

Lab5. Linux Xilinx Video Pipeline

ZynqMP PL영역에 Xilinx mipi csi2, frame buffer writer IP를 사용하여 Video Pipeline을 구성하고 PCAM 5C Camera Module을 연결하여 Camera 영상을 획득하는 방법을 익힌다.

1. HW preparation

보드에 Usb-to-Uart, PCAM 5C Camera, Mini DP to HDMI Adapter를 연결한다. Usb-to-Uart를 host의 usb 포트에 연결한다. Mini DP to HDMI Adapter는 Monitor와 연결한다.

2. Export Vivado Project

Ultra96v1(hw4_v1.tcl) 또는 Ultra96v2(hw4_v2.tcl) Vivado Project를 만든다.

```
$ cd ~/work/zynqmp_linux/  
$ vivado -nolog -nojournal -mode batch -source hw4_v1.tcl  
$ cd hw4  
$ vivado hw4.xpr
```

또는

```
$ cd ~/work/zynqmp_linux/  
$ vivado -nolog -nojournal -mode batch -source hw4_v2.tcl  
$ cd hw4  
$ vivado hw4.xpr
```

Bitstream을 생성하고 HW export를 한다.

3. Petalinux Project Update with new HW

다음의 명령을 사용하여 hw4/ 의 xsa파일을 기초로 하여 Petalinux Project(ultra96)의 HW를 변경한다.

```
$ cd ~/work/zynqmp_linux/petalinux/ultra96
$ petalinux-config --silentconfig --get-hw-description=../../hw4/
```

4. New Device Tree Generation

다음의 명령으로 new HW에 기초한 Device Tree를 Generation 한다.

```
$ cd ~/work/zynqmp_linux/petalinux/ultra96
$ petalinux-build -c device-tree -x configure
```

Petalinux Project(ultra96) 폴더 아래의 components/plnx_workspace/device-tree/device-tree/pl.dtsi의 내용을 확인한다. pl.dtsi은 변경된 PL영역의 HW IP들에 대한 Device Tree 정보를 가지고 있다.

5. Device Tree Modification

다음 명령으로 Device Tree를 수정한다.

```
$ cd ~/work/zynqmp_linux/petalinux/ultra96
$ vi project-spec/meta-user/recipe-bsp/device-tree/files/system-user.dtsi
```

Video Pipeline을 구성한다.

Ultra96v1은 line5-54이 Ultra96v2는 line49-98이 변경된 부분이다.

```
hokim@envy: /media/hokim/data/work/zynqmp_linux/petalinux/ultra96
5 &amba_pl {
6     pcam_clk: pcam_clk {
7         compatible = "fixed-clock";
8         #clock-cells = <0>;
9         clock-frequency = <12000000>;
10    };
11 };
12
13 &i2csw 1 {
14     ov5640: camera@3c {
15         compatible = "ovti,ov5640";
16         reg = <0x3c>;
17         clock-names = "xclk";
18         clocks = <&pcam_clk>;
19         powerdown-gpios = <&gpio 36 1>;
20         reset-gpios = <&gpio 39 1>;
21
22         port {
23             ov5640_out: endpoint {
24                 remote-endpoint = <&csiss_in>;
25                 clock-lanes = <0>;
26                 data-lanes = <1 2>;
27             };
28         };
29     };

```

29,1 13%

그림 1 Device Tree Modification1(Ultra96v1)

```
hokim@envy: /media/hokim/data/work/zynqmp_linux/petalinux/ultra96
30 };
31
32 &mipi_csi2_rx_subsys0 {
33     compatible = "xlnx,mipi-csi2-rx-subsystem-4.0";
34     reset-gpios = <&gpio 78 1>;
35 };
36
37 &csiss_port0 {
38     /delete-property/ xlnx,cfa-pattern;
39     xlnx,video-format = <0>;
40 };
41
42 &csiss_port1 {
43     /delete-property/ xlnx,cfa-pattern;
44     xlnx,video-format = <0>;
45 };
46
47 &csiss_in {
48     data-lanes = <1 2>;
49     remote-endpoint = <&ov5640_out>;
50 };
51
52 &v_frbuff_wr_0 {
53     compatible = "xlnx,axi-frmbuf-wr-v2.1";
54 };
30,1 96%
```

그림 2 Device Tree Modification2(Ultra96v1)

```
hokim@envy: /media/hokim/data/work/zynqmp_linux/petalinux/ultra96
49 &amba_pl {
50     pcam_clk: pcam_clk {
51         compatible = "fixed-clock";
52         #clock-cells = <0>;
53         clock-frequency = <12000000>;
54     };
55 };
56
57 &i2csw_1 {
58     ov5640: camera@3c {
59         compatible = "ovti,ov5640";
60         reg = <0x3c>;
61         clock-names = "xclk";
62         clocks = <&pcam_clk>;
63         powerdown-gpios = <&gpio 36 1>;
64         reset-gpios = <&gpio 39 1>;
65
66         port {
67             ov5640_out: endpoint {
68                 remote-endpoint = <&csiss_in>;
69                 clock-lanes = <0>;
70                 data-lanes = <1 2>;
71             };
72         };
73     };
};
```

그림 3 Device Tree Modification1(Ultra96v2)

```
hokim@envy: /media/hokim/data/work/zynqmp_linux/petalinux/ultra96
74 };
75
76 &mipi_csi2_rx_subsys0 {
77     compatible = "xlnx,mipi-csi2-rx-subsystem-4.0";
78     reset-gpios = <&gpio 78 1>;
79 };
80
81 &csiss_port0 {
82     /delete-property/ xlnx,cfa-pattern;
83     xlnx,video-format = <0>;
84 };
85
86 &csiss_port1 {
87     /delete-property/ xlnx,cfa-pattern;
88     xlnx,video-format = <0>;
89 };
90
91 &csiss_in {
92     data-lanes = <1 2>;
93     remote-endpoint = <&ov5640_out>;
94 };
95
96 &v_frbuff_wr0 {
97     compatible = "xlnx,axi-frmbuf-wr-v2.1";
98 };
```

그림 4 Device Tree Modification2(Ultra96v2)

6. Update BOOT.BIN, image.ub

새로운 HW를 위한 BOOT.BIN과 image.ub를 다음과 같이 Update 한다.

```
$ cd ~/work/zynqmp_linux/petalinux/ultra96
$ petalinux-build -c virtual/boot-bin
$ petalinux-package --force --boot --fsbl images/linux/zynqmp_fsbl.elf --u-boot
images/linux/u-boot.elf --pmufw images/linux/pmufw.elf --fpga
images/linux/system.bit
$ scp images/linux/{BOOT.BIN,image.ub} root@172.30.1.39:/media/card
```

7. Test

보드를 다시 boot하고 다음을 Test한다. output.mp4 Camera 동영상파일이고, 마지막 gst-launch-1.0명령어는 Monitor에 Camera영상이 보여지게 한다.

```
ultra96$ reboot
ultra96$ i2cdetect -l
i2c-3  i2c      i2c-0-mux (chan_id 1)      I2C adapter
i2c-1  i2c      ZynqMP DP AUX          I2C adapter
i2c-8  i2c      i2c-0-mux (chan_id 6)      I2C adapter
i2c-6  i2c      i2c-0-mux (chan_id 4)      I2C adapter
i2c-4  i2c      i2c-0-mux (chan_id 2)      I2C adapter
i2c-2  i2c      i2c-0-mux (chan_id 0)      I2C adapter
i2c-0  i2c      Cadence I2C at ff030000    I2C adapter
i2c-9  i2c      i2c-0-mux (chan_id 7)      I2C adapter
i2c-7  i2c      i2c-0-mux (chan_id 5)      I2C adapter
i2c-5  i2c      i2c-0-mux (chan_id 3)      I2C adapter
ultra96$ i2cdetect -y -r 3
      0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:      -- - - - - - - - - - - - - - - - -
10: -- - - - - - - - - - - - - - - - -
20: -- - - - - - - - - - - - - - - - -
30: -- - - - - - - - - - - - - UU - - - -
```

40: ---

50: ---

60: ---

70: --- UU ---

ultra96\$ ls /dev/media*

/dev/media0

ultra96\$ media-ctl -d /dev/media0 -p

Device topology

- entity 1: vcap_mipi output 0 (1 pad, 1 link)

type Node subtype V4L flags 0

device node name /dev/video2

pad0: Sink

<- "80000000.mipi_csi2_rx_subsystem":0 [ENABLED]

- entity 5: ov5640 3-003c (1 pad, 1 link)

type V4L2 subdev subtype Sensor flags 0

device node name /dev/v4l-subdev0

pad0: Source

[fmt:JPEG_1X8/640x480@1/30 field:none colorspace:jpeg xfer:srgb

ycbcr:601 quantization:full-range]

-> "80000000.mipi_csi2_rx_subsystem":1 [ENABLED]

- entity 7: 80000000.mipi_csi2_rx_subsystem (2 pads, 2 links)

type V4L2 subdev subtype Unknown flags 0

device node name /dev/v4l-subdev1

pad0: Source

[fmt:UYVY8_1X16/1920x1080 field:none colorspace:srgb]

-> "vcap_mipi output 0":0 [ENABLED]

pad1: Sink

[fmt:UYVY8_1X16/1920x1080 field:none colorspace:srgb]

```

    <- "ov5640 3-003c":0 [ENABLED]
ultra96$ media-ctl -d /dev/media0 -V '"ov5640 3-003c":0
[fmt:UYVY/1920x1080@1/30 field:none]'
ultra96$ media-ctl -d /dev/media0 -p
- entity 5: ov5640 3-003c (1 pad, 1 link)
    type V4L2 subdev subtype Sensor flags 0
    device node name /dev/v4l-subdev0
    pad0: Source
        [fmt:UYVY8_1X16/1920x1080@1/30 field:none colorspace:srgb xfer:srgb
ycbcr:601 quantization:full-range]
    -> "80000000.mipi_csi2_rx_subsystem":1 [ENABLED]
ultra96$ gst-launch-1.0 -v v4l2src device=/dev/video2 num-buffers=15 ! capsfilter
caps='video/x-raw,width=1920,height=1080,format=YUY2' ! fpsdisplaysink video-
sink='filesink location=/run/out.yuv'

```

```

$ scp root@172.30.1.39:/run/out.yuv .
$ ffmpeg -f rawvideo -vcodec rawvideo -s 1920x1080 -r 15 -pix_fmt yuyv422 -i
out.yuv -c:v libx264 -preset ultrafast -qp 0 output.mp4

```

```

ultra96$ modetest -D fd4a0000.zynqmp-display
Encoders:
id  crtc    type    possible crtcs  possible clones
38  37  TMDS    0x00000001  0x00000000

Connectors:
id  encoder status    name          size (mm)  modes  encoders
39  38  connected  DP-1         510x290    27  38

```


modes:

name refresh (Hz) hdisp hss hse htot vdisp vss vse vtot)

1920x1080 60 1920 2068 2112 2200 1080 1116 1121 1125 148500 flags:

phsync, pvsync; type: preferred, driver

CRTCs:

id fb pos size

37 71 (0,0) (1920x1080)

1920x1080 60 1920 2068 2112 2200 1080 1116 1121 1125 148500 flags:

phsync, pvsync; type: preferred, driver

props:

Planes:

id crtc fb CRTC x,y x,y gamma size possible crtcs

35 0 0 0,0 0,0 0 0x00000001

formats: VYUY UYVY YUYV YVYU YU16 YV16 YU24 YV24 NV16 NV61 GREY Y10
BG24 RG24 XB24 XR24 XB30 XR30 YU12 YV12 NV12 NV21 XV15 XV20

props:

7 type:

flags: immutable enum

enums: Overlay=0 Primary=1 Cursor=2

value: 0

36 37 71 0,0 0,0 0 0x00000001

formats: AB24 AR24 RA24 BA24 BG24 RG24 RA15 BA15 RA12 BA12 RG16 BG16

props:

7 type:

flags: immutable enum

enums: Overlay=0 Primary=1 Cursor=2

value: 1

28 alpha:

flags: range

values: 0 255

value: 255

29 g_alpha_en:

flags: range

values: 0 1

value: 1

```
ultra96$ modetest -D fd4a0000.zynqmp-display -w 36:g_alpha_en:0
```

```
ultra96$ gst-launch-1.0 -v v4l2src device=/dev/video2 io-mode=dmabuf !
```

```
capsfilter caps=video/x-raw,width=1920,height=1080,format=YUY2 ! fpsdisplaysink
```

```
fps-update-intervalvideo-sink=1000 signal-fps-measurements=true text-
```

```
overlay=false sync=false video-sink='kmssink bus-id=fd4a0000.zynqmp-display'
```