

Making Everything Easier!™

Novelty Edition

Device Tree

FOR DUMMIES

Learn to:

- Boot your system with a Device Tree
- Understand the basic syntax of the Device Tree
- Learn about Device Tree bindings and their rules

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Agenda

- ▶ User perspective: booting with the Device Tree
- ▶ Basic Device Tree syntax and compilation
- ▶ Simple example of Device Tree fragment
- ▶ Overall organization of a Device Tree
- ▶ Examples of Device Tree usage
- ▶ General considerations about the Device Tree in Linux

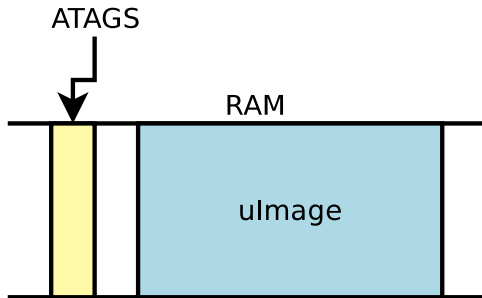


User perspective: before the Device Tree

- ▶ The kernel contains the entire description of the hardware.
- ▶ The bootloader loads a single binary, the kernel image, and executes it.
 - ▶ `uImage` or `zImage`
- ▶ The bootloader prepares some additional information, called `ATAGS`, which address is passed to the kernel through register `r2`
 - ▶ Contains information such as memory size and location, kernel command line, etc.
- ▶ The bootloader tells the kernel on which board it is being booted through a *machine type* integer, passed in register `r1`.
- ▶ U-Boot command: `bootm <kernel img addr>`
- ▶ Barebox variable: `bootm.image`



User perspective: before the Device Tree



`r1 = <machine type>`
`r2 = <pointer to ATAGS>`

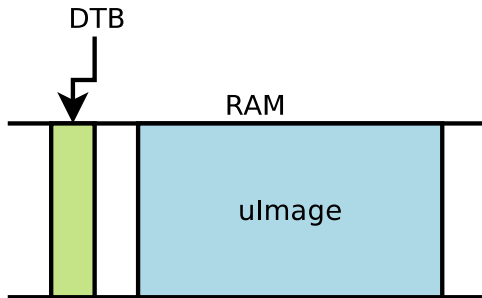


User perspective: booting with a Device Tree

- ▶ The kernel no longer contains the description of the hardware, it is located in a separate binary: the *device tree blob*
- ▶ The bootloader loads two binaries: the kernel image and the *DTB*
 - ▶ Kernel image remains `uImage` or `zImage`
 - ▶ DTB located in `arch/arm/boot/dts`, one per board
- ▶ The bootloader passes the DTB address through `r2`. It is supposed to adjust the DTB with memory information, kernel command line, and potentially other info.
- ▶ No more *machine type*.
- ▶ U-Boot command:
`boot[mz] <kernel img addr> - <dtb addr>`
- ▶ Barebox variables: `bootm.image`, `bootm.oftree`



User perspective: booting with a Device Tree



r1 = don't care

r2 = <pointer to DTB>



User perspective: compatibility mode for DT booting

- ▶ Some bootloaders have no specific support for the Device Tree, or the version used on a particular device is too old to have this support.
- ▶ To ease the transition, a *compatibility* mechanism was added: `CONFIG_ARM_APPENDED_DTB`.
 - ▶ It tells the kernel to look for a DTB right *after* the kernel image.
 - ▶ There is no built-in Makefile rule to produce such kernel, so one must manually do:

```
cat arch/arm/boot/zImage arch/arm/boot/dts/myboard.dtb > my-zImage  
mkimage ... -d my-zImage my-uImage
```

- ▶ In addition, the additional option `CONFIG_ARM_ATAG_DTB_COMPAT` tells the kernel to read the *ATAGS* information from the bootloader, and update the DT using them.



What is the Device Tree ?

- ▶ Quoted from the *Power.org Standard for Embedded Power Architecture Platform Requirements (ePAPR)*
 - ▶ The ePAPR specifies a concept called a device tree to describe system hardware. A boot program loads a device tree into a client program's memory and passes a pointer to the device tree to the client.
 - ▶ A device tree is a tree data structure with nodes that describe the physical devices in a system.
 - ▶ An ePAPR-compliant device tree describes device information in a system that cannot be dynamically detected by a client program.



Basic Device Tree syntax

```
/ {  
    node@0 {  
        a-string-property = "A string";  
        a-string-list-property = "first string", "second string";  
        a-byte-data-property = [0x01 0x23 0x34 0x56];  
  
        child-node@0 {  
            first-child-property;  
            second-child-property = <1>;  
            a-reference-to-something = <&node1>;  
        };  
  
        child-node@1 {  
        };  
    };  
  
    node1: node@1 {  
        an-empty-property;  
        a-cell-property = <1 2 3 4>;  
  
        child-node@0 {  
        };  
    };  
};
```

Node name

Unit address

Property name

Property value

Properties of node@0

Bytestring

A phandle
(reference to another node)

Label

Four cells (32 bits values)



From source to binary

- ▶ On ARM, all **Device Tree Source** files (DTS) are for now located in `arch/arm/boot/dts`
 - ▶ `.dts` files for board-level definitions
 - ▶ `.dtsi` files for included files, generally containing SoC-level definitions
- ▶ A tool, the **Device Tree Compiler** compiles the source into a binary form.
 - ▶ Source code located in `scripts/dtc`
- ▶ The **Device Tree Blob** is produced by the compiler, and is the binary that gets loaded by the bootloader and parsed by the kernel at boot time.
- ▶ `arch/arm/boot/dts/Makefile` lists which DTBs should be generated at build time.

```
dtb-$(CONFIG_ARCH_MVEBU) += armada-370-db.dtb \  
    armada-370-mirabox.dtb \  
...
```



Exploring the DT on the target

- ▶ In `/sys/firmware/devicetree/base`, there is a directory/file representation of the Device Tree contents

```
# ls -l /sys/firmware/devicetree/base/
total 0
-r--r--r--    1 root    root      4 Jan  1 00:00 #address-cells
-r--r--r--    1 root    root      4 Jan  1 00:00 #size-cells
drwxr-xr-x    2 root    root      0 Jan  1 00:00 chosen
drwxr-xr-x    3 root    root      0 Jan  1 00:00 clocks
-r--r--r--    1 root    root     34 Jan  1 00:00 compatible
[...]
-r--r--r--    1 root    root      1 Jan  1 00:00 name
drwxr-xr-x   10 root    root      0 Jan  1 00:00 soc
```

- ▶ If `dtc` is available on the target, possible to "unpack" the Device Tree using:
`dtc -I fs /sys/firmware/devicetree/base`



A simple example, DT side

```
auart0: serial@8006a000 {
```

Defines the "programming model" for the device. Allows the operating system to identify the corresponding device driver.

```
compatible = "fsl,imx28-auart", "fsl,imx23-auart";
```

Address and length of the register area.

```
reg = <0x8006a000 0x2000>;
```

Interrupt number.

```
interrupts = <112>;
```

DMA engine and channels, with names.

```
dmass = <&dma_apbx 8>, <&dma_apbx 9>;
```

```
dma-names = "rx", "tx";
```

Reference to the clock.

```
clocks = <&clks 45>;
```

The device is not enabled.

```
status = "disabled";
```

```
};
```

Taken from arch/arm/boot/dts/imx28.dtsi



A simple example, driver side (1)

The compatible string used to bind a device with the driver

```
static struct of_device_id mxs_auart_dt_ids[] = {
    {
        .compatible = "fsl,imx28-auart",
        .data = &mxs_auart_devtype[IMX28_AUART]
    }, {
        .compatible = "fsl,imx23-auart",
        .data = &mxs_auart_devtype[IMX23_AUART]
    }, { /* sentinel */ }
};
MODULE_DEVICE_TABLE(of, mxs_auart_dt_ids);
[...]
static struct platform_driver mxs_auart_driver = {
    .probe = mxs_auart_probe,
    .remove = mxs_auart_remove,
    .driver = {
        .name = "mxs-auart",
        .of_match_table = mxs_auart_dt_ids,
    },
};
```

Code from `drivers/tty/serial/mxs-auart.c`



A simple example, driver side (2)

- ▶ `of_match_device` allows to get the matching entry in the `mxs_auart_dt_ids` table.
- ▶ Useful to get the driver-specific `data` field, typically used to alter the behavior of the driver depending on the variant of the detected device.

```
static int mxs_auart_probe(struct platform_device *pdev)
{
    const struct of_device_id *of_id =
        of_match_device(mxs_auart_dt_ids, &pdev->dev);

    if (of_id) {
        /* Use of_id->data here */
        [...]
    }
    [...]
}
```



A simple example, driver side (3)

- ▶ Getting a reference to the clock
 - ▶ described by the `clocks` property
 - ▶ `s->clk = clk_get(&pdev->dev, NULL);`
- ▶ Getting the I/O registers *resource*
 - ▶ described by the `reg` property
 - ▶ `r = platform_get_resource(pdev, IORESOURCE_MEM, 0);`
- ▶ Getting the interrupt
 - ▶ described by the `interrupts` property
 - ▶ `s->irq = platform_get_irq(pdev, 0);`
- ▶ Get a DMA channel
 - ▶ described by the `dmaz` property
 - ▶ `s->rx_dma_chan = dma_request_slave_channel(s->dev, "rx");`
 - ▶ `s->tx_dma_chan = dma_request_slave_channel(s->dev, "tx");`
- ▶ Check some custom property
 - ▶ `struct device_node *np = pdev->dev.of_node;`
 - ▶ `if (of_get_property(np, "fsl,uart-has-rtscs", NULL))`



Device Tree inclusion

- ▶ Device Tree files are not monolithic, they can be split in several files, including each other.
- ▶ `.dtsi` files are included files, while `.dts` files are *final* Device Trees
- ▶ Typically, `.dtsi` will contain definition of SoC-level information (or sometimes definitions common to several almost identical boards).
- ▶ The `.dts` file contains the board-level information.
- ▶ The inclusion works by **overlaying** the tree of the including file over the tree of the included file.
- ▶ Inclusion using the DT operator `/include/`, or since a few kernel releases, the DTS go through the C preprocessor, so `#include` is recommended.



Device Tree inclusion example

Definition of the AM33xx SoC

```
/ {
    compatible = "ti,am33xx";
    [...]
    ocp {
        uart0: serial@44e09000 {
            compatible = "ti,omap3-uart";
            reg = <0x44e09000 0x2000>;
            interrupts = <72>;
            status = "disabled";
        };
    };
};
```

am33xx.dtsi



Definition of the BeagleBone board

```
#include "am33xx.dtsi"

/ {
    compatible = "ti,am335x-bone", "ti,am33xx";
    [...]
    ocp {
        uart0: serial@44e09000 {
            pinctrl-names = "default";
            pinctrl-0 = <&uart0_pins>;
            status = "okay";
        };
    };
};
```

am335x-bone.dts



Compiled DTB

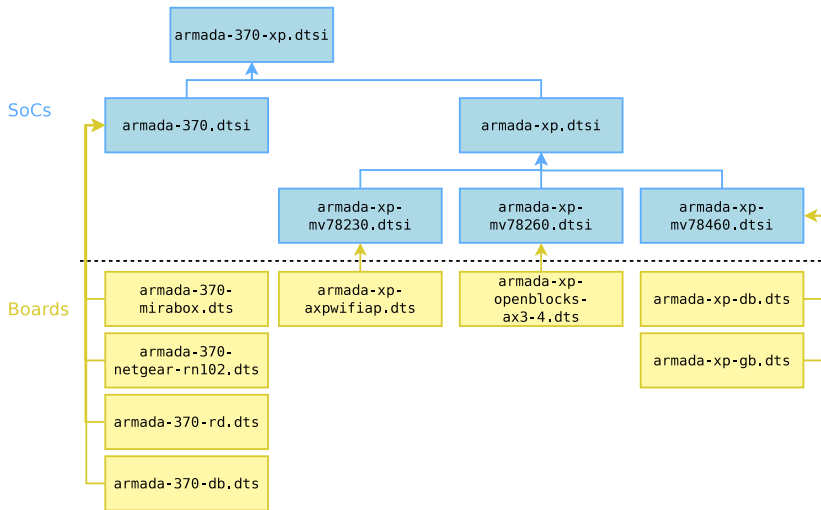
```
/ {
    compatible = "ti,am335x-bone", "ti,am33xx";
    [...]
    ocp {
        uart0: serial@44e09000 {
            compatible = "ti,omap3-uart";
            reg = <0x44e09000 0x2000>;
            interrupts = <72>;
            pinctrl-names = "default";
            pinctrl-0 = <&uart0_pins>;
            status = "okay";
        };
    };
};
```

am335x-bone.dtb

Note: the real DTB is in binary format.
Here we show the text equivalent of the
DTB contents;



Device Tree inclusion example (2)





Concept of Device Tree binding

- ▶ Quoting the *ePAPR*:
 - ▶ This chapter contains requirements, known as **bindings**, for **how specific types and classes of devices are represented in the device tree**.
 - ▶ The `compatible` property of a device node describes the specific binding (or bindings) to which the node complies.
 - ▶ When creating a new device tree representation for a device, a **binding should be created that fully describes the required properties and value of the device**. This set of properties shall be sufficiently descriptive to provide device drivers with needed attributes of the device.



Documentation of Device Tree bindings

- ▶ All Device Tree bindings recognized by the kernel are documented in `Documentation/devicetree/bindings`.
- ▶ Each binding documentation described which properties are accepted, with which values, which properties are mandatory vs. optional, etc.
- ▶ All new Device Tree bindings must be reviewed by the *Device Tree maintainers*, by being posted to `devicetree@vger.kernel.org`. This ensures correctness and consistency across bindings.

```
OPEN FIRMWARE AND FLATTENED DEVICE TREE BINDINGS
M:      Rob Herring <rob.herring@calxeda.com>
M:      Pawel Moll <pawel.moll@arm.com>
M:      Mark Rutland <mark.rutland@arm.com>
M:      Stephen Warren <swarren@wwwdotorg.org>
M:      Ian Campbell <ijc+devicetree@hellion.org.uk>
L:      devicetree@vger.kernel.org
```



Device Tree binding documentation example

* Freescale MXS Application UART (AUART)

Required properties:

- compatible : Should be "fsl,<soc>-auart". The supported SoCs include imx23 and imx28.
- reg : Address and length of the register set for the device
- interrupts : Should contain the auart interrupt numbers
- dmas: DMA specifier, consisting of a phandle to DMA controller node and AUART DMA channel ID.
Refer to dma.txt and fsl-mxs-dma.txt for details.
- dma-names: "rx" for RX channel, "tx" for TX channel.

Example:

```
auart0: serial@8006a000 {  
    compatible = "fsl,imx28-auart", "fsl,imx23-auart";  
    reg = <0x8006a000 0x2000>;  
    interrupts = <112>;  
    dmas = <&dma_apbx 8>, <&dma_apbx 9>;  
    dma-names = "rx", "tx";  
};
```

Note: Each auart port should have an alias correctly numbered in "aliases" node.

Example:

[...]

[Documentation/devicetree/bindings/tty/serial/fsl-mxs-auart.txt](#)



Device Tree organization: top-level nodes

Under the root of the Device Tree, one typically finds the following top-level nodes:

- ▶ A `cpus` node, which sub-nodes describing each CPU in the system.
- ▶ A `memory` node, which defines the location and size of the RAM.
- ▶ A `chosen` node, which defines *parameters chosen or defined by the system firmware at boot time*. In practice, one of its usage is to pass the kernel command line.
- ▶ A `aliases` node, to define shortcuts to certain nodes.
- ▶ One or more nodes defining the *buses* in the SoC.
- ▶ One or mode nodes defining on-board devices.



Device Tree organization: imx28.dtsi

arch/arm/boot/dts/imx28.dtsi

```
/ {  
    aliases { ... };  
    cpus { ... };  
  
    apb@80000000 {  
        apbh@80000000 {  
            /* Some devices */  
        };  
  
        apbx@80040000 {  
            /* Some devices */  
        };  
    };  
  
    ahb@80080000 {  
        /* Some devices */  
    };  
};
```




i.MX28 buses organization

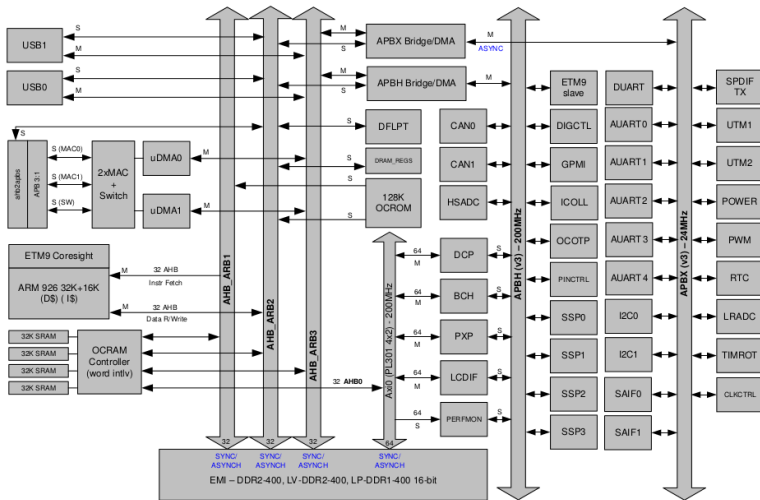


Figure 1-2. i.MX28 SOC System Buses



Device Tree organization: imx28-evk.dts

arch/arm/boot/dts/imx28-evk.dts

```
/ {  
    model = "Freescale i.MX28 Evaluation Kit";  
    compatible = "fsl,imx28-evk", "fsl,imx28";  
  
    memory {  
        reg = <0x40000000 0x08000000>;  
    };  
  
    apb@80000000 {  
        apbh@80000000 { ... };  
        apbx@80040000 { ... };  
    };  
  
    ahb@80080000 { ... };  
  
    sound { ... };  
    leds { ... };  
    backlight { ... };  
};
```



Top-level compatible property

- ▶ The top-level `compatible` property typically defines a compatible string for the board, and then for the SoC.
- ▶ Values always given with the most-specific first, to least-specific last.
- ▶ Used to match with the `dt_compat` field of the `DT_MACHINE` structure:

```
static const char *mxs_dt_compat[] __initdata = {  
    "fsl,imx28",  
    "fsl,imx23",  
    NULL,  
};  
  
DT_MACHINE_START(MXS, "Freescale MXS (Device Tree)")  
    .dt_compat      = mxs_dt_compat,  
    [...]            
MACHINE_END
```

- ▶ Can also be used within code to test the machine:

```
if (of_machine_is_compatible("fsl,imx28-evk"))  
    imx28_evk_init();
```



Bus, address cells and size cells

Inside a bus, one typically needs to define the following properties:

- ▶ A `compatible` property, which identifies the bus controller (in case of I2C, SPI, PCI, etc.). A special value `compatible = "simple-bus"` means a simple memory-mapped bus with no specific handling or driver. Child nodes will be registered as *platform devices*.
- ▶ The `#address-cells` property indicate how many cells (i.e 32 bits values) are needed to form the base address part in the `reg` property.
- ▶ The `#size-cells` is the same, for the size part of the `reg` property.
- ▶ The `ranges` property can describe an *address translation* between the child bus and the parent bus. When simply defined as `ranges;`, it means that the translation is an identity translation.



simple-bus, address cells and size cells

```
apbh@80000000 {
    compatible = "simple-bus";
    #address-cells = <1>;
    #size-cells = <1>;
    reg = <0x80000000 0x3c900>;
    ranges;

    [...]

    hsadc: hsadc@80002000 {
        reg = <0x80002000 0x2000>;
        interrupts = <13>;
        dmas = <&dma_apbh 12>;
        dma-names = "rx";
        status = "disabled";
    };

    [...]
};
```



I2C bus, address cells and size cells

```
i2c0: i2c@80058000 {  
    #address-cells = <1>;  
    #size-cells = <0>;  
    compatible = "fsl,imx28-i2c";  
    reg = <0x80058000 0x2000>;  
    interrupts = <111>;  
    [...]  
  
    sgtl5000: codec@0a {  
        compatible = "fsl,sgtl5000";  
        reg = <0x0a>;  
        VDDA-supply = <&reg_3p3v>;  
        VDDIO-supply = <&reg_3p3v>;  
        clocks = <&saif0>;  
    };  
  
    at24@51 {  
        compatible = "at24,24c32";  
        pagesize = <32>;  
        reg = <0x51>;  
    };  
};
```



Interrupt handling

- ▶ `interrupt-controller;` is a boolean property that indicates that the current node is an interrupt controller.
- ▶ `#interrupt-cells` indicates the number of cells in the `interrupts` property for the interrupts managed by the selected interrupt controller.
- ▶ `interrupt-parent` is a *phandle* that points to the interrupt controller for the current node. There is generally a top-level `interrupt-parent` definition for the main interrupt controller.



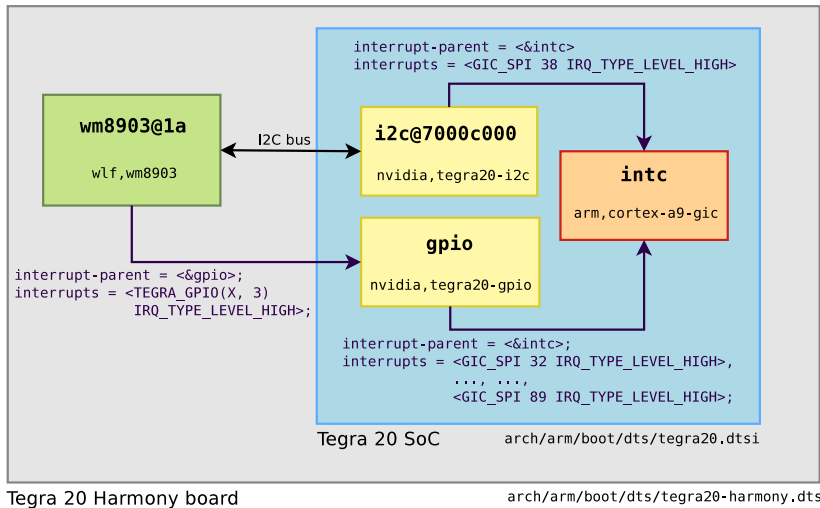
Interrupt example: imx28.dtsi

```
/ {
    interrupt-parent = <&icoll>;
    apb@80000000 {
        apbh@80000000 {
            icoll: interrupt-controller@80000000 {
                compatible = "fsl,imx28-icoll", "fsl,icoll";
                interrupt-controller;
                #interrupt-cells = <1>;
                reg = <0x80000000 0x2000>;
            };

            ssp0: ssp@80010000 {
                [...]
                interrupts = <96>;
            };
        };
    };
};
```




A more complicated example on Tegra 20





Interrupt example: tegra20.dtsi

```
/ {
    interrupt-parent = <&intc>;

    intc: interrupt-controller {
        compatible = "arm,cortex-a9-gic";
        reg = <0x50041000 0x1000 0x50040100 0x0100>;
        interrupt-controller;
        #interrupt-cells = <3>;
    };

    i2c@7000c000 {
        compatible = "nvidia,tegra20-i2c";
        reg = <0x7000c000 0x100>;
        interrupts = <GIC_SPI 38 IRQ_TYPE_LEVEL_HIGH>;
        #address-cells = <1>;
        #size-cells = <0>;
        [...]
    };

    gpio: gpio {
        compatible = "nvidia,tegra20-gpio";
        reg = <0x6000d000 0x1000>;
        interrupts = <GIC_SPI 32 IRQ_TYPE_LEVEL_HIGH>, <GIC_SPI 33 IRQ_TYPE_LEVEL_HIGH>,
            [...], <GIC_SPI 89 IRQ_TYPE_LEVEL_HIGH>;
        #gpio-cells = <2>;
        gpio-controller;
        #interrupt-cells = <2>;
        interrupt-controller;
    };
};
```



Interrupt example: tegra20-harmony.dts

```
i2c@7000c000 {
    status = "okay";
    clock-frequency = <400000>;

    wm8903: wm8903@1a {
        compatible = "wlf,wm8903";
        reg = <0x1a>;
        interrupt-parent = <&gpio>;
        interrupts = <TEGRA_GPIO(X, 3) IRQ_TYPE_LEVEL_HIGH>;

        gpio-controller;
        #gpio-cells = <2>;

        micdet-cfg = <0>;
        micdet-delay = <100>;
        gpio-cfg = <0xffffffff 0xffffffff 0 0xffffffff 0xffffffff>;
    };
};
```



DT is hardware description, not configuration

- ▶ The Device Tree is really a hardware description language.
- ▶ It should **describe the hardware layout**, and how it works.
- ▶ But it should **not describe which particular hardware configuration** you're interested in.
- ▶ As an example:
 - ▶ You may describe in the DT whether a particular piece of hardware supports DMA or not.
 - ▶ But you may not describe in the DT if you *want* to use DMA or not.



DT bindings as an ABI

- ▶ Since the DT is OS independent, it should also be stable.
- ▶ The original idea is that DTBs can be flashed on some devices by the manufacturer, so that the user can install whichever operating system it wants.
- ▶ Once a Device Tree binding is defined, and used in DTBs, it should no longer be changed anymore. It can only be extended.
- ▶ This normally means that **Device Tree bindings become part of the kernel ABI**, and it should be handled with the same care.
- ▶ However, kernel developers are realizing that this is really hard to achieve and slowing down the integration of drivers.
 - ▶ The ARM Kernel Mini-summit discussions have relaxed those rules.
 - ▶ There will be additional discussions during the Kernel Summit, with final conclusions published afterwards.



Basic guidelines for binding design

- ▶ **A precise compatible string is better than a vague one**
 - ▶ You have a driver that covers both variants T320 and T330 of your hardware. You may be tempted to use `foo,t3xx` as your compatible string.
 - ▶ Bad idea: what if T340 is slightly different, in an incompatible way? You'd better use `foo,t320` for both T320 and T330.
- ▶ **Do not encode too much hardware details in the DT**
 - ▶ When two hardware variants are quite similar, some developers are tempted to encode all the differences in the DT, including register offsets, bit masks or offsets.
 - ▶ Bad idea: it makes the binding more complex, and therefore less resilient to future changes. Instead, use two different compatible strings and handle the differences in the driver.



Future directions

- ▶ More DT bindings for **various subsystems**
- ▶ A **tool to validate DTS against bindings**
 - ▶ Currently, the DT compiler only makes syntax checks, no conformance checks against bindings.
 - ▶ Proposal from Benoit Cousson and Fabien Parent, `[RFC 00/15] Device Tree schemas and validation`
 - ▶ Talk from Tomasz Figa at this ELC.
- ▶ **Take out the Device Tree source files from the kernel tree**
 - ▶ DTs are OS independent, so they can be used for other purposes than just Linux. They are already used by Barebox or U-Boot.
 - ▶ Having them outside of the kernel reduces the amount of *churn* in the kernel source.
 - ▶ But is IMO likely to cause a huge number of compatibility issues.



References

- ▶ Power.org™ Standard for Embedded Power Architecture Platform Requirements (ePAPR), http://www.power.org/resources/downloads/Power_ePAPR_APPROVED_v1.0.pdf
- ▶ DeviceTree.org website, <http://www.devicetree.org>
- ▶ Device Tree documentation in the kernel sources, `Documentation/devicetree`
- ▶ The Device Tree kernel mailing list, <http://dir.gmane.org/gmane.linux.drivers.devicetree>

Questions?

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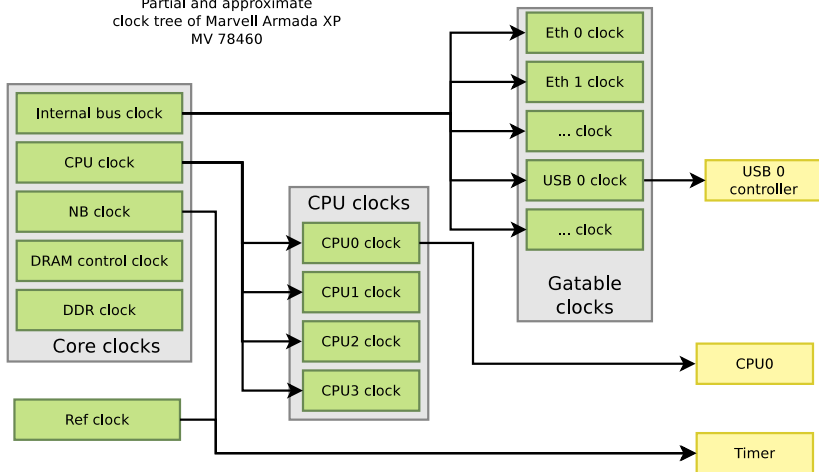
<http://free-electrons.com/pub/conferences/2014/elc/petazzoni-device-tree-dummies/>

Backup slides



Clock tree example, Marvell Armada XP

Partial and approximate
clock tree of Marvell Armada XP
MV 78460





Clock examples: instantiating clocks

```
soc {
    coreclk: mvebu-sar@18230 {
        compatible = "marvell,armada-xp-core-clock";
        reg = <0x18230 0x08>;
        #clock-cells = <1>;
    };

    cpuclock: clock-complex@18700 {
        #clock-cells = <1>;
        compatible = "marvell,armada-xp-cpu-clock";
        reg = <0x18700 0xA0>;
        clocks = <&coreclk 1>;
    };

    gateclk: clock-gating-control@18220 {
        compatible = "marvell,armada-xp-gating-clock";
        reg = <0x18220 0x4>;
        clocks = <&coreclk 0>;
        #clock-cells = <1>;
    };
}

clocks {
    /* 25 MHz reference crystal */
    refclk: oscillator {
        compatible = "fixed-clock";
        #clock-cells = <0>;
        clock-frequency = <25000000>;
    };
};
```



Clock examples: consuming clocks

CPU, using a cpuclock

```
cpu@0 {  
    device_type = "cpu";  
    compatible = "marvell,sheeva-v7";  
    reg = <0>;  
    clocks = <&cpuclock 0>;  
};
```

Timer, using either a coreclk or refclk

```
timer@20300 {  
    compatible = "marvell,armada-xp-timer";  
    clocks = <&coreclk 2>, <&refclk>;  
    clock-names = "nbclk", "fixed";  
};
```

USB, using a gateclk

```
usb@52000 {  
    compatible = "marvell,orion-ehci";  
    reg = <0x52000 0x500>;  
    interrupts = <47>;  
    clocks = <&gateclk 20>;  
    status = "disabled";  
};
```



pinctrl binding: consumer side

- ▶ The *pinctrl* subsystem allows to manage pin muxing.
- ▶ In the Device Tree, devices that need pins to be muxed in a certain way must declare the *pinctrl* configuration they need.
- ▶ The `pinctrl-<n>` properties allow to give the list of *pinctrl* configuration needed for a certain *state* of the device.
- ▶ The `pinctrl-names` property allows to give a name to each state.
- ▶ When a device is probed, its `default` *pinctrl* state is requested automatically.

```
ssp0: ssp@80010000 {  
    pinctrl-names = "default";  
    pinctrl-0 = <&mmc0_8bit_pins_a  
                &mmc0_cd_cfg &mmc0_sck_cfg>;  
    [...]  
};
```



pinctrl configurations

- ▶ A *pinctrl* configuration provides a list of pins and their configuration.
- ▶ Such configurations are defined as *sub-nodes* of the *pinctrl* device, either at the SoC-level, or board-level.
- ▶ The binding for such configurations is highly dependent on the specific *pinctrl* driver being used.

i.MX28

```
mmc0_8bit_pins_a: mmc0-8bit@0 {  
    fsl,pinmux-ids = <  
        0x2000 /* MX28_PAD_SSPO_DATA0__SSPO_D0 */  
        0x2010 /* MX28_PAD_SSPO_DATA1__SSPO_D1 */  
        [...]  
        0x2090 /* MX28_PAD_SSPO_DETECT__SSPO_... */  
        0x20a0 /* MX28_PAD_SSPO_SCK__SSPO_SCK */  
    >;  
    fsl,drive-strength = <1>;  
    fsl,voltage = <1>;  
    fsl,pull-up = <1>;  
};
```

Marvell Kirkwood

```
pmx_nand: pmx-nand {  
    marvell,pins = "mpp0", "mpp1", "mpp2", "mpp3",  
        "mpp4", "mpp5", "mpp18",  
        "mpp19";  
    marvell,function = "nand";  
};
```