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# PLATFORM ADAPTATION AND BRING-UP GUIDE

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Linux Release 32 and Jetson Nano



## Document Change History

DA\_09361-001

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## Table of Contents

<b>Platform Adaptation and Bring-Up .....</b>	<b>1</b>
Board Naming.....	1
Placeholders in the Porting Instructions.....	2
Root Filesystem Configuration.....	2
Pinmux Changes.....	3
Exporting Pinmux for U-Boot .....	3
Exporting Pinmux for the L4T Linux Kernel .....	5
Porting U-Boot .....	5
Porting the Linux Kernel.....	6
Porting USB .....	8
USB Structure .....	8
UPHY Lane Assignment .....	8
Required Device Tree Changes .....	11
For a Host-Only Port .....	11
For an OTG (On-The-Go) Port.....	14
Fan speed control mapping table .....	24
Other Considerations When Porting .....	25
eHardware Bring-Up Checklist .....	25
Before Power-On .....	26
Initial Power-On .....	26
Initial Software Flashing .....	26
Power .....	26
Power Optimization .....	26
USB 2.0 PHY .....	27
USB 3.0 .....	27
HDMI .....	27
Audio .....	28
UART .....	28
SD Card (SDMMC1) .....	28
Fan .....	28
Sensors I2C: General .....	29
Sensors I2C: Touch Screen (Optional).....	29
PEX (Optional) .....	29
SATA (Optional) .....	29
Embedded Display(s) (Optional).....	29
Imager(s) (Optional) .....	30
Software Bring-Up Checklist .....	30

Preparation ..... 30

Bring-up Hardware Validation..... 31

U-Boot Port and Boot Validation..... 31

Kernel and Peripherals, Port and Validation..... 31

System Power and Clocks ..... 31

List of Figures

Figure 1. An OTG port connector ..... 15

Figure 2. Example of an OTG port's general design..... 17

List of Tables

Table 1. Available outputs for the P3449 carrier board ..... 9

Table 2. UPHY lane assignment use cases ..... 9

# Platform Adaptation and Bring-Up

This document is for software developers whose target is the NVIDIA® Jetson Nano™ module. It describes how to port the NVIDIA® Tegra® Linux Driver Package (L4T) and the U-Boot boot loader from NVIDIA® Jetson Nano™ Developer Kit to other hardware platforms.

For all of the procedures in this document, the L4T release includes code for the Jetson Nano Developer Kit (P3450) that can serve as an example.

## Board Naming

To support your base board in L4T, you must choose a simple lower-case, alphanumeric name for your board, possibly including dashes (-) or underscores (\_), but no spaces. Following are some examples of valid board names:

```
jetson-nano  
jetson-tx1  
p3450
```

The name you choose will appear in file names and path names in U-Boot and Linux kernel source code and in user-visible device tree file names, and will be exposed to the user via the U-Boot command prompt and various Linux kernel `/proc` files.

You must also choose a similarly constructed vendor name. The same character set rules apply, as in this example:

```
nvidia
```

In this document:

- `<board>` represents your board name.
- `<vendor>` represents your vendor name.

**Note:** Do not simply re-use and modify the existing Jetson Nano Developer Kit code without choosing and using your own board name. If you do not use your own board name it will not be obvious to Jetson Nano users whether modified source code supports your board or the original Jetson Nano Developer Kit carrier board.

## Placeholders in the Porting Instructions

The sections below refer to filenames and pathnames that contain the following placeholders. Substitute an appropriate value for each placeholder when you enter the commands.

- `<function>` is a functional module name, such as `power-tree`, `pinmux`, `sdmmc-drv`, `keys`, `comm` (Wi-Fi/Bluetooth®), `camera`, etc.
- `<board>` is a name you have chosen to represent your platform. For example, `p3449` is the name of the Jetson Nano Developer Kit carrier board. Note that NVIDIA `<board>` names use lower case letters only.
- `<som>` is a System on a Module (SOM) board name, such as `3448`.
- `<version>` is a board version number, such as `a00`. Files for NVIDIA reference boards include a version number. Files for customer platforms need not include one.
- `<vendor>` is your organization's name, or the name of your board's vendor.
- `<root>` is the device that holds the platform's root file system. At present the only supported value is `emmc/sdcard`.

## Root Filesystem Configuration

Tegra Linux platforms can use any standard or customized Linux root filesystem (rootfs) that is appropriate for their targeted embedded applications.

However, certain settings must be configured in the rootfs's boot-up framework to set default configuration after boot, or some of the core functionalities will not run as expected.

For example:

1. The system must be configured to execute the `nv.sh` and `nvfb.sh` scripts in `etc` at boot-up because they perform some basic default board initialization in the kernel. It is advisable to add to the `etc/` folder but never delete anything from it.
2. The Xorg and X libraries must be correctly configured for the target device.
3. The `nvpmode1` clock and frequency must be configured for the target device.

These rootfs configurations and customizations are provided in this driver package in the directory and its subdirectories:

```
Linux_for_Tegra/nv_tegra/
```

You must incorporate the relevant customization for your target rootfs from this location.

**Note:** For the sample Ubuntu root filesystem provided by NVIDIA, this customization is applied using the script `Linux_for_Tegra/apply_binaries.sh`.

## Pinmux Changes

If your board schematic differs from that for Jetson Nano Developer Kit carrier board, you must change the pinmux configuration applied by the software.

To define your board's pinmux configuration, you must obtain `Jetson_Nano_customer_pinmux_release.xlsm` from NVIDIA and customize it for the configuration of your board using the following procedures.

### To customize the pinmux spreadsheet

1. Create a copy of the file with a name based on your board name, e.g. `<board>_pinmux.xlsm`.
2. Ensure that the new file is writable.
3. On a Windows PC, open the new file in Microsoft Excel.
4. If Microsoft Excel displays any warnings such as "PROTECTED VIEW" or "SECURITY WARNING," click Enable Editing or Enable Content, so that you can save your changes to the new file.
5. Rename the Jetson Nano Configuration tab based on the name of your board:
  1. Right click the Jetson Nano Configuration tab at the bottom of the window.
  2. Click the Rename menu option.
  3. Type your board name into the tab, then press ENTER.
6. Modify columns AE through AO of the spreadsheet as required by the pinmux configuration for your board, based on the schematic.

Once the spreadsheet reflects the configuration you want, export the configuration data in a format that U-Boot and the Linux kernel can use.

## Exporting Pinmux for U-Boot

U-Boot uses a header file to define the pinmux configuration. You can generate this header file using the `tegra-pinmux-scripts` tool.

## To customize tegra-pinmux-scripts for your board

1. Obtain `tegra-pinmux-scripts` by running the following commands on your Linux system:

```
$ git clone https://github.com/NVIDIA/tegra-pinmux-scripts.git
$ cd tegra-pinmux-scripts
```

2. In the `tegra-pinmux-scripts` directory, open `csv-to-board.py` in a text editor.
3. Locate the definition of the `supported_boards` data structure, at approximately line 50.
4. Add an entry for your board to the `supported_boards` data structure as in this example, substituting the board's name for `<board>`:

```
'<board>': {
    # <board>_pinmux.xlsm worksheet <board>
    'filename': 'csv/<board>.csv',
    'rsvd_0based': False,
},
```

5. Save the file and exit the editor.
6. Commit the change to your local Git repository:

```
$ git add csv-to-board.py
$ git commit -a -m "Add support for <board>" -s
```

`tegra-pinmux-scripts` reads a CSV (Comma Separated Values) version of the pinmux spreadsheet as input.

## To save the spreadsheet in CSV format

1. In Microsoft Excel, click the File tab.
2. On the File tab, click Save As.
3. From Save as type, choose CSV (MS-DOC) (\*.csv).
4. Verify that the file name ends in `.csv`, but otherwise matches the file name in your changes to `csv-to-board.py`.
5. Click Save.
6. Copy the CSV file to the `csv/` directory of `tegra-pinmux-scripts` on your Linux system.



## To generate the U-Boot pinmux header file

1. Enter the following command in the `tegra-pinmux-scripts` directory to import the data into the `tegra-pinmux-script` internal format:

```
$ ./csv-to-board.py <board>
```

Optionally, use the `--csv <csv_file_name>` command line option to specify the CSV file to import. This allows you to copy the CSV file to an arbitrary location on your Linux system.

2. Enter the following command to generate the U-Boot pinmux header file:

```
$ ./board-to-uboot.py <board> > pinmux-config-<board>.h
```

Later you will copy `pinmux-config-<board>.h` into the U-Boot source tree.

## Exporting Pinmux for the L4T Linux Kernel

The Linux kernel uses device tree files to define the pinmux configuration. You can generate these files directly from the Excel spreadsheet.

### To generate device tree files for your pinmux configuration

1. In the spreadsheet, click Generate DT.
2. Answer “yes” to the prompt that asks whether you wish to generate the DT files.
3. Provide the name of your board when prompted.

The device tree files are saved in the same location as the Excel spreadsheet. After the file is generated, make sure that the file name matches the one you use in your kernel code. Correct the file name if there is a mismatch. Later, you will copy the device tree files into the Linux kernel source tree.

## Porting U-Boot

Perform the following actions in the U-Boot source code to add support for your board.

1. Copy `include/configs/p3450-porg.h` to `include/configs/<board>.h`.
2. Edit the set of enabled devices and features in `<board>.h` as appropriate for your board. For example, you must change the following:

```
#define CONFIG_TEGRA_BOARD_STRING      "NVIDIA P3450-Porg"
```

3. Copy `arch/arm/dts/tegra210-p3450-porg.dts` to `arch/arm/dts/tegra210-<board>.dts`.
4. Edit the set of enabled devices and their parameters (e.g. GPIO and IRQ IDs) in `tegra210-<board>.dts` as appropriate for your board.

You may have to add, remove, or edit nodes and properties.

**Note:** U-Boot and the Linux kernel do not always use exactly the same device tree schema (bindings) to represent the same data. Follow examples from U-Boot rather than from the Linux kernel.

5. Add `tegra210-<board>.dtb` to `arch/arm/dts/Makefile`.
6. Copy `configs/p3450-porg_defconfig` to `configs/<board>_defconfig`.
7. Edit `<board>_defconfig` to refer to your board name.
8. Edit `arch/arm/mach-tegra/tegra210/Kconfig` to add target config and `Kconfig`.
9. Copy the `board/nvidia/p3450-porg/` directory to `board/<vendor>/<board>/`.
10. Edit all of the files in `board/<vendor>/<board>/` to refer to your board name rather than to `P3450-Porg`. The files in this directory contain many instances of the `P3450-Porg` board name.
11. Edit `board/<vendor>/<board>/MAINTAINERS` to provide the correct maintainer contact information for your board.
12. Edit `board/<vendor>/<board>/<board>.c` to provide the correct PMIC programming for your board, if required.
13. Copy the pinmux header you generated (`pinmux-config-<board>.h`) to the `board/<vendor>/<board>/` directory.

## Porting the Linux Kernel

If you replace the standard base board (P3449) with your own board, or you enable/disable any feature from the P3449 device tree, you must review the `.dts` file in `hardware/nvidia/platform/t210/porg`.

1. To see the complete device tree node, run these commands to convert the final provided `.dtb` file:

```
dtc -I dtb -O dts tegra210-porg-p3448-0000-a00.dtb > ~/tegra210-porg-p3448-0000-a00.dts
dtc -I dts -O dtb ~/tegra210-porg-p3448-0000-a00.dts > tegra210-porg-p3448-0000-a00.dtb
```

You can then make any necessary changes to the nodes defined in the folder and regenerate the DTB. You can also add your board specific DTSI file and include it in the main `.dts` file.

If you are replacing the P3449 with your own base board, look out for "P3449" strings in the DTB and make sure you understand them and replace them according to your needs.

2. Copy the generated DTB to the following directory for flashing:

```
Linux_for_Tegra/kernel/dtb/
```

To provide plugin manager support, the kernel DTB is not included in the file system along with the kernel image in the boot directory. Instead, the kernel DTB is selected from the DTB partition and modified by CBoot. CBoot passes it on to U-Boot, which in turn passes it to the kernel without changing any of the data.

- To flash the Linux kernel, copy the image to the `Linux_for_Tegra/kernel` folder, then execute this command:

```
sudo ./flash.sh <platform> mmcblk0p1
```

Optionally, you can perform a secure copy to copy the kernel image to the boot partition of the target system and reboot. But DTB you need to flash.

3. Copy `Linux_for_Tegra/jetson-nano.conf` to `Linux_for_Tegra/<board>.conf`.
4. Edit `SYSBOOTFILE` in `<board>.conf` to refer to your board.

For the detailed information about `.dts` files, refer to the documentation at `Documentation/devicetree/bindings` in the NVIDIA released Linux kernel source package.

## Porting USB

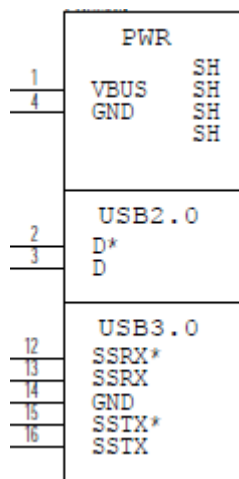
Jetson Nano can support up to three SuperSpeed USB ports. In some implementations not all of these ports can be used because of UPHY lane sharing among PCIE and XUSB.

The Jetson P3449 carrier board is designed and verified for one USB 3.0 port. If you design your own carrier board, consult the NVIDIA team to verify the UPHY lane mapping and compatibility between P3449 and your custom board.

## USB Structure

A SuperSpeed USB port has nine pins:

- VBUS
- GND
- D+/D-
- SSTX+/SSTX- (SuperSpeed data transmit)
- SSRX+/SSRX- (SuperSpeed data receive)
- GND\_DRAIN for drain wire termination and managing EMI, RFI, and signal integrity



The D+/D- signal pins connect to UTMI pads. The SSTX/SSRX signal pins connect to UPHY and are handled by a single UPHY lane. As UPHY lanes are shared between PCIE, SATA, UFS, and XUSB, UPHY lanes must be assigned according to the custom carrier board's requirements.

## UPHY Lane Assignment

Universal Physical Layer (**UPHY**) is a physical I/O interface layer that can serve multiple types of interfaces, e.g. USB and PCIE. A single UPHY lane can support multiple types of interfaces.

The Jetson P3449 carrier board is designed and verified for one USB 3.0 port. The verified use cases and their UPHY lane assignments are shown in Table 1 and Table 2.

Table 1. Available outputs for the P3449 carrier board

Output Type	Number of Outputs
USB 3.0	1
PCIe	1 x4

Table 2. UPHY lane assignment use cases

Lane	Pin Names	Functions
0	N/A	PCIe x1 C1
1	PEX_TX1 PEX_RX1	PCIe x4 C0 (L3/L2/L1/L0)
2	PEX_TX2 PEX_RX2	
3	PEX_TX3 PEX_RX3	
4	PEX_TX4 PEX_RX4	
5	N/A	N/A
6	PEX_TX6 PEX_RX6	USB3.0 P0

Jetson Nano and the supporting software are designed to support the configurations in these tables. However, the tables list only one of two possible configurations. See the *NVIDIA Jetson Nano Technical Reference Manual (TRM)* and consult with NVIDIA for further information before you design your custom board.

Lane assignment can be defined by the PCIe subnode under `xusb_padctl` in the corresponding device tree file. The device tree's `xusb_padctl` node follows the conventions of the document:

```
kernel/kernel-4.9/Documentation/devicetree/bindings/pinctrl/pinctrl-
bindings.txt
```

The PCIe subnode lists the functions assigned to UPHY lanes.

- **nvidia,function**

A string containing the name of the function to mux to the pin or group. It must be one of these values:

- xusb
- pcie-x1
- pcie-x4

Take Table 2, for example. Create a PCIe subnode and property under `xusb_padctl` based on the device tree structure described above:

```
xusb_padctl@7009f000 {
    ...
    pcie {
        status = "okay"
        lanes {
            pcie-0 {
                status = "okay"
                nvidia,function = "pcie-x1";
            };
            pcie-1 {
                status = "okay"
                nvidia,function = "pcie-x4";
            };
            pcie-2 {
                status = "okay"
                nvidia,function = "pcie-x4";
            };
            pcie-3 {
                status = "okay"
                nvidia,function = "pcie-x4";
            };
            pcie-4 {
                status = "okay"
                nvidia,function = "pcie-x4";
            };
            pcie-5 {
                status = "okay"
                nvidia,function = "xusb";
            };
            pcie-6 {
                status = "okay"
                nvidia,function = "xusb";
            };
        };
    };
    ...
};
```

**Note:**

UPHY lane 0 and UPHY lane 5 are not exposed, and can only be assigned to the **pcie-x1** and **xusb** functions.

## Required Device Tree Changes

This section gives step-by-step guidance for checking schematics and configuring USB ports in the device tree. All of the examples are based on the design of the Jetson Nano P3449 carrier board.

### For a Host-Only Port

This section uses U27, a USB 3.0 Realtek SuperSpeed on-board hub, as an example of a host-only port.

### Go Through the Schematics

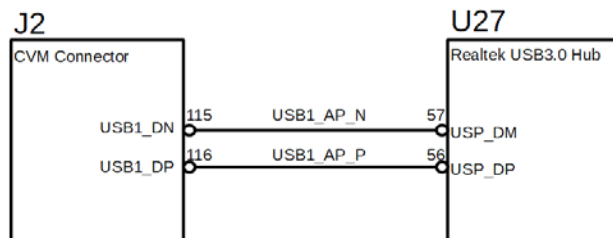
**Note:**

The P3449 carrier board's schematic file, **P2822\_B02\_Concept\_schematics.pdf**, is included in *Jetson Nano Developer Kit Carrier Board Design Files*, available at:

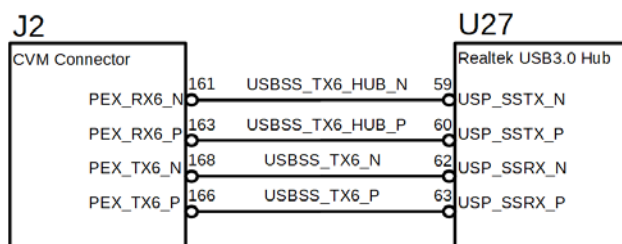
<http://developer.nvidia.com/embedded/dlc/jetson-xavier-developer-kit-carrier-board-design-files-b03>

Check the USB 3.0 Realtek SuperSpeed hub on the P3449 carrier board and find the pin names of the wired socket to the P3448.

- USB 2.0 signal pins D+/D- (USB\_DP/USB\_DM) wire out from U27 and lead to 115 (USB1\_DN) and 116 (USB1\_DP) on the CVM socket.



- USB 3.0 differential signal pairs (USP\_SSTX\* and USP\_SSRX\*) wire out from U27 and lead to 168 (PEX\_TX6\_N), 166 (PEX\_TX6\_P), 161 (PEX\_RX6\_N), and 163 (PEX\_RX6\_P) on the CVM socket.



Through the schematic, you can conclude that for U27:

- The USB 2.0 signal pair is wired to UTMI pad 1 (USB2 port 1).
- The USB 3.0 signal pairs are wired to UPHY lane 6 (USB 3.0 port 0 according to UPHY lane mapping).

## The xusb\_padctl Node

The device tree's `xusb_padctl` node follows the conventions of `pinctrl-bindings.txt`. It contains two groups of named pads and ports which describe USB2 and USB3 signals along with parameters and port numbers. The name of each parameter description subnode in pads and ports must be in the form `<type>-<port_number>`, where `<type>` is `usb2` or `usb3`, and `<port_number>` is the associated port number.

### The pads Subnode

The properties of the pads subnode are:

- **nvidia,function**

A string containing the name of the function to mux to the pin or group. Must be `xusb`.

### The ports Subnode

- **mode**

A string that describes USB port capability. A port for USB2 must have this property. It must be one of these values:

- `host`
- `device`
- `otg`

- **nvidia,usb2-companion**

The USB2 port (0, 1, 2, or 3) to which the port is mapped. A port for USB3 must have this property.

- **nvidia,oc-pin**

The overcurrent VBUS pin the port is using. The value must be positive or zero.

**Note:**

Overcurrent detection and handling for U27, the Realtek SuperSpeed hub on the P3499 carrier board, are controlled by the hub itself. Therefore, you need not set this property.

- **vbus-supply**

VBUS regulator for the corresponding UTMI pad. Set to `&battery_reg` for a dummy regulator.

**Note:**

As the Realtek SuperSpeed hub is always connected to the root hub port on a P3449, You need not control hub power, just enable it with `VDD_HUB_3V3`. Therefore, you must set dummy regulators for U27 on the P3449 carrier board.

For the detailed information about `xusb_padctl`, refer to the documentation at:



```
kernel/kernel-
4.9/Documentation/devicetree/bindings/pinctrl/nvidia,tegra210-
padctl.txt
```

As an example consider U27, the Realtek SuperSpeed hub, which is always connected to USB2 port 1 and USB3 port 0 on the root hub. Create a pad/port node and property list for U27 based on the device tree structure described above:

```
xusb_padctl: xusb_padctl@7009f000 {
    ...
    pads {
        usb2 {
            status = "okay";
            lanes {
                ...
                usb2-1 {
                    nvidia,function = "xusb";
                    status = "okay";
                };
                ...
            };
        };
        pcie {
            status = "okay";
            lanes {
                ...//UPHY lane assignment
            };
        };
    };
    ports {
        usb2-1 {
            mode = "host";
            vbus-supply = <&battery_reg>;
            status = "okay";
        };
        ...
        usb3-0 {
            nvidia,usb2-companion = <1>;
            status = "okay";
        };
        ...
    };
};
```

## Under the xusb Node

The Jetson Nano xHCI controller complies with xHCI specifications, which support both USB 2.0 HighSpeed/FullSpeed/LowSpeed and USB 3.0 SuperSpeed protocols.

- **phys**

Must contain an entry for each entry in phy-names.

- **phy-names**

Must include an entry for each PHY used by the controller. Names must be of the form <type>-<port\_number>, where <type> is "usb2" or "usb3".

- **nvidia,boost\_cpu\_freq**

Set the value to which CPU frequency will be boosted. This is only the minimum frequency, DVFS can scale up CPU frequency further based on need and cpu loading. CPU boost frequency through PMQOS is enabled for the xHCI controller only when this field's is greater than zero. The boost is applicable only for bulk and isoc transfers; other endpoints do not need to be boosted.

- **nvidia,boost\_cpu\_trigger**

Minimum buffer length of the bulk or isoc transfers beyond which to boost frequency.

- **nvidia,xusb-padctl**

A pointer to the xusb-padctl node.

For the detailed information about xHCI, see the documentation at:

```
kernel/kernel-
4.9/Documentation/devicetree/bindings/pinctrl/nvidia,tegra210-xusb.txt
```

Consider U27, the Realtek SuperSpeed hub, as an example. Create an xHCI node and property list for U27 based on the device tree structure described above:

```
xusb@70090000 {
    ...
    phys = <&{/xusb_padctl@7009f000/pads/usb2/lanes/usb2-1}>,
          <&{/xusb_padctl@7009f000/pads/pcie/lanes/pcie-6}>;
    phy-names = "usb2-1", "usb3-0";
    nvidia,xusb-padctl = <&xusb_padctl>;
    status = "okay";
    ...
};
```

## For an OTG (On-The-Go) Port

USB On-The-Go, often abbreviated **USB OTG** or just **OTG**, is a specification that allows USB to act as a host or a device on the same port. A USB OTG port can switch back and forth between the roles of host and device.

This section uses J28, a USB 2.0 Micro B connector, as an example of an OTG port.

An OTG port adds a fifth pin, called the ID pin, to the standard USB connector. An OTG cable has a USB Type A plug on one end and a Type B plug on the other end. The Type A plug's ID pin is grounded, while the Type B plug's ID pin is floating. A device with a Type A plug inserted becomes an OTG A-device (host), and a device with a Type B plug inserted becomes a B-device (device).

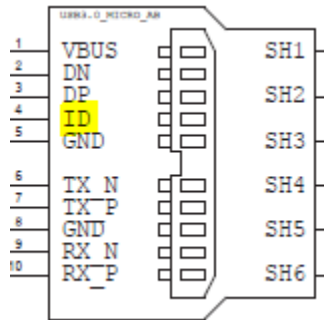


Figure 1. An OTG port connector

**Note:** Because its ID pin is floating, J28 is fixed in the device role in the Jetson Nano Developer Kit. It cannot function as a host, e.g. to connect a flash drive, keyboard, or mouse.

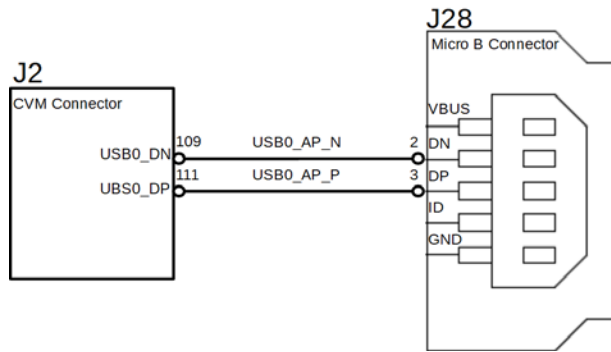
## Go Through the Schematics

Refer to the P3449 carrier board's schematic file, `P2822_B02_Concept_schematics.pdf`, which is in *Jetson Nano Developer Kit Carrier Board Design Files*, available at:

<http://developer.nvidia.com/embedded/dlc/jetson-xavier-developer-kit-carrier-board-design-files-b03>

Check the USB connectors on the P3449 carrier board and find the wired socket location to P3448.

- USB 2.0 signal pins D+/D- (DP and DN) wire out from J28 and lead to 111 (USB0\_DP) and 109 (USB0\_DN) on the CVM socket.



The USB 2.0 Micro B connector, J28, supports only HighSpeed mode, and does not have USB 3.0 signal pairs. See the *NVIDIA Jetson Nano Technical Reference Manual (TRM)* and consult with NVIDIA for further information before you design your custom board.

From the schematic, you can see that for J28:

- The USB 2.0 signal pair is wired to UTMI pad 0 (USB2 port 0).

### The External Connector Class (extcon)

External connectors, which may have different types of cables attached (USB, TA, HDMI, Analog A/V, and others), often have device drivers that detect state changes at the port, and separate device drivers that do something according to the state changes.

The **External Connector Class**, `extcon`, supports the use of a notifier for passing information such as state changes between device drivers.

Port switching between the roles of an OTG port is generally controlled by the host driver (xHCI) and device driver (xUDC), and can be defined by the state of the ID pin and the `VBUS_DETECT` pin.

**Note:** Because its ID pin is floating, J28 is fixed in the device role in the Jetson Nano Developer Kit. It cannot function as a host, e.g. to connect a flash drive, keyboard, or mouse.

For example, suppose `GPIO_PCC4` is the `VBUS_DETECT` pin and `GPIO_PZ1` is the ID pin. To complete the device tree node:

1. Find the corresponding GPIO states on the `VBUS_DETECT` pin and ID pin.

Generally, the ID pin is designed as internal pull high (logical high). With a Type A plug connected the ID pin is pulled to ground (logical low), while with a Type B plug connected or no cable connected it remains logical high.

The operation of the `VBUS_DETECT` pin depends on the device's design. Consider the schematic in Figure 2, for example:

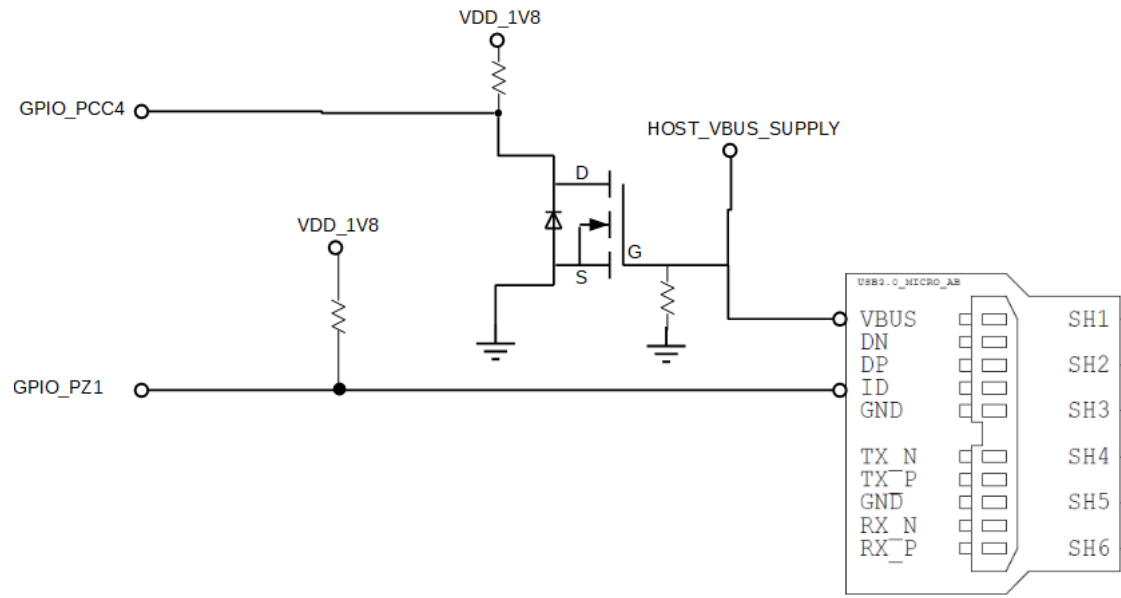


Figure 2. Example of an OTG port's general design

With a Type B plug connected VBUS\_DETECT is logical low because VBUS is provided from an external power supply. When no cable is connected it is logical high.

**Note:** VBUS\_DETECT is initially logical high, then logical low because VBUS is provided by the host controller. Therefore the state of the VBUS\_DETECT pin does not matter when the OTG port is operating in the host role.

2. Create a table of GPIO states and their corresponding output cable states like the one in Table 3.

Table 3. GPIO states and corresponding output cable states

GPIO_PZ1 (ID)	GPIO_PCC4 (VBUS_DETECT)	EXTCON_STATE
1	1	0x0 (EXCON_NONE)
0	0	0x2 (EXTCON_USB_HOST)
0	1	0x2 (EXTCON_USB_HOST)
1	0	0x1 (EXTCON_USB)

## Under the extcon Node

Port switching between the roles of an OTG port is defined by the state of the ID pin and the VBUS\_DETECT pin and the settings of the external connector class.

Create an `extcon` device node and property list using the properties listed below and the table of GPIO states and cable states (Figure 2).

- **compatible**  
Value must be `extcon-gpio-states`.
- **extcon-gpio,name**  
Name of the `extcon` device.
- **gpios**  
List of the GPIOs.
- **extcon-gpio,irq-flags**  
IRQ flags for GPIO.
- **extcon-gpio,debounce**  
Debounce time in milliseconds.
- **extcon-gpio,wait-for-gpio-scan**  
Wait timeout in milliseconds for scanning all GPIOs' states after a GPIO state change is detected and debounce time has passed.
- **extcon-gpio,out-cable-names**  
Output cable names.
- **extcon-gpio,cable-states**  
GPIO states and their corresponding output cable states. The value is an array of byte values. Each even-numbered byte is a GPIO state, and the following odd-numbered byte is the corresponding output cable state.
- **cable-connected-on-boot**  
Name of the output cable connected on boot, expressed as an index into `extcon-gpio,out-cable-names`. The first element is index 0, and so on. If not specified, the system assumes that no cable is to be connected. This property is valid if no GPIOs are provided for cable states.
- **wakeup-source**  
A Boolean; true if the device can wake up the system.

For the detailed information about `extcon`, refer to the documentation at:

```
kernel/kernel-4.9/Documentation/devicetree/bindings/extcon/extcon-gpio-states.txt
```

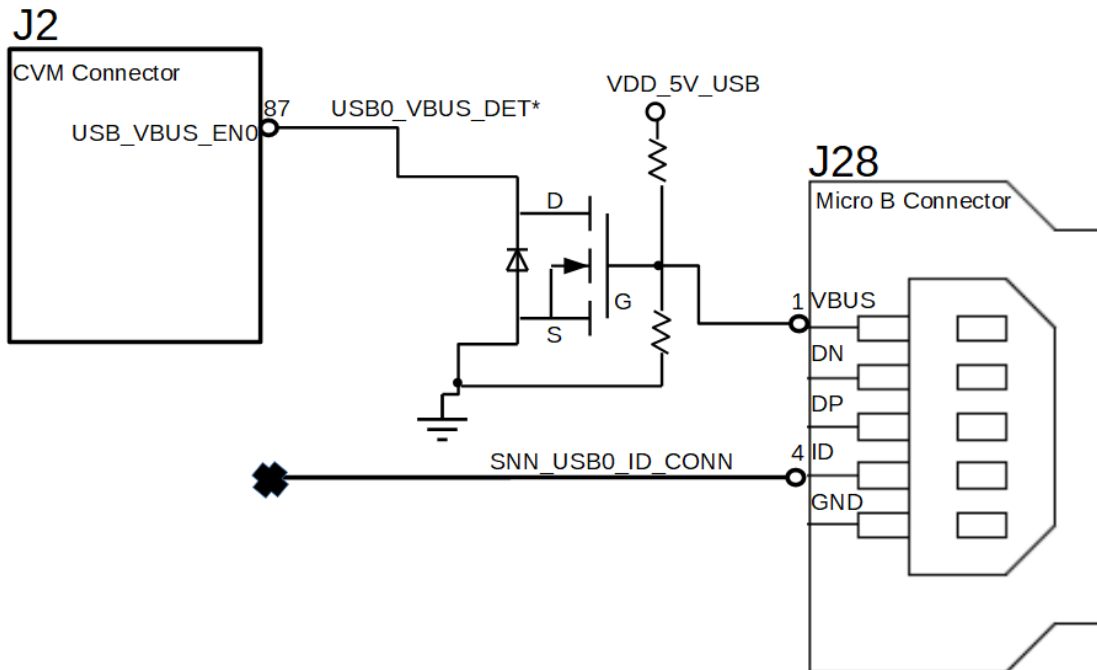
- Create an extcon device node and property list based on the device tree structure described above and the table of GPIO states and cable states in Table 3. This example shows a node definition which assumes GPIO\_PCC4 is the VBUS\_DETECT pin and GPIO\_PZ1 is the ID pin.

```

vbus_id_extcon: usb_otg {
    compatible = "extcon-gpio-states";
    extcon-gpio,name = "VBUS_ID";
    extcon-gpio,wait-for-gpio-scan = <0>;
    extcon-gpio,cable-states = <0x3 0x0
                                0x0 0x2
                                0x1 0x2
                                0x2 0x1>;
    gpios = <&gpio TEGRA_GPIO(CC, 4) 0
            &gpio TEGRA_GPIO(Z, 1) 0>;
    extcon-gpio,out-cable-names =
        <EXTCON_USB EXTCN_USB_HOST EXTCN_NONE>;
    #extcon-cells = <1>;
};

```

The USB 2.0 Micro B connector, J28, has the connector's ID pin floating and the VBUS\_DETECT pin of the connector wired out to USB\_VBUS\_EN0, which corresponds to GPIO\_PCC4. Hence J28 can only function in the device role.



This is the table of GPIO states on J28 and their corresponding output cable states:

GPIO_PCC4 (VBUS_DETECT)	EXTCON_STATE
1	0x0 (EXCON_NONE)
0	0x1 (EXTCON_USB)

This is the `extcon` device node and property list based on the device tree structure described above and the table of GPIO states and corresponding output cable states for GPIO\_PCC4, customized for Jetson Nano, where the ID pin is floating the port is fixed in the device role:

```
vbus_id_gpio_extcon: usb_otg {
    compatible = "extcon-gpio-states";
    extcon-gpio,name = "VBUS";
    extcon-gpio,wait-for-gpio-scan = <0>;
    extcon-gpio,cable-states = <0x0 0x1
                                0x1 0x0>;
    gpios = <&gpio TEGRA_GPIO(CC, 4) 0>;
    extcon-gpio,out-cable-names =
        <EXTCON_USB EXTCON_USB_HOST EXTCON_NONE>;
    #extcon-cells = <1>;
};
```

**Note:** Check the pinmux table for the GPIO that corresponds to the ID pin and VBUS\_DETECT pin.

## Under the xusb\_padctl Node

`xusb_padctl` settings for an OTG port are the same as for a host-only port except that the mode must be `otg`.

For the example of J28, the USB 2.0 Micro B connector, create a pad/port node and property list:

```
xusb_padctl: xusb_padctl@7009f000 {
    ...
    pads {
        usb2 {
            lanes {
                usb2-0 {
                    nvidia,function = "xusb";
                    status = "okay";
                };
                ...
            };
        };
        pcie {
            lanes {
```



```

        ...
    };
};
ports {
    usb2-0 {
        mode = "otg";
        vbus-supply = <&p3449_vdd_usb_vbus>;
        status = "okay";
    };
    ...
};
};

```

## Under the xHCI Node

The xHCI settings for an OTG port are the same as for a host-only port except for these additional `extcon` settings:

- **extcon-cables**

OTG support. Must contain a pointer to the `extcon-cable` entry for the USB ID pin. When the `extcon` cable state is 0, the OTG port transitions to the host role.

- **extcon-cable-names**

Must be `id`.

- **#extcon-cells**

Number of cells in the `extcon` specifier. Must be 1.

For the example of J28, the USB2.0 Micro B connector, create an xHCI node and property list based on the device tree structure described in [Under the extcon Node](#) for a host-only port, plus the additional settings above:

```

xusb@70090000 {
    ...
    extcon-cables = <&vbus_id_gpio_extcon 1>;
    extcon-cable-names = "id";
    #extcon-cells = <1>;
    phys = <&{/xusb_padctl@7009f000/pads/usb2/lanes/usb2-0}>;
    phy-names = "usb2-0";
    nvidia,xusb-padctl = <&xusb_padctl>;
    status = "okay";
    ...
};

```

## Under the xUDC Node

The Jetson Nano xUDC controller supports both USB 2.0 HighSpeed/FullSpeed and USB 3.0 SuperSpeed protocols.

These are the device tree node properties that apply to the xUDC node:

- **extcon-cables**  
OTG support. Must contains an `extcon-cable` entry that detects the USB VBUS pin. When the `extcon` cable state is 1, OTG port transitions to the device role.
- **extcon-cable-names**  
Must be `vbus`.
- **charger-detector**  
USB charger detection support. Must be the phandle of the USB charger detection driver DT node.
- **phys**  
An array; must contain pointers to the nodes that define each PHY in `phy-names`.
- **phy-names**  
An array; must contain an entry for each PHY used by the controller. Names must be in the form `<type>-<port_number>`, where `<type>` is `usb2` or `usb3`.
- **nvidia,boost\_cpu\_freq**  
The value to which CPU frequency is to be boosted. This is only the minimum frequency; DVFS can scale up CPU frequency further based on need and CPU load. CPU boost frequency through PMQOS is enabled for the xUDC controller only when this field's value is greater than zero. The boost is applicable only to large bulk transfers on bulk endpoints; other endpoints do not need to be boosted.
- **nvidia,xusb-padctl**  
A pointer to the `xusb-padctl` node.

For the detailed information about xUDC, refer to the documentation at:

```
kernel/kernel-4.9//Documentation/devicetree/bindings/pinctrl/nvidia,tegra210-xudc.txt
```

For the example of J28, the USB2.0 Micro B connector, create an xUDC node and property list for J28 based on the device tree structure described above:

```
xudc@700d0000 {
    extcon-cables = <& vbus_id_gpio_extcon 0>;
    extcon-cable-names = "vbus";
```

```
#extcon-cells = <1>;
phys = <&{/xusb_padctl@7009f000/pads/usb2/lanes/usb2-0}>,
phy-names = "usb2";
nvidia,xusb-padctl = <&xusb_padctl>;
status = "okay";
};
```

## To resolve possible UPHY lane mapping issues

If you suspect a UPHY lane mapping issue, enter this command to check the lane assignments:

```
./devmem 0x7009f028
```

(The hexadecimal number is the register address of the UPHY lane mux. It may be considered a constant.)

Bits	Reset	Description
25-24	0x01	UPHY_LANE6
23-22	0x01	UPHY_LANE5
21-20	0x03	UPHY_LANE4
19-18	0x03	UPHY_LANE3
17-16	0x03	UPHY_LANE2
15-14	0x03	UPHY_LANE1
13-3	—	Reserved
2-0	—	Identify the function that owns the lane: <ul style="list-style-type: none"> <li>• 0 = PCIE_X1</li> <li>• 1 = USB3_SS</li> <li>• 3 = PCIE_X4</li> </ul>

If a target UPHY Lane is not owned by the correct function, check the values of the PCIe subnode and properties under `xusb_padctl` to be sure that the target lane is assigned correctly.

**Note:** Before designing your custom board, verify the lane mapping by consulting the *Jetson Nano OEM Product Design Guide*, available at:  
<https://developer.nvidia.com/embedded/dlc/jetson-xavier-oem-product-designguide>

## Fan speed control mapping table

The temperature to fan speed mapping table can be modified with device tree properties.

The fan's thermal zone temperature is approximated by the average of the CPU and GPU SOC thermal sensor readings. Fan speed is controlled by the PWM signal; its pulse width range is 0-255 units.

The mapping between temperature and fan speed is defined by thermal trips and fan cooling states. The thermal trips refer to the fan thermal zone's temperature in degrees Celsius, and the fan cooling state are the PWM signal's corresponding pulse widths. You can define trip temperatures and the corresponding cooling states by creating a custom fan mapping table.

The fan trip temperatures are defined by the `active_trip_temps` property in the file:

```
hardware/nvidia/platform/t210/porg/kernel-dts/porg-platforms/tegra210-
porg-thermal-fan-est.dtsi
```

This example defines a set of fan thermal zone trip points:

```
thermal-fan-est {
    name = "thermal-fan-est";
    compatible = "thermal-fan-est";
    status = "okay";
    num_resources = <0>;
    shared_data = <&thermal_fan_est_shared_data>;
    trip_length = <10>;
    active_trip_temps = <0 51000 61000 71000 82000
                        140000 150000 160000 170000 180000>;
    active_hysteresis = <0 15000 9000 9000 10000
                        0 0 0 0 0>;
};
```

The fan cooling states are defined by the `active_pwm` property in the file:

```
hardware/nvidia/platform/t210/porg/kernel-dts/porg-platforms/tegra210-
porg-pwm-fan.dtsi
```

This example defines a corresponding set of cooling states:

```
pwm-fan {
    compatible = "pwm-fan";
    status = "okay";
    pwms = <&tegra_pwm 3 45334>;
};
```

```

shared_data = <&pwm_fan_shared_data>;
active_pwm = <0 80 120 160 255 255 255 255 255 255>;
};

```

## Other Considerations When Porting

This section discusses some other considerations and recommendations to keep in mind when porting.

## eHardware Bring-Up Checklist

This section provides a checklist for the platform hardware bring-up process.

- To change your project's name, rename `jetson-nano.conf`.
- You need not specify an EEPROM board ID for your base board.
- If you are changing DDR in the CVM P3448, be sure to get the DDR memory training parameters generated and update them in the `emc_memory` section of the kernel DTB.
- If you don't want to use the Dynamic Freq and Voltage Scaling feature, you can disable it from Kernel Config.
- If you want to change secondary boot storage to EMMC, you must specify the size of the EMMC in `jetson-nano.conf`. Below are the parameters in the file which you must review.

```

ODMDATA=0x84000;
CHIPID=0x21;
EMMC_BCT=P3448_A00_4GB_Micron_4GB_lpddr4_204Mhz_P987.cfg;
EMMC_CFG=flash_l4t_t210_spi_p3448.xml;
EMMC_SIZE=4194304;                # Size of primary boot device
ITS_FILE=;
SYSBOOTFILE=p3450-porg/extlinux.conf;
DTB_FILE=tegra210-porg-p3448-0000-a00.dtb;
# To configure whether to use U-Boot,
# do either of the following before running flash.sh:
# 1) Set environment variable USE_UBOOT to 0 or 1.
# 2) Edit the line below to set USE_UBOOT to 0 or 1.
if [ -z "${USE_UBOOT}" ]; then
    USE_UBOOT=1;                  # you can disable uboot
fi;
ROOTFSSIZE=14GiB;                # System.img size
CMDLINE_ADD="console=ttyS0,115200n8 console=tty0 fbcon=map:0
net.ifnames=0"; # you can add delete kernel command line here

```

## Before Power-On

Make sure that the Jetson Nano board is connected to the BTB connector correctly and securely.	<input type="checkbox"/>
Verify that power supplies are not shorted to ground or to other power supplies.	<input type="checkbox"/>

## Initial Power-On

Verify that VDD_IN from carrier board is 5 V.	<input type="checkbox"/>
Verify that CARRIER_WR_ON goes to HIGH when power is turned on.	<input type="checkbox"/>
Verify that system can enter force recovery.	<input type="checkbox"/>

## Initial Software Flashing

Verify that system can be flashed with TegraFlash.	<input type="checkbox"/>
Verify that TegraBoot and U-Boot run to completion by checking log output.	<input type="checkbox"/>
Verify that OS runs to desktop.	<input type="checkbox"/>
Verify that any UARTs intended for debugging are enabled and functional.	<input type="checkbox"/>

## Power

Verify that all supplies required on at power-on are enabled appropriately.	<input type="checkbox"/>
Verify that all supplies required off at power-on are not enabled initially.	<input type="checkbox"/>
Verify that you can enable and disable each controllable supply, and you can set different voltage levels if applicable.	<input type="checkbox"/>
Verify that carrier board power-on sequence starts after CARRIER_PWR_ON signal is asserted.	<input type="checkbox"/>

## Power Optimization

Capture CPU PWR Request entering and exiting Deep Sleep (LP0). Ensure that CPU PWR Request and associated power rail sequence meets <i>Tegra Data Sheet</i> requirements.	<input type="checkbox"/>
Verify that all rails that must be off in Deep Sleep (LP0) are off.	<input type="checkbox"/>
Verify that all rails that must be on in Deep Sleep (LP0) are on.	<input type="checkbox"/>
Verify that required rails are back and at correct voltage upon hardware control exiting Deep Sleep (LP0).	<input type="checkbox"/>

## USB 2.0 PHY

Verify that USB0 supports USB recovery (device mode).	<input type="checkbox"/>
Verify that USB0 device mode works with intended peripheral types, if supported.	<input type="checkbox"/>
Verify USB0, USB1 and or USB2 host mode, if implemented.	<input type="checkbox"/>
Verify USB0 Device/Host detection, if supported.	<input type="checkbox"/>
Verify that USB PHYs go to lowest power mode when not used or when the system is in low power mode.	<input type="checkbox"/>
Verify that AVDD_USB and AVDD_PLL_UTMIP are off during Deep Sleep (LP0).	<input type="checkbox"/>
Capture USB0_D+/D- signals at both ends of link (connector and test points near Jetson Nano).	<input type="checkbox"/>
Capture USB2_D+/D- signals at both ends of link (connector and test points near Jetson Nano).	<input type="checkbox"/>
Using USB-IF procedures, verify that signals meet requirements (correct EYE height/width, etc).	<input type="checkbox"/>
If USB signals do not meet requirements, use the <i>Tegra USB Tuning Guide</i> to adjust settings until requirements are met.	<input type="checkbox"/>

## USB 3.0

Verify USB 3.0 host mode.	<input type="checkbox"/>
Verify USB 3.0 device mode, if enabled.	<input type="checkbox"/>
Verify that the USB 3.0 interface goes to the lowest power mode when not used or when the system is in low power mode.	<input type="checkbox"/>

## HDMI

Verify that HDMI™ compatible display works at 1080p.	<input type="checkbox"/>
Verify that display is detected properly (HPD).	<input type="checkbox"/>
Verify that HDMI reads and writes to the display using DDC interface.	<input type="checkbox"/>
Verify that HDMI related rails are powered off when not used or system is in Deep Sleep (LP0) or Suspend (LP1).	<input type="checkbox"/>
Capture HDMI signals at the connector (using appropriate test fixture and termination).	<input type="checkbox"/>
Verify that signal quality is acceptable (meets EYE diagram, etc.). Consult <i>Tegra HDMI Tuning Guide</i> for details.	<input type="checkbox"/>
If HDMI signals do not meet requirements, use the <i>Tegra HDMI Tuning Guide</i> to adjust settings until requirements are met.	<input type="checkbox"/>

## Audio

Verify reads and writes on I2C interface used for audio codec.	<input type="checkbox"/>
Verify that playback works properly on speakers, headphones, and headset.	<input type="checkbox"/>
Verify that capture works properly: Sound is recorded from microphone/headset if supported.	<input type="checkbox"/>
Verify that tones, voice, etc. can be heard from speakers or headphones/headset.	<input type="checkbox"/>
Verify that audio codec goes to lowest power mode when not in use or system enters low power mode.	<input type="checkbox"/>
Capture signals at receiver end of link, if accessible, for each I2S I/FT used.	<input type="checkbox"/>
Verify that signal quality is acceptable. Look for excessive over/undershoot and glitches on signal edges.	<input type="checkbox"/>

## UART

Verify that the processor's TX/RX/CTS/RTS lines connect to the device's RX/TX/RTS/CTS lines for each UART used.	<input type="checkbox"/>
Verify that signal quality is acceptable. Look for excessive over/undershoot and glitches on signal edges.	<input type="checkbox"/>

## SD Card (SDMMC1)

Verify proper connectivity by setting processor pins to GPIOs, if necessary, to debug.	<input type="checkbox"/>
Verify that basic SD commands operate properly.	<input type="checkbox"/>
Verify reads and writes for a variety of SD cards.	<input type="checkbox"/>
Verify that SD card insertion detection works and wakes system, if supported.	<input type="checkbox"/>
Verify that SD card write protect works, if implemented.	<input type="checkbox"/>
Verify that SD card goes to low power mode or rails are powered off when not used or in low power system state.	<input type="checkbox"/>
Verify that signal quality is acceptable when probed at receiver end (socket or test points near BTB connector or both for bidirectional signals). Look for excessive over/undershoot and glitches on signal edges and abnormal clock duty cycle.	<input type="checkbox"/>

## Fan

Verify that CVM's PWM and TACH lines connected to fan's PWM and TACH lines.	<input type="checkbox"/>
Verify that fan speed is changed based on PWM signal pulse width.	<input type="checkbox"/>
Verify that fan's RPM can be measured using TACH pin.	<input type="checkbox"/>



## Sensors I2C: General

Verify that addresses of all I2C devices appear correctly, and no unknown ghost devices appear.	<input type="checkbox"/>
Verify that signal quality is acceptable, including rise times of signals, when probed at BTB connector and devices.	<input type="checkbox"/>

## Sensors I2C: Touch Screen (Optional)

Verify that reads and writes on I2C or SPI to touch screen controller are functional (reading device ID or a similar register is successful).	<input type="checkbox"/>
Verify that interrupts are generated properly.	<input type="checkbox"/>
Verify functionality of touch screen.	<input type="checkbox"/>
Verify that touch screen controller goes to lowest power mode when not used, or system is in low power state.	<input type="checkbox"/>

## PEX (Optional)

Verify proper connectivity by checking lanes.	<input type="checkbox"/>
Verify that any implemented PEX interfaces transition to the lowest power state in Deep Sleep (LP0) and Suspend (LP1).	<input type="checkbox"/>
Verify that signal quality is acceptable when probed at receiver end of link near processor and device. Look for excessive over/undershoot and glitches on signal edges.	<input type="checkbox"/>

## SATA (Optional)

Verify proper connectivity by checking diff lines.	<input type="checkbox"/>
Verify that any implemented SATA interfaces transition to the lowest power state in Deep Sleep (LP0) and Suspend (LP1).	<input type="checkbox"/>
Verify that signal quality is acceptable when probed at receiver end of link near processor and device. Look for excessive over/undershoot and glitches on signal edges.	<input type="checkbox"/>

## Embedded Display(s) (Optional)

Verify that I2C or other control interface is able to perform writes and reads to display.	<input type="checkbox"/>
Verify that each embedded display shows correct colors.	<input type="checkbox"/>
Verify that each embedded display's backlight is enabled when in normal display mode.	<input type="checkbox"/>
Verify that each embedded display's backlight brightness can be adjusted properly.	<input type="checkbox"/>
Verify that each embedded display's backlight is disabled when in a low power mode.	<input type="checkbox"/>
Verify that each embedded display (and any display bridge) transitions to the lowest	<input type="checkbox"/>

power state in Deep Sleep (LP0) and Suspend (LP1).	
Verify that power on/off sequencing of rails associated with each display meets manufacturer's requirements.	<input type="checkbox"/>
Verify DSI, LVDS or eDP timing (see <i>Tegra DC and DSI Debugging Guide</i> for details on how and what to verify).	<input type="checkbox"/>
Probe DSI, LVDS or eDP signals near panel driver, or at connector/test points if access to driver is not possible, and verify that signal quality is acceptable. Look for excessive over/undershoot and glitches on signal edges.	<input type="checkbox"/>

## Imager(s) (Optional)

Verify that I2C interface writes and reads work for all cameras.	<input type="checkbox"/>
Verify that preview displays properly for all cameras.	<input type="checkbox"/>
Verify that still capture works for all cameras.	<input type="checkbox"/>
Verify that video capture works for all cameras.	<input type="checkbox"/>
Verify that all flashes operate properly.	<input type="checkbox"/>
Verify that any available autofocus mechanism functions properly.	<input type="checkbox"/>
Verify that privacy LED operates properly, if implemented.	<input type="checkbox"/>
Verify that cameras and related circuitry enter lowest power mode when not used or system is in a low power mode.	<input type="checkbox"/>
Verify that power on/off sequencing of rails associated with imager module meets manufacturer's requirements.	<input type="checkbox"/>
Probe MCLK output at recommended test points and verify that signal quality is acceptable. Look for excessive over/undershoot and glitches on signal edges.	<input type="checkbox"/>
Look for excessive over/undershoot and glitches on signal edges.	<input type="checkbox"/>

## Software Bring-Up Checklist

This section provides a checklist for the software bring-up process.

### Preparation

Verify board BCT.	<input type="checkbox"/>
Verify operation eMMC with the NVIDIA Diagnostic Tool.	<input type="checkbox"/>
Obtain board schematics and component data sheets.	<input type="checkbox"/>
Verify power tree.	<input type="checkbox"/>
Review board pinmux.	<input type="checkbox"/>

## Bring-up Hardware Validation

Power and Reset Sequence, Power Rail Check	<input type="checkbox"/>
Recovery Mode	<input type="checkbox"/>
NvTest (Tegra MODS) DDR, eMMC, CPU	<input type="checkbox"/>
JTAG connection check	<input type="checkbox"/>

## U-Boot Port and Boot Validation

TegraFlash	<input type="checkbox"/>
UART output	<input type="checkbox"/>
KBD connection	<input type="checkbox"/>
Board config/PMIC regulator config/Pinmux/Review device tree	<input type="checkbox"/>
Verify FS support/Config boot scripts (bootcmd)	<input type="checkbox"/>
Boot to U-Boot	<input type="checkbox"/>
Boot to kernel	<input type="checkbox"/>
Boot to kernel command line or custom desktop	<input type="checkbox"/>

## Kernel and Peripherals, Port and Validation

Device tree review, Pinmux, GPIO, Wake pins	<input type="checkbox"/>
PMU and regulator drivers	<input type="checkbox"/>
Display/HDMI	<input type="checkbox"/>
Audio codec	<input type="checkbox"/>
Microphone and speaker	<input type="checkbox"/>
USB	<input type="checkbox"/>
SD card	<input type="checkbox"/>
Thermal Sensor	<input type="checkbox"/>
EMC DFS table	<input type="checkbox"/>
Ethernet	<input type="checkbox"/>
SATA	<input type="checkbox"/>
PCIe	<input type="checkbox"/>

## System Power and Clocks

CPU/CORE/GPU DVFS	<input type="checkbox"/>
EMC DFS table	<input type="checkbox"/>

CPU/CORE EDP	<input type="checkbox"/>
GPU EDP	<input type="checkbox"/>
System EDP (containing current monitor and voltage comparator)	<input type="checkbox"/>
Power off	<input type="checkbox"/>
LP0 (optional)	<input type="checkbox"/>
CPU power down (LP2)	<input type="checkbox"/>
BCT, full-speed	<input type="checkbox"/>

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