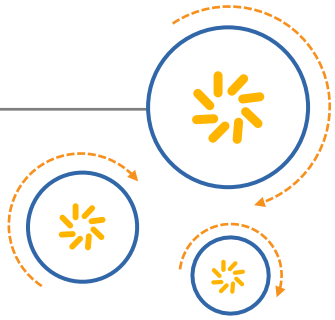
Qualcomm Technologies, Inc.



Multimedia Driver Development and Bringup Guide – Camera

80-NU323-2 H

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Revision history

Revision	Date	Description
A	November 2014	Initial release
B	January 2015	Updated for MSM8992 chipset
C	February 2015	Updated Chapter 7
D	April 2015	Update for MSM8952 and MSM8996 chipsets
E	December 2015	Updated Section 3.3.2.7.1
F	May 2016	Updated the following: ▪ Section 3.1 ▪ Title of Chapter 7 to include MSM8998
G	November 2016	Updated Sections 3.3.2.4 and 3.3.2.7.1
H	January 2017	Added Section 3.3.2.7.2 Updated Section 3.3.2.7.1 Updated the table in Section 3.3.2.4 Updated Section 9.2.1 Updated the following to include SDM660/SDM630: ▪ Note in Section 3.1 ▪ Chapter 7

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1 Introduction

1.1 Purpose

This document provides driver development guidelines for the camera sensor and associated modules, and describes how to bring up the camera on the MSM8x26/MSM8x28, MSM8926/MSM8928, MSM8974, APQ8084, MSM8992, MSM8994, MSM8996, MSM8909, MSM8916, MSM8952, MSM8936/MSM8939, MSM8998, SDM660, and SDM630 Android platform.

Driver development guidelines and bringup procedures for other multimedia technologies are described in separate documents:

- *Multimedia Driver Development and Bringup Guide* – Audio (80-NU323-1)
- *Multimedia Driver Development and Bringup Guide* – Display (80-NU323-3)
- *Multimedia Driver Development and Bringup Guide* – Video (80-NU323-5)

The camera sensor framework includes the configuration of the following components:

- Sensor
- CSIPHY
- CSID
- Camera Control Interface (CCI)
- Actuator
- Flash
- EEPROM
- Chromatix™

Much of the information in this document is generic to Linux camera code on all MSM8x26/MSM8x28, MSM8926/MSM8928, MSM8974, APQ8084, MSM8992, MSM8994, MSM8996, MSM8909, MSM8916, MSM8952, MSM8936/MSM8939 chipsets, but the document has been written based on the MSM8916 code base. Chipset-specific differences are covered in their separate sections.

1.2 Conventions

Function declarations, function names, type declarations, attributes, and code samples appear in a different font, for example, `#include`.

Code variables appear in angle brackets, for example, `<number>`.

Commands to be entered appear in a different font, for example, **`copy a:*.* b:`**.

Button and key names appear in bold font, for example, click **Save** or press **Enter**.

Shading indicates content that has been added or changed in this revision of the document.

1.3 Technical assistance

For assistance or clarification on information in this document, submit a case to Qualcomm Technologies, Inc. (QTI) at https://createpoint.qti.qualcomm.com/.

If you do not have access to the CDMATech Support website, register for access or send email to support.cdmatech@qti.qualcomm.com.

2 Pre-Bringup Guidelines

This chapter provides useful information on how to search existing PVL driver and understand impact of non-PVL component selection on overall camera schedule. It is recommended that the readers of this document review this information before proceeding with camera bring-up.

2.1 Guidelines for camera sensor selection and development timeframes

To understand the guidelines for camera selection and the development time/resource investment based on it, see Solution [00028471].

2.2 Accessing PVL drivers

For guidelines on how to access PVL (Preferred Vendor List) drivers, see *Qualcomm Createpoint Hardware Component Quick Start Guide (English)* (80-NC193-10) or *Qualcomm Createpoint Hardware Component Quick Start Guide (Chinese)* (80-NC193-10SC). Using these guidelines, one could query the PVL camera drivers list for a specific chipset, and download one or more drivers.

2.3 Useful resources

Review important documents listed under section “Sensor bring up” of Solution [00028470], and start sensor bring-up. If issues are encountered during the process, QTI Customer Engineering can help via a Salesforce case. For guidance on correct problem area identification, see Solution [00028523].

3 Sensor Driver Bringup

This chapter provides information necessary to bring up camera sensor hardware on the Android platform with an MSM8916 device.

NOTE: Unless specified otherwise, all information applies to Bayer sensors.

3.1 Reference drivers for YUV and Bayer sensors

This section shows the list of reference drivers for both Bayer and YUV sensors for MSM8916.

Bayer reference drivers

User space drivers are located in $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/sensor_libs/.

- imx135_lib.c/h
- ov2680_lib.c
- ov2720_lib.c
- ov9724_lib.c
- s5k3l1yx_lib.c

YUV reference drivers

User space drivers are located in $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/sensor_libs/.

- sp1628_lib.c
- SKUAA-Shengtai-hi256_lib.c
- ov5645_lib.c
- mt9m114_lib.c

Kernel drivers are located in kernel/drivers/media/platform/msm/camera_v2/sensor.

- sp1628.c
- hi256.c
- ov5645.c
- mt9m114.c

NOTE: In newer baselines for MSM8996/MSM8998/SDM660/SDM630, the kernel implementation for YUV sensor drivers is moved to user space; OV5645 sensor driver can serve as a reference for this update.

3.2 Files to be modified to add new driver

This section lists the files that must be modified to write a new sensor driver.

Bayer sensor

The device tree source file is <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi. Customers should use camera slots as shown here:

```
qcom,camera@0 {
        cell-index = <0>;
        compatible = "qcom,camera";
        . . .
}
```

Config

In vendor/qcom/proprietary/common/config/device-vendor.mk, make entry of the new libraries in the file to include in the build.

In $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/module/sensor_init.c, add sensor name in sensor_libs[] array.

NOTE: The kernel nodes are generic. There is no need to change them if the QTI schematics are followed.

NOTE: A change in this file must be made based on the customer's hardware design.

The user space sensor driver is <sensor>_lib.c/h and Android.mk in $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/sensor_libs/, for example, imx135_lib.c/h.

In addition to the driver file, Android.mk must be modified (refer to the reference makefile).

NOTE: For a 64-bit processor, use the arm64 directory instead of arm.

YUV sensor

The device tree source file is <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi. Customers should add a new entry in the .dtsi file as shown here:

```
qcom,camera@78 {
        compatible = "ovti,ov5645";
        . . .
}
```

The user space sensor driver is <sensor>_lib.c and Android.mk in $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/sensor_libs/, for example, sp1628_lib.c.

In addition to the driver file, Android.mk must be modified (refer to the reference makefile).

The kernel sensor driver is <sensor>.c and Makefile in kernel/drivers/media/platform/msm/camera_v2/sensor/.

Also, the CONFIG_<sensor> flag must be added in <target>_defconfig located in kernel/arch/arm/configs/.

Config

In vendor/qcom/proprietary/common/config/device-vendor.mk, make entry of the new libraries in the file to include in the build.

NOTE: A change in this file must be made based on the customer's hardware design.

NOTE: For a 64-bit processor, use the arm64 directory instead of arm.

As shown in the above example, for the Bayer sensor the concept of camera slots (0/1/2) is introduced, whereas in the YUV sensor a new entry must be added in dtsi.

NOTE: Begin with reference files when writing a new driver.

3.3 Source code explanation

3.3.1 Kernel driver

This section provides information necessary for creating the kernel driver.

3.3.1.1 GPIO config

As shown below, the customer can configure sensor-specific GPIOs based on the target board. For explanations on each property, refer to documents in the following location:

kernel/Documentation/devicetree/bindings/media/video/

GPIO can be configured one of two ways, based on the software being used.

Using pinctrl

For the chipsets using pinctrl framework (for example, MSM8909, MSM8916, MSM8936, MSM8939, MSM8992, MSM8994, and so on), pinctrl node entries in .dtsi can be used to configure GPIOs, for example:

```
pinctrl-names = "cam_default", "cam_suspend";
pinctrl-0 = <&cam_sensor_mclk0_default &cam_sensor_rear_default>;
pinctrl-1 = <&cam_sensor_mclk0_sleep &cam_sensor_rear_sleep>;
```

The phandles pointing at a pin configuration node, listed under pinctrl-XX entries above are defined in msmXXXX-pinctrl.dtsi. For MSM8916, it would be at kernel/arch/arm/boot/dts/qcom/msm8916-pinctrl.dtsi.

Using GPIO control

For chipsets not using pinctrl framework (for example, MSM8x26/MSM8x28, MSM8926/MSM8928, MSM8974, MSM8084, MSM8952, MSM8996, and so on), GPIO node entries in .dtsi can be used to configure GPIOs, for example:

```
gpios = <&msm_gpio 26 0>,
   <&msm_gpio 35 0>,
   <&msm_gpio 34 0>;
qcom,gpio-reset = <1>;
qcom,gpio-standby = <2>;
qcom,gpio-req-tbl-num = <0 1 2>;
qcom,gpio-req-tbl-flags = <1 0 0>;
qcom,gpio-req-tbl-label = "CAMIF_MCLK",
   "CAM_RESET1",
   "CAM_STANDBY";
```

For chipsets having a CCI hardware block, there are dedicated GPIOs for data and clock. Because these GPIOs are dedicated to the CCI master, the customer must use these settings if CCI is used for camera I2C. For example, the following pinctrl or GPIO control-based examples show dedicated GPIO pins 29 and 30 for CCI.

Using pinctrl

```
pinctrl-names = "cci_default", "cci_suspend";
pinctrl-0 = <&cci0_default>;
pinctrl-1 = <&cci0_sleep>;
```

The phandles pointing at a pin configuration node, listed under pinctrl-XX entries above are defined in msmXXXX-pinctrl.dtsi. For MSM8916, it would be at kernel/arch/arm/boot/dts/qcom/msm8916-pinctrl.dtsi.

Using GPIO control

```
gpios = <&msm_gpio 29 0>,
   <&msm_gpio 30 0>;
qcom,gpio-tbl-num = <0 1>;
qcom,gpio-tbl-flags = <1 1>;
qcom,gpio-tbl-label = "CCI_I2C_DATA0",
      "CCI_I2C_CLK0";
```

CCI has two independent masters (0 and 1, available). In most uses cases, using one CCI master is enough. However, in certain cases two CCI masters can be used. For example, if the front and rear cameras happen to have the same I2C slave address, connecting each camera to a different CCI master with independent physical GPIO pins for CCI masters can resolve the conflicting I2C slave address problem.

```
qcom,cci-master = <0>;
```

3.3.1.2 Clock-related settings

In the .dts file, for each sensor node, the customer can configure clock source as follows:

```
clocks = <&clock_gcc clk_mclk0_clk_src>,
               <&clock_gcc clk_gcc_camss_mclk0_clk>;
clock-names = "cam_src_clk", "cam_clk";
```

The ordering of the lists in the two properties is important. The nth clock-name will correspond to the nth entry in the clock's property. Thus, in the DT snippets above, cam_src_clk would correspond to clk_mclk0_clk_src, cam_clk would correspond to clk_gcc_camss_mclk0_clk, and so on.

The customer does not need to change this, as it is parsed in the clock framework.

NOTE: For MSM8916, it is recommended that sensor driver settings be configured for 23.88 MHz MCLK input. Although drivers written with 24 MHz MCLK input assumption generally will not have functionality issues, some might show banding artifacts with light sources operating at variable frequency like 50 Hz.

3.3.1.3 Power handler

PMIC case

```
cam_vdig-supply = <&pm8916_s4>;
cam_vana-supply = <&pm8916_l17>;
cam_vio-supply = <&pm8916_l6>;
cam_vaf-supply = <&pm8916_l10>;
```

GPIO case

```
gpios = <&msm_gpio 27 0>,
            <&msm_gpio 28 0>,
            <&msm_gpio 33 0>,
            <&msm_gpio 114 0>,
            <&msm_gpio 110 0>;
qcom,gpio-reset = <1>;
qcom,gpio-standby = <2>;
qcom,gpio-vdig = <3>;
qcom,gpio-vana = <4>;
qcom,gpio-req-tbl-num = <0 1 2 3 4>;
qcom,gpio-req-tbl-flags = <1 0 0 0 0>;
qcom,gpio-req-tbl-label = "CAMIF_MCLK",
                          "CAM_RESET",
                          "CAM_STANDBY",
                          "CAM_VDIG",
                          "CAM_VANA";
```

- CAM_VANA – Supply voltage (analog)
- CAM_VDIG – Supply voltage (digital)
- CAM_VAF – Supply voltage (actuator voltage)
- CAM_VIO – Input/output voltage (digital)

3.3.1.4 I2C slave configuration

YUV sensor

In the .dtsi file:

```
qcom,camera@78 {
          compatible = "ovti,ov5645";
          reg = <0x78 0x0>;
          qcom,slave-id = <0x78 0x300a 0x5645>;
```

This is an 8-bit address where 7 MSB are I2C slave address and 1 LSB is write flag 0.

NOTE: For Bayer, see Section 3.3.2.3.

3.3.2 User space driver

This section provides information necessary for creating the user space driver.

3.3.2.1 Sensor init parameters

The sensor init parameters include the modes supported (2D/3D) and the position (FRONT/ BACK) of the camera in the device and the mount angle. If the mount angle is specified as 360, then the driver will pick up the mount angle specified in the kernel dtsi.

```
static struct msm_sensor_init_params sensor_init_params = {
  .modes_supported = CAMERA_MODE_2D_B,
  .position = BACK_CAMERA_B,
  .sensor_mount_angle = SENSOR_MOUNTANGLE_360,
};
```

3.3.2.2 Sensor output parameters

The sensor out parameter includes the output format, which specifies whether the sensor is Bayer or YUV. The connection mode specifies interface between the sensor and receiver (MIPI or parallel). The output size is specified in the raw_output.

```
static sensor_output_t sensor_output = {
  .output_format = SENSOR_BAYER,
  .connection_mode = SENSOR_MIPI_CSI,
  .raw_output = SENSOR_10_BIT_DIRECT,
};
```

3.3.2.3 Bayer slave configuration

The Sensor slave configuration information must provide the following information.

```
static struct msm_camera_sensor_slave_info sensor_slave_info = {
  /* Camera slot where this camera is mounted */
  .camera_id = CAMERA_0,
  /* sensor slave address */
  .slave_addr = 0x20,
  /* sensor address type */
  .addr_type = MSM_CAMERA_I2C_WORD_ADDR,
  /* sensor id info*/
  .sensor_id_info = {
    /* sensor id register address */
    .sensor_id_reg_addr = 0x0016,
    /* sensor id */
    .sensor_id = 0x0135,
```

```
  },
  /* power up / down setting */
  .power_setting_array = {
    .power_setting = power_setting,
    .size = ARRAY_SIZE(power_setting),
  },
. . .
```

This is an 8-bit address where 7 MSB are I2C slave address and 1 LSB is write flag 0.

NOTE: For YUV, see Section 3.3.1.4.

3.3.2.3.1 Sensor chip-id

The Sensor model ID/chip ID register must be identified from the data sheet and entered in the sensor_id_info.

```
.sensor_id_info = {
    /* sensor id register address */
    .sensor_id_reg_addr = 0x0016,
    /* sensor id */
    .sensor_id = 0x0135,
  },
```

3.3.2.3.2 Power-up/-down sequence

Sensor power sequence is added in an array using the msm_sensor_power_setting structure in each user space sensor driver.

```
static struct msm_sensor_power_setting power_setting[] = {
. . .
}
```

Both power-up and power-down sequences can be added in the msm_sensor_power_setting_array structure. If a power_down_setting/size_down member is not added as shown below, the power-down sequence will be the reverse of the power-up sequence.

```
.power_setting_array = {
    .power_setting = power_setting,
    .size = ARRAY_SIZE(power_setting),
 },
```

This power_setting will point to an array that has information on GPIO/CLK/VREG to be used to configure each sensor.

```
static struct msm_sensor_power_setting power_setting[] = {
  {
    .seq_type = SENSOR_VREG,
    .seq_val = CAM_VDIG,
    .config_val = 0,
    .delay = 0, //this delay is in ms
  },
  {
    .seq_type = SENSOR_VREG,
    .seq_val = CAM_VANA,
    .config_val = 0,
    .delay = 0, //this delay is in ms
  },
  . . .
```

This structure will be used in msm_camera_power_up() in the kernel to configure the sensor for the power-up sequence.

Refer to enums in kernel/include/media/msm_cam_sensor.h.

For YUV camera driver, msm_sensor_power_setting should be made in the kernel driver instead of the user space driver. For more details, refer to one of YUV reference drivers listed in Section 3.1.

Depending on the customer hardware design, the power source can be provided by PMIC or through GPIOs as shown below in the .dtsi file.

3.3.2.4 Dimensions table

A dimension table is added using the sensor_lib_out_info_t structure as shown in this example.

```
static struct sensor_lib_out_info_t sensor_out_info[] = {
{
/* full size @ 24 fps*/
.x_output = 4208,
.y_output = 3120,
.line_length_pclk = 4572,
.frame_length_lines = 3142,
.vt_pixel_clk = 360000000,
.op_pixel_clk = 360000000,
.binning_factor = 1,
.max_fps = 24.01,
.min_fps = 7.5,
.mode = SENSOR_DEFAULT_MODE,
},
```

- x_output – Active width
- y_output – Active height
- line_length_pclk – Width including blanking

NOTE: In the case of certain sensors, the horizontal blanking value programmed to the sensor registers could differ from the actual blanking value output by the sensor. Therefore, it is recommended that the measured (actual) blanking value be used when calculating the value of the line_length_pclk parameter.

- frame_length_lines – Height including blanking
- vt_pixel_clk(video timing clk value) – Virtual clock value used for calculating shutter time, and used by AEC for correcting banding artifacts

  vt_pixel_clk = line_length_pclk * frame_length_lines * frame rate
- op_pixel_clk – Represents how much data comes out of the camera over MIPI lanes to set the VFE clock

  op_pixel_clk = (total data rate from sensor)/bits-per-pixel

  For example, if the MIPI DDR clock value (speed of the clock lane of the MIPI camera sensor) is 300 MHz, and the sensor transmits on 4 lanes, each lane has a 600 MHz data rate. Thus, the total data rate is 2400 MHz. For 10 bits per pixel Bayer data, this translates to the op_pixel_clk value of 2400/10 = 240 MHz. These values must be filled in accordance with the sensor specifications.

  These values can be calculated based on the register settings configured for the camera sensor.

NOTE: The following are requirements for minimum blanking time:

Chipset	Minimum hblank requirement	Minimum vblank requirement
MSM8x26/MSM8926/MSM8974	32	64
MSM8916/MSM8939	32	64
MSM8952/MSM8956/MSM8976	64	64
MSM8992/MSM8994	64	64
MSM8996/MSM8998/SDM660/SDM630	64	64

Assumes the highest of all simultaneously configured resolutions on VFE output for any use case is 1280 x 720. If customer camera sensor does not meet these blanking requirements or have an use case where highest configured resolution on VFE output for any use case is smaller than 1280 x 720, contact QTI's camera customer engineering team via a case with more details.

3.3.2.5 Chromatix parameters

The Chromatix parameters must be updated for each resolution with the proper header. Chromatix header generation is discussed in *Chromatix 6 Camera Tuning* (80 NK872-2).

```
static struct sensor_lib_chromatix_t imx135_chromatix[] = {
     {
```

```
.common_chromatix = IMX135_LOAD_CHROMATIX(common),
.camera_preview_chromatix = IMX135_LOAD_CHROMATIX(snapshot), /* RES0 */
.camera_snapshot_chromatix = IMX135_LOAD_CHROMATIX(snapshot), /* RES0 */
.camcorder_chromatix = IMX135_LOAD_CHROMATIX(default_video), /* RES0 */
.liveshot_chromatix = IMX135_LOAD_CHROMATIX(liveshot), /* RES0 */
          },
       }
```

3.3.2.6 Sensor register address

The register address fields for the exposure and output dimension must be filled with the proper values based on the sensor datasheet.

3.3.2.6.1 Exposure register address

```
static struct msm_sensor_exp_gain_info_t exp_gain_info = {
 .coarse_int_time_addr = 0x0202,
 .global_gain_addr = 0x0205,
 .vert_offset = 4,
};
```

- vert_offset – The integration line count should always be less than frame_length_lines by this margin when we configure to the max.

NOTE: Refer to the datasheet to get this offset (margin for coarse integration time).

3.3.2.6.2 Output register address

Register addresses for sensor cutout (x_output and y_output), frame_length_lines, and line_length_pclk must be configured based on the register specs in the camera sensor datasheet.

```
static struct msm_sensor_output_reg_addr_t output_reg_addr = {
  .x_output = 0x034C,
  .y_output = 0x034E,
  .line_length_pclk = 0x0342,
  .frame_length_lines = 0x0340,
};
```

3.3.2.7 MIPI receiver configuration

The sensor streams the imaging data in the MIPI CSI2 protocol. The QTI receiver receives it via MIPI CSI PHY and CSID.

3.3.2.7.1 CSI-DPHY config

This structure shows CSI lane parameters.

```
static struct csi_lane_params_t csi_lane_params = {
  .csi_lane_assign = 0x4320,
  .csi_lane_mask = 0x1F,
  .csi_if = 1,
  .csid_core = { 0 },
  .csi_phy_sel = 0,
};

static struct msm_camera_csi2_params imx135_csi_params = {
  .csid_params = {
    .lane_cnt = 4,
    .lut_params = {
      .num_cid = ARRAY_SIZE(imx135_cid_cfg),
      .vc_cfg = {
        &imx135_cid_cfg[0],
        &imx135_cid_cfg[1],
        &imx135_cid_cfg[2],
      },
    },
  },
  .csiphy_params = {
    .lane_cnt = 4,
    .settle_cnt = 0x1B,
    .combo_mode = 1, //Present on recent builds
  },
};
```

- csi_lane_assign – Sometimes customer hardware may be designed with different pin mapping compared to the MSM™ chipset's reference pin map for camera data lanes, for example, sensor data lane 0 may be connected to MSM data lane 4. The csi_lane_assign parameter can be configured to address such cases. This is a 16-bit value, with the meaning of each bit field presented as follows:

Bit position	Represents
15:12	MSM side PHY lane number, where sensor's data lane 3 is connected
11:8	MSM side PHY lane number, where sensor's data lane 2 is connected
7:4	MSM side PHY lane number, where sensor's data lane 1 is connected
3:0	MSM side PHY lane number, where sensor's data lane 0 is connected

NOTE: Lane 1 is reserved for the clock. Customers should not use this lane for mapping any data lanes.

- csi_lane_mask – This 8-bit field indicates which MIPI lanes are valid and enabled.

When a single camera is connected on the combo PHY, the value would be interpreted as:

Bit position	Represents
7:5	Reserved
4	Is data lane 3 valid? ▪ 0 – No ▪ 1 – Yes
3	Is data lane 2 valid? ▪ 0 – No ▪ 1 – Yes
2	Is data lane 1 valid? ▪ 0 – No ▪ 1 – Yes
1	Is clock lane valid? ▪ 0 – No ▪ 1 – Yes **Note:** This should always be set to 1.
0	Is data lane 0 valid? ▪ 0 – No ▪ 1 – Yes

For example, value 0x1F indicates that the camera has 4 valid data lanes and a clock lane.

When two cameras are connected (Cam0: 2 lanes camera connected to lanes 2:0; Cam1: 1 lane camera connected on lanes 4:3), the value would be interpreted as:

Bit position	Represents
7:5	Reserved
4	Is data lane 1 of Cam1 valid? ▪ 0 – No ▪ 1 – Yes
3	Is clock lane of Cam1 valid? ▪ 0 – No ▪ 1 – Yes **Note:** When camera is present, this should always be set to 1.
2	Is data lane 1 of Cam0 valid? ▪ 0 – No ▪ 1 – Yes
1	Is clock lane of Cam0 valid? ▪ 0 – No ▪ 1 – Yes **Note:** When camera is present, this should always be set to 1.
0	Is data lane 0 of Cam0 valid? ▪ 0 – No ▪ 1 – Yes

- csi_if – Not used
- csid_core – An index of the CSID hardware used by the sensor; two sensors operating concurrently cannot use the same value for this setting.
- csi_phy_sel – An index of the CSI-PHY core used by the sensor; should be unique for each sensor, unless an external MIPI bridge connects two sensors to the same PHY interface on the MSM. This value should be configured based on the customer's hardware schematic diagram.
- lane_cnt – The number of data lanes on which the sensor outputs data for a given mode of operation; this value is determined by the sensor's maximum data lanes capability (given in the datasheet) along with sensor register settings configured in the driver.
- combo_mode – Value 0 indicates that one camera is connected to the given PHY interface. Value 1 indicates that two cameras are sharing this PHY interface, in which case:
  - First camera – This is connected to PHY lanes 2:0. Clock lane is connected to PHY lane 1. Data lanes (up to 2) can be connected to either of PHY lanes 0 or 2.
  - Second camera – This is connected to PHY lanes 4:3. Clock lane is connected to PHY lane 4. Data lane can be connected to PHY lane 3.
- settle_cnt (aka Settle count) – This value must be configured, based on the sensor's output characteristics, to ensure the sensor's PHY transmitter does not have sync issues with the MSM's PHY receiver.
  - For 28nm and smaller MSM parts, use following formula to calculate settle count:

    settle_cnt = T(HS_SETTLE)_avg /T(TIMER_CLK),

    where T(HS_SETTLE)_avg = (T(HS_SETTLE)_min + T(HS_SETTLE)_max) / 2, as indicated by sensor datasheet.

- TIMER_CLK refers to the operating frequency of PHY interface to which camera sensor is connected (for example, CAMSS_PHY0_CSI0PHYTIMER_CLK for PHY0). This value is set in kernel/arch/arm/boot/dts/msm/msmXXXX-camera.dtsi file, where XXXX refers to the MSM chipset being used. It can also be confirmed during camera streaming by checking appropriate clock information via adb shell. For example, following commands can be issued via command prompt to confirm PHY0 timer clock value:

```
adb root
adb remount
adb shell
cd /sys/kernel/debug/clk/camss_phy0_csi0phytimer_clk
cat measure
```

- T(TIMER_CLK) is the duration of a clock cycle when operating frequency is equal to TIMER_CLK, and is represented in Nano second unit. For example, T(TIMER_CLK) for TIMER_CLK 200 MHz is (1 * (10^9))/(200 * (10^6)) = 5ns.

NOTE: If the value calculated using the formula given above does not work as expected, alternate lower values between T(HS_SETTLE)_avg/T(TIMER_CLK) and T(HS_SETTLE)_min/T(TIMER_CLK) could be tried.

- For 45nm MSM parts, use similar formula as the one for 28nm MSM part, with T(TIMER_CLK) replaced with T(DDR_CLK).
  - DDR_CLK refers to the operating frequency of MIPI CLK lane of camera sensor, and is determined via camera sensor PLL configuration set via camera sensor driver.
  - T(DDR_CLK) is duration of a clock cycle when operating frequency is equal to DDR_CLK, and is represented in nano second unit. For example, T(DDR_CLK) for DDR_CLK 200 MHz is (1 * (10^9))/(200 * (10^6)) = 5ns.

  Definition for T(HS_SETTLE) can be found in MIPI(R) Alliance Specification for D-PHY (Version 1.1).

  In case the factors indicated above vary between various streaming modes the sensor operates at, settle_cnt must be configured separately for each unique streaming mode in the camera sensor driver.

3.3.2.7.2 CSI-CPHY config

NOTE: This section was added to this document revision.

For the CPHY config, set the is_csi_3phase to 1 and follow the table listed below for lane_cnt, lane_mask and lane_assign.

```
.csi_params =
{
  .lane_cnt = 3,
  .settle_cnt = 0xA,
  .is_csi_3phase = 1,
},
```

	3 trio	2 trio	1 trio
lane_cnt	3	2	1
lane_mask	0x7	0x3	0x1
lane_assign	0x210	0x10	0x0

3.3.2.7.3 VFE clock rate calculation

Operating frequency of the clk lane of camera sensor (aka MIPI DDR clk) and number of active data lanes determine total data rate (throughput) from camera sensor for a given mode of operation. Data rate per lane is double the speed of MIPI DDR clk. For example, camera sensor operating at MIPI DDR clk of 200 MHz and 4 active data lanes would have total data rate of 1600 Mbps (200 * 2 = 400 Mbps data rate per lane).

Data rate varies based on resolution of each frame, extra/dummy pixels/lines, H blanking, V blanking, MIPI packet overhead, bits per pixel, data format, whether there are multiple data streams interleaved within and data rate/overhead characteristics of each stream, and so on. For initial camera bringup in a given mode of operation, calculate:

*X = Frame width * (Frame height * V blank) * bits per pixel * frames per second * (overhead from MIPI protocol and other streams)*

Find the closest value in VFE clk plan for the given MSM that is higher than X and use that as the initial value for VFE clk.

3.3.2.7.4 CSI-D configuration

```
static struct msm_camera_csid_vc_cfg imx135_cid_cfg[] = {
  { 0, CSI_RAW10, CSI_DECODE_10BIT },
  { 1, 0x35, CSI_DECODE_8BIT },
  { 2, CSI_EMBED_DATA, CSI_DECODE_8BIT}
};
```

The first entry for each row above is called Channel ID (CID). Each unique combination of Virtual Channel (VC) and Data Type (DT) should map to a unique CID value. Possible CID values for a given VC are:

- 0 – 0, 1, 2, 3
- 1 – 4, 5, 6, 7
- 2 – 8, 9, 10, 11
- 3 – 12, 13, 14, 15

In the imx135_cid_cfg example above, all three streams with data types CSI_RAW10, 0x35, CSI_EMBED_DATA are sent by the camera sensor in VC 0. Thus, the CID values are within the range 0 to 3.

3.3.2.8 Register settings

The camera sensor registers are configured for the streaming via I2C. The sensor can also be configured for other specific operations as described in this section.

3.3.2.8.1 Init settings

Perform a one-time register config at camera startup.

```
static struct msm_camera_i2c_reg_setting init_reg_setting[] = {
. . .
}
```

3.3.2.8.2 Grouphold on settings

The runtime updates for exposure settings are assigned too many registers (coarse integration time, framelengthlines, and gain) and they must be changed within one frame period of the image. These registers are double buffered type and have the “grouped parameter hold” function to behave to be updated at once. When the “grouped parameter hold” register is set to 1, the transmitted data are held in the buffer registers.

```
static struct msm_camera_i2c_reg_setting groupon_settings = {
. . .
}
```

3.3.2.8.3 Grouphold off settings

When the “grouped parameter hold” register is set to 0, the exposure register values are updated as if they are transmitted at the same time and realize a smooth transition of parameter changes at the frame boundary.

```
static struct msm_camera_i2c_reg_setting groupoff_settings = {
. . .
}
```

3.3.2.8.4 Resolution settings

The sensor can be operated in multiple modes, for example, Preview with quarter resolution and Snapshot with full resolution. The different resolutions can be configured as shown below.

```
static struct msm_camera_i2c_reg_setting res0 _settings[] = {
. . .
}
static struct msm_camera_i2c_reg_setting res1_settings[] = {
. . .
}
```

3.3.2.8.5 Exposure settings

For the AEC algorithm, real gain is used. For sensor hardware real gain must be converted to register gain in order to configure the sensor. The customer must implement the following functions for that purpose, based on the sensor datasheet. Refer to the analog and digital gain setting section in the sensor datasheet.

```
xxxx_real_to_register_gain()
xxxx_register_to_real_gain()
```

This function calculates the next exposure configuration for both exposure time and gain.

```
xxxx_calculate_exposure()
```

This function prepares the next exposure configure array.

```
xxxx_fill_exposure_array()
```

NOTE: Refer to reference drivers.

3.3.2.8.6 Start streaming settings

A MIPI data packet is bounded by Start of Transmission (SoT) and End of Transmission (EoT).

- SoT – LP11→LP01→LP00
- EoT – LP00→LP11

In the sensor driver, the following settings should be configured to match this guideline.

Take the clock and data lanes from LP11 to HS Tx state:

```
static struct msm_camera_i2c_reg_array start_reg_array[] = {
  { 0x0100, 0x01 },
};
```

3.3.2.8.7 Stop streaming settings

The stop streaming settings should put clock and data lanes of the sensor in the LP11 state. Not doing this correctly can cause an inconsistency in MIPI camera sync with the MSM.

```
static struct msm_camera_i2c_reg_array stop_reg_array[] = {
  { 0x0100, 0x00 },
};.
```

3.3.3 Using QUP/SPI

For the BLSP configuration, see *BAM Low-Speed Peripherals for Linux Kernel Configuration and Debugging Guide* (80-NE436-1). Although this document is not specifically for MSM8916, the same concept is applicable. For chipsets that do not have CCI hardware, QUP is used to perform I2C transactions with camera.

NOTE: Customers needing to configure QUP/SPI on chipset with CCI hardware must contact QTI.

3.3.4 Updating CCI operation speed

Following I2C specification, CCI (for chipsets where it is present) can operate between 100 and 400 kHz and is controlled by a parameter named i2c_freq_mode within the structure msm_camera_sensor_slave_info. Refer to the IMX135 sensor driver file $(MM_CAMERA_DIR)/ mm-camera2/media-controller/modules/sensors/sensor_libs/ imx135/imx135_lib.c for an example.

```
static struct msm_camera_sensor_slave_info sensor_slave_info = {

  . . .

  /*sensor i2c frequency*/
.i2c_freq_mode = I2C_FAST_MODE,

. . .

};
```

The available I2C frequency modes are defined in kernel/include/media/msm_cam_sensor.h: standard (100 kHz), fast (400 kHz), and Custom mode.

```
enum i2c_freq_mode_t {
   I2C_STANDARD_MODE,
   I2C_FAST_MODE,
   I2C_CUSTOM_MODE,
   I2C_MAX_MODES,
};
```

For Custom mode, in the case of MSM8916, the CCI tuning parameters setting information can be found in kernel/arch/arm/boot/dts/qcom/msm8916-camera.dtsi.

```
&i2c_freq_custom {
   qcom,hw-thigh = <15>;
   qcom,hw-tlow = <28>;
   qcom,hw-tsu-sto = <21>;
   qcom,hw-tsu-sta = <21>;
   qcom,hw-thd-dat = <13>;
   qcom,hw-thd-sta = <18>;
   qcom,hw-tbuf = <25>;
   qcom,hw-scl-stretch-en = <1>;
   qcom,hw-trdhld = <6>;
   qcom,hw-tsp = <3>;
   status = "ok";
};
```

If a custom CCI configuration is used then the speed of I2C frequency information can be calculated by the formula:

CCI clock = (src clock) / (hw_thigh + hw_tlow)

Because the CCI clock frequency is typically 19.2 MHz, for the standard CCI frequency case, it is:

CCI clock = 19.2 MHz / (78 + 114) = 100 kHz

If there is no CCI hardware, or when QUP is used for I2C, QUP speed can be set to either 100 or 400 kHz from the .dtsi file. For more details, see entry qcom,clk-freq-out of node i2c_3 in file kernel/arch/arm/boot/dts/qcom/msm8909.dtsi in Section 8.1.

4 AF Actuator Driver

This chapter provides guidelines to customers who write their own AF actuator driver by looking at the reference AF actuator driver provided in the base build.

4.1 AF actuator driver directory structure

Customers who want to write a new AF actuator driver can refer to the following reference AF actuator driver. This example involves actuator dw9714, which is used by the imx135 sensor driver in the base build.

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/actuator_libs/dw9714/
  - Android.mk
  - dw9714_actuator.c
  - dw9714_actuator.h
- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/actuators/0301/dw9714/
  - Android.mk
  - camcorder/
    - Android.mk
    - dw9714_camcorder.c
    - dw9714_camcorder.h
  - camera/
    - Android.mk
    - dw9714_camera.c
    - dw9714_camera.h
- <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi

4.2 Files to update/add

The following specified files must be updated or modified to add a new AF actuator driver.

4.2.1 Updating a device tree file

In the target's camera .dtsi file, for example, msm8916-camera-sensor-mtp.dtsi, add an entry for the actuator node and assign qcom,actuator-src with actuator node.

- <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi

```
&cci{
        actuator0: qcom,actuator@6e {
                cell-index = <3>;
                reg = <0x6c>;
                compatible = "qcom,actuator";
                qcom,cci-master = <0>;
        };
        qcom,camera@0 {
                qcom,actuator-src = <&actuator0>;
        };
}
```

4.2.2 Setting up AF actuator power

Refer to each reference chipset platform DTSI file to specify the AF actuator power because the correct specification may be slightly different. In MSM8916, the cam_vaf-supply is specified with camera sensor node, however, in MSM8992, MSM8994, MSM8996, MSM8952, it is specified in MSM8992, MSM8994, MSM8996, MSM8952 actuator node:

Here is an example for MSM8916:

Note that the power supply of AF is specified together with the camera sensor and it is the fourth entry in the list of each vreg name, type, min-voltage, max-voltage and op-mode.

```
&cci {
    ...
    qcom,camera@0 {
         ...
         cam_vdig-supply = <&pm8916_s4>;
         cam_vana-supply = <&pm8916_l17>;
         cam_vio-supply = <&pm8916_l6>;
         cam_vaf-supply = <&pm8916_l10>;
         qcom,cam-vreg-name = "cam_vdig", "cam_vio", "cam_vana",
                              "cam_vaf";
         qcom,cam-vreg-type = <0 1 0 0>;
         qcom,cam-vreg-min-voltage = <2100000 0 2850000 2800000>;
         qcom,cam-vreg-max-voltage = <2100000 0 2850000 2800000>;
```

```
qcom,cam-vreg-op-mode = <200000 0 80000 100000>;
```

Here is an example for MSM8992/MSM8994:

The voltage regulator (PMIC) is specified under “qcom,actuator” device tree node.

```
&cci {
   actuator0: qcom,actuator@0 {
        ...
        cam_vaf-supply = <&pm8994_l23>;
        qcom,cam-vreg-name = "cam_vaf";
        qcom,cam-vreg-min-voltage = <2800000>;
        qcom,cam-vreg-max-voltage = <2800000>;
        qcom,cam-vreg-op-mode = <100000>;
   };
```

4.2.3 Adding optional GPIO control pin for actuator

In some cases, the GPIO pin can be used for the actuator power source instead of the default voltage regulator from PMIC. The voltage regulator node information is covered in the previous section and should be deleted first, then the following DTSI device tree properties must be added:

Here is an example for MSM8916:

```
   &cci{
        qcom,camera@0 {
             qcom,actuator-src = <&actuator0>;
             ...
             qcom,actuator-vcm-pwd = <gpio number for VCM power>;
             qcom,actuator-vcm-enable = <gpio number for VCM eanble>;        };
   }
```

In case of MSM8916, the GPIO call sequence (that is, gpio_set_value_cansleep) can be found in msm_actuator_power_up() / msm_actuator_power_down().

Here is an example for MSM8992/MSM8994:

```
   &cci{
           qcom,camera@0 {
                 ...
                 gpios = <&msm_gpio 27 0>, ...
                 ...
                 qcom,gpio-vaf = <0>; /* The first array item */
                 ...
                 qcom,gpio-req-tbl-label = "CAM_VAF",
                 ...
           };
   }
```

For MSM8992/MSM8994, the GPIO for actuator (“qcom,gpio-vaf”) is referred by the index of the GPIO list of camera sensor node. In the camera sensor power sequence, for example, msm_camera_power_up/down), the actuator power will be enabled or disabled.

4.2.4 Updating a sensor driver file

Considering the imx135_lib.c driver file as an example, the actuator_name field in the sensor_lib_t structure must be populated to associate an actuator driver with the sensor.

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/sensor_libs/imx135/imx135_lib.c

```
static sensor_lib_t sensor_lib_ptr = {
  /* sensor slave info */
  .sensor_slave_info = &sensor_slave_info,
  /* sensor init params */
  .sensor_init_params = &sensor_init_params,
  /* sensor actuator name */
.actuator_name = "dw9714",
```

4.2.5 Adding AF actuator files

The following <actuator>_actuator.c and <actuator>_actuator.h files must be added for a new actuator driver.

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/actuator_libs/<actuator>/
  - Android.mk
  - <actuator>_actuator.c
  - <actuator>_actuator.h

The <actuator>_actuator.c file is a simple layer that returns actuator_lib_ptr.

```
#include "actuator_driver.h"

static actuator_driver_ctrl_t actuator_lib_ptr = {
#include "<actuator>__actuator.h"
};

void *actuator_driver_open_lib(void)
{
  return &actuator_lib_ptr;
}
```

The <actuator>_actuator.h file should have the following parameters defined for actuator tuning. Some parameters in this file are derived from the actuator datasheet and some are a result of the AF tuning performed.

```
{
    /* actuator_params_t */
    {
      /* module_name */
      "abico",
      /* actuator_name */
      "dw9714",
      /* 8 bit i2c_addr */
      0x18,
      /* i2c_data_type. Check actuator data sheet for i2c data type */
      MSM_ACTUATOR_BYTE_DATA/MSM_ACTUATOR_WORD_DATA,
      /* i2c_addr_type Check actuator data sheet for i2c addr type*/
      MSM_ACTUATOR_BYTE_ADDR/MSM_ACTUATOR_WORD_ADDR,
      /* act_type */
      ACTUATOR_VCM/ACTUATOR_PIEZO,
      /* data_size */
      10,
      /* af_restore_pos */
      0,
      /* msm_actuator_reg_tbl_t */
      {
        /* reg_tbl_size */
        1,
        /* msm_actuator_reg_params_t */ Check the actuator data sheet for
eeprom current programing method.
        {
          /* reg_write_type;hw_mask; reg_addr; hw_shift >>; data_shift << */
          {MSM_ACTUATOR_WRITE_DAC, 0x0000000F, 0xFFFF, 0, 4},
        },
      }
      /* init_setting_size */
      0,
      /* init_settings */
      {
   /* Check actuator data sheet for init_setting register write sequence .
It shall look like the e.g. given below*/
   /* reg_addr, addr_type, reg_data, data_type, i2c_operation, delay/*
        {0xEC, MSM_ACTUATOR_BYTE_ADDR, 0xA3, MSM_ACTUATOR_BYTE_DATA,
MSM_ACT_WRITE, 0},
      },
    }, /* actuator_params_t */
Following actuator_tune_params_t are derived from the AF tuning.
    /* actuator_tuned_params_t */
    {
      /* scenario_size */
      {
        /* scenario_size[MOVE_NEAR] */
```

```
        2,
        /* scenario_size[MOVE_FAR] */
        3,
      },

      /* ringing_scenario */
      {
        /* ringing_scenario[MOVE_NEAR] */
        {
          4,
          41,
        },
        /* ringing_scenario[MOVE_FAR] */
        {
          8,
          22,
          41,
        },
      },

      /* intial_code */ This represent the initial step after which actuator
move the lens position linearly.
      0,
      /* region_size */ This number represent into how many region the
total lens step sizes are divided into.
      2

      /* region_params */ Following regions are devided into number specified
in region_size.
      {
        /* step_bound[0] - macro side boundary */
        /* step_bound[1] - infinity side boundary */
        /* Region 1 */
        {
          .step_bound = {2, 0},
          .code_per_step = 85,
        },
        /* Region 2 */
        {
          .step_bound = {41, 2},
          .code_per_step = 9,
        },
      }
      {
        /* damping */
        {
          /* damping[MOVE_NEAR] */
          {
```

```
            /* scenario 1 */
          /* Number of scenarios depends on the size defined in scenario_size */
            {
              /* region 1 */
              {
                .damping_step = 0x1FF,
                .damping_delay = 7000,
                .hw_params = 0x0000000C,
              },
              /* region 2 */
              {
                .damping_step = 0x1FF,
                .damping_delay = 7000,
                .hw_params = 0x7,
              }
              ,
            }
            ,
          }
        },

        {
          /* damping[MOVE_FAR] */
          {
            /* scenario 1 */
            {
              /* region 1 */
              {
                .damping_step = 0x1FF,
                .damping_delay = 7000,
                .hw_params = 0x0000000C,
              },
              /* region 2 */
              {
                .damping_step = 0x1FF,
                .damping_delay = 4500,
                .hw_params = 0x0000007,
              },
            },
          },
        },
      },
    }, /* actuator_tuned_params_t */
  },
```

4.2.6 Adding AF algorithm tuning files

The following AF algorithm tuning files must be added for Camera and Camcorder modes. For information on AF algorithm tuning, see *Camera Auto Focus Tuning Guide* (80-N8459-1).

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/actuators/0301/<actuator>/
  - Android.mk
  - camcorder/
    - Android.mk
    - <actuator>_camcorder.c
    - <actuator>_camcorder.h
  - camera/
    - Android.mk
    - <actuator>_camera.c
    - <actuator>_camera.h

5 LED Flash Driver

This chapter provides guidelines to customers who write their own LED Flash driver by looking at a reference LED Flash driver provided in the base build.

5.1 LED Flash driver directory structure

The reference LED Flash driver can be PMIC-based, QUP/I2C-based or CCI-based (for chipsets having CCI hardware block). This example uses the LED Flash driver adp1660.c file.

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/led_flash/
  - led_flash.c
  - led_flash.h
- kernel/drivers/media/platform/msm/camera_v2/sensor/flash/
  - Makefile
  - adp1660.c – QUP/I2C-based LED Flash driver
  - msm_led_flash.c – Generic LED Flash driver that handles user space IOCTLs
  - msm_led_flash.h – Generic LED Flash driver header file
  - msm_led_i2c_trigger.c – QUP/I2C- or CCI-based LED Flash interface driver
  - msm_led_torch.c – PMIC-based LED torch driver
  - msm_led_trigger.c – PMIC-based LED Flash driver
- <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi

5.2 Files to be modified

The following specified files must be updated or modified to add a new LED Flash driver.

5.2.1 Updating a device tree file

In the target camera .dtsi file, for example, msm8916-camera-sensor-mtp.dtsi, add an entry for led_flash node and assign qcom,led-flash-src with led_flash node.

- <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi

Depending on the LED Flash hardware, OEMs can decide which type of interface driver to configure. Some LED Flash hardware needs a power supply at input to turn it on/off. For such LED Flash hardware, OEMs can use a PMIC-based LED Flash driver to supply current/power from the PMIC IC. This driver is very simple and just calls PMICAPIs to control the current/power level for different Flash states. Other LED Flash hardware must be programmed with register settings to turn it on/off. For that hardware, OEMs can use either QUP-/I2C-based LED Flash drivers.

Node entry in the device tree file will change based on the type of LED Flash driver – PMIC-based, I2C-based, or CCI-based.

For more details and explanation of each field in the device tree file, refer to the kernel at kernel/Documentation/devicetree/bindings/media/video$ vi msm-camera-flash.txt.

PMIC-based LED Flash driver

```
&soc {
    led_flash0: qcom,camera-led-flash {
         cell-index = <0>;
         compatible = "qcom,camera-led-flash";
         qcom,flash-type = <1>;
         qcom,torch-source = <&pm8941_torch>;
         qcom,flash-source = <&pm8941_flash0 &pm8941_flash1>;
    };
};
```

QUP-/I2C-based LED Flash driver

```
&i2c {
led_flash0: qcom,led-flash@60 {
       cell-index = <0>;
       reg = <0x60>;
       qcom,slave-id = <0x60 0x00 0x0011>;
       compatible = "qcom,led-flash";
       qcom,flash-name = "adp1600";
       qcom,flash-type = <1>;
       qcom,gpio-no-mux = <0>;
       gpios = <&msmgpio 18 0>,
               <&msmgpio 19 0>;
       qcom,gpio-flash-en = <0>;
       qcom,gpio-flash-now = <1>;
```

```
        qcom,gpio-req-tbl-num = <0 1>;
        qcom,gpio-req-tbl-flags = <0 0>;
        qcom,gpio-req-tbl-label = "FLASH_EN",
                "FLASH_NOW";
};
};

&cci {
```

CCI-based LED Flash driver

```
    led_flash0: qcom,led-flash@66 {
         cell-index = <0>;
         reg = <0x66>;
         qcom,slave-id = <0x66 0x00 0x0011>;
         compatible = "rohm-flash,bd7710";
         label = "bd7710";
         qcom,flash-type = <1>;
         qcom,gpio-no-mux = <0>;
         qcom,enable_pinctrl;
         pinctrl-names = "cam_flash_default", "cam_flash_suspend";
         pinctrl-0 = <&cam_sensor_flash_default>;
         pinctrl-1 = <&cam_sensor_flash_sleep>;
         gpios = <&msm_gpio 36 0>,
              <&msm_gpio 32 0>,
              <&msm_gpio 31 0>;
         qcom,gpio-flash-reset = <0>;
         qcom,gpio-flash-en = <1>;
         qcom,gpio-flash-now = <2>;
         qcom,gpio-req-tbl-num = <0 1 2>;
         qcom,gpio-req-tbl-flags = <0 0 0>;
         qcom,gpio-req-tbl-label = "FLASH_RST",
              "FLASH_EN",
              "FLASH_NOW";
         qcom,cci-master = <0>;
    };
```

NOTE: For any of the three LED Flash drivers above, the following entry must be added to associate it with the sensor:

```
qcom,camera@0 {
       qcom,led-flash-src = <&led_flash0>;
};
};
```

For QUP-/I2C-based entry into the camera .dtsi file, the &i2c node shall be defined earlier in the target .dtsi file, for example, msm8916-mtp.dtsi. The following snippet of the example code shows which QUP node is connected to &i2c. To create a new QUP device node, see *BAM Low-Speed Peripherals for Linux Kernel Configuration and Debugging Guide* (80-NE436-1).

```
i2c: i2c@f9928000 { /* BLSP1 QUP6 */
        cell-index = <6>;
        compatible = "qcom,i2c-qup";
        #address-cells = <1>;
        #size-cells = <0>;
        reg-names = "qup_phys_addr";
        reg = <0xf9928000 0x1000>;
        interrupt-names = "qup_err_intr";
        interrupts = <0 100 0>;
        qcom,i2c-bus-freq = <100000>;
        qcom,i2c-src-freq = <19200000>;
        qcom,sda-gpio = <&msmgpio 16 0>;
        qcom,scl-gpio = <&msmgpio 17 0>;
        qcom,master-id = <86>;
};
```

For a PMIC-based LED Flash driver, flash-source and torch-source parameters in the camera .dtsi file supplied by PMIC IC and their handler are defined in kernel/arch/arm/boot/dts/<target>-leds.dtsi, for example, msm8916-leds.dtsi.

```
qcom,leds@d300 {
   status = "okay";
   pm8941_flash0: qcom,flash_0 {
        qcom,max-current = <1000>;
        qcom,default-state = "off";
        qcom,headroom = <3>;
        qcom,duration = <1280>;
        qcom,clamp-curr = <200>;
        qcom,startup-dly = <3>;
        qcom,safety-timer;
        label = "flash";
        linux,default-trigger =
             "flash0_trigger";
```

```
            qcom,id = <1>;
            linux,name = "led:flash_0";
            qcom,current = <625>;
        };

        pm8941_flash1: qcom,flash_1 {
            qcom,max-current = <1000>;
            qcom,default-state = "off";
            qcom,headroom = <3>;
            qcom,duration = <1280>;
            qcom,clamp-curr = <200>;
            qcom,startup-dly = <3>;
            qcom,safety-timer;
            linux,default-trigger =
                "flash1_trigger";
            label = "flash";
            qcom,id = <2>;
            linux,name = "led:flash_1";
            qcom,current = <625>;
        };

        pm8941_torch: qcom,flash_torch {
            qcom,max-current = <200>;
            qcom,default-state = "off";
            qcom,headroom = <0>;
                qcom,startup-dly = <1>;
                linux,default-trigger =
                    "torch_trigger";
                label = "flash";
                qcom,id = <2>;
                linux,name = "led:flash_torch";
                qcom,current = <200>;
                qcom,torch-enable;
            };
        };
    . . .
    };
```

5.2.2 Changing GPIO pin number for CCI-based case

If GPIO pin numbers must be changed, change the following two places:

- kernel/arch/arm/boot/dts/<target>-camera-sensor-mtp.dtsi (for example, msm8916-camera-sensor-mtp.dtsi):

```
pinctrl-names = "cam_flash_default", "cam_flash_suspend";
pinctrl-0 = <&cam_sensor_flash_default>;
```

```
pinctrl-1 = <&cam_sensor_flash_sleep>;
gpios = <&msm_gpio 36 0>,
  <&msm_gpio 32 0>,
  <&msm_gpio 31 0>;
qcom,gpio-flash-reset = <0>;
qcom,gpio-flash-en = <1>;
qcom,gpio-flash-now = <2>;
```

The following configuration can be changed based on the hardware schematic design (GPIO 36, 31, 32):

```
gpios = <&msm_gpio 36 0>,
  <&msm_gpio 32 0>,
  <&msm_gpio 31 0>;
```

- kernel/arch/arm/boot/dts/<target>-camera-sensor-mtp.dtsi (for example, msm8916-camera-sensor-mtp.dtsi):

```
cam_sensor_flash {
    /* FLSH_RESET,FLASH_EN,FLASH_NOW */
    qcom,pins = <&gp 36>, <&gp 31>,<&gp 32> ;
    qcom,num-grp-pins = <3>;
    qcom,pin-func = <0>;
    label = "cam_sensor_flash";
    /* active state */
    cam_sensor_flash_default: default {
        drive-strength = <2>; /* 2 MA */
        bias-disable = <0>; /* No PULL */
    };
    /*suspended state */
    cam_sensor_flash_sleep: sleep {
        drive-strength = <2>; /* 2 MA */
        bias-pull-down = <0>; /* PULL DOWN */
    };
};
```

The following configuration can be changed based on the hardware schematic design (GPIO 36, 31, 32):

```
    qcom,pins = <&gp 36>, <&gp 31>,<&gp 32> ;
```

5.2.3 Adding an LED Flash driver file

For QUP/I2C-based and CCI-based LED Flash drivers, add the <led>.c file, for example, adp1660.c, in the following directory:

- FILE – kernel/drivers/media/platform/msm/camera_v2/sensor/flash/
  - <led>.c

The following data structures and functions must be implemented in the <led>.c driver file.

For a QUP-/I2C-based LED Flash driver, the i2c_driver structure and probe function must be defined as follows:

```
static struct i2c_driver <led>_i2c_driver = {
        .id_table = <led>_i2c_id,
        .probe  = msm_flash_adp1660_i2c_probe,
        .remove = __exit_p(msm_flash_<led>_i2c_remove),
        .driver = {
                .name = FLASH_NAME,
                .owner = THIS_MODULE,
                .of_match_table = <led>_trigger_dt_match,
        },
};

static int msm_flash_<led>_i2c_probe(struct i2c_client *client,
                const struct i2c_device_id *id)
{
        if (!id) {
                pr_err("msm_flash_<led>_i2c_probe: id is NULL");
                id = <led>_i2c_id;
        }

        return msm_flash_i2c_probe(client, id);
}
```

For a CCI-based LED Flash driver, the platform_driver structure and probe function must be defined as follows:

```
static struct platform_driver <led>_platform_driver = {
        .probe = msm_flash_<led>_platform_probe,
        .driver = {
                .name = "qcom,led-flash",
                .owner = THIS_MODULE,
                .of_match_table = <led>_trigger_dt_match,
        },
};

static int msm_flash_<led>_platform_probe(struct platform_device *pdev)
```

```
{
        const struct of_device_id *match;
        match = of_match_device(<led>_trigger_dt_match, &pdev->dev);
        if (!match)
                return -EFAULT;
        return msm_flash_probe(pdev, match->data);
}
```

On successful probe, the msm_led_flash_ctrl_t structure is fully populated and a v4l2 node is created for an LED Flash driver.

```
static struct msm_led_flash_ctrl_t fctrl = {
        .flash_i2c_client = &<led>_i2c_client,
        .reg_setting = &<led>_regs,
        .func_tbl = &<led>_func_tbl,
};
```

The following function table should be initialized with appropriate functions from the msm_led_i2c_trigger.c LED Flash interface driver. This function table is the same for QUP-/I2C-based and CCI-based LED Flash drivers.

```
static struct msm_flash_fn_t <led>_func_tbl = {
        .flash_get_subdev_id = msm_led_i2c_trigger_get_subdev_id,
        .flash_led_config = msm_led_i2c_trigger_config,
        .flash_led_init = msm_flash_led_init,
        .flash_led_release = msm_flash_led_release,
        .flash_led_off = msm_flash_led_off,
        .flash_led_low = msm_flash_led_low,
        .flash_led_high = msm_flash_led_high,
};
```

- .flash_get_subdev_id() – This function returns the subdev_id of the client.
- .flash_led_config () – This is a handler function to handle a user space command to configure LED with different states, for example, LOW, HIGH, OFF, RELEASE, and so on.
- .flash_led_init() – In this function, LED Flash init_settings are written to the LED hardware. The LED Flash datasheet provides the sequence of register settings needed to write to the LED hardware.

  The following is an example init_setting struct. Refer to the LED Flash datasheet for reg_init setting, size of the init_array, addr_type, data_type, and delay.

```
static struct msm_camera_i2c_reg_setting <led>_init_setting = {
        .reg_setting = <led>_init_array,
        .size = ARRAY_SIZE(<led>_init_array),
        .addr_type = MSM_CAMERA_I2C_BYTE_ADDR,
        .data_type = MSM_CAMERA_I2C_BYTE_DATA,
        .delay = 0,
};
```

  In case of CCI-based LED Flash, CCI hardware is also initialized in this function.
- .flash_led_release() – This function is called during the camera close sequence. All the GPIOs are turned off here, and in case of a CCI-based LED Flash driver, it will deinit the CCI hardware.
- .flash_led_off() – This function is called to turn off the LED from a LOW or HIGH state. In this function LED Flash driver off_settings are written to the LED hardware. For off_setting, refer to the LED Flash driver datasheet.

  The following is an example of an off_setting struct. Refer to the LED Flash driver datasheet for off_settings, size of the off_array, addr_type, data_type, and delay.

```
static struct msm_camera_i2c_reg_setting <led>_off_setting = {
        .reg_setting = <led>_off_array,
        .size = ARRAY_SIZE(<led>_off_array),
        .addr_type = MSM_CAMERA_I2C_BYTE_ADDR,
        .data_type = MSM_CAMERA_I2C_BYTE_DATA,
        .delay = 0,
};
```

- .flash_led_low() – This function is called to set the LED to a LOW state. In this function, LED Flash driver low_settings are written to the LED hardware. For low_setting, refer to the LED Flash driver datasheet.

The following is an example of a low_setting struct. Refer to the LED Flash driver datasheet for low_settings, size of the low_array, addr_type, data_type, and delay.

```
static struct msm_camera_i2c_reg_setting <led>_low_setting = {
        .reg_setting = <led>_low_array,
        .size = ARRAY_SIZE(<led>_low_array),
        .addr_type = MSM_CAMERA_I2C_BYTE_ADDR,
        .data_type = MSM_CAMERA_I2C_BYTE_DATA,
        .delay = 0,
};
```

- .flash_led_high() – This function is called to set the LED to a HIGH state. In this function, LED Flash driver high_settings are written to the LED hardware. For high_setting, refer to the LED Flash driver datasheet.

  The following is an example of a high_setting struct. Refer to the LED Flash datasheet for high_settings, size of the high_array, addr_type, data_type, and delay.

```
static struct msm_camera_i2c_reg_setting <led>_high_setting = {
        .reg_setting = <led>_high_array,
        .size = ARRAY_SIZE(<led>_high_array),
        .addr_type = MSM_CAMERA_I2C_BYTE_ADDR,
        .data_type = MSM_CAMERA_I2C_BYTE_DATA,
        .delay = 0,
};
```

5.2.4 Adding PWM-based flash drivers

For adding PWM-based LED flash drivers, check the case system solution #00028369 – "How to use GPIO to generate PWM on MSM8926". For different targets, implement the changes mentioned in the case system solution #00028369 in a similar fashion.

6 EEPROM Driver

This chapter provides guidelines to customers who write their own EEPROM driver by looking at a reference EEPROM driver provided in the base build.

6.1 EEPROM driver directory structure

This example uses the EEPROM driver sunny_q5v22e.

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/eeprom/
  - eeprom.c
  - eeprom.h
- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/eeprom_libs/sunny_q5v22e/
  - Android.mk
  - sunny_q5v22e_eeprom.c
- <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi

6.2 Files to be modified

The following specified files must be updated or modified to add a new EEPROM driver.

6.2.1 Updating a device tree file

In the target's camera .dtsi file, for example, msm8916-camera-sensor-mtp.dtsi, add an entry for EEPROM node and assign qcom,eeprom-src with EEPROM node.

- <target>_camera*.dtsi in kernel/arch/arm/boot/dts/qcom/, for example, msm8916-camera-sensor-mtp.dtsi

The <target>_camera*.dtsi file must be updated with the following .dtsi fields. For explanations of each field in the device tree file, refer to the kernel at kernel/Documentation/devicetree/bindings/media/video/msm-eeprom.txt.

```
&cci {
                eeprom3: qcom,eeprom@6c {
                cell-index = <3>;
                reg = <0x6c>;
                qcom,eeprom-name = "sunny_q5v22e";
                compatible = "qcom,eeprom";
                qcom,slave-addr = <0x20>;
                qcom,cci-master = <0>;
```

```
            qcom,num-blocks = <4>;
            qcom,page0 = <1 0x0100 2 0x01 1 1>;
            qcom,poll0 = <0 0x0 2 0 1 1>;
            qcom,mem0 = <0 0x0 2 0 1 0>;
            qcom,page1 = <1 0x3d84 2 0xc0 1 1>;
            qcom,poll1 = <0 0x0 2 0 1 1>;
            qcom,mem1 = <0 0x3d00 2 0 1 0>;
            qcom,page2 = <1 0x3d88 2 0x7010 2 1>;
            qcom,poll2 = <0 0x0 2 0 1 1>;
            qcom,mem2 = <0 0x3d00 2 0 1 0>;
            qcom,page3 = <1 0x3d8A 2 0x70F4 2 1>;
            qcom,pageen3 = <1 0x3d81 2 0x01 1 10>;
            qcom,poll3 = <0 0x0 2 0 1 1>;
            qcom,mem3 = <228 0x7010 2 0 1 1>;

            cam_vdig-supply = <&pm8226_l5>;
            cam_vana-supply = <&pm8226_l19>;
            cam_vio-supply = <&pm8226_lvs1>;
            qcom,cam-vreg-name = "cam_vdig","cam_vana", "cam_vio";
            qcom,cam-vreg-type = <0 1 2>;
            qcom,cam-vreg-min-voltage = <1200000 2850000 0>;
            qcom,cam-vreg-max-voltage = <1200000 2850000 0>;
            qcom,cam-vreg-op-mode = <200000 80000 0>;
            qcom,gpio-no-mux = <0>;
            gpios = <&msmgpio 26 0>,
                    <&msmgpio 37 0>,
                    <&msmgpio 36 0>;
            qcom,gpio-reset = <1>;
            qcom,gpio-standby = <2>;
            qcom,gpio-req-tbl-num = <0 1 2>;
            qcom,gpio-req-tbl-flags = <1 0 0>;
            qcom,gpio-req-tbl-label = "CAMIF_MCLK",
                    "CAM_RESET1",
                    "CAM_STANDBY";
            qcom,cam-power-seq-type = "sensor_vreg","sensor_vreg",
                    "sensor_vreg", "sensor_clk",
                    "sensor_gpio", "sensor_gpio";
            qcom,cam-power-seq-val = "cam_vdig","cam_vana",
                    "cam_vio", "sensor_cam_mclk",
                    "sensor_gpio_reset",
                    "sensor_gpio_standby";
            qcom,cam-power-seq-cfg-val = <1 1 1 24000000 1 1>;
            qcom,cam-power-seq-delay = <1 1 1 5 5 10>;
    };


    qcom,camera@20 {
```

```
                qcom,eeprom-src = <&eeprom3>;
        };
};
```

6.2.2 Updating a sensor driver file

Considering the ov5648_lib.c driver file as an example, the eeprom_name field in the sensor_lib_t structure must be populated to associate an EEPROM driver with the sensor.

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/sensor_libs/ov5648_q5v22e/ ov5648_q5v22e_lib.c

```
static sensor_lib_t sensor_lib_ptr = {
  /* sensor slave info */
  .sensor_slave_info = &sensor_slave_info,
  /* sensor init params */
  .sensor_init_params = &sensor_init_params,
 /* sensor eeprom name */
  .eeprom_name = "sunny_q5v22e",
```

6.2.3 Adding an EEPROM driver file

The following <eeprom>.c file must be added for a new EEPROM driver.

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/eeprom_libs/eeprom/
  - Android.mk
  - <eeprom>.c

  Any new <eeprom>.c file should have the following function pointers mapped and defined in it. Any of these functions not defined in that EEPROM driver must be set to NULL.

```
static eeprom_lib_func_t <eeprom>_lib_func_ptr = {

  .get_calibration_items = NULL,
  .format_calibration_data = NULL,
  .do_af_calibration = NULL,
  .do_wbc_calibration = NULL,
  .do_lsc_calibration = NULL,
  .do_dpc_calibration = NULL,
  .get_dpc_calibration_info = NULL,
  .get_raw_data = NULL,
};
```

- .get_calibration_items() – This function should return the configuration supported by the EEPROM module. Based on the configuration supported in EEPROM, that specific flag is set to TRUE or FALSE.

```
void <eeprom>_get_calibration_items(void *e_ctrl)
{
  sensor_eeprom_data_t *ectrl = (sensor_eeprom_data_t *)e_ctrl;
  eeprom_calib_items_t *e_items = &(ectrl->eeprom_data.items);
  e_items->is_insensor = TRUE;
  e_items->is_afc = FALSE;
  e_items->is_wbc = TRUE;
  e_items->is_lsc = TRUE;
  e_items->is_dpc = FALSE;
}
```

- Is_insensor – This flag is set to TRUE if the EEPROM configuration is supported in the sensor module itself. No external EEPROM is available.
- Is_afc – This flag is set to TRUE if it supports the AF calibration.
- Is_wbc – This flag is set to TRUE if it supports the white balance calibration.
- Is_lsc – This flag is set to TRUE if it supports the lens shading calibration.
- Is_dpc – This flag is set to TRUE if it supports defect pixel correction.

- .format_calibration_data() – This function is used to format the data that can be written to the eeprom/sensor module. Check the eeprom/sensor datasheet for addr_type, data_type, and register settings. At the end of this function, reg_setting should have the data for wb, lsc, afc, dpc, and so on in eeprom/sensor-understandable format.

```
void <eeprom>_format_calibration_data(void *e_ctrl) {
  SLOW("Enter");
  sensor_eeprom_data_t *ectrl = (sensor_eeprom_data_t *)e_ctrl;
  uint8_t *data = ectrl->eeprom_params.buffer;

  g_reg_setting.addr_type = MSM_CAMERA_I2C_WORD_ADDR;
  g_reg_setting.data_type = MSM_CAMERA_I2C_BYTE_DATA;
  g_reg_setting.reg_setting = &g_reg_array[0];
  g_reg_setting.size = 0;
  g_reg_setting.delay = 0;
  <eeprom>_format_wbdata(ectrl);
  <eeprom>_format_lensshading(ectrl);

  SLOW("Exit");
}
```

- .do_af_calibration() – This function should handle any AF-related calibration operations, formatting data and writing to the EEPROM for AF calibration.
- .do_wbc_calibration() – This function should handle any white balance-related calibration operations, formatting data and writing to the EEPROM for white balance calibration.

- .do_lsc_calibration() – This function should handle any lens shading correction-related calibration operations, formatting data and writing to the EEPROM for lens shading calibration.
- .do_dpc_calibration() – This function should handle any defect pixel correction-related calibration operations, formatting data and writing to the EEPROM for defect pixel correction calibration.

7 Updates to MSM8952/MSM8992/MSM8994/MSM8996/ MSM8998/SDM660/SDM630

This chapter describes the different sensor driver structure in the new MSM8952, MSM8992, MSM8994, MSM8996, MSM8998, SDM660, and SDM630 code.

7.1 Sensor driver changes

7.1.1 User space changes

From MSM8994.LA.1.1, the sensor driver structure has been reorganized. The main structure and the driver configuration remain largely same, but some naming conventions of structure members have been changed, notably for “array” type with postfix “_a”.

Also, the driver file style has been changed so that most of the data information has moved to its header file. For example, file ov4688_lib.c is now a short file with a handle of functions only:

- sensor_real_to_register_gain()
- sensor_register_to_real_gain()
- sensor_calculuate_exposure()
- sensor_fill_exposure_array()
- sensor_open_lib()

Most of the data structure mentioned in Section 3.3.2 moved to its corresponding header files. Check file ov4688_lib.h. In addition to the I2C register array structures, now it has a single consolidated data structure, sensor_lib_ptr. In fact, the nested structure can be constructed by multiple assignments like the previous driver, which has equivalent data. For the minor change of the naming changes, refer to file vendor/qcom/proprietary/mm-camerasdk/sensor/includes/sensor_lib.h.

```
typedef struct {
  /* sensor slave info */
  struct msm_camera_sensor_slave_info sensor_slave_info;
. . .
  /* resolution config table */
  struct sensor_res_cfg_table_t sensor_res_cfg_table;
```

```
  struct sensor_lib_out_info_array     out_info_array;
  struct sensor_lib_csi_params_array   csi_params_array;
  struct sensor_lib_crop_params_array  crop_params_array;
  struct sensor_lib_chromatix_array    chromatix_array;
```

For kernel header changes, refer the header file kernel/include/media/msm_camsensor_sdk.h.

```
struct msm_sensor_power_setting_array {
    struct msm_sensor_power_setting  power_setting_a[MAX_POWER_CONFIG];
    struct msm_sensor_power_setting *power_setting;
    uint16_t size;
    struct msm_sensor_power_setting
power_down_setting_a[MAX_POWER_CONFIG];
    struct msm_sensor_power_setting *power_down_setting;
    uint16_t size_down;
};

struct msm_camera_csid_lut_params {
    uint8_t num_cid;
    struct msm_camera_csid_vc_cfg vc_cfg_a[MAX_CID];
    struct msm_camera_csid_vc_cfg *vc_cfg[MAX_CID];
};
```

NOTE: New array type members power_setting_a and vc_cfg_a have been added.

7.2 LED flash driver changes

The unified flash driver has been added to support different types of flashes (I2C, PMIC and GPIO)

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/flash/flash.c/h

A generic kernel driver has been added so that it can receive the same IOCTL calls from user space to control different types of flashes.

- Kernel/drivers/media/platform/msm/camera_v2/sensor/flash/msm_flash.c/h

7.2.1 PMIC-based

7.2.1.1 User space changes

In user space, related files are located in following directory

- $(MM_CAMERA_DIR)/mm-camera2/media-controller/modules/sensors/flash_libs/pmic/

User space driver sends configuration data for following configuration types to kernel driver to configure PMIC accordingly.

- CFG_FLASH_INIT
- CFG_FLASH_RELEASE

- CFG_FLASH_OFF
- CFG_FLASH_LOW
- CFG_FLASH_HIGH

7.2.1.2 Kernel space changes

Depending on the power source, customers might have to change dtsi file, for example, kernel/arch/arm/boot/dts/qcom/msm8994-camera-sensor-mtp.dtsi&soc {

```
led_flash0: qcom,camera-flash {
   cell-index = <0>;
   compatible = "qcom,camera-flash";
   qcom,flash-type = <1>;
   qcom,flash-source = <&pmi8994_flash0 &pmi8994_flash1>;
   qcom,torch-source = <&pmi8994_torch0 &pmi8994_torch1>;
   };
              };
```

NOTE: If customers need to use PMIC-based solution different than the software/hardware design, the customers are requested to discuss the requirements with QTI via the Salesforce case system.

Refer to kernel/Documentation/devicetree/bindings/media/video/msm-camera-flash.txt

7.2.2 I2C/GPIO-based

The reference drivers for I2C/GPIO-based flash drivers are not part of reference builds, but these can be enabled using unified flash architecture on customer devices. Customers are requested to discuss the requirements further with QTI via the Salesforce case system.

8 Updates to MSM8909

This chapter describes the different driver structure in the MSM8909 code.

8.1 No CCI hardware

The major difference on MSM8909 is the absence of a CCI hardware block compared to other chipsets, MSM8916, MSM8974, and so on. This means all camera driver-specific entries in dtsi file, for example, kernel/arch/arm/boot/dts/qcom/msm8909-camera-sensor-mtp.dtsi, would be listed under legacy i2c node. For example:

```
&i2c_3 {

   actuator0: qcom,actuator@0 {
   . . .
   };

   eeprom0: qcom,eeprom@6c{
   . . .
   };

   led_flash0: qcom,led-flash@60 {
   . . .
   };

   qcom,camera@0 {
   . . .
   };

   qcom,camera@1 {
   . . .
   };

};
```

Reference to the node &i2c_3 indicates that BLSP1 QUP3 is used for camera operations on MSM8909. This node is defined in kernel/arch/arm/boot/dts/qcom/msm8909.dtsi:

```
i2c_3: i2c@78b7000 { /* BLSP1 QUP3 */
       compatible = "qcom,i2c-msm-v2";
       #address-cells = <1>;
       #size-cells = <0>;
       reg-names = "qup_phys_addr", "bam_phys_addr";
       reg = <0x78b7000 0x1000>,
             <0x7884000 0x23000>;
       interrupt-names = "qup_irq", "bam_irq";
       interrupts = <0 97 0>, <0 238 0>;
       clocks = <&clock_gcc clk_gcc_blsp1_ahb_clk>,
                <&clock_gcc clk_gcc_blsp1_qup3_i2c_apps_clk>;
       clock-names = "iface_clk", "core_clk";
       qcom,clk-freq-out = <100000>; //NOTE: This can be set to 400000 if
400 KHz frequency is required
       qcom,clk-freq-in  = <19200000>;
       pinctrl-names = "i2c_active", "i2c_sleep";
       pinctrl-0 = <&i2c_3_active>;
       pinctrl-1 = <&i2c_3_sleep>;
       qcom,noise-rjct-scl = <0>;
       qcom,noise-rjct-sda = <0>;
       qcom,bam-pipe-idx-cons = <8>;
       qcom,bam-pipe-idx-prod = <9>;
       qcom,master-id = <86>;
};
```

8.2 Reference drivers

MSM8909 MTP uses rear camera OV8858 (module part q8v19w). Thus, the for driver code references, refer to ov8858_q8v19w_lib.c. For EEPROM, refer to sunny_ov8858_q8v19w_eeprom.c.

9 Troubleshooting

This chapter describes the debugging processes to follow should you encounter any errors upon creating or configuring the components for camera bringup. Troubleshooting should be performed in the order presented in this chapter.

9.1 Sensor troubleshooting

This section describes the various processes to follow when sensor module mount/probe failures are present.

9.1.1 Module mount

9.1.1.1 Bayer sensor

1. Open the sensor file.
2. Note the sensor_slave_info array camera_id value.

```
static struct msm_camera_sensor_slave_info sensor_slave_info = {
    /* Camera slot where this camera is mounted */
    .camera_id = CAMERA_0,
    /* sensor slave address */
    .slave_addr = 0x20,
    /* sensor address type */
    .addr_type = MSM_CAMERA_I2C_WORD_ADDR,
    /* sensor id info */
```

3. Note the value for the cell-index value in the sensor dtsi file.

```
qcom,camera@0 {
        cell-index = <0>;
        compatible = "qcom,camera";
        reg = <0x0>;
        qcom,csiphy-sd-index = <0>;
        qcom,csid-sd-index = <0>;
        qcom,mount-angle = <90>;
        qcom,actuator-src = <&actuator0>;
        qcom,led-flash-src = <&led_flash0>;
        cam_vdig-supply = <&pm8916_s4>;
        cam_vana-supply = <&pm8916_l17>;
        cam_vio-supply = <&pm8916_l6>;
        cam_vaf-supply = <&pm8916_l10>;
        qcom,cam-vreg-name = "cam_vdig", "cam_vio", "cam_vana",
                                                    "cam_vaf";
```

4. The value for sensor_slave_info array camera_id should be the same as the cell-index value in the sensor dtsi file.

9.1.1.2 YUV sensor

1. Add the following sensor dtsi settings to the board camera dtsi file (arch/arm/boot/dts).

   If you are viewing this document using a color monitor, or if you print this document to a color printer, **red boldface** indicates code that must be **added**.

```
qcom,camera@78 {
     compatible = "qcom,ABC";
     reg = <0x78>;
     qcom,slave-id = <0x78 0x0016 0x0135>;
     XXXXXX
    };
```

   The value in **red boldface** in the example is a unique value. It represents the camera id at the dtsi tree. Here, we use 78, so if you bring up another camera, you cannot use 78 again.

2. Add camera clk source to arch/arm/mach-msm/clock-xxxx.c

   - For MSM8974, MSM8x26/28, and MSM8926/28

```
CLK_LOOKUP("cam_src_clk", mclk0_clk_src.c, "78.qcom,camera"),
CLK_LOOKUP("cam_clk", camss_mclk0_clk.c, "78.qcom,camera"),
```

   - For MSM8916/MSM8936/MSM8909/MSM8084/MSM8992/MSM8994 and later, clk_mclk1_clk_src and clk_gcc_camss_mclk1_clk settings are specified in the .dtsi file. See kernel/arch/arm/boot/dts/qcom/msm8916-camera-sensor-mtp.dtsi for an example.

9.1.2 Module probe

9.1.2.1 Power up/down sequence

1. Define a macro to enable the log in the file “msm_camera_dt_util.c” as shown.

```
--- a/drivers/media/platform/msm/camera_v2/sensor/io/msm_camera_dt_util.c
+++ b/drivers/media/platform/msm/camera_v2/sensor/io/msm_camera_dt_util.c
@@ -18,7 +18,7 @@

 #define CAM_SENSOR_PINCTRL_STATE_SLEEP "cam_suspend"
 #define CAM_SENSOR_PINCTRL_STATE_DEFAULT "cam_default"
-/*#define CONFIG_MSM_CAMERA_DT_DEBUG*/
+#define CONFIG_MSM_CAMERA_DT_DEBUG*/
 #undef CDBG
 #ifdef CONFIG_MSM_CAMERA_DT_DEBUG
 #define CDBG(fmt, args...) pr_err(fmt, ##args)
```

2. Search for the keyword “msm_camera_power_up” from the kernel log. The log will point out the failed sequence type.

3. Ensure the power up/down setting array meets the sensor specification.

   The following code snip is an example of where in the code that the power up/down sequence is configured.

```
static struct msm_sensor_power_setting power_setting[] = {
     {
          .seq_type = SENSOR_VREG,
          .seq_val = CAM_VDIG,
          .config_val = 0,
          .delay = 0,
     },
     {
          .seq_type = SENSOR_VREG,
          .seq_val = CAM_VANA,
          .config_val = 0,
          .delay = 0,
     },
     {
          .seq_type = SENSOR_VREG,
          .seq_val = CAM_VIO,
          .config_val = 0,
          .delay = 0,
     },
```

   More examples can be found in the following file:
   Vendor/qcom/proprietary/mm-camera/mm-camera2/
   media-controller/modules/sensors/sensor_libs/xxxx/ xxxx_lib.c

9.1.2.2 CCI

The CCI performs I2C operation for camera slave devices. Some hardware components cannot run I2C Speed mode, which may cause issues. This section describes how to change the I2C Speed mode.

1. Enable logging in the CCI release source file (kernel/drivers/media/platform/msm/camera_v2/sensor/cci/msm_cci.c) to validate register settings.

2. Change the CCI I2C speed by changing the i2c_freq_mode value:
   - I2C_FAST_MODE – 400 KHz
   - I2C_STANDARD_MODE – 100 KHz

```
static struct msm_camera_sensor_slave_info sensor_slave_info = {
  /* Camera slot where this camera is mounted */
  .camera_id = CAMERA_0,
  /* sensor slave address */
  .slave_addr = 0x20,
  /* sensor address type */
  .addr_type = MSM_CAMERA_I2C_WORD_ADDR,
  /* Slave I2C Frequency */
  .i2c_freq_mode = I2C_FAST_MODE,
  /* sensor id info*/
  .sensor_id_info = {
    /* sensor id register address */
    .sensor_id_reg_addr = 0x0016,
    /* sensor id */
    .sensor_id = 0x0135,
  },
  /* power up / down setting */
  .power_setting_array = {
    .power_setting = power_setting,
    .size = ARRAY_SIZE(power_setting),
    .power_down_setting = power_down_setting,
    .size_down = ARRAY_SIZE(power_down_setting),
  },
};
```

3. Enabling CCI clock stretch:

   For the sensors that mandate the I2C master (CCI) clock stretch feature to operate properly, try setting the property “qcom,hw-scl-stretch-en” to 1 in dtsi file:

```
. . .
qcom,hw-scl-stretch-en = <1>;
. . .
```

   Although this change should not cause functional issues, I2C speed would be reduced, as the master (CCI) now must listen to the slow rising SCL signals instead of determining all the timing based on the internal CCI clock. It is recommended that customers do thorough stress testing of I2C functionality when making this change, and update QTI via Salesforce case in case of any issues.

9.1.2.3 MCLK

MCLK is set to 24 MHz by default in the msm_sensor.c file.

```
static struct msm_cam_clk_info cam_xxxx_clk_info[] = {
     [SENSOR_CAM_MCLK] = {"cam_src_clk", 24000000},
     [SENSOR_CAM_CLK] = {"cam_clk", 0},
};
```

The MCLK value can be specified, for example 19.2 MHz in the sensor power setting array.

```
static struct msm_sensor_power_setting abc_power_setting[] = {
   {
        .seq_type = SENSOR_CLK,
        .seq_val = SENSOR_CAM_MCLK,
        .config_val = 19200000,
        .delay = 1,
   },
}
```

For MSM8916 and MSM8939, the recommended MCLK is 23.88 MHz. It is acceptable to configure the sensor with the assumption of 24 MHz input MCLK though. To set this for MSM8916, set the following entry in the file, kernel/arch/arm/boot/dts/qcom/msm8916-camera-sensor-mtp.dtsi

```
qcom,mclk-23880000 = <1>;
```

9.2 ISP troubleshooting

9.2.1 SOF IRQ timeout

1. Open mm-camera/mm-camera2/media-controller/mct/bus/mct_bus.c
2. Search for “mct_bus_sof_thread_run” function and look for error print “SOF freeze; Sending error message.”. Check if this message is present in the logs:
   - If yes, it means that the ISP has not received the SOF IRQ from the kernel and CSID/CSIPHY/CAMIF must be checked.
   - If no, it means that the ISP has received frames from the sensor.

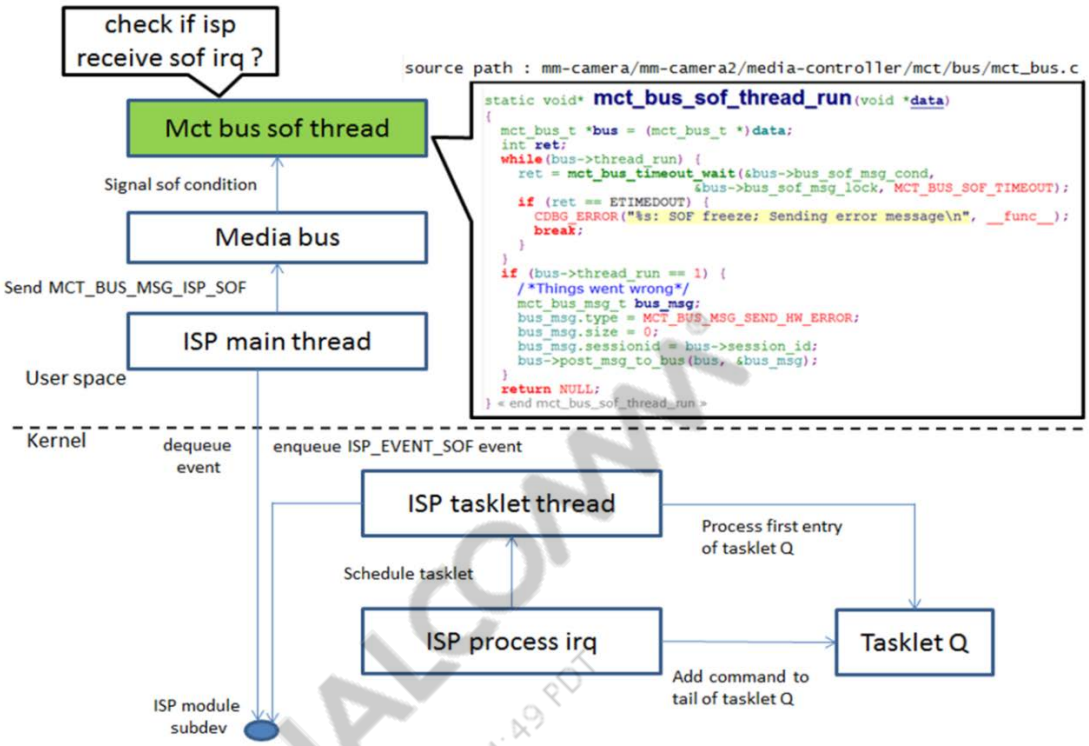

Figure 9-1 SOF IRQ timeout

9.2.2 VFE overflow

Overflows occur when the VFE clock is set less than the output MIPI data rate of the sensor. Figure 9-2 illustrates an overflow due to VFE clock less than the sensor output MIPI data rate.

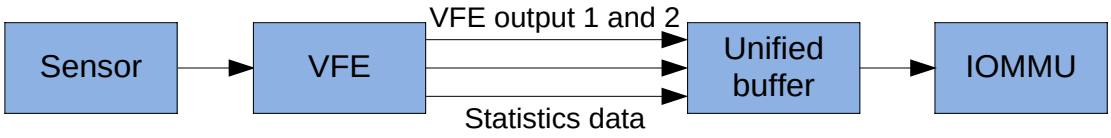

Figure 9-2 VFE overflow

To determine if an overflow has occurred, examine the overflow log files located at:

- kernel/drivers/media/platform/msm/camera_v2/isp/msm_ispxx.c
- kernel/drivers/media/platform/msm/camera_v2/ispif/msm_ispif.c

The typical overflow log entry will appear as:

```
<3>[2019.674774] msm_ispif_read_irq_status: pix intf 0 overflow.
<3>[2019.700866] msm_ispif_read_irq_status: pix intf 0 overflow.
```

Increasing the VFE clock will prevent overflow. To change the VFE clock, open the file at Vendor/qcom/proprietary/mm-camera/mm-camera2/media-controller/modules/sensors/sensor_libs/xxxx/ xxxx_lib.c and edit the op_pixel_clk parameter.

9.2.3 CAMIF error status

A CAMIF error occurs when there is a mismatch between the declared sensor output size and the actual sensor output that is received by the VFE.

1. To verify the settings, perform a dump of the CAMIF settings with the isp_hw_camif_dump_cfg function in the isp_hw.c file.

```
static void isp_hw_camif_dump_cfg(struct msm_vfe_pix_cfg *pix_cfg)
{
  CDBG("%s: =====dump Camif cfg for PIX interface====\n", __func__);
  CDBG("%s: camif input type = %d\n", __func__,
    pix_cfg->camif_cfg.camif_input);
  CDBG("%s: camif pixel pattern = %d\n", __func__, pix_cfg->pixel_pattern);
  CDBG("%s: camif input_format= %d\n", __func__, pix_cfg->input_format);

  CDBG("%s: camif first_pix = %d\n", __func__, pix_cfg->camif_cfg.first_pixel);
  CDBG("%s: camif last_pix = %d\n", __func__, pix_cfg->camif_cfg.last_pixel);
  CDBG("%s: camif first_line = %d\n", __func__, pix_cfg->camif_cfg.first_line);
  CDBG("%s: camif last_line = %d\n", __func__, pix_cfg->camif_cfg.first_line);
  CDBG("%s: camif pixels per line = %d\n",
    __func__,  pix_cfg->camif_cfg.pixels_per_line);
  CDBG("%s: camif lines per frame = %d\n", __func__,
    pix_cfg->camif_cfg.lines_per_frame);
}
```

2. Compare the frame size indicated in the debug messages against the ISP sensor frame size.

   In the following CAMIF error example, the error status, 0x9a70a00 indicates an ISP receive frame size of 2471x2560 (0x9a7 = 2471, 0xa00 = 2560).

```
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: =====dump
Camif cfg for PIX interface====
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
input type = 3
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
pixel pattern = 6
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
input_format= 0
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
first_pix = 0
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
last_pix = 6527
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
first_line = 0
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
last_line = 0
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
pixels per line = 6528
01-01 08:07:20.175 E/mm-camera(  302): isp_hw_camif_dump_cfg: camif
lines per frame = 2448
01-01 08:07:24.335 E/klogd   (  640): [   81.563301]
msm_vfe40_process_error_status: camif error status: 0x9a70a00
```

3. If there is a mismatch, the following may be the root cause:
   - Check if sensor settings are correct and meet the resolution size. For example, the sensor is configured to output 12 MB size but the ISP is configured to receive 8 MB size.
   - It is possible that some sensors cannot guarantee that the very first frame after the new resolution settings are sent to the sensor is of the requested size. In these cases, work with the sensor vendor to fix the issue."

9.3 CSID troubleshooting

In order to troubleshoot CSID, all CSID IRQs must be enabled to check if CSID receives mipi data or error bit IRQs.

If you are viewing this document using a color monitor, or if you print this document to a color printer, **red boldface** indicates code that is to be **added**, and ~~blue strikethrough~~ indicates code that is to be replaced or removed.

```
--- a/drivers/media/platform/msm/camera_v2/sensor/csid/msm_csid.c
+++ b/drivers/media/platform/msm/camera_v2/sensor/csid/msm_csid.c
@@ -25,12 +25.15 @@
 #define CSID_VERSION_V30                0x30000000
 #define MSM_CSID_DRV_NAME               "msm_csid"

 #define DBG_CSID      0
 #define DBG_CSID      1

 #define TRUE      1
 #define FALSE     0

 #undef CDBG
 #define CONFIG_MSMB_CAMERA_DEBUG
 #ifdef CONFIG_MSMB_CAMERA_DEBUG
 #define CDBG(fmt, args...) pr_err(fmt, ##args)
 #else
@@ -83,8 +89,8 @@ static void msm_csid_set_debug_reg(void __iomem
*csidbase,
 {
   uint32_t val = 0;
```

```
    val = ((1 << csid_params->lane_cnt – 1) << 20;
    msm_camera_io_w(0x7f010800 | val, csidbase + CSID_IRQ_MASK_ADDR);
    msm_camera_io_w(0x7f010800 | val, csidbase + CSID_IRQ_CLEAR_CMD_ADDR);
    msm_camera_io_w(0xFFFFFFFF | val, csidbase + CSID_IRQ_MASK_ADDR);
    msm_camera_io_w(0xFFFFFFFF | val, csidbase + CSID_IRQ_CLEAR_CMD_ADDR);
 }
#else
static void msm_csid_set_debug_ref(void __iomem *csidbase,
```

Checking to see if CSID receives MIPI data

To see if CSID receives MIPI data, examine IRQ bits 0 through 7.

- CAMSS_A_CSID_X_CSID_IRQ_STATUS bit 0-3 (where X is the bit number) – These IRQs fire when the CSID core receives an SOT on PHY data lines 0-3
- CAMSS_A_CSID_X_CSID_IRQ_STATUS bit 4-7 (where X is the bit number) – These IRQs fire when the CSID core receives an EOT on PHY data lines 0-3

The following log example shows a normal 4-lane sensor CSID IRQ status log.

```
<3>[ 272.271075] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.276101] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.281099] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.286133] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.291164] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.296193] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.301232] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.306248] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.311300] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
<3>[ 272.316342] msm_csid_irq CSID0_IRQ_STATUS_ADDR = 0xdd
```

If any mipi signal error IRQs fired, see [Q5] for the CSID IRQ bit definition, check with the sensor vendor, or modify the sensor settle count.

9.4 DPHY troubleshooting

This section describes two methods of DPHY troubleshooting.

Checking the DPHY debug logs

In order to troubleshoot DPHY, DPHY debug logs must be enabled to check if the hardware register, CAMSS_A_CSI_PHY_**X**_MIPI_CSIPHY_INTERRUPT_STATUS**Y**, receives any IRQ errors.

```
--- a/drivers/media/platform/msm/camera_v2/sensor/csiphy/msm_csiphy.c
+++ b/drivers/media/platform/msm/camera_v2/sensor/csiphy/msm_csiphy.c
@@ -21,7 +21.7 @@
 #include “msm_sd.h”
 #include “msm_csiphy_hwreg.h”
 #include “msm_camera_io_util.h”
```

```
#define DBG_CSIPHY          0
#define DBG_CSIPHY          1

#define V4L2_IDENT_CSIPHY                50003
#define CSIPHY_VERSION_V22               0x01
@@ -30,6 +30,7 @@
#define MSM_CSIPHY_DRV_NAME              “msm_csiphy”

#undef CDBG
#define CONFIG_MSMB_CAMERA_DEBUG
#ifdef CONFIG_MSMB_CAMERA_DEBUG
#define CDBG(fmt, args...) pr_err(fmt, ##args)
#else
```

The following log example shows a normal CSIPHY IRQ status log.

```
<3>[ 1027.268003] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS0 = 0x0
<3>[ 1027.268020] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS1 = 0x0
<3>[ 1027.268036] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS2 = 0x0
<3>[ 1027.268052] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS3 = 0x0
<3>[ 1027.268068] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS4 = 0x0
<3>[ 1027.268084] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS5 = 0x0
<3>[ 1027.268100] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS6 = 0x0
<3>[ 1027.268116] c0 18360 [CAM] msm_csiphy_irq MIPI_CSIPHY1_INTERRUPT_STATUS7 = 0x0
```

If any CSIPHY signal error IRQs fired, see [Q5] for the CSID IRQ bit definition, check with the sensor vendor, or modify the sensor settle count.

Checking the DPHY index and hardware layout relationship

If there are issues with the DPHY, there may be a mismatch between the DPHY index and hardware layout. Compare the values in the sensor dtsi settings with the corresponding values in the sensor's xxxx_lib.c file. The values must match for proper operation. The items in bold indicate the current parameter and its corresponding hardware index.

Sensor's dtsi settings	Sensor's xxxx_lib.c file

qcom,camera@78 {
compatible = "qcom,ABC";
XXXXXX
qcom,csiphy-sd-index = <1>;
// DPHY index
qcom,csid-sd-index = <**3**>;
// CSID index
XXXXXX
	static struct csi_lane_params_t
	csi_lane_params = {
	.csi_lane_assign = 0x4320,
	.csi_lane_mask = 0x7,
	// 1 lane : 0x3 ,
	2 lane : 0x7 ,
	4 lane : 0x1F
	.csi_if = 1,
	.csid_core = {3}, // CSID index
	.csi_phy_sel = **1**, // DPHY index

A References

A.1 Related documents

Title	Number
Qualcomm Technologies, Inc.	
Multimedia Driver Development and Bringup Guide – Audio	80-NU323-1
Multimedia Driver Development and Bringup Guide – Display	80-NU323-3
Multimedia Driver Development and Bringup Guide – Video	80-NU323-5
Chromatix™ 6 Camera Tuning!!	80-NK872-2
Camera Auto Focus Tuning Guide	80-N8459-1
BAM Low-Speed Peripherals for Linux Kernel Configuration and Debugging Guide	80-NE436-1
MSM8960 Voice/Audio Topology and Tools Overview	80-N7634-1
Qualcomm Createpoint Hardware Component Quick Start Guide (English)	80-NC193-10
Qualcomm Createpoint Hardware Component Quick Start Guide (Simplified Chinese)	80-NC193-10SC

A.2 Acronyms and terms

Acronym or term	Definition
AF	Auto Focus
GCDB	Global Components Database
IRQ	Interrupt Request
QRD	Qualcomm Reference Design
SOF	Start of Frame