ECE 471 – Embedded Systems Lecture 32

Vince Weaver

http://web.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

30 November 2020

Announcements

- HW#10 will be posted.
- Will send out tentative presentations order
- Final is on Wednesday, December 16th at 12:15PM, online
- Remember to do course evaluations
- Midterms are almost graded
- HW#9 will be graded soon

More I/O on the Pi

Camera Port

- The SoC has dedicated hardware for driving cameras

- 5megapixel, CSI port (Camera Serial Interface) plus i2c bus to command it.

- Can read data in parallel, directly, without needing USB overhead.

- These chips often used in cell-phones, so makes sense to have support for camera-phone without extra chip being needed.

Touchscreen Display Port

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

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

PCIexpress 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