Herd Your Boards, Become a Farmer

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About Me (and Linux)

Hobbyist

1994 Linux/m68k on Amiga

1997 Linux/PPC on CHRP

1997 FBDev

Sony

2006 Linux on PS3/Cell

SONY

Glider bvba

2013 Renesas ARM-based SoCs

RENESAS

Why a Board Farm?

Board on Your Desk

Advantages

- ✓ Easy to setup
- ✓ Easy to interact with

Disadvantages

- X One too many boards (*boards are cheap*), outgrowing your desk
- X Too much noise
- X Home Office: Significant other, family members

How many boards on your desk?

Why a Board Farm?

Organizing Development Boards in a Board Farm

Advantages

- ✓ Less clutter on your desk
- ✓ Centralization
- ✓ Automatization
- ✓ (Worldwide) Remote access
- ✓ Board sharing

Disadvantages

- X (More) Complex setup
- X How to interact with your board?

Board Farm Requirements

Basic

Power & Serial Console

Intermediate

- Reset ($\neq$ powercycle $\neq$ software reboot)
- Wake-Up
- Soft Power-On
- Input buttons
- Measure Power Consumption

Advanced

- Video in & out
- . . . (add yours) . . .

Board Farm Building Blocks

Single Development Board

Picture

Board Farm Building Blocks

Board Farm

Picture

Power Control

Power Outlet Control

- Classical solution
- Multiple interface options (Ethernet/serial)
- Metering
- Fine for your freezer or washing machine
- Overkill for many low-power embedded boards

Picture

Power Control

Relay Board

- Multiple interface options (GPIO, I2C, USB, Ethernet)
  - Beware multiple boards with identical MAC addresses!
- Overkill for many low-power embedded boards

Picture

Power Control

BayLibre ACME

- Cape for BeagleBone Black
- OR . . . connect to anything that has an I2C bus
- Up to 8 channels ($\times$ max. 2 capes)

Picture

Power Control

BayLibre ACME

- Power Control and Voltage/Current Monitoring:
  - Jack Power Probe (2.1/5.5mm Center-pos, up to 20V/6A)
  - USB Power Probe (Mini-B, up to 1A)
  - Not good enough for the z890 ◡̈
- Measurement only:
  - HE10 Power Probe (up to 150mA/1.5A/10A)
  - Temperature Probe

Picture

Power Measurement

- Measure Voltage (U)
- Measure Current (I) across a Measurement Resistor (R)
  - Ohm's law: $U = R \times I$
  - picture
- Power consumption: $P = U \times I$
  - Whole board
  - Subsystem power rails

Console

- Serial consoles
  - Legacy DB9/DB25 serial → USB-serial adapter
  - 1.8V/3.3V/5V UART → USB-serial adapter
  - On-board USB-serial chip
  - 96Boards UART
- ⇒ USB hub with many ports (may need power)
- Use `udev` rules to pin names to your serial ports

  `/etc/udev/rules.d/99-usb-serial.rules`

```
SUBSYSTEM=="tty", ATTRS{idVendor}=="0403", ATTRS{idProduct}=="6001", \
    ATTRS{serial}=="A900YDVW", SYMLINK+="tty-ape6evm"
SUBSYSTEM=="tty", DRIVERS=="mos7840", ATTRS{port_number}=="0", \
    SYMLINK+="tty-aten0"
```

- Beware USB-serial chips with identical serial numbers!
  Fortunately USB devices can be addressed by topology

  `/dev/serial/by-path/...`

Network

- Ethernet Switch
  - Beware multiple boards with identical MAC addresses!
- Wireless Access Point
- Similar to networking *normal* Linux machines

Interaction

- Mostly input and control
- Output: complicated beyond console
- May require creative and custom solutions

Interaction

Switches and Buttons

- System Reset
- System Wake-Up
- Soft Power-On
- Generic input (e.g. keypad)
- ...

Interaction

Switches and Buttons: Trips & Tricks

- JTAG has reset
- Wake-Up needs an IRQ, or GPIO with interrupt capability
- Add any GPIO on expansion connector to gpio-keys in DT, to avoid having to solder a wire to a switch

```
keyboard {
        compatible = "gpio-keys";
        pinctrl-names = "default";
        pinctrl-0 = <&keyboard_pins>;
        key-wakeup {
              gpios = <&gpio2 1 GPIO_ACTIVE_LOW>;
              label = "EXIO-D-50";
              linux,code = <KEY_WAKEUP>;
        };
};
&pfc {
        keyboard_pins: keyboard {
                pins = "GP_2_1";
                bias-pull-up;
        }
};
```

Interaction

Signal Inputs

- 2.54mm female/male header picture
- 2 mm female/male header picture
- Unpopulated header picture
- High-density connector picture
  - Breakout boards: buy or build yourself
  - *Extreme Wiring on the Prototyping Board*
    `http://elm-chan.org/docs/wire/wiring_e.html`
- Solder to switch, or other component
- Signals are usually asserted by grounding
- Sometimes asserted by pulling high
  - Positive voltage supply may be missing on connector ☹

Interaction

How to Control All Those Signals?

- GPIOs with/without driving transistors/MOSFETs
  - X No isolation
- Relay board
  - Electromagnetically controlled switch
  - ✓ Isolation
  - ✓ Readily available
  - X Noisy
  - Overkill for most input signals

Interaction

How to Control All Those Signals?

- Optocouplers
  - Light controlled switch picture
  - ✓ Isolation
  - ✓ Can switch +1.8V, +3.3V, +5V, . . .
  - Add a relay if needed
  - Polarity!
- Via I2C or SPI GPIO expander
- picture

Management Host

- Control and monitor all blocks
- Provide services
- Old PC, embedded x86
- Embedded Development Boards becoming more powerful
  - E.g. BeagleBone Black, Raspberry Pi, . . .

Power Supplies

- Each board comes with its own power supply
- Wall wart rats nest
- picture Can we improve upon?
- Powered USB hub for e.g. Beowulf of Raspberry Pis
- Barrel jack splitters (2-way, 4-way) picture
  - Usually limited to 2A, maximum current is seldom advertized

Board Power Needs

- Most boards take either 5V or 12V
- Different connectors types, voltages, and polarities
  - 2.1/5.5mm or 2.5/5.5mm jack picture
    - 5V, 7.5V, 9V, 12V, . . .
    - Most (not all!) are Center-positive
  - EIAJ connector, Center-positive, 2A

EIAJ-01	0–3.15V	2.35/0.7mm	picture
EIAJ-02	3.15–6.3V	4.0/1.7mm	picture
EIAJ-03	6.3–10.5V	4.75/1.7mm	picture
EIAJ-04	10.5–13.5V	5.5/3.4/1.0mm	picture
EIAJ-05	13.5–18V	6.5/4.4/1.4mm	picture

    - 96Boards uses EIAJ-03 at 8-18V ☹
  - USB mini/micro-B
- Need for conversion when used with ACME

Single Power Supply

- My needs:
  - 8 Boards + Management Host & Control Hardware
  - 13A @ 5V
  - 28A @ 12V
  - Absolute maximum ratings!
- Lab power supply
- PC power supply

PC Power Supply

Multiple Output Voltages

+5V	For development boards
+12V	For development boards
	▸ Single or Dual Rail!
+3.3V	For an MSP430 LaunchPad?
-12V	Not so useful without real RS232

Management Host Features

+5Vsb	2A is ample
PS_ON	Remote control

PC Power Supply

Minimum Load?

Older supplies may need some load to work

- Look for *Haswell C6/C7 Zero Load Support*
- Use e.g. Ethernet switch as load, or load resistors

Voltage stability

- Not so much of an issue anymore
  - Single rail 12V with DC/DC convertors for 3.3 and 5V
  - SoCs run at low voltages, board has own PMIC
  - Boards that need stable +5V signals typically run from 12V
  - Any boards that still need stable +12V signals?
- Power Supply needs some time to stabilize!
  - Turn power supply on first, individual boards last
  - Turn indvidual boards off first, power supply last
  - `PWR_OK` signal

PC Power Supply

Safety

Watch out for high currents!

- Typical 650W PC Power Supply
  - 52A @ 12V
  - 22A @ 5V
  - Low voltage, but high current, needs thick wires
  - My induction stove needs only 32A (@230V, though)
- Do not feed everything from one wire!
  - 4A per wire
  - Modular Power Supply can still be handy
- Fuses for individual boards
  - The PS should be designed to survive a short circuit
  - Your Raspberry Pi may not (at 20A)

PC Power Supply

Tips & Tricks

- Use Ethernet switch with 12V input (some need e.g. 7.5V)
- Most USB hubs need 5V

- +12V rail is the major rail on modern supplies
- +5V limited to 20–25A, independent of total wattage
- Many boards that need 5V? $\rightarrow$ add a DC/DC convertor

PC Power Supply

Before 3D Printing, There Existed LEGO

pictures

Software Side

GPIO Control

- Add PFC8574 GPIO expander at I2C address 0x24:

```
if i2cget -y 1 0x24 >& /dev/null; then
        echo pcf8574 0x24 > \
                /sys/class/i2c-adapter/i2c-1/new_device
        for i in $(seq 480 487); do
                echo $i > /sys/class/gpio/export
        done
fi
```

- Toggle reset line at gpio 480 using sysfs:

```
echo out > /sys/class/gpio/gpio480/direction
sleep 0.2
echo in > /sys/class/gpio/gpio480/direction
```

- Should try new GPIO chardev interface . . .

Software Side

ACME

- Sigrok integration
- PulseView GUI
- Command line

```
# sigrok-cli --driver=baylibre-acme --samples=1
FRAME-BEGIN
P1_ENRG_PWR: 1.225000 W
P1_ENRG_CURR: 0.246000 A
P1_ENRG_VOL: 5.019000 V
...
FRAME-END
```

- sysfs GPIO for board power control, or `sigrok-cli`
- `/etc/init.d/S95acme-init` powers on all boards during boot up ☹

```
- echo 1 > /sys/class/gpio/gpio$GPIO/value
+ echo 0 > /sys/class/gpio/gpio$GPIO/value
```

Software Side

- Booting (TFTP / NFS root): cfr. board on your desk
- Automated boot
- Boot testing
- Auto-bisecting regressions
- Join `kernelci.org`?

Q *How can I participate in the boot test phase?*
A *The best way to participate is to send us your boards*

Source: `https://kernelci.org/faq`

Advanced

- JTAG
- VNC for display output
- Remote access
- Virtualization to isolate multiple users
- ...

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Questions?