ECE 471 – Embedded Systems
Lecture 12

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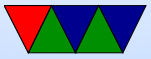
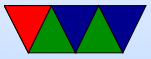
Announcements

- Homework #2. Due date extended until Friday 5pm.
- Hopefully everyone has the Gumstix board working
- Midterm scheduled for October 22nd
- Read Chapter 9



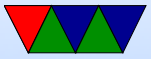
Interrupts

- What are interrupts?
- Something happens, signal pulled up, CPU stops executing (possibly flushing the pipeline), PC changes to handler address, may look up in vector table.
- Alternatives (polling)
- Precise vs non-precise
- Hardware issues: (complicate hardware, restarting



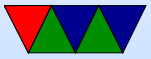
instruction stream, when can you be interrupted, flushing pipelines, priority levels)

- Software issues: capturing, restarting code, latency, performance
- When in control can often cli/sti stop start interrupts to avoid code being interrupted. Why is this dangerous?
- Linux NAPI – switch to polling if interrupt rate too high



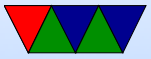
ARM Interrupts

- 7 types. Data Abort, Fast Interrupt Request, Interrupt Request, Prefetch Abort, Software Interrupt, Reset, Undefined Instruction
- ARM designed with fast interrupts in mind
- On interrupt: cspr saved to specific spsr, pc saved to special lr, cpsr set to exception mode, pc points to address handler
- Vector table, holds instructions branched to on irq.



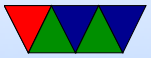
Usually a branch or move insn to an irq handler

- Priority mechanism, when happen at same time



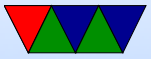
Interrupt Sources

- Data Abort – missing memory
- prefetch – trying to fetch next instruction
- swi – syscall
- undefined – emulate missing. why same priority swi and undefined? swi insn is never undefined



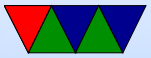
Register Contents

- r13 (sp) r14 (lr) r15 (pc) special cased, bank switched in
- return address. Either next insn, or current insn if has to be re-executed (a bad memory, redo now paged in)



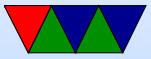
Interrupt Controllers

- Interrupt controllers, map many interrupts to two irq lines
- irq – low priority, high latency – system timer
- firq – fast, dma transfers?



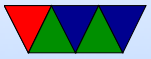
Interrupt Latency

- fastest – nested – ack right away (quiet the hardware) then re-enable so other interrupts not ignored
- prioritized – ignore interrupts of same or higher while servicing: higher priority end up w lower latency
- (NMI interrupts, x86)



Interrupt Stacks

- irq stacks
- separate from user stacks to avoid buggy code causing problems
- sp is one of banked regs

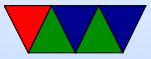


Vectors

From Table 9.2 of textbook

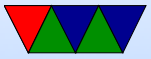
Exception	Mode	Vector Table Offset	Priority
Reset	SVC	0x00	1
Undefined Instruction	UND	0x04	6
Software Interrupt	SVC	0x08	6
Prefetch Abort	ABT	0x0c	5
Data Abort	ABT	0x10	2
n/a	–	0x14	–
IRQ	IRQ	0x18	4
FIQ	FIQ	0x1c	3

FIQ can immediately follow w no branch



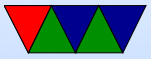
Benefits of an OS

If you have an OS, no need to worry about most of this unless you are coding it up yourself.



DMA

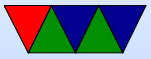
- Direct memory access
- Devices can write directly to memory without going through the CPU.
  Saves a load/store loop on the CPU.
- CPU sets up the transfer, then can do other things.
  Often notified of completion by an interrupt



Detecting Devices

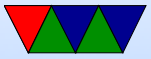
There are many ways to detect devices

- Guessing – can be bad if you guess wrong and the hardware reacts poorly to having unexpected data sent to it
- Standards – always knowing that, say, VGA is at address 0xa0000. PCs get by with defacto standards
- Enumerable hardware – busses like USB and PCI allow you to query hardware to find out what it is and where



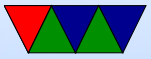
it is located

- Hard-coding – have a separate kernel for each possible board, with the locations of devices hard-coded in. Not very maintainable in the long run.
- Device Trees – see next slide



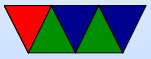
Devicetree

- Traditional Linux ARM support a bit of a copy-paste and #ifdef mess
- Each new platform was a compile option. No common code; kernel for pandaboard not run on beagleboard not run on gumstix, etc.
- Work underway to be more like x86 (where until recently due to PC standards a kernel would boot on any x86)
- A “devicetree” passes in enough config info to the kernel



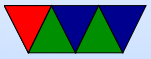
to describe all the hardware available. Thus kernel much more generic

- Still working on issues with this.



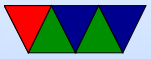
Compiling your Own Kernel

- fun
- may have to do a lot if embedded programmer
- patch the kernel too
- not as scary as it sounds
- Follow linux-kernel list
- Send patches. There are rules, but not hard.

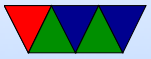


Real Time OS

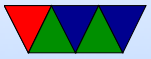
- Who uses realtime?
- realtime used by musicians, important to have low-latency when recording
- Goal not performance, but response time
- Code must meet deadlines
- Predictability/Determinism



- How long is the deadline? For example, ATM, 1s enough?
- "hard" real time vs soft real time usually hard means people die if deadline missed
- Scheduler
- Interrupts (latency)
- Context-switch time how to speed up? low number of state saved floating point values in drivers

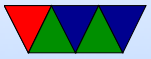


- Low jitter



PREEMPT Kernel

- Linux PREEMPT_RT
- Faster response times
- Remove all unbounded latencies



Co-operative real-time Linux

- Xenomai
- Linux run as side process, sort of like hypervisor