

UG10167

i.MX DSP User's Guide

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User guide

Document information

Information	Content
Keywords	i.MX, Linux, LF6.6.36_2.1.0
Abstract	This document provides an overall introduction to the DSP including system architecture, file organization, DSP-related toolchain, and so on.



1 Introduction

This document provides an overall introduction to the DSP including system architecture, file organization, DSP-related toolchain, and so on. This document helps with the overall understanding of the DSP-related code. Currently, the DSP is used to decode and encode audio streams on the i.MX 8QuadXPlus, i.MX 8QuadMax, i.MX 8M Plus, and i.MX 8ULP platforms.

The current DSP framework can support several clients. They support these codecs:

Decoder:

- AAC-LC
- AAC plus(HE-AAC/HE-AACv2)
- BSAC
- DAB+
- MP2
- MP3
- DRM
- SBC
- OGG
- AMR-NB
- AMR-WB
- WMA
- WAV
- OPUS

Encoder:

- SBC

For details on how to harness the power processing of the DSP by running Zephyr RTOS on the DSP, while running Linux OS on the main Cortex-A core, see the *Running Zephyr RTOS on Cadence Tensilica HiFi 4 DSP* ([AN13970](#)).

This covers simple and more complex examples, such as `hello_world` or IPC samples.

In the application note, all examples are explained using the existing drivers and/or frameworks from the Linux OS and Zephyr RTOS.

2 System Architecture

[Figure 1](#) and [Figure 2](#) provide the overall system architecture of the DSP-related code.

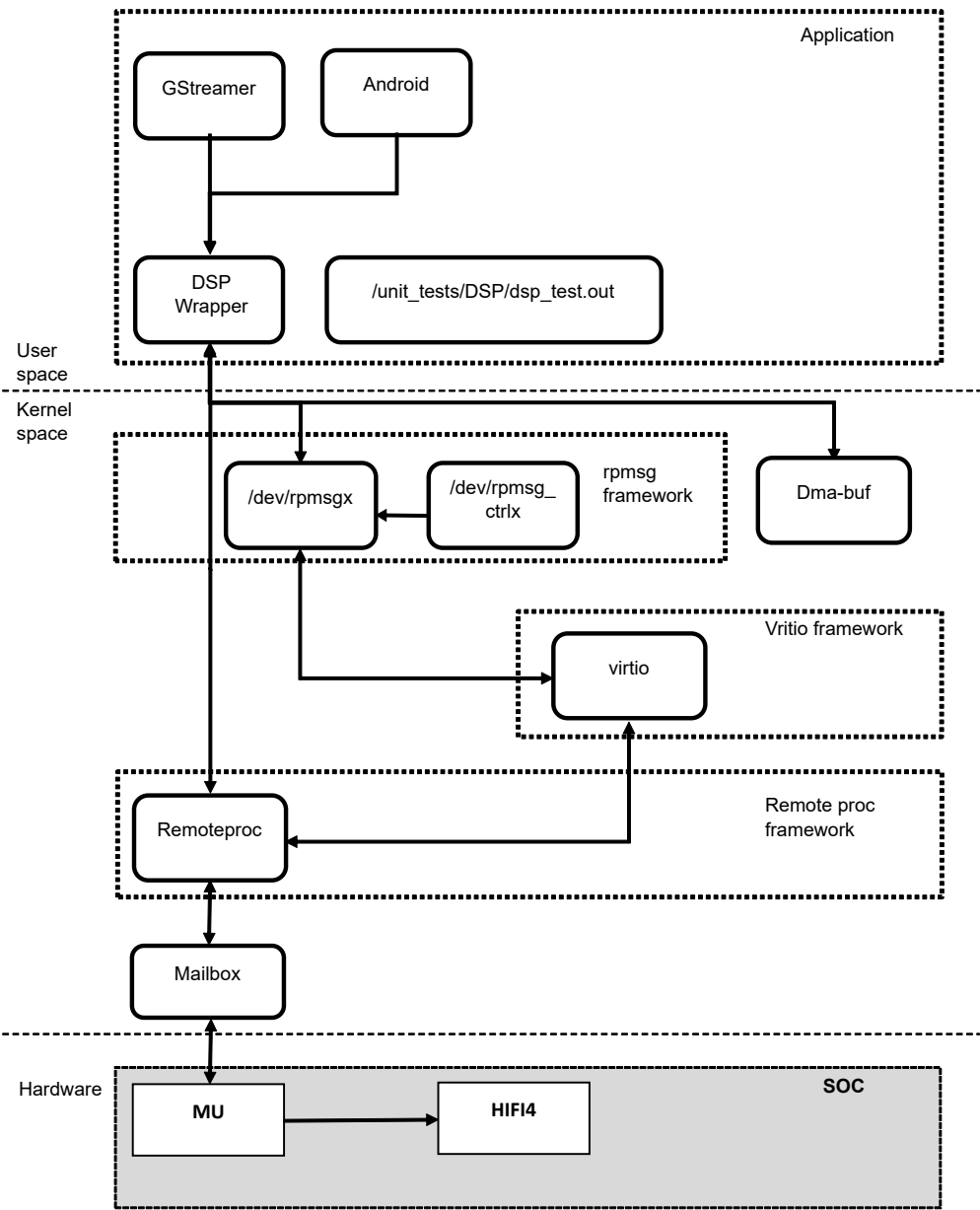


Figure 1. Software architecture for Cortex-A cores running Linux OS

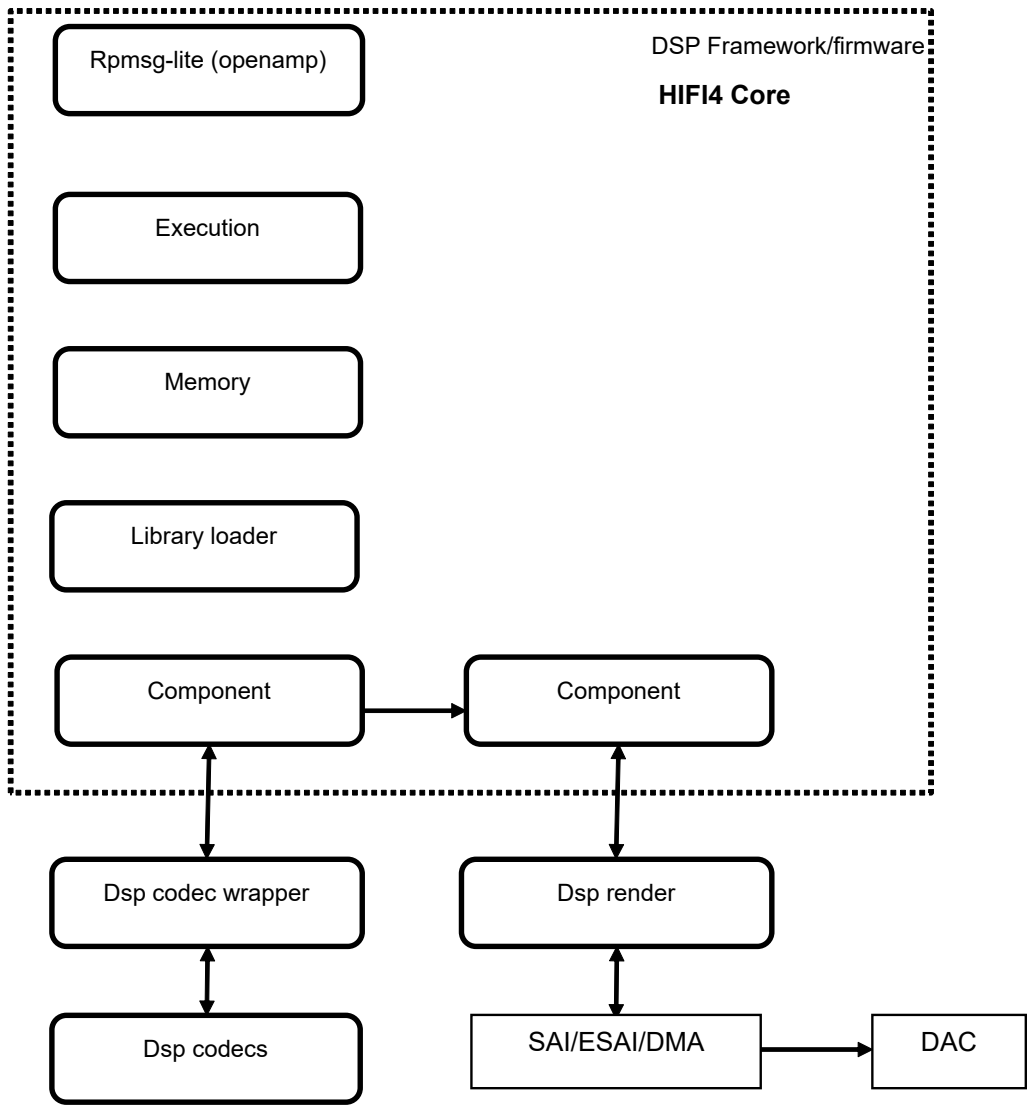


Figure 2. Software architecture for DSP processor

The DSP-related code includes the DSP framework, DSP remoteproc driver, DSP wrapper, unit test, DSP codec wrapper, and DSP codec.

- The DSP framework is a firmware code which runs on the DSP core. The DSP driver is used to load the DSP firmware into the memory and transfer messages between the user space and the DSP framework.

- The remoteproc and RPMsg framework is used to transfer messages between the Cortex-A cores and the DSP cores. The Message Unit (MU) is used to trigger interrupts between the Cortex-A cores and DSP cores when messages are placed into the vring buffer.
- The DSP wrapper and the unit test are the application code in the user space, which uses the rpmsg_char interface to transfer messages between the DSP remoteproc driver and the user space. In addition, the DSP wrapper is used to provide unified interfaces for the GStreamer.
- The DSP codec provides the actual decoding and encoding functions.
- The DSP codec wrapper is a wrapping code for the DSP codec and provides unified interfaces for the DSP framework.

2.1 Remote processor start

To start the firmware, use the following command.

```
Board $> echo start >/sys/class/remoteproc/remoteprocX/state
```

Note:

Some platform may have multiple remoteproc devices, so users need to check the name of each remoteproc device by using `cat > /sys/class/remoteproc/remoteprocX/name` to find the proper X for DSP.

The name of DSP is `imx-dsp-rproc`.

2.2 Remote processor stop

To stop the firmware, use the following command.

```
Board $> echo stop >/sys/class/remoteproc/remoteprocX/state
```

2.3 Resource table example

```
#define NUM_VRINGS 0x02
/* Place resource table in special ELF section */
__attribute__((section(".resource_table")))
const struct remote_resource_table resources = {
/* Version */
1,
/* Number of table entries */
NO_RESOURCE_ENTRIES,
/* reserved fields */
{
0,
0,
},
/* Offsets of rsc entries */
{
offsetof(struct remote_resource_table, user_vdev),
},
/* SRTM virtio device entry */
{
RSC_VDEV,
7,
0,
RSC_VDEV_FEATURE_NS,
0,
```

```
0,  
0,  
NUM_VRINGS,  
{0, 0},  
},  
/* Vring rsc entry - part of vdev rsc entry */  
{VDEV0_VRING_DA_BASE, VRING_ALIGN, RL_BUFFER_COUNT, 0, 0},  
{VDEV0_VRING_DA_BASE + VRING_SIZE, VRING_ALIGN, RL_BUFFER_COUNT, 1, 0},  
};
```

3 File Organization

The DSP framework, DSP wrapper, and unit test code are in the <https://github.com/NXP/imx-audio-framework> repository. Use the following command to clone the Git repository and check out the branch matching with the Linux release:

```
git clone https://github.com/NXP/imx-audio-framework.git --recursive
```

The DSP remoteproc driver code belongs to the Linux OS kernel.

DSP codecs originated from Cadence are license-restricted: A license authorization is required from NXP Marketing to access them in binary format.

3.1 DSP remoteproc driver

The driver is under the remoteproc framework. The remote processor (RPROC) framework allows the different platforms/architectures to control (power on, load firmware, power off) remote processors while abstracting the hardware differences. For more details, refer to the below link.

<https://www.kernel.org/doc/Documentation/remoteproc.txt>

The DSP remoteproc driver code is in the Linux OS kernel. It includes the following files:

- *drivers/remoteproc/imx_dsp_rproc.c*
- *drivers/rpmsg/rpmsg_char.c*
- *drivers/rpmsg/rpmsg_ctrl.c*
- *drivers/rpmsg/rpmsg_ns.c*

3.2 DSP framework

The DSP framework code is in this folder:

- *imx-audio-framework/dsp_framework*
- *imx-audio-framework/dsp_framework/rpmsg-lite*

The rpmsg-lite code is copied from <https://github.com/NXPmicro/rpmsg-lite>.

3.3 DSP wrapper and unit test

The DSP wrapper and unit test are in these folders:

- *imx-audio-framework/dsp_wrapper*
- *imx-audio-framework/unit_test*

3.4 Interface header files

The DSP-related code includes these four interface header files:

- *imx-audio-framework/include/mxc_dsp.h*
- *imx-audio-framework/dsp_framework/plugins/audio_codec/dsp_codec_interface.h*
- *imx-audio-framework/dsp_wrapper/include/uni_audio/fsl_unia.h*
- *imx-audio-framework/dsp_wrapper/include/uni_audio/fsl_types.h*

The *mxc_dsp.h* file is the same as the header file in the Linux OS kernel. This file includes the interfaces and command definitions that are used by the DSP wrapper and unit test. The *dsp_codec_interface.h* file wraps the DSP codec's header files. It includes unified interfaces and command definitions which can be used by the DSP framework. The *fsl_unia.h* and *fsl_types.h* header files include the interfaces and command definitions which can be used by GStreamer.

4 Building DSP Framework on Linux OS

Before you compile the DSP-related code, set up the DSP-related toolchains. The DSP framework, DSP codec wrapper, and DSP codec use Xtensa development toolchain.

4.1 Installing Xtensa development toolchain

The Xtensa development toolchain consists of two components, which are installed separately in the Linux OS, including:

- Configuration-independent Xtensa Tool
- Configuration-specific core files and Xtensa Tool

The configuration-independent Xtensa Tool is released by Cadence. For the current code, the version of the tool is *XtensaTools_RI_2023_11_linux.tgz*, which is updated from *XtensaTools_RI_2020_4_linux.tgz*. The two versions are compatible. You can download this package from the Xtensa Xplorer.

The configuration-specific core files and the Xtensa Tool are released by NXP. The following are the packages for each platform:

- i.MX 8QuadMax and i.MX 8QuadXPlus:

```
- hifi4_nxp_v5_3_1_prod_linux.tgz
- hifi4_nxp_v5_3_1_prod_win32.tgz
```

These packages can also be obtained from <https://tensilicatools.com/platform/imx8qm/> or <https://tensilicatools.com/platform/imx8qxp/>.

- i.MX 8M Plus:

```
- hifi4_mscale_v2_0_2_prod_linux.tgz
- hifi4_mscale_v2_0_2_prod_win32.tgz
```

These packages can also be obtained from <https://tensilicatools.com/platform/i-mx8mp/>.

- i.MX 8ULP:

```
- hifi4_nxp2_s7_v2_1a_prod_linux.tgz
- hifi4_nxp2_s7_v2_1a_prod_win32.tgz
```

These packages can be obtained from <https://tensilicatools.com/platform/i-mx-8ulp/>.

When you have these two components, you can set up the toolchain as follows:

- Open the *imx-audio-framework* folder and execute these commands:

```
mkdir -p ./imx-audio-toolchain/Xtensa_Tool/tools mkdir -p ./imx-audio-toolchain/Xtensa_Tool/builds
```

- Set up the configuration-independent Xtensa Tool:

```
cd imx-audio-toolchain/Xtensa_Tool
tar zxvf XtensaTools_RI_2023_11_linux.tgz -C ./tools
```

- Set up the configuration-specific core files and the Xtensa Tool:

```
cd imx-audio-toolchain/Xtensa_Tool
tar zxvf hifi4_nxp_v5_3_1_prod_linux.tgz -C ./builds
```

- Install the Xtensa development toolchain:

```
cd imx-audio-toolchain/Xtensa_Tool
./builds/RI-2023.11-linux/hifi4_nxp_v5_3_1_prod/install --xtensa-tools ./tools/RI-2023.11-linux/XtensaTools --registry ./tools/RI-2023.11-linux/XtensaTools/config
```

- Set the PATH environment variable:

```
export PATH=./imx-audio-toolchain/Xtensa_Tool/tools/RI-2023.11-linux/XtensaTools/bin:$PATH
```

- Set the LM_LICENSE_FILE environment variable.

The Xtensa development tools use FLEXlm for license management. The FLEXlm licensing is required for tools such as the Xtensa Explorer, TIE Compiler, and Xtensa C and C++ compiler. If you want to use a floating license, install the FLEXlm license manager and set the LM_LICENSE_FILE environment variable. If there is any problem, you can find useful information in the *Xtensa Development Tools Installation Guide User's Guide.doc* document provided by Cadence.

After the above steps, the Xtensa development toolchain is set up successfully. In addition, the Xtensa Tools and additional tools are provided as 32-bit (x86) binaries. They are supported on 32-bit (x86) systems, and also on recent 64-bit (x86-64) systems that have appropriate 32-bit compatibility packages installed. If you use a 64-bit system (for example; Ubuntu 16.04), install the 32-bit compatibility packages first. Use these commands:

```
sudo apt-get install lib32ncurses5 lib32z1 sudo dpkg --add-architecture i386
```

```
sudo apt-get install libc6:i386 libstdc++6:i386
```

4.2 Building DSP framework

After installing the DSP-related toolchains on your Linux OS server, you can compile the DSP framework. Execute the “make” command in the *imx-audio-framework* folder to compile the DSP framework. This way also builds the DSP wrapper and unit test. If you want to compile the DSP framework separately, see the README file in the *imx-audio-framework* folder. After the compiling process, you can find the binary files in the *imx-audio-framework/release* folder.

For the DSP framework, different commands generate different frameworks for different platforms:

- *imx-audio-framework/release/hifi4_imx8qmexp.bin*
- *imx-audio-framework/release/hifi4_imx8mp.bin*
- *imx-audio-framework/release/hifi4_imx8ulp.bin*

By default, the command generates the *hifi4_imx8qmexp.bin* file. With the “PLATF=imx8m” attribute, it generates the *hifi4_imx8mp.bin* file. With the “PLATF= imx8ulp” attribute, it generates the *hifi4_imx8ulp* file. With the “DEBUG=1” attribute, it generates the firmware with the debug information. You can see the debug information using UART. For details, see Section [Section 4.3](#).

4.3 DSP DEBUG

Building the DSP framework with the extra “DEBUG=1” attribute, the DSP can print the debug information using the UART console. To enable this feature, do some changes in the kernel and in the DSP side. For a different platform, prepare a different board and different changes. The following sections describe what need to change for different platforms.

4.3.1 Enabling DSP debug on i.MX 8M Plus

Enable the UART for DSP print debug information in the i.MX 8M Plus board and add the UART clock in the DTS file and the UART module driver in the DSP.

1. Add the UART clock and pinctrl in the DTS.

Add the UART clock and pinctrl in the DSP node as follows:

```
&dsp {
compatible = "fsl,imx8mp-dsp-v1"; memory-region = <&dsp_reserved>; reg = <0x0
0x3B6E80000x0 0x88000>;
pinctrl-0 = <&pinctrl_uart4>;
clocks = <&audiomix_clk IMX8MP_CLK_AUDIOMIX_OCRAMA_IPG>,
...
<&audiomix_clk IMX8MP_CLK_AUDIOMIX_ASRC_IPG>,
<&clk IMX8MP_CLK_UART4_ROOT>,
<&clk IMX8MP_CLK_UART4_ROOT>;
clock-names =
"ocram", "audio_root", "audio_axi", "core", "debug", "mu2", "sdma_root",
"sai_ipg", "sai_mclk", "asrc_ipg", "uart_ipg", "uart_per";
...
fsl,dsp-firmware = "imx/dsp/hifi4.bin"; status = "okay";
};
```

Then generate the DTB file, replacing the old one.

2. Add the UART driver in the DSP.

By default, the DSP side already supports enabling the UART. Build the DSP firmware with the “DEBUG=1” attribute to generate the *hifi4_imx8mp.bin* file, rename it to *hifi4.bin*, and copy it to the board.

3. Run the DSP and print the debug information.

Run one instance and the following debug information is printed on the fourth serial COM port:

```
DSP Start.....
core initialized
Response queue: write = 0x0 / read = 0x0 Command queue: write = 0x10001 /
read = 0x0 ext_msg: [client:0]:(80008004,4,1000) Response queue: write =
0x0 / read = 0x0 Command queue: write = 0x10001 / read
= 0x10001
alloc size out: 943feff8 4104 avail mem: 16773104 Response queue: write =
0x0 / read = 0x0
Response[client: 0]:(80048000,4,1000)
Command queue: write = 0x10001 / read = 0x10001 Response queue: write =
0x10001 / read = 0x10001
Command queue: write = 0x20002 / read = 0x10001 ext_msg: [client: 0]:
(80008004,80000001,15) Response
queue: write = 0x10001 / read = 0x10001
```

4.3.2 Enabling DSP DEBUG on i.MX QuadXPlus

To enable the DSP DEBUG on the i.MX QuadXPlus platform, you need only one base board, as shown in [Figure 3](#).



Figure 3. i.MX8-8X-BB

Connect the RS-232 to a PC and connect the base board to the i.MX QuadXPlus board.

1. Add the UART clock and pinctrl in the DTS.
Add the UART clock and pinctrl in the DSP node as follows:

```
dsp: dsp@596e8000 {
compatible = "fsl,imx8qxp-dsp"; reg = <0x596e8000 0x88000>;
clocks = ...
<&uart2_lpcg 1>, <&uart2_lpcg 0>; clock-names = ... "uart_ipg",
"uart_per";
assigned-clocks = <&clk IMX_SC_R_UART_2 IMX_SC_PM_CLK_PER>;
assigned-clock-rates = <80000000>;
...
status = "disabled";
};
```

Then build the image instead of the old one.

2. Modify the DSP side.

The DSP supports the LPUART driver in the *dsp_framework/arch/peripheral.c* file. Change the LPUART_BASE from 0x5a090000 to 0x5a080000:

```
diff --git a/dsp_framework/arch/board.h b/dsp_framework/arch/
board.h
index 9e04e64e821c..75a15fd09f0d 100644
--- a/dsp_framework/arch/board.h
+++ b/dsp_framework/arch/board.h
@@ -138,7 +138,7 @@ enum {
#define MUB_BASE (MU_PADDR)
#define SYSTEM_CLOCK (600000000UL)
-#define LPUART_BASE (0x5a090000)
+#define LPUART_BASE (0x5a080000)
#define UART_CLK_ROOT (80000000)
#endif /*PLATF_8ULP */
```

Then build the DSP with “DEBUG=1” and copy it to the board.

3. Run the DSP and print the debug information.

This part is the same as on the i.MX 8M Plus board. Select the proper serial COM port and you will see the debug information. The debug information cannot print on the i.MX 8QuadMax board, because the UART is taken.

4.3.3 Enabling DSP debug on i.MX 8ULP

Enable the LPUART for DSP print debug information on the i.MX 8ULP board and add the UART clock in the DTS file and the UART module driver in the DSP.

1. Add the LPUART clock and pinctrl in the DSP node as follows (base on L5.10.52_2.1.0).
2. Make sure the LPUART clock rate is 48 MHz.
3. Rework the board, connect the USB interface to “HIFI4 Debug UART” (J3).

```
diff --git a/arch/arm64/boot/dts/freescale/imx8ulp-evk.dts b/arch/arm64/boot/
dts/freescale/imx8ulp-evk.dts
index 9109e5d7c44c..dae9ec616234 100644
--- a/arch/arm64/boot/dts/freescale/imx8ulp-evk.dts
+++ b/arch/arm64/boot/dts/freescale/imx8ulp-evk.dts
@@ -213,6 +213,9 @@ mipi_dsi_out: endpoint {
};

&dsp {
+    pinctrl-names = "default", "sleep";
+    pinctrl-0 = <&pinctrl_lpuart6>;
+    pinctrl-1 = <&pinctrl_lpuart6>;
    assigned-clocks = <&cg2 IMX8ULP_CLK_HIFI_SEL>;
    assigned-clock-parents = <&cg2 IMX8ULP_CLK_PLL4>;
    memory-region = <&dsp_vdev0buffer>, <&dsp_vdev0vring0>,
@@ -364,7 +367,7 @@ &lpuart6 {
    pinctrl-names = "default", "sleep";
    pinctrl-0 = <&pinctrl_lpuart6>;
    pinctrl-1 = <&pinctrl_lpuart6>;
-    status = "okay";
+    status = "disabled";
};

&lpuart7 {
diff --git a/arch/arm64/boot/dts/freescale/imx8ulp.dtsi b/arch/arm64/boot/dts/
freescale/imx8ulp.dtsi
index 2dfac8f7200d..c00051602303 100644
--- a/arch/arm64/boot/dts/freescale/imx8ulp.dtsi
```

```

+++ b/arch/arm64/boot/dts/freescale/imx8ulp.dtsi
@@ -271,8 +271,9 @@ dsp: dsp@21170000 {
        clocks = <&cg2 IMX8ULP_CLK_HIFI_DIVCORE>,
                <&cg2 IMX8ULP_CLK_LPAV_BUS_DIV>,
                <&cg2 IMX8ULP_CLK_HIFI_DIVPLAT>,
-               <&pcc5 IMX8ULP_CLK_MU3_B>;
-               clock-names = "dsp_clk1", "dsp_clk2", "dsp_clk3",
+               <&pcc5 IMX8ULP_CLK_MU3_B>,
+               <&pcc4 IMX8ULP_CLK_LPUART6>;
+               clock-names = "dsp_clk1", "dsp_clk2", "dsp_clk3",
        "per_clk1", "per_clk2";
        firmware-name = "imx/dsp/hifi4.bin";
        mbox-names = "tx", "rx", "rxdb";
        mbox-names = <&mu3 0 0>,
        (END)

```

Then generate the DTB file, replacing the old one. Run the DSP and print the debug information.

Run one instance, and then the following debug information is printed on the serial COM port:

```

DSP Start.....
core initialized
...

```

5 Building DSP Framework on Windows OS

The DSP framework can be built also on Windows OS. The Xplorer software can be used to build the DSP framework on Windows OS. This chapter explains how to use Xplorer to build the DSP framework. First, install the Xtensa Xplorer IDE. You can download the Xplorer IDE and Xplorer license form Cadence.

Note: Log into the XPG Cadence website to download installers for the Xplorer IDE, Xtensa tools, and so on. For NXP internal use, contact the DSP owner to get the NXP common XPG login credentials. The Xplorer 10.1.11 version is used as an example and its default installation folder is `C:\usr\xtensa`.

5.1 Adding new configuration packages

Currently, the `hifi4_nxp_v5_3_1_prod_win32.tgz` configuration package, which is updated from the `hifi4_nxp_v3_3_1_prod_win32.tgz` configuration package, is used to build the DSP framework on Windows OS. Add this configuration package into Xplorer before building the code. You can get this configuration package and the corresponding memory map linker files from NXP. The required files are as following:

- `hifi4_nxp_v5_3_1_prod_win32.tgz`
- `memmap/mainsim` folder

When you have the DSP configuration package, you can add a new configuration package into Xplorer as follows:

1. Download and install Xtensa Tools for Xplorer.

If you do not have the Xtensa Tools, you shall download and install it using Xplorer. Currently, the Xtensa Tool that we use is `XtensaTools_RI_2023_11_win32.tgz`. You can first open the Xplorer software and click the “RI 2023.11” option in the “XPG View” panel and select the “tools->Xtensa Tools->Xtensa Tools 14.11 for Windows” option. After you select it, you can click the download button to start the downloading process.

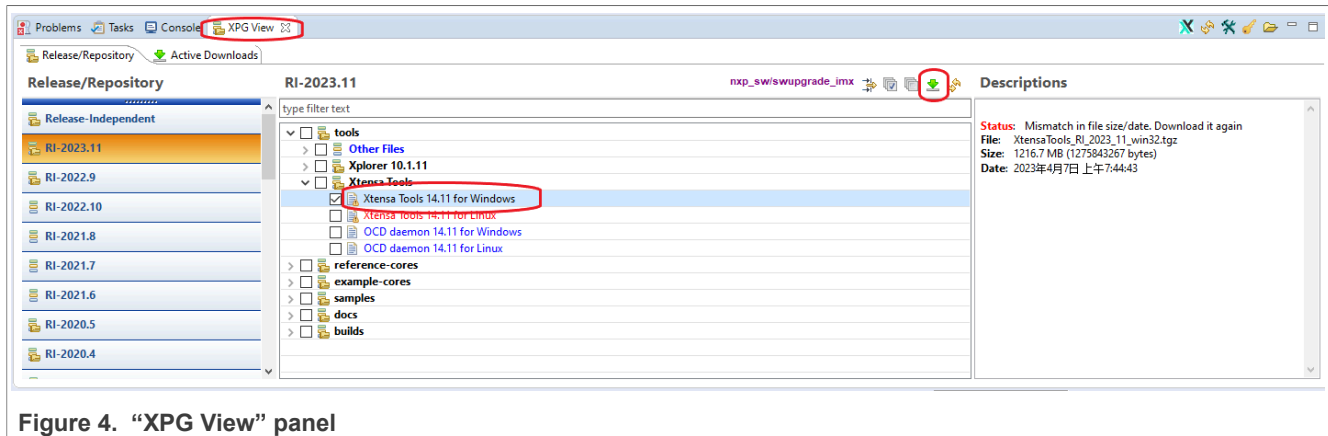


Figure 4. “XPG View” panel

After the download finishes, right-click the “Xtensa Tools 14.11 for Windows” option and select the “Install Xtensa Tools...” option in the new dialog. The installing process takes some time.

The Xtensa Tool is installed successfully after this step. You can see this folder in the Xplorer’s installing folder if everything is OK:

`C:\usr\xtensa\XtDevTools\install\tools\RI-2023.11-win32`

2. Add the configuration package into Xplorer.

When you have the `hifi4_nxp_v5_3_1_prod_win32.tgz` package from NXP, you can add it into Xplorer. The first thing to do is to create a folder called `build` in Xplorer’s installing path if the `build` folder is not created already. The total path after this operation is as follows:

`C:\usr\xtensa\XtDevTools\downloads\RI-2023.11\build`

3. Place the `hifi4_nxp_v5_3_1_prod_win32.tgz` package into the new `build` folder.

`C:\usr\xtensa\XtDevTools\downloads\RI-2023.11\build\hifi4_nxp_v5_3_1_prod_win32.tgz`

4. After you have performed the above steps, you can click the refresh button in the “XPG View” panel and find the “build” option in this panel.

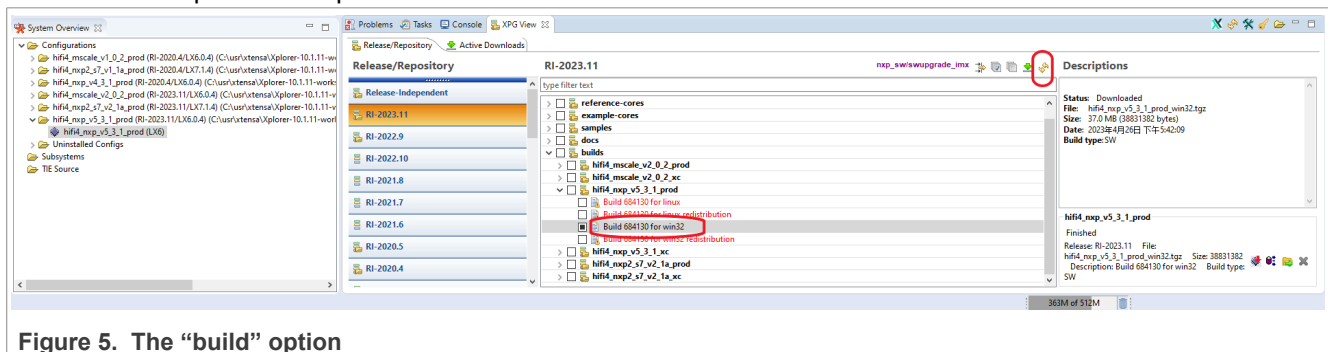


Figure 5. The “build” option

5. Right-click the `build->hifi4_nxp_v5_3_1_prod_win32.tgz` package and click the “Install Build...” option in the new dialog to start the installing process. This takes some time. You can see the following folder in the Xplorer’s installing folder if everything is OK.

`C:\usr\xtensa\XtDevTools\install\builds\RI-2023.11-win32\hifi4_nxp_v5_3_1_prod`

6. Add the new memmap linker files into Xplorer.

After you add the `hifi4_nxp_v5_3_1_prod_win32.tgz` configuration package into Xplorer, you can add the new memmap linker files.

After you complete the above three steps, the new configuration package is successfully added into Xplorer.

5.2 Creating the DSP framework Xplorer project

The DSP framework project must be created before using Xplorer to build it. The DSP framework code is in the `imx-audio-framework` package: `imx-audio-framework\dsp_framework`

You can create the DSP framework as follows:

1. Open Xplorer and click the “File->New->Xtensa C/C++ project” option in the menu bar. The following dialog box appears.

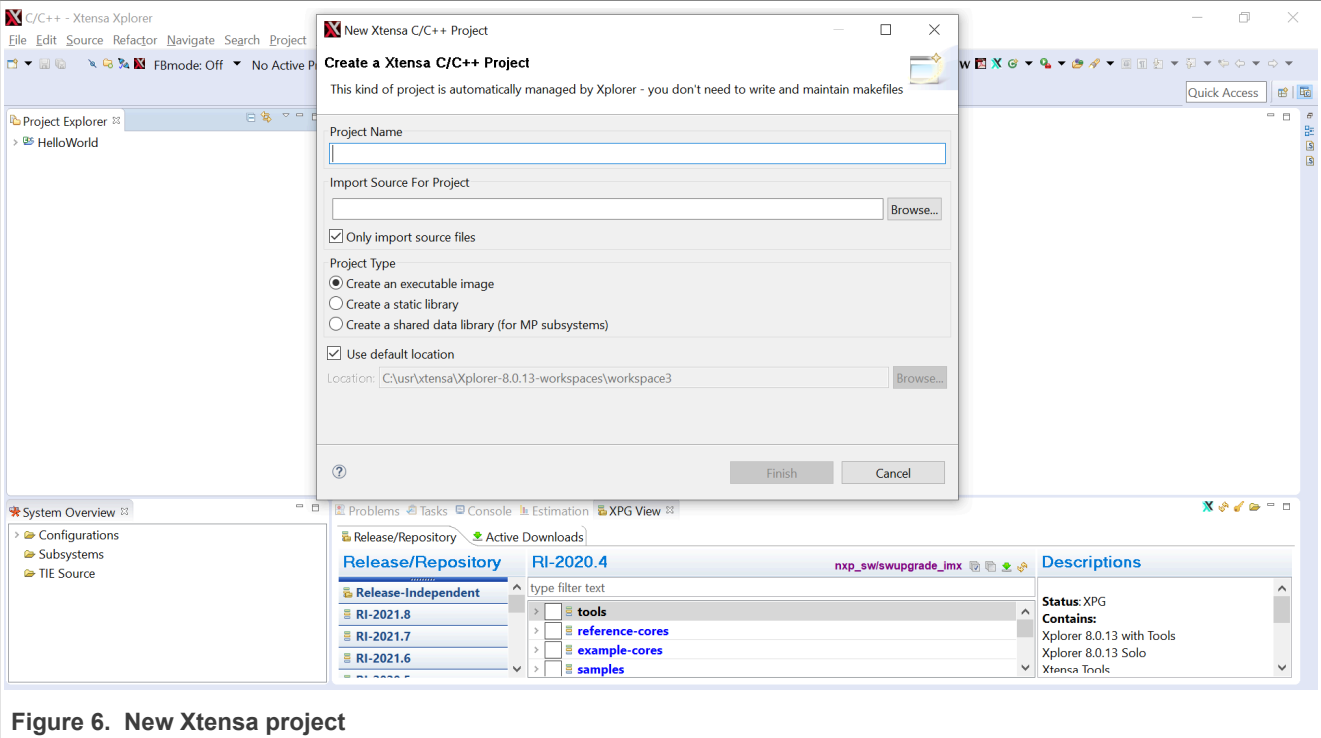


Figure 6. New Xtensa project

2. Enter the project name and import DSP framework source code into the “New Xtensa C/C++ Project” dialog. Then click the “Finish” button.

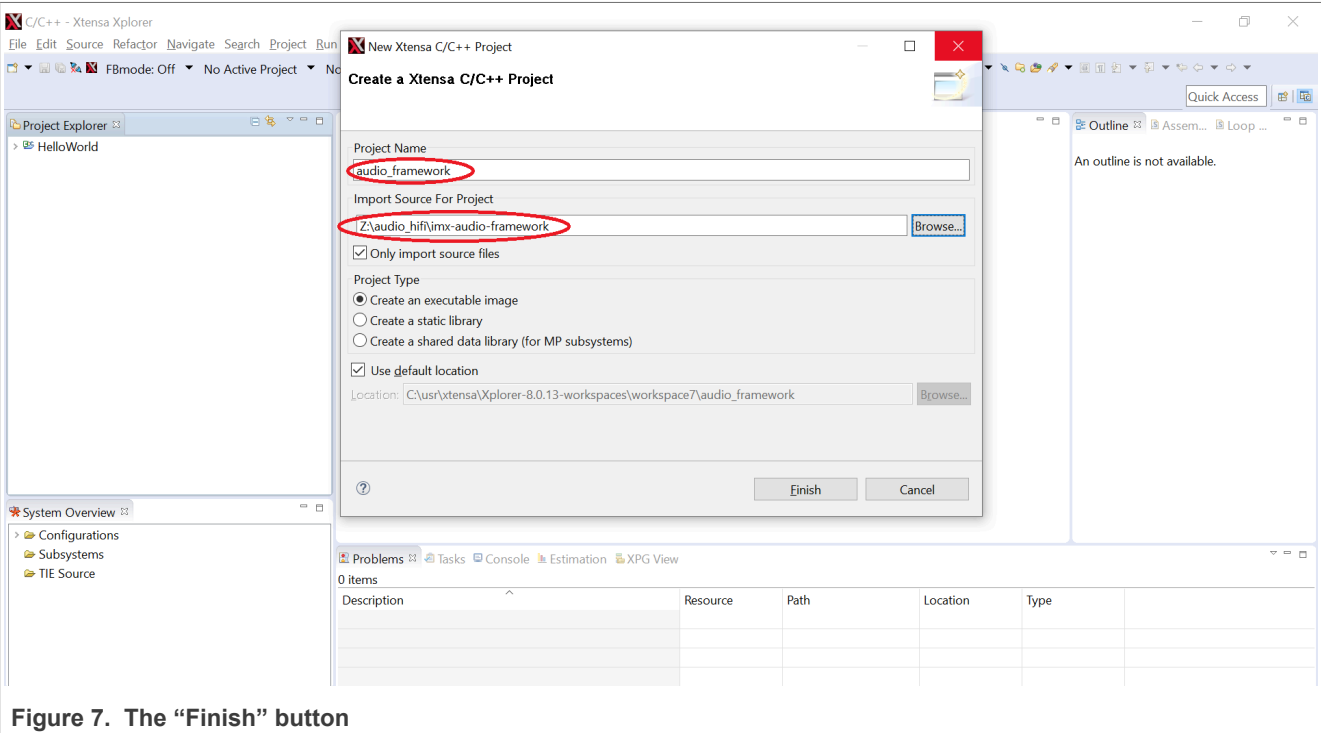


Figure 7. The “Finish” button

After the above two steps, the DSP framework project is successfully created. You can see the project as shown in the following figure.

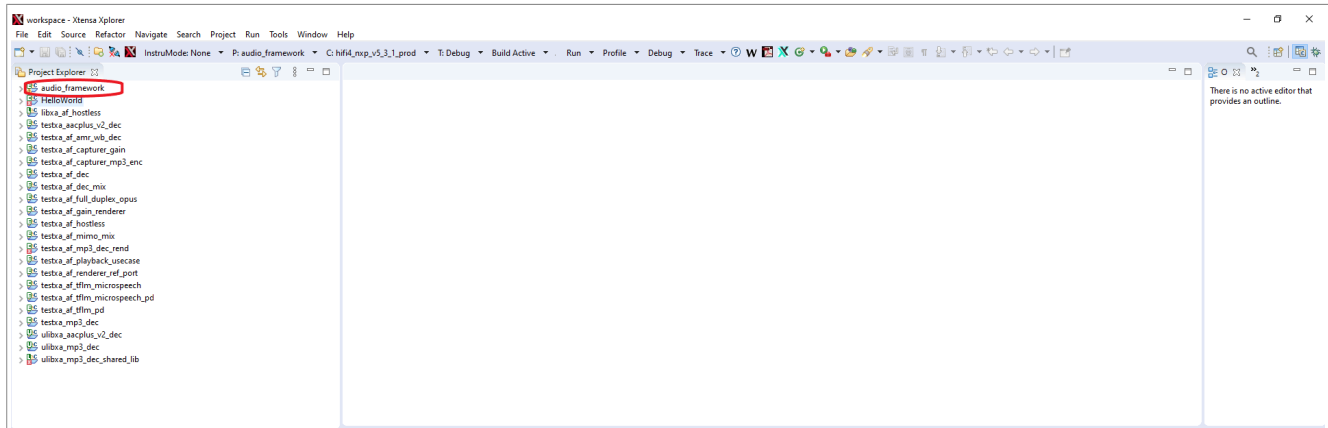


Figure 8. DSP framework project

5.3 Building DSP framework

When you created the DSP framework project, you can build its code. Choose the *memmap* linker files before the building process.

1. Right-click the name of the DSP framework project in the “Project Explorer” panel and choose the “Build Properties...” option. You will see the “Build Properties for dsp_framework” dialog. The dialog is shown in Figure 9.

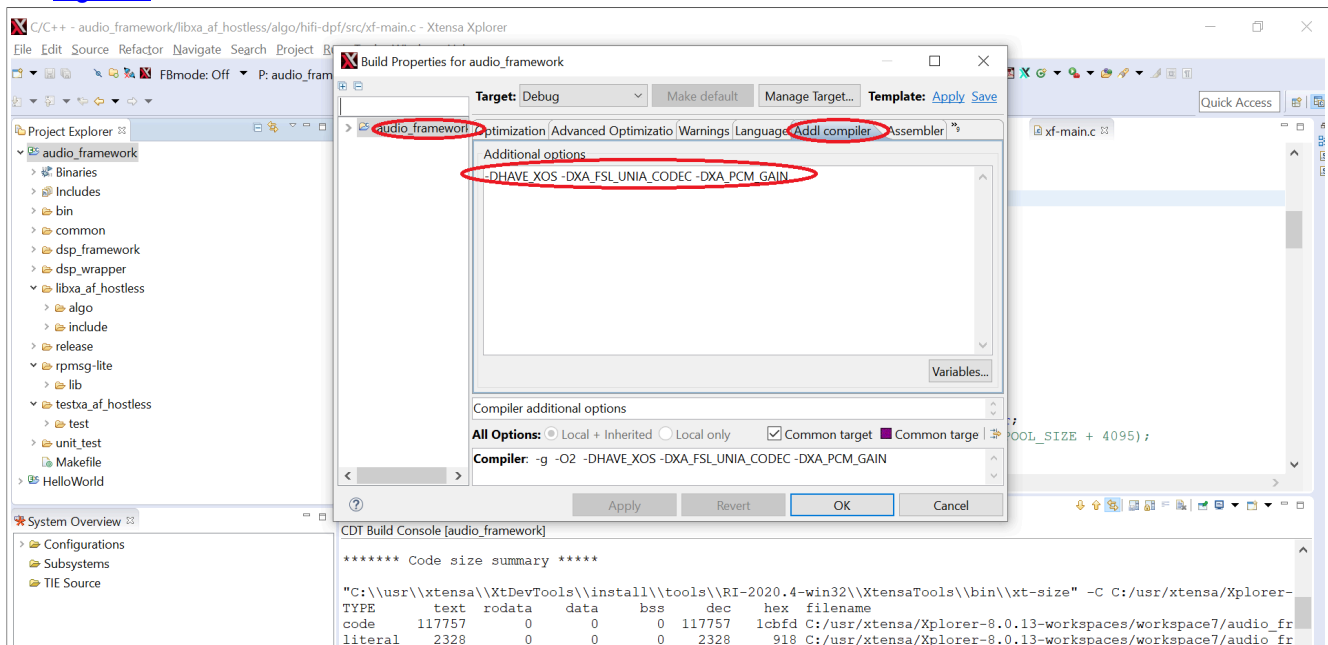


Figure 9. “Build Properties” dialog

2. Click “Add compiler” to add options. Add the “-DPLATF_8M” attribute to build the firmware for i.MX 8M Plus. Add the “-DPLATF_8ULP” attribute to build the firmware for i.MX 8ULP. Add the “-DDEBUG” attribute to build the firmware with the print debug information. The “-DHAVE_XOS -DXA_FSL_UNIA_CODEC -DXA_PCM_GAIN” option is required.
3. Click the “Linker” option and configure the custom LSP path. Select “imx8” for i.MX 8QuadMax and i.MX 8QuadXPlus, “imx8m” for i.MX 8M Plus, and “imx8ulp” for i.MX 8ULP.

4. as shown in [Figure 10](#). Click the “OK” button to finish this process. The “-lxs -lxtutil” option is required.

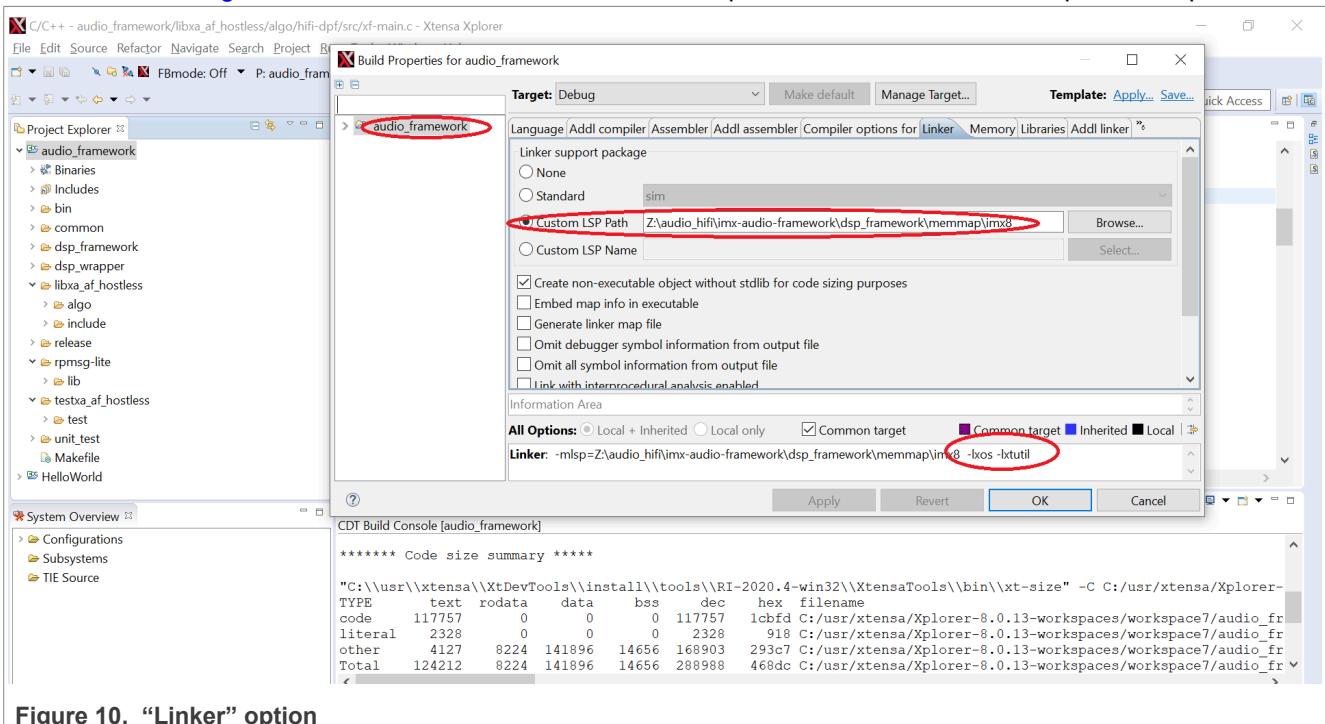


Figure 10. “Linker” option

5. When you configured the *memmap* linker files, you can choose the *dsp_framework* project and the required DSP configuration to start the building process. The configuration is as follows:

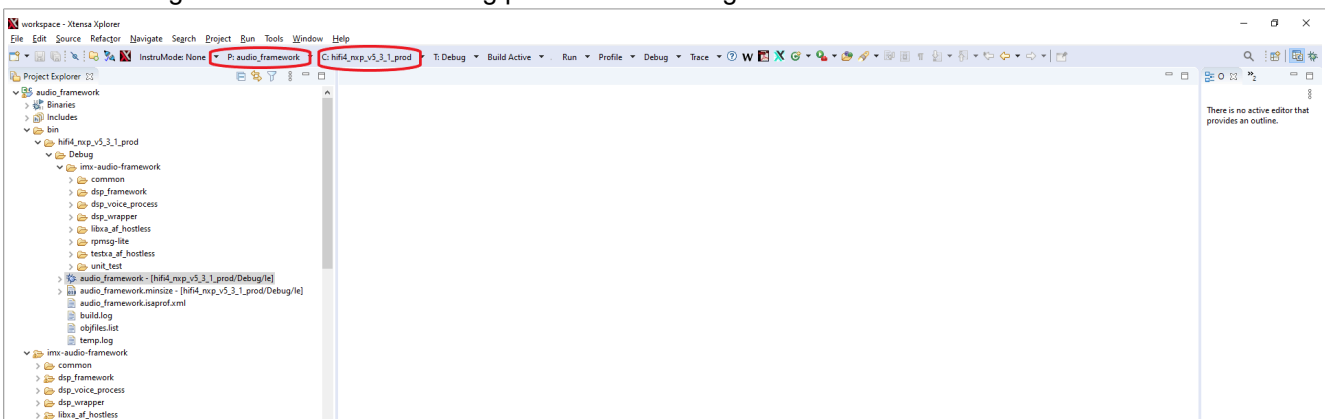


Figure 11. Build process configuration

6. Click the “Build Active->Build Active” option to start building the DSP framework. This takes some time.
a. In “Build -> Exclude”, right-click the folder or files to exclude C files.

```

rpsmsg_lite/lib/rpsmsg_lite/porting/
rpsmsg_lite/lib/rpsmsg_lite/rpsmsg_queue.c
common/
dsp_wrapper/
unit_test/
testxa_af_hostless/test/src/
testxa_af_hostless/test/plugins/cadence/      (except "pcm_gain" folder and
xa-factory.c C file)
libxa_af_hostless/algo/host-apf/
libxa_af_hostless/algo/hifi-dpf/src/xf-main.c
libxa_af_hostless/algo/hifi-dpf/src/xf-msgq1.c

```



```
dsp_voice_process/
```

- b. In "Auto Includes Settings -> Manage", right click the folder to exclude headers. Change the "Auto Includes" to "Manual". Remove the following files:
`libxa_af_hostless/include/sysdeps/freertos/include`
`libxa_af_hostless/include/sysdeps/linux/include`
7. After performing the above steps, you get the binary file called *audio_framework* (which is the firmware of the DSP) in the following folder.
`C:\usr\xtensa\Xplorer-10.1.11-workspaces\workspace\audio_framework\bin\hifi4_nxp_v5_3_1_prod\Debug\audio_framework`
To use this binary file to run on a real board, rename the *audio_framework* binary file as *hifi4.bin* and place it to a right place of "rootfs".

6 Building DSP Wrapper and Unit Test

Before you compile the DSP wrapper and the unit test, set up the related toolchain. The DSP wrapper and the unit test use the Linaro compiler toolchain for the Yocto platform.

6.1 Installing Linaro compiler toolchain

Currently, the Yocto toolchain is used to compile the DSP wrapper and the unit test's code for the Yocto platform. Use `source environment-setup-armv8a-poky-linux` to set up the yocto gcc toolchain. If you want to successfully build the code, you can get more information from the *Makefile* file of the DSP wrapper and the unit test.

6.2 Building the code

When the Linaro toolchain is successfully installed on your server, you can compile the DSP-related code. You can execute the "make" command in the *imx-audio-framework* folder to compile the DSP wrapper and the unit test. If you want to compile them separately, see the *README* file in the *imx-audio-framework* folder. After the compiling process, you can find the binary files in the *imx-audio-framework/release* folder.

For the DSP wrapper:

- *imx-audio-framework/release/wrapper/lib_dsp_wrap_arm_elinux.so*

For the unit test:

- *imx-audio-framework/release/exe/dsp_test*
- *imx-audio-framework/release/exe/dsp_rend_test.out*
- *imx-audio-framework/release/exe/dsp_capturer_test.out*
- *imx-audio-framework/release/exe/dsp_voiceproc_test.out*

6.3 Installing Android toolchain

For building the DSP wrapper for Android, the toolchain used is `android-ndk64-r10e-standalone`, which can be downloaded from the Android website.

7 Usage of DSP Binary Files

7.1 Getting DSP binary files

You can get the DSP binary files of the DSP framework, DSP wrapper, and unit test directly from NXP or compile the source code to produce them yourself. You can also obtain DSP codec binary files directly from NXP. DSP codecs originated from Cadence are license-restricted: A license authorization is required from NXP Marketing to access them.

The location for all prebuilt binaries not requiring any NXP Marketing authorization is on the Yocto mirror server.

7.2 Binary files in Linux OS rootfs

To run these binary files, place them into the Linux OS rootfs. The location of the DSP framework is determined by the DSP remoteproc driver, so you shall keep it in the specified place. The location of the DSP wrapper is determined by the GStreamer and you shall keep it in the specified place. You can change the location of the unit test. The binary files are in these folders:

- The unit test is here (default path):
`/unit_tests/DSP/dsp_test.out`
- The DSP framework is here:
`/lib/firmware/imx/dsp/hifi4.bin`
- The DSP wrapper is here:
`/usr/lib/imx-mm/audio-codec/wrap/lib_dsp_wrap_arm_elinux.so`
- You can keep the DSP codec wrapper and the DSP codec in these folders of the Linux OS rootfs (These libraries require authorization from NXP Marketing):
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_codec_wrap.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_mp3_dec.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_aac_dec.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_bsac_dec.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_dabplus_dec.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_drm_dec.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_mp2_dec.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_sbc_dec.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_dsp_sbc_enc.so`
- Add DSP NXP codec wrapper library (WMA10 library requires authorization from NXP Marketing, others are on the Yocto Mirror Server):
`/usr/lib/imx-mm/audio-codec/dsp/lib_mp3d_wrap_dsp.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_aacd_wrap_dsp.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_vorbisd_wrap_dsp.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_wma10d_wrap_dsp.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_nbamrd_wrap_dsp.so`
`/usr/lib/imx-mm/audio-codec/dsp/lib_wbamrd_wrap_dsp.so`

7.3 Unit test and playing

7.3.1 dsp_test

After placing the binary files into the correct location of the rootfs, you can decode or encode audio streams directly using the unit test binary file. To decode one *.mp3 file, use this command:

```
./dsp_test -f1 -d16 -itest.mp3 -otest.pcm
```

```
dsp_test.out -f3 -r32 -t49 -dl6 -ithetest_48000ps_chbr32.nac -  
othetest_48000ps_chbr32.pcm  
dsp_test.out -f4 -il2-fl111.mp2 -ol2-fl111.pcm
```

For more information about the `dsp_test`, use this command:

```
./dsp_test
```

To play one music file using the GStreamer and DSP wrapper, use this command:

```
gplay-1.0 test.mp3
```

The `dsp_rend_test.out` supports compress playback, and the `dsp_capturer_test.out` supports record. Those features are now usable on the i.MX 8M Plus board. After changing the dtb, whose filename is: *imx8mp-evk-dsp.dtb*, you can hear the sound by running the command:

```
dsp_rend_test.out -f10 -isyz_short.mp3
```

And record the sound by running the command:

```
dsp_capturer_test.out -outfile:out.pcm -samples:300000
```

Note: To record the sound, connect the i.MX 8M Plus board to the 8MIC-PRI-MX8 board first.

The `dsp_voiceproc_test.out` supports dummy voice process by processing the playback and record stream in the DSP. The test is only a frame and does not realize the function. Test the case by running the command:

```
/unit_test/DSP/dsp_voiceproc_test.out -f10 -C2 -isyz_short.mp3 -oout.pcm
```

8 Building Codec Wrapper and Codec Library

The library of the DSP codec wrapper and DSP codec is the loadable library. This chapter describes how to make the loadable library for the DSP.

The DSP loadable library is available as two different types: a fixed-location overlay and a position-independent library.

- For a fixed-location overlay, you can load the code into a predetermined location in the memory.
- For a position-independent library, you can load the code at an address determined during runtime.

You can link the loadable library using a special LSP named “pload” or “pisplitload” (see the *Xtensa Linker Support Packages (LSPs) Reference Manual*). The binary files that are used by the DSP framework belong to the position-independent library, so this chapter briefly discusses how to generate the position-independent library. For more detailed information, see Chapter 4 of the *Xtensa System Software Reference Manual*.

A position-independent library can be loaded and run at any address that supports both code and data, like a normal system RAM. Alternatively, you can use the “pisplitload” LSP to load the code and data into separate memory blocks located in local RAMs. The library location must be decided before the runtime.

The Xtensa development toolchain must be installed before making a loadable library. After that, you can follow the steps below.

8.1 Finding custom LSPs

The loadable libraries must be linked to a custom linker support package. For the position-independent libraries, you do not have to generate or edit an LSP. Instead, you must link your position-independent library using the standard “pisplitload” LSP that is provided as a part of your configuration.

8.2 Source code modifying and compiling

The API only allows the main program to directly access a single symbol in the library, the “_start” symbol. The library cannot access any symbols in the main program directly. Any other symbol's address must be passed to or from the library as an argument to the “_start” function. This code is an example:

```
#include <stdio.h>
/* declare a printf function pointer */ int (*printf_ptr)(const char *format,
...);
/* replace all calls to printf with calls through the pointer */ #define printf
printf_ptr
/* This is the function provided by the library */ char *
interface_func(unsigned int input)
{
printf("executing function interface_func\n"); 13
return "this is string returned from interface_func";
}
void * _start(int (*printf_func)(const char *format, ...))
{
printf_ptr = printf_func;
/* The main application wants to call the function interface_func, but can't
directly reference it. Therefore, this function returns a pointer to it, and
the main application will be able to call it via this pointer. */
return interface_func;
}
```

The main application calls the “_start” function, passes a pointer to “printf”, and takes a pointer to *interface_func()* in return. If the library and the main program must communicate a value of more than one symbol, then the “_start” function call can return arrays of pointers, rather than single pointers.

After finishing your source code, you can use “xt-xcc” of the Xtensa development toolchain to compile the code. Because the position-independent libraries can be loaded at any address, make sure that the code in the library is position-independent using the “-fpic” flag along with your normal compile options, as shown here:

```
xt-xcc -O3 -o library.o -c library.c
```

8.3 Linking the library code

In this step, link the library code into a loadable library using the appropriate LSP. For position-independent library, you can use this command:

```
xt-xcc -mlsp=pisplitload -Wl,--shared-pagesize=128 -Wl,-pie -lgcc -lc -o
library.so library.o
```

After this command, you can get a position-independent library with the code and data loadable separately. If you want to get a contiguous position-independent library, you can use this command.

```
xt-xcc -mlsp=piload -Wl,--shared-pagesize=128 -Wl,-pie -lgcc -lc -o library.so
library.o
```

After the linking stage, you can get a loadable library which can be loaded by the DSP framework. The current DSP framework only supports loading the code and data sections separately.

9 Memory Allocation for DSP

The DSP firmware is loaded into the memory by the DSP remoteproc driver. The loading address is defined by the memory map linker files of the Xtensa development toolchain. You may change the loading address based on the memory map list of i.MX 8QuadXPlus, as shown in [Table 1](#).

Table 1. Memory allocation on i.MX8 QuadXPlus

Cortex-A35/Cortex-M4	DSP	Content
—	0x80000000 - 0x806FFFFFFF	Reserved (cannot be used)
0x59700000 - 0x5971FFFF	0x80700000 - 0x8071FFFF	DSP OCRAM-system RAM
0x59720000 - 0x5973FFFF	0x80720000 - 0x8073FFFF	DSP OCRAM-system ROM
—	0x80740000 - 0x80FFFFFFF	Reserved (cannot be used)
0x80700000 - 0x8073FFFF	—	Linux OS kernel (not visible from DSP)
0x81000000 - 0x9FFFFFFF	0x81000000 - 0x9FFFFFFF	SDRAM

Note: 0x80700000 - 0x8071FFFF in the DDR range and without the ocram aliasing, the HiFi4 can have access to this DDR addresses. Once the aliasing is enabled, the HiFi4 does not access the DDR, but its dedicated ORCAM is at this address range. (The reason is that every 512 MB in 4 GB space has dedicated cache attribute).

Currently, the Linux OS kernel reserves the memory for the DSP in the SDRAM separately. The range of the reserved memory is 0x92400000 ~ 0x943fffff (32 MB). You may set this reserved memory by changing the *imx8x-mek.dtsi* file in the *linux-kernel/arch/arm64/boot/dts/freescale* folder.

```
reserved-memory {
.....
dsp_reserved: dsp@92400000 {
reg = <0 0x92400000 0 0x10000000>;
no-map;
};
dsp_reserved_heap: dsp_reserved_heap {
reg = <0 0x93400000 0 0xef0000>;
no-map;
};
dsp_vdev0vring0: vdev0vring0@942f0000 {
reg = <0 0x942f0000 0 0x8000>;
no-map;
};
dsp_vdev0vring1: vdev0vring1@942f8000 {
reg = <0 0x942f8000 0 0x8000>;
no-map;
};
dsp_vdev0buffer: vdev0buffer@94300000 {
compatible = "shared-dma-pool";
reg = <0 0x94300000 0 0x100000>;
no-map;
};
.....
}
```

The DSP remoteproc driver splits the current reserved memory into five parts. One part is used to store the DSP firmware and the other part is a scratch memory for the DSP framework. The detailed information about these five parts is shown in [Table 2](#).

Table 2. Five memory parts

0x92400000 - 0x933FFFFFFF	DSP firmware (16 MB)
0x93400000 - 0x942FFFFFFF	Scratch memory (16 MB)
0x942F0000 - 0x942F7FFF	vdev0vring0
0x942F8000 - 0x942FFFFFFF	vdev0vring1
0x94300000 - 0x943FFFFFFF	vdev0buffer

Note: If you make changes in the memory map linker files of the Xtensadevelopment toolchain, make the related changes for the DSP remoteproc driver.

Note: For i.MX 8ULP and i.MX 8M Plus memory allocation, check the DTS of each platform.

10 NatureDSP Library Support

NatureDSP Library is an extensive library, containing the most commonly used signal processing functions: FFT, FIR, vector, matrix, and common mathematics. API and programing guide is in [hifi4_library/doc/NatureDSP_Signal_Library_Reference_HiFi4.pdf](#), and performance data is in [hifi4_library/doc/NatureDSP_Signal_Library_Performance_HiFi4.pdf](#).

NatureDSP Library package is license restricted on the i.MX platform. License authorization is required from the NXP marketing for the users to access the source code.

NatureDSP Library supported on the i.MX platform uses the same architecture as DSP framework. It is a separate firmware.

Firmware location: `rootfs: /lib/firmware/imx/dsp/ hifi4_naturedsp.bin`

Unit test location: `rootfs: /unit_tests/DSP/naturedsp_test`

How to test:

Find the remoteproc instance for DSP, because we may have other remoteproc for the Cortex-M core

```
root@imx8ulpvk:~# cat /sys/class/remoteproc/remoteproc1/name
imx-dsp-rproc
```

Change the default firmware for DSP

```
root@imx8ulpvk:~# echo imx/dsp/hifi4_naturedsp.bin > /sys/class/remoteproc/remoteproc1/firmware
```

Run unit test:

```
root@imx8ulpvk:~# /unit_tests/DSP/naturedsp_test -func
root@imx8ulpvk:~# /unit_tests/DSP/naturedsp_test -mips
```

11 Note About the Source Code in the Document

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12 Revision History

The following table provides the revision history for this document.

Table 3. Revision history

Document ID	Release date	Description
UG10167 v.LF6.6.36_2.1.0	30 September 2024	Upgraded to the 6.6.36 kernel.
IMXDSPUG_6.6.23_2.0.0	28 June 2024	Upgraded to the 6.6.23 kernel, U-Boot v2024.04, TF-A v2.10, OP-TEE 4.2.0, Yocto 5.0 Scarthgap, and added the i.MX 91 as Alpha quality, i.MX 95 as Beta quality.
IMXDSPUG v.LF6.6.3_1.0.0	29 March 2024	Upgraded to the 6.6.3 kernel.
IMXDSPUG v.LF6.1.55_2.2.0	12/2023	Upgraded to the 6.1.55 kernel.
IMXDSPUG v.LF6.1.36_2.1.0	09/2023	Upgraded to the 6.1.36 kernel.
IMXDSPUG v.LF6.1.22_2.0.0	06/2023	Upgraded to the 6.1.22 kernel.
IMXDSPUG v.LF6.1.1_1.0.0	03/2023	Upgraded to the 6.1.1 kernel.
IMXDSPUG v.LF5.15.71_2.2.0	12/2022	Upgraded to the 5.15.71 kernel.
IMXDSPUG v.LF5.15.52_2.1.0	09/2022	Upgraded to the 5.15.52 kernel, and added the i.MX 93.
IMXDSPUG v.LF5.15.32_2.0.0	06/2022	Upgraded to the 5.15.32 kernel, U-Boot 2022.04, and Kirkstone Yocto.
IMXDSPUG v.LF5.15.5_1.0.0	03/2022	Updated the Section "File organization" and added Appendix B.
IMXDSPUG v.LF5.10.72_2.2.0	12/2021	This document is published with the Linux software document package from this release.
IMXDSPUG v.6	11/2021	<ul style="list-style-type: none">• Added OPUS decoder in Section 1• Updated Figure 10• Added note in Section 5.3

Table 3. Revision history...continued

Document ID	Release date	Description
		<ul style="list-style-type: none">Added compress playback feature for i.MX 8MP board in Section 7.3.1Removed the path of configurable memory map file from Section 4.1
IMXDSPUG v.5	09/2021	<ul style="list-style-type: none">Added i.MX 8ULP supportRemoved the cplay and LPA supportAdded Section 2.1, Section 2.2, and Section 2.3Updated Section 2, Section 3.2, Section 3.1, Section 4.3.1, Section 4.3.2, and Section 9Updated Figure 1Added Figure 2Changed "DSP driver" to "DSP remoteproc driver" in Section 3
IMXDSPUG v.4	01/2021	Updated the version of the toolchain. Added details about the firmware generation and the LPA.
IMXDSPUG v.3	09/2020	Added support for the i.MX8 MP board. Added support for *.wav files playback by the ALSA compressed interface. Added details about DSP framework building.
IMXDSPUG v.2	05/2020	Updated sections Section 1 , Section 4.2 , and Section 7.2 .
IMXDSPUG v.1	01/2019	Added details about using the sound card feature that allows users to play .mp3 files over ALSA compressed interface.
IMXDSPUG v.0	06/2018	Initial release.

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