DSP User’s Guide

Revision History

VERSION	DATE	AUTHOR	CHANGE DESCRIPTION
1.0	11-Feb-2018	Weiguang Kong	Initial Draft
1.1	20-April-2018	Weiguang Kong	Change hifi name to dsp

Table of Contents

1 Introduction

This document is the overall introduction of the dsp, include system architecture, file organization, dsp related toolchain and so on. From this document, users can have an overall understanding of dsp related code. Currently, the dsp is used to decode and encode audio streams on imx8qxp platform. It supports the following codecs. In addition, for current dsp framework, it can support up to 64 clients to run together.

Decoder:

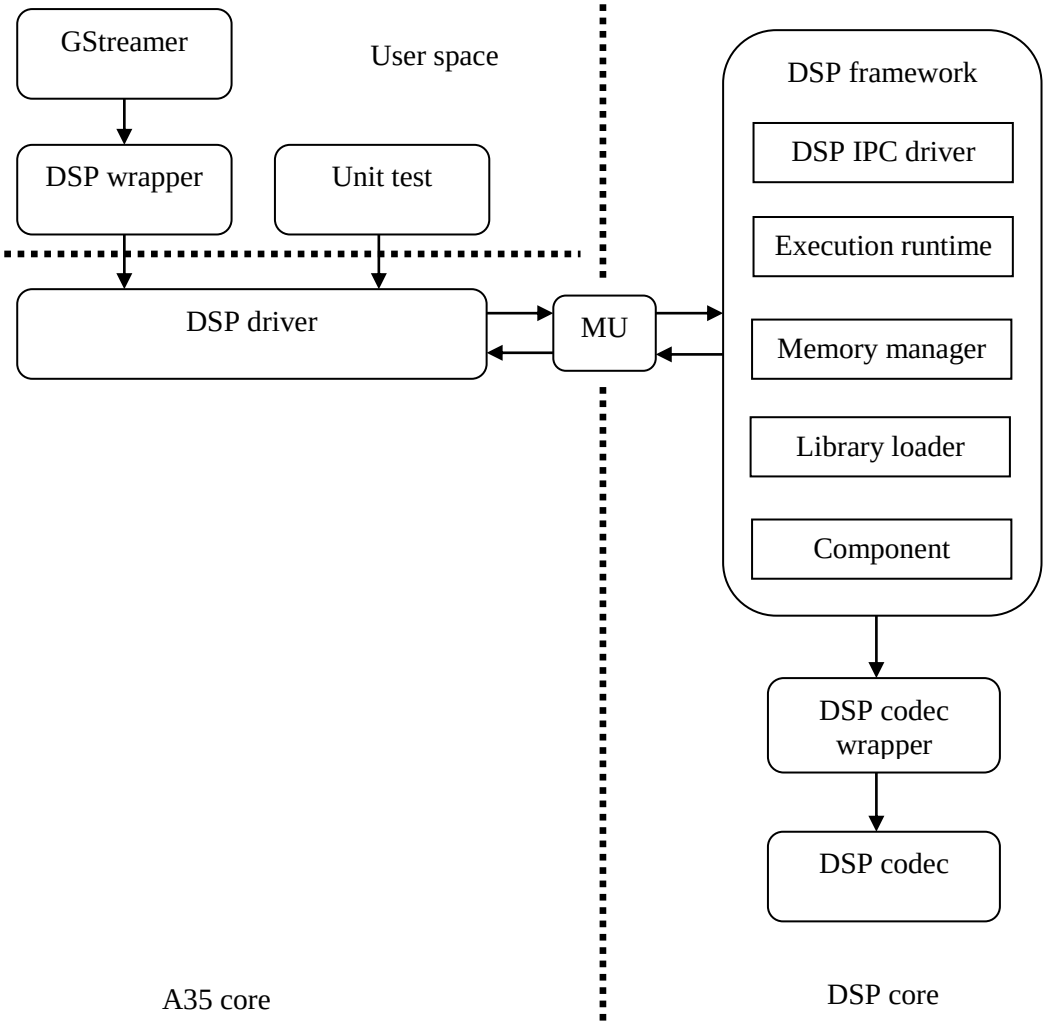
- AAC-LC
- AAC plus(HE-AAC/HE-AACv2)
- BSAC
- DAB+
- MP2
- MP3
- DRM
- SBC

Encoder:

- SBC

2 System Architecture

The following figure gives the overall system architecture of dsp related code.



The dsp related code mainly includes dsp framework, dsp driver, dsp wrapper, unit test, dsp codec wrapper and dsp codec. The dsp framework is the firmware code which is running on the dsp core. The dsp driver is used to load dsp firmware into memory and transfer messages between user space and dsp framework. A shared ring buffer is used to transfer messages between A35 and dsp core. The MU(message unit) is used to trigger interrupt between A35 and dsp core when messages are placed into the ring buffer. The dsp wrapper and unit test are application code in user space, which use ioctl() interface to transfer messages between dsp driver and user space. In addition, the dsp wrapper is used to provide unified interfaces for the GStreamer. The dsp codec provides 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.

3 File Organization

The dsp framework, dsp wrapper and unit test's code are placed in imx-audio-framework package. The dsp driver's code belongs to linux kernel. The dsp codec wrapper and dsp codec are license restricted code, license authorization is required if you want to get them.

3.1 DSP driver

The dsp driver's code can be found in linux kernel, it includes 5 files and the detailed information is as following.

linux-kernel/sound/soc/fsl/fsl_dsp.c
linux-kernel/sound/soc/fsl/fsl_dsp.h
linux-kernel/sound/soc/fsl/fsl_dsp_proxy.c
linux-kernel/sound/soc/fsl/fsl_dsp_proxy.h
linux-kernel/include/uapi/linux/mxc_dsp.h

3.2 DSP framework

The dsp framework's code is placed in the following path.

imx-audio-framework/dsp_framework

3.3 DSP wrapper and unit test

The dsp wrapper and unit test are placed in the following path.

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

3.4 Interface header files

The dsp related code mainly include 4 interface header files.

imx-audio-framework/include/mxc_dsp.h
imx-audio-framework/dsp_framework/component/audio/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 same as the header file in linux kernel, this file includes the interfaces and command definitions, which will be used by dsp wrapper and unit test. Similarly, 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 dsp framework. The fsl_unia.h and fsl_types.h header files include interfaces and command definitions, which can be used by GStreamer.

4 DSP toolchain setup

Before you compile dsp related code, you should set up dsp related toolchains firstly. The dsp framework, dsp codec wrapper and dsp codec use Xtensa development toolchain. The dsp wrapper and unit test use the Linaro compiler toolchain for yocto platform.

4.1 Xtensa development toolchain

Xtensa development toolchain consist of two components that are installed separately on your linux system, including:

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

For Configuration-independent Xtensa Tool, it is released by Cadence. For current code, the version of this tool is XtensaTools_RF_2016_4_linux.tgz. You can use two ways to get this package, one is downloading it from Xtensa Xplorer, the other is getting it from other people who have installed the Xtensa Xplorer.

For Configuration-specific core files and Xtensa Tool, it is released by NXP. For current code, the version of this tool is hifi4_nxp_v3_3_1_2_dev_linux.tgz. In addition, you should also get the configurable memory map linker files from NXP, these files will be placed in memmap/mainsim folder.

Once you have gotten these two components, you can set up this toolchain as the following steps.

- Enter imx-audio-framework folder and execute the following command
  mkdir -p ./imx-audio-toolchain/Xtensa_Tool/tools
  mkdir -p ./imx-audio-toolchain/Xtensa_Tool/builds
- Set up Configuration-independent Xtensa Tool
  cd imx-audio-toolchain/Xtensa_Tool
  tar zxvf XtensaTools_RF_2016_4_linux.tgz -C ./tools
- Set up Configuration-specific core files and Xtensa Tool
  cd imx-audio-toolchain/Xtensa_Tool
  tar zxvf hifi4_nxp_v3_3_1_2_dev_linux.tgz -C ./builds
- Copy configurable memory map files to the following path
  cd imx-audio-toolchain/Xtensa_Tool
  cp -r memmap/mainsim ./builds/ RF-2016.4-linux/hifi4_nxp_v3_3_1_2_dev/xtensa-elf/lib
- Install Xtensa development toolchain
  cd imx-audio-toolchain/Xtensa_Tool
  ./ builds/RF-2016.4-linux/hifi4_nxp_v3_3_1_2_dev/install --xtensa-tools ./tools/RF-2016.4-linux/XtensaTools --registry ./tools/RF-2016.4-linux/XtensaTools/config
- Set the PATH environment variable
  export PATH= ./imx-audio-toolchain/Xtensa_Tool/tools/RF-2016.4-linux/XtensaTools/bin:$PATH
- Set the LM_LICENSE_FILE environment variable

Xtensa development tools use FLEXlm for license management. FLEXIm licensing is required for tools such as the Xtensa Xplorer, TIE Compiler, Xtensa C and C++ compiler. So if you plan to use a floating license, you need to install the FLEXIm license manager and set the LM_LICENSE_FILE environment variable. If any problem, you can find useful information from Cadence's document.

Xtensa® Development Tools Installation Guide User's Guide.doc

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 examples ubuntu 16.04(64-bit), you should install 32-bit compatibility packages firstly. You can use the following commands.

```
sudo apt-get install lib32ncurses5 lib32z1
sudo dpkg --add-architecture i386
sudo apt-get install libc6:i386 libstdc++6:i386
```

4.2 Linaro compiler toolchain

Currently, gcc-linaro-4.9-2015.02-3-x86_64_aarch64-linux-gnu toolchain is used to compile the dsp wrapper and unit test's code for yocto platform. This toolchain should be placed in /usr folder of your linux server if you want to build code successfully, you can get more information from the Makefile file of dsp wrapper and unit test.

5 Usage of DSP binary files

5.1 Get DSP binary files

You can get dsp binary files from NXP directly or compile the source code to produce them by yourself.

After dsp related toolchains have been installed on your server successfully, you can compile the dsp related code. You can just execute make command in imx-audio-framework folder to compile dsp framework, dsp wrapper and unit test. If you want to compile them separately, you can refer the REAME file in imx-audio-framework folder. After the compiling process, you can find the binary files in imx-audio-framework/release folder.

For dsp framework:
imx-audio-framework/release/hifi4.bin
For dsp wrapper:
imx-audio-framework/release/wrapper/lib_dsp_wrap_arm_elinux.so
For unit test:
imx-audio-framework/release/exe/dsp_test

For dsp codec wrapper and dsp codec's binary files, you need to get the authorization.

5.2 Binary files in linux rootfs

If you want to use these binary files to run, you should place them into linux rootfs. The location of each binary is as following. For dsp framework, its location is determined by dsp driver, so you should keep it in the following place. For dsp wrapper, its location is determined by GStreamer, you should keep it in the following place. For unit test, you can change its location by yourself.

For dsp framework:
/lib/firmware/imx/dsp/hifi4.bin
For dsp wrapper:
/usr/lib/imx-mm/audio-codec/wrap/lib_dsp_wrap_arm_elinux.so
For dsp codec wrapper and dsp codec, you can keep them in the following place of linux rootfs.
/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

5.3 Unit test and playing

After you have placed these binary files into correct location of rootfs. If you want to decode or encode audio streams directly, you can use the unit test binary file. For example, if you want to decode one .mp3 file, you can use the following command.

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

You can get more help information about dsp_test by executing the following command.

```
./dsp_test
```

If you want to play one music by using GStreamer and dsp wrapper, you can use gplay and execute the following command.

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

6 Memory allocation for DSP

The dsp firmware is loaded into memory by dsp driver, the loading address is decided by memory map linker files of Xtensa development toolchain. You can change the loading address based on the following memory map list of imx8qxp.

Cortex-A35/Cortex-M4	DSP	Content
	0x80000000 ~ 0x806FFFFF	Reserved (Cannot be used)
0x59700000 ~ 0x5971FFFF	0x80700000 ~ 0x8071FFFF	DSP OCRAM-System RAM
0x59720000 ~ 0x5973FFFF	0x80720000 ~ 0x8073FFFF	DSP OCRAM-System ROM
	0x80740000 ~ 0x80FFFFFF	Reserved (Cannot be used)
0x80700000 ~ 0x8073FFFF		Linux kernel (not visible from DSP)
0x81000000 ~ 0x9FFFFFFF	0x81000000 ~ 0x9FFFFFFF	SDRAM

Currently, linux kernel has reserved one memory for the dsp in SDRAM separately. The range of this reserved memory is 0x8e000000 ~ 0x8fffffff (32M bytes). You can set this reserved memory by changing the fsl-imx8qxp.dtsi file in linux-kernel/arch/arm64/boot/dts/freescale folder.

```
reserved-memory {
    …….

    dsp_reserved: dsp@0x8e000000 {
        no-map;
        reg = <0  0x8e000000  0  0x1fffffff>;
    };

    ……......
}
```

For current reserved memory, dsp driver has split it into two parts. One part is used to keep the dsp firmware, the other part is considered as scratch memory for dsp framework. The detailed information about these two parts is as following.

0x8e000000 ~ 0x8eFFFFFF	DSP firmware(16M bytes)
0x8f000000 ~ 0x8FFFFFFF	Scratch memory(16M bytes)

Notice that if you make some changes for memory map linker files of Xtensa development toolchain, please do related changes for the dsp driver.

7 Make loadable library for DSP

The dsp loadable library is available as two different types: a fixd-location overlay and a position-independent library. For a fixed-location overlay, you can load code into a predetermined location in memory. For a position-independent library, you can load code at an address determined at run time. You can link the loadable library using a special LSP named piload or pisplitload(see the Xtensa Linker Support Packages(LSPs) Reference Manual). For our binary files that are used by dsp framework, it belongs to the position-independent library, so this chapter briefly documents the flow to generate the position-independent library. You can get more detailed information from the Chapter 4 of Xtensa System Software Reference Manual.

A position-independent library can be loaded and run at any address that supports both code and data, like normal system RAM. Alternatively, you can use the pisplitload LSP to load code and data into separate memory blocks located in local RAMs. Library location need to be decided until run time.

Before making loadable library, Xtensa development toolchain should be installed firstly, then you can follow the steps below.

7.1 Finding the Custom LSPs

Loadable libraries need to be linked with a custom linker support package. For position-independent libraries, you don't need to generate or edit an LSP. Instead, you will link your position independent library by using the standard pisplitload LSP provided as part of your configuration.

7.2 Modifying and Compiling the Source Code

The API only allows the main program to directly access a single symbol in the library, the _start symbol. The library can't directly access any symbols in the main program. Any other symbol's address must be passed to or from the library as an argument to the _start function. The following 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");
```

```
    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 _start, passing a pointer to printf, and taking a pointer to interface_func() in return. If the library and the main program need to communicate the value of more than one symbol, then _start can take can return arrays of pointers, rather than just single pointers.

After you have finished your source code, you can use xt-xcc of Xtensa development toolchain to compile the code. For position-independent libraries, because it can be loaded at any address, make sure that the code in the library is position-independent by using the -fpic flag along with your normal compile options, as shown below:

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

7.3 Linking the Library Code

In this step, you will link the library code into a loadable library using the appropriate LSP. For position-independent library, you can use the following 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 code and data loadable separately. If you want to get a contiguous position-independent library, you can use the following 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 dsp framework. In addition, for current dsp framework, it can only support loading code and data section separately.