpufreq/scaling_max_freq
/mnt/riscv/mount_d # cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_cur_freq
3750
/mnt/riscv/mount_d #
```



# Linux Kernel Development



## ■ Module support

- Support all relocation types in kernel module for RV32 and RV64
- Merged to mainline and well verified
- <https://lkml.org/lkml/2018/3/15/121>
- <https://lkml.org/lkml/2018/11/12/1820>

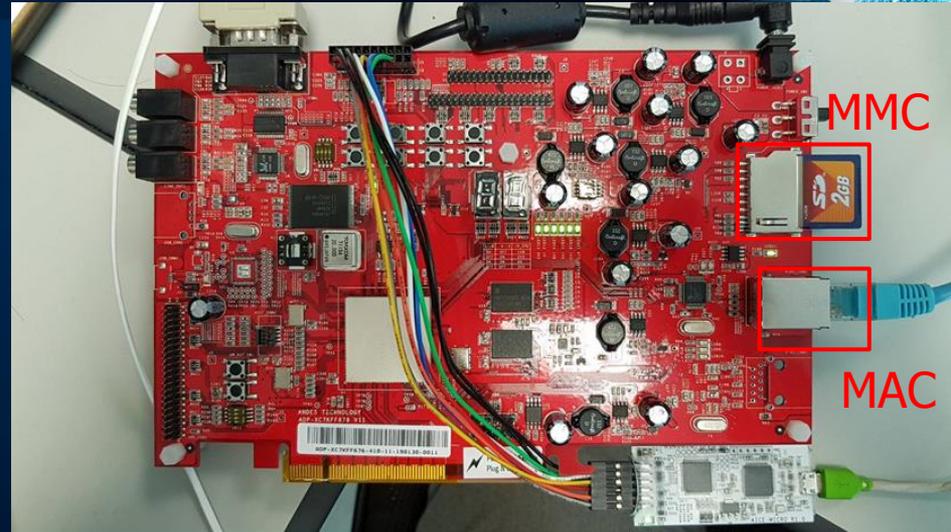
## ■ Patchset for non-coherent agent RISC-V cores

- A general framework for RISC-V cores without coherent agent
- Useful for customers who care die size
- Well verified in AE350 platform
- <https://lkml.org/lkml/2018/10/31/431>

# Linux Kernel Development

## ■ Fedora on Andes AE350

- AX25(Andes RISC-V core)
- A platform with mmc and mac
- Able to run Fedora distribution
  - ◆ ([f30, Fedora-Minimal-Rawhide-20190226.n.0, fedora-riscv64-minimal-rawhide.ks, riscv64](#))
- Able to install packages
- Will be talked at 10:15



MMC

MAC

```
[root@fedora-riscv ~]# cat /proc/cpuinfo
hart      : 0
isa       : rv64i2p0m2p0a2p0f2p0d2p0c2p0xv5-0p0
mmu       : sv39
```

Andes v5 AX25

```
[root@fedora-riscv ~]# uname -a
Linux fedora-riscv 4.17.0-00250-gd63b2bc-dirty #4 PREEMPT Wed Feb 27 11:3
[root@fedora-riscv ~]#
```

Fedora

```
htop                riscv64                2.2.0-2.fc29
-----
transaction Summary
-----
install 1 Package

total download size: 98 k
installed size: 213 k
s this ok [y/N]: y
downloading Packages:
top-2.2.0-2.fc29.riscv64.rpm

total
running transaction check
transaction check succeeded.
running transaction test
transaction test succeeded.
running transaction
Preparing          :
Installing         : htop-2.2.0-2.fc29.riscv64
Running scriptlet : htop-2.2.0-2.fc29.riscv64
Verifying          : htop-2.2.0-2.fc29.riscv64

installed:
htop-2.2.0-2.fc29.riscv64

complete!
root@fedora-riscv ~]#
```

Use dnf to install htop rpm

# u-Boot Development

## ■ u-Boot

- SMP support (Reviewing)
- S-mode support
- More drivers supported in AE350
  - ◆ mmc, mac, smc, spi
- SiFive FU540 board support
- Merged and verified patchset from contributors(SiFive, WD)



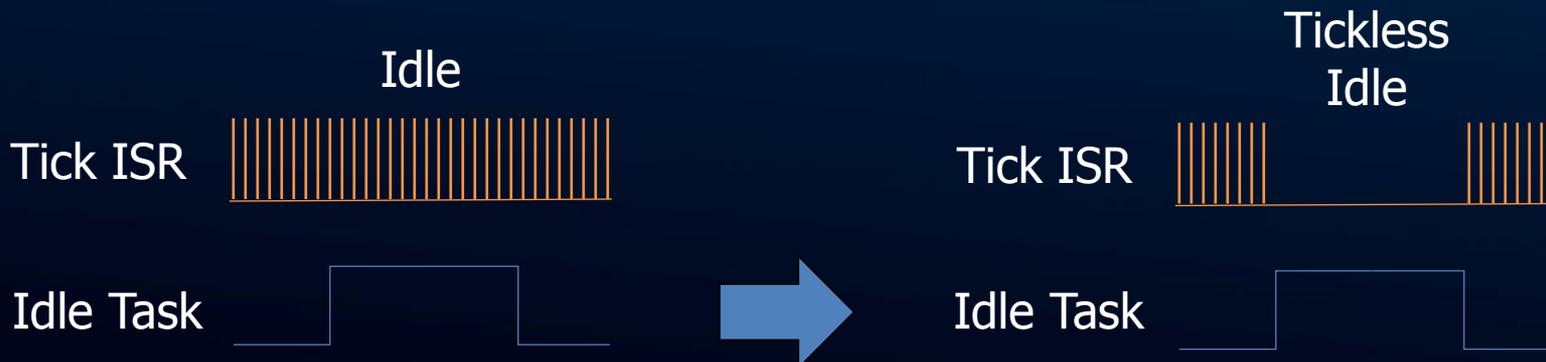
```
U-Boot 2018.11-00208-ga8cb78f (Nov 20 2018 - 17:29:58 +0800)

CPU:   rv64imafdc
Model: andestech,ax25
DRAM:  1 GiB
Flash: 64 MiB
MMC:   mmc@f0e00000: 0
Loading Environment from SPI Flash... SF: Detected mx25u1635e with page size 256 Bytes, erase size 4 KiB, total 2 MiB
OK
In:    serial@f0300000
Out:   serial@f0300000
Err:   serial@f0300000
Net:   no alias for ethernet0

Warning: mac@e0100000 (eth0) using random MAC address - 5e:cc:27:0d:56:31
eth0: mac@e0100000
RISC-V #
```

# FreeRTOS Development

- Pass FreeRTOS testsuite
- Support AE250/AE350
- Low power support
  - Based on FreeRTOS tickless-idle mode
  - Based on RISC-V standard mtime/mtimecmp
  - Reduce power consumption by stopping periodic tick interrupt in the idle mode



# FreeRTOS Development

## Awareness debugging

### Task information

task name	number	priority	start of
PolSEM1	18	0	0x20a4
Registers			
SetB	27	0	0x20f4
Registers			
\$x1	\$x2	\$x3	\$x4
0x00000000000001afa	0x0000000000020fa40	0x0000000000200948	0x0000
\$x5	\$x6	\$x7	\$x8
0x000000000020fcc0	0x0000000000000001	0x0000000000000001	0x0000
\$x9	\$x10	\$x11	\$x12
0x000000000020f3f0	0x0000000000000000	0x000000000020fcc0	0x0000
\$x13	\$x14	\$x15	\$x16
0x0000000000000000	0x000000000020fcc0	0x0000000000000001	0x0000
\$x17	\$x18	\$x19	\$x20
0x0000000000216f20	0x0000000000200610	0x00000000002005e8	0xa5a5
\$x21	\$x22	\$x23	\$x24
0xa5a5a5a5a5a5a5a5	0xa5a5a5a5a5a5a5a5	0xa5a5a5a5a5a5a5a5	0xa5a5
\$x25	\$x26	\$x27	\$x28
0xa5a5a5a5a5a5a5a5	0xa5a5a5a5a5a5a5a5	0xa5a5a5a5a5a5a5a5	0x0000
\$x29	\$x30	\$x31	\$EPC
0x0000000000216f20	0x00000000002171c0	0x0000000000000050	0x0000
\$f0	\$f1	\$f2	
0xa5a5a5a5a5a5a5a5	0xa5a5a5a5a5a5a5a5	0xa5a5a5a5a5a5a5a5	0xa5a5

FreeRTOS-V5 Debug [Application Program]

```
taskENTER_CRITICAL();
```

Kernel Awareness

### Event information

queue name	handler ad...	max len...	item s...	mess...	waiting ...	waitin...
Suspended_Test_Q	0x200860	1	4	0	0	0
Pend Tasks						
Block_Time_Queue	0x203530	5	8	5	1	0
Pend Tasks						
task name	number					
BTest2	7					
Counting_Sem_1	0x2047b0	200	0	178	0	0
Pend Tasks						
Counting_Sem_2	0x204860	200	0	35	0	0
Pend Tasks						
Gen_Queue_Test	0x205ab0	5	4	0	0	0
Pend Tasks						
Gen_Queue_Mutex	0x206450	1	0	0	0	0
Pend Tasks						
Recursive_Mutex	0x208840	1	0	0	0	1
Pend Tasks						
Counting_Sem_1	0x20a390	1	0	1	0	0
Pend Tasks						
Counting_Sem_2	0x20b630	1	0	1	0	0
Pend Tasks						
TmrQ	0x2007a0	5	32	0	0	1
Pend Tasks						

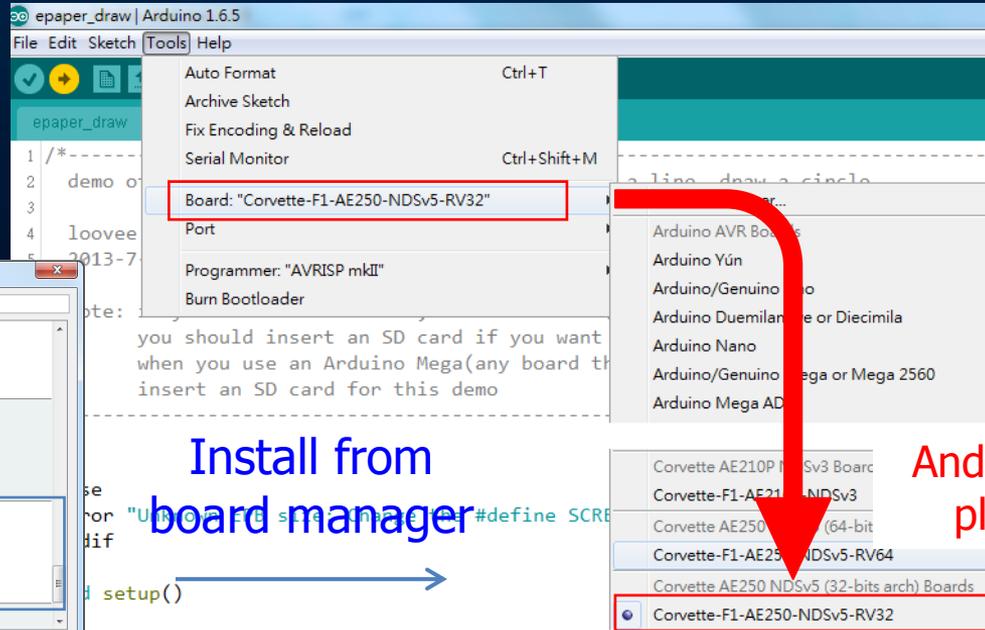
task name	number	priority	start of st...	top of st...	status
GenQ	10	0	0x202fc0	0x2032c0	Ready
Registers					
PolSEM1	18	0	0x205520	0x205850	Ready
Registers					
CNT_INC	1	0	0x200580	0x2008b0	Ready
Registers					
SetB	27	0	0x207e40	0x208140	Ready
Registers					
PolSEM2	19	0	0x2059a0	0x205cd0	Ready
Registers					
Math1	22	0	0x206c70	0x206ab0	Ready
Registers					
Math2	23	0	0x206c40	0x206f60	Ready
Registers					
Tmr Tst	36	5	0x20a600	0x20a930	Delayed
Registers					
BTest1	6	4	0x201c80	0x201fb0	Delayed
Registers					
Rec1	15	2	0x204700	0x204a50	Delayed
Registers					
Tmr Svc	42	6	0x2215f8	0x221d40	Delayed
Registers					
StatCreate	34	2	0x220530	0x220bf0	Delayed

# Arduino Development

- **Arduino programming language and standard libraries support**
  - Support Arduino language reference APIs
  - Support standard library
- **Arduino Software (IDE) compatible package**



Corvette F1



Install from  
board manager

Andes RISC-V  
platforms



# Future Work of Linux



## ■ Verifications

- LTP and Linux kernel selftest

## ■ New features

- The Kernel Address Sanitizer (KASAN) support
- ASID support
- Non-MMU support
- AMP support
- Real-time Linux support
- Enhanced perf support

## ■ Thanks to all the contributors



**Thank you**