

ECE 471 – Embedded Systems

Lecture 33

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Announcements

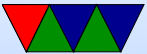
- HW#10 was posted.
- Will send out tentative presentations order
- Final is on Wednesday, December 15th at 9:30am, Barrows 131
- Remember to do course evaluations
- HW#9 will be graded soon
- Remember to return parts if you have them



Gave Back and Went Over Midterm #2



More I/O on the Pi



Starting Programs at Boot

- init process starts first
- Traditionally would start various shell scripts under /etc (the name and order of these can vary a lot)
- Possibly with advent of systemd this will change
- Currently you can still put things you want to run at start in /etc/rc.local



UART – serial port

- Note: Asynchronous, no clock (unlike USART)
how do both sides agree on speed?
- Often useful on embedded boards and old systems, might be only way to reliably connect
- RS-232, originally for teletypes
- 3-15V high, -3 to -15V low
- start/stop bits, parity, bit-size
- Hardware vs Software flow control
- Speeds 300bps - 115000bps and beyond



- 50feet (15m) w/o special cables
- 3-pin version (transmit, receive ground). Also 5-pin HW flow control (CTS/RTS). Can have 2-pin version if only want to transmit
- These days often hook up USB connector
- What does 9600N81 mean?



Pi Serial Ports

- Raspberry Pi has two serial ports, good one and lousy one
They switched them up with Pi3
- Pi does TTL (5v/0) not RS232
- Does support HW flow control, but need to activate those pins custom, is a bit complicated
- Use TTL to USB serial converter usually.
Tell story of the prolific bricking the firmware?



Pi SMI

- <https://iosoft.blog/2020/07/16/raspberry-pi-smi>
- Secondary Memory Interface
- Available on Pis
- Allows creating wide parallel bus out of GPIOs
- Not well documented



Bluetooth

- Basic unit: piconet, master node and up to seven *active* slave nodes within 10m
- Many can exist in an area, and can be connected by a bridge. Connected piconets are called a scatternet
- There can also be up to 255 “parked” nodes in a picnoet
- When parked, can only respond to activation on beacon
- Hold and siff?
- Slaves designed to be cheap, so dumb. Master is smart and runs them. slave/slave communication not possible



- Master broadcasts clock 312.5us. Master transmits in even, slave in odd.
- Radio layer – 2.4GHz, 10 meters. 79 channels of 1MHz.
- pairing
- Bluetooth V1.1 has 13 different application protocols.
- Bluetooth 4.0 (Bluetooth Low Energy) (2010)
 - 25Mbps/200 feet
 - Entirely new stack, designed for low power rapid setup links
 - Not backwards compatible, but same frequency range
 - New profiles



- Linux interface: depends on type. Filetransfer/obex.
Audio (looks like an audio driver) network device, serial device



Bluetooth and Linux

- Two competing stacks, BlueZ and Affix

```
sudo bluetoothctl
```

```
[sudo] password for vince:
```

```
[NEW] Controller B8:27:EB:52:DD:E8 linpack-test
```

```
[bluetooth]# power on
```

```
Changing power on succeeded
```

```
[bluetooth]# scan on
```

```
Discovery started
```

```
[CHG] Controller B8:27:EB:52:DD:E8 Discovering:
```



```
[NEW] Device AC:37:43:89:4C:02 HTC BS 02CA47
```

```
[NEW] Device AC:37:43:89:2F:86 HTC BS 86B06E
```

```
[CHG] Device AC:37:43:89:2F:86 RSSI: -90
```

```
[bluetooth]# scan on
```

```
Failed to start discovery: org.bluez.Error.InPr
```

```
[bluetooth]# connect AC:37:43:89:4C:02
```

- obexpushd. Appears as serial port?



Ethernet

- Old, complicated standard, whole way up to 100GBps
- Modern form is often RJ-45, twisted pairs
- Power over ethernet (only Pi3B+ support)
- PiB models have 10/100 Mbps, Pi3B+ has “gigabit”
- Connected to on-board USB hub



HDMI

- High-Definition Multimedia Interface (2003)
- Compatible with DVI (if no copy protection used)
- Video, audio (up to 8 channels), CEC (consumer electronics control), ethernet
- No support for captions
- DDC – i2c bus, used for EDID (getting device info) and HDCP (copy protection)



- TDMS – transition minimized differential signaling
Video, then during scan line breaks, audio, etc
- CEC – control up to 15 devices with one remote control
(one wire serial bus)
- Various versions, various fees



Other video ports

- NTSC/composite – Pi has (hidden on later models)
- VGA (analog) – hard to get on Pi
- DSI connector – for touchscreen
- DVI
- Thunderbolt
- Displayport



- USB?



Wireless / Wifi

- Wireless ethernet
- 2.4GHz or 5GHz



PCIe

- Pi-4 has it built in
- But you have to desolder the wifi(?) chip and put lots of tiny wires on. People have done this
- Less intrusive, can get it with a Pi Compute Module



CANbus

- Automotive. Introduced by BOSCH, 1983
- One of OBD-II protocols
- differential, 2 wires, 1MBps important things like engine control
- single wire, slower cheaper, hvac, radio, airbags



CANbus Protocol

- id, length code, up to 8 bytes of data id (usually 11 or 29 bits) type and who is sending it. Also priority (lower is higher) length is 4 bits. some always send 8 and pad with zeros
- Type is inferred from id. Can be things like engine RPM, etc
- DBC database has the ids and values. ASCII text database, hard to get legally.



- Dominant/Recessive. Message with lowest ID wins arbitration.
- CAN-FD – extended version with larger sizes



CANbus Linux

- Can4linux – `open("/dev/can0"); read(); write();`
External project?
- SocketCAN – contributed by Volkswagen. In kernel.
Uses socket interface. `/Documentation/networking/can.txt`



CANbus on Pi

- Not by default
- Can get SPI to CANbus adapters



ISA Bus

- Introduced with IBM-PC in 1981
- 8-bit (4.77MHz) then 16-bit (8MHz)
- +/-5V, +/-12V, 8 data, 20 address, DMA, IRQ
- Replaced by VLB (more pins, extra header), EISA (double pins in same connector), MCA micro-channel (different proprietary from IBM)



- Not enumerable at first, set jumpers. Later “Plug-n-Play”



LPC Bus

- Low-pin-count bus
- Intel, 1998, try to get rid of ISA
- Things like PS/2, Serial ports, floppy, etc.
Still used for TPM Trusted Computing nonsense
- Replace 16-bit 8.33MHz parallel bus with 4-bit wide 33.3MHz bus. Only 7 wires. Easier to route than 72



“Conventional” PCI Bus

- Peripheral Component Interconnect
- Enumerable
- 1993, intel
- 62-pins, parallel, 133MB/s
- Extended with 32 or 64-bit versions, 33 or 66MHz, 3.3 or 5V. All slight differences in connectors to support all that.



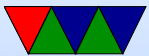
- AGP (Accelerated Graphics Card) for graphics cards. 1997. Direct connect to CPU (not shared), multiple channels, faster clock
- PCI-X 1998, extension to 133MHz. Not to be confused with PCI-Express (PCIe)



PCI protocol

- 256B Config space, mapped into CPU address. Small area system can probe, used to setup larger mappings
- Can have on-board ROM that can be executed. Problem when using on non-x86 systems (emulators needed? special [expensive] PowerPC versions?)
- Latency timers keep bus-master from hogging bus
- 4 interrupt lines, can be shared. Level rather than edge-triggered interrupts make sharing easier





PCIe

- PCI-express, 2003
- Serial, replaced point-to-point with lanes, packet-based
x1, x2, x4, x8 x16, x32
- Compatible with PCI at software level
- Differential Signaling
- External – Thunderbolt



- Serial better due to timing skew
- New x86 audrino quark has PCIe



PCleexpress Mini

- PCIe x1, USB, SMBus, etc
- Smaller card



PCMCIA Bus

- Personal Computer Memory Control International Association
- 16-bit
- Cardbus, 32-bit
- Mostly replaced these days



PC/104 Bus

- Stackable small x86 boards usually
- Run ISA or PCI signals up vertically



VME Bus

- m68k bus but generic enough
- Still found in some embedded systems



Other

- SATA, eSATA, PATA, SCSI (disk drives)
- Firewire
- RapidIO
- Quickpath QPI
- Hypertransport
- Thunderbolt (requested)



- List of competing busses at end of USB wiki article



PWM Linux

- Available on GPIO18 (pin 12) (also GPIO19 on newer)
- Assuming 4.9 kernel or later (sets up proper clock) just edit config.txt and add dtoverlay=pwm
- reboot. lsmod should show pwm_bcm2835 loaded
- <https://www.kernel.org/doc/Documentation/pwm.txt>
- sysfs interface
 - `cat /sys/class/pwm/pwmchip0/npwm`
 - `echo "0" > /sys/class/pwm/pwmchip0/export`
 - `echo "1000" > /sys/class/pwm/pwmchip0/pwm0/period`



- `echo "500" > /sys/class/pwm/pwmchip0/pwm0/duty_cycle`
- `echo "1" > /sys/class/pwm/pwmchip0/pwm0/enable`
- Feel free to use `wiring-pi` or similar

