CSCI 4974 / 6974
Hardware Reverse Engineering

Lecture 16: Printed circuit board RE
Homework 2: PCB RE

• Due last day of class, teams of 2
• Go to one of the tech dumps and find a PCB
• Take photos of both sides, both overview and closeups of interesting areas
• Identify as many ICs as you can
• Draw a block diagram of the board and make a ~10 minute presentation describing its functionality
Today's agenda

- Common structures and what they mean
  - Full circuit extraction leaves nothing to chance
  - But it's sloow!
  - What part of the board is interesting?
Part datasheets

- Extremely helpful in IDing unknown parts
- Even if you can't get the full datasheet you may find a “product brief” that hints at its function
- alldatasheet.com and family are useful for finding obsolete/rare datasheets
Decoupling capacitors

- Local power filtering for high-speed devices
  - Generally tiny ceramic caps
  - Surrounding device on top side
  - Underneath device on bottom side
- Lots of them indicate a large, complex device
  - This is usually obvious just by looking at it
  - Can be helpful at finding things you can't see
  - Ex: bottom-side board photo in press release
Decoupling capacitors
Differential pairs

- Represent signal as difference of two voltages
  - 1 if $X_P > X_N$, else 0
- Better noise immunity
  - Noise couples into both sides approx. equally
- Less radiated EMI
  - Smaller loop area = less efficient antenna
- Often an indicator of high-speed serial data
  - DVI, HDMI, SATA, PCIe, Ethernet, DisplayPort
Differential pairs
Length matching

- May be seen on single-ended or differential
- Used for minimizing skew on fast signals
- Typically a sign of a high-speed data bus
Length matching
DRAM

- DDR and older may be TSOP
- DDR2/3 are BGAs
  - Three rows of balls in each of two columns
  - Several lengths (78, 96 balls) for x4/x8/x16
DDR2 SDRAM
DRAM

- Volatile memory
- May be possible to sniff with fast oscilloscope
- Lines are very sensitive to interference
  - Careful setup required to keep system working
Crystals/oscillators

- Small metal cans
  - may be TH or SMD
- Usually labeled with a frequency in MHz
Crystals/oscillators

- Frequency markings may hint at circuit function
  - 32768 Hz = realtime clock
  - 3.579545 MHz = NTSC video colorburst
  - 4.43361875 MHz = PAL video colorburst
  - 6/12/24/48 MHz = USB
  - 25 MHz = Ethernet
- Others
Crystals/oscillators

- Possible attack point for clock glitching
- Harder to exploit if target has PLL :(
NAND flash

- Wide TSOP, 48 pins
  - Same package is sometimes used for NOR
- Easy to dump, but without FTL may be hard to make sense of image
NAND flash

- Sometimes seen in large BGAs
- These are usually only used in SSDs etc
Serial EEPROM

- Usually SOIC8, rarely SSOP or CSBGA
- Part numbers usually have “24” plus a number for capacity
  - 24LC16 = 16 Kb
  - 24C256 = 256 Kb
Serial EEPROM

- Compatible parts made by many vendors
- Sizes range from 128 bits to 2 Mb
- Standardized 2-wire I2C serial interface
- Can desolder and dump, or sniff in circuit
  - Big SOIC pins are easy to get probe clips onto
Serial NOR flash

- Usually SOIC8, sometimes socketed DIP8 or larger SOIC with some unused pins
- Part numbers often have "25" plus a number for capacity
  - N25Q128 = 128 mbits
  - M25PE80 = 8 mbits
Serial NOR flash

- Compatible parts made by many vendors
- Sizes range from 512Kb to 1Gb
- Standardized 4-wire SPI serial interface
- Can desolder and dump, or sniff in circuit
  - Big SOIC pins are easy to get probe clips onto
DC-DC switching power supplies

- Single controller chip
  - Usually low-pin-count QFN/BGA/SSOP
- Two or more large capacitors
- One large inductor
Find the SMPS (3 total)
Find the SMPS (3 total)
Video processing

- Anything in threes
  - Fast ADCs
  - Fast DACs
  - RAM
EMI cans

- Metal “can” soldered over part of the board
- Keeps interference from crossing
- Used to shield
  - Noisy stuff (keep radiated emissions down)
  - Sensitive stuff (keep external noise out)
- Usually, not always, a sign of RF communications
EMI cans
Firmware version labels

- Stick-on label with numbers and text
- Also can be a color-coded ink dot
- Denotes something programmable
  - May contain valuable data
Program/debug ports

- Extremely useful!
  - May allow full control of target board
  - Even if firmware readout is disabled, JTAG boundary scan may allow some connectivity to be extracted
- Pads may be present even if connector isn't populated
  - You should recognize common pinouts
Microchip ICSP

- Used with PIC microcontrollers
- Five or six pins at 0.1” pitch
  - MCLR (chip reset)
  - Vdd
  - Vss
  - PGD (bidir serial data)
  - PGC (serial clock)
  - PGM/LVP (low-voltage prog mode, optional)
Microchip ICSP

- Male pins on USB keypad
Microchip ICSP

- Unpopulated on Digilent Atlys
Microchip ICSP

- Fine-pitch (0.05”) unpopulated on PICkit3
Xilinx JTAG

- Used with Xilinx FPGA/CPLD devices
- 2x7 pins at 2mm pitch
  - Usually a keyed connector
ARM JTAG/SWD

- ARM makes IP cores, not silicon
- Several common pinouts in use
Traditional ARM JTAG/SWD

- 20 pin 0.1"
- No examples handy :(
Cortex JTAG/SWD

- 10 pin 0.05"
- No examples handy :(
Cortex JTAG/SWD + trace

- 20 pin 0.05” on BeagleBone Black (not populated)
Altera JTAG

- 2x5 pin unpopulated
Test points

- Unmasked vias or bare copper pads
- Sometimes labeled “TPx” in silkscreen
Test points

- Often give access to extremely useful signals!
- Anything that was interesting for board bring-up/test is probably going to be helpful for RE
Serial ports

- Usually 3 or 4 pins at 0.1”
  - [Vdd], TXD, RXD, GND
  - May also have CTS/RTS lines
- Check with oscilloscope during boot
- May provide console access or debug logs
  - Boot loaders sometimes allow memory dumps
Serial port

- Serial port on unknown wireless router
In-class exercise
In-class exercise
In-class exercise
In-class exercise
Questions?

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- Image credit: Some images CC-BY from:
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