Document Information

<table>
<thead>
<tr>
<th>Information</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keywords</td>
<td>i.MX 8M Plus, HiFi 4 DSP, Zephyr, Linux</td>
</tr>
<tr>
<td>Abstract</td>
<td>This document explains how to launch the application on the HiFi 4 DSP, how the HiFi 4 DSP and main core communicate together, and how to get the output of the application.</td>
</tr>
</tbody>
</table>
1 Introduction

Running Zephyr on Arm Cortex-A or Cortex-M cores is widely discussed and there are many examples on how to implement it. However, many Cortex-based MCUs and MPUs are choosing to also incorporate on-chip DSPs to offload computationally intensive tasks.

The Cadence Tensilica HiFi 4 DSP is one such example of a high-performance embedded digital signal processor (DSP) optimized for audio, voice, or neural network processing. This application note highlights 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.

This document covers a simple example, such as “hello_world”, however, other samples can also be used. The document explains:

- How to launch the application on the HiFi 4 DSP
- How the HiFi 4 DSP and main core communicate together
- How to get the output of the application

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

2 Hardware platform

The i.MX 8M Plus EVK board is based on NXP i.MX 8M Plus applications processor, which is composed of:

- 4x Arm Cortex-A53 up to 1.8 GHz
- 1x Arm Cortex-M7 up to 800 MHz
- Cadence Tensilica HiFi 4 DSP up to 800 MHz

Figure 1 shows the top view of the i.MX 8M Plus EVK board.

![Figure 1. i.MX 8M Plus EVK board top view](image_url)
3 Zephyr OS

The Zephyr Project, is a scalable real-time operating system (RTOS) supporting multiple hardware architectures, optimized for resource constrained devices, and built with security in mind. It is based on a small-footprint kernel designed for use on resource-constrained systems.

NXP offers various evaluation and prototyping platforms that the Zephyr OS can support. Developers are able to easily tailor a solution to meet their needs using a true open source project with hardware, developer tools, and sensor and device drivers. Security enhancements with Zephyr OS enable the simple implementation of device management, connectivity stacks, and file systems.

For further detail on Zephyr RTOS, visit www.zephyrproject.org/.

4 HiFi 4 audio DSP

The HiFi 4 Audio Engine is a highly optimized audio processor geared for efficient execution of audio and voice codecs and pre- and post-processing modules.

In Zephyr, the board that supports the Audio DSP from i.MX 8M Plus is nxp_adsp_imx8m.

4.1 Supported features

The Zephyr nxp_adsp_imx8m board configuration supports the following hardware features.

<table>
<thead>
<tr>
<th>Interface</th>
<th>Controller</th>
<th>Driver/component</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTICK</td>
<td>On-chip</td>
<td>systick</td>
</tr>
<tr>
<td>CLOCK</td>
<td>On-chip</td>
<td>clock_control</td>
</tr>
<tr>
<td>PINMUX</td>
<td>On-chip</td>
<td>pinmux</td>
</tr>
<tr>
<td>UART</td>
<td>On-chip</td>
<td>serial port-polling; serial port-interrupt</td>
</tr>
</tbody>
</table>

The default configuration can be found in the defconfig file: boards/xtensa/nxp_adsp_imx8m/nxp_adsp_imx8m_defconfig.

Other hardware features are not currently supported by the port.

4.2 Connections and IOs

The i.MX 8M Plus EVK board is tested with the following pinmux controller configuration.

<table>
<thead>
<tr>
<th>Board name</th>
<th>SoC name</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>UART4 RXD</td>
<td>UART4_TXD</td>
<td>UART console</td>
</tr>
<tr>
<td>UART4 TXD</td>
<td>UART4_RXD</td>
<td>UART console</td>
</tr>
</tbody>
</table>

4.3 System clock

The HiFi 4 DSP core is configured to run at 800 MHz clock speed.
4.4 Serial port

The i.MX 8M Plus SoC has four UARTs. Only UART_4 is configured for the DSP console and the remaining UARTs are not used/tested.

5 Building and running a Zephyr sample on HiFi 4 DSP

This section describes the steps to build and run a Zephyr sample on HiFi 4 DSP.

5.1 hello_world application

The Zephyr's hello_world application is a simple sample that can be used with any Supported boards and prints "Hello World" to the console.

5.2 Load the app on DSP

To load an application on the DSP, use Linux remoteproc driver.

In Linux, a generic i.MX remoteproc driver and a DSP-specific driver (imx_dsp_rproc) is already available.

Since the app is running on the DSP, use the imx_dsp_rproc driver. For this enable CONFIG_IMX_DSP_REMOTEPROC in Linux kernel.

5.2.1 Steps to run hello_world on DSP

Following are the steps to run the hello_world app on HiFi 4 DSP from i.MX 8M Plus.

5.2.1.1 Compile hello_world app

Compile the hello_world application in Zephyr for i.MX 8M Plus DSP, that is, nxp_adsp.imx8m board in Zephyr. To enable UART, use the nxp_adsp.imx8m_uart.overlay DTC overlay file and the nxp_adsp.imx8m_uart.conf config fragment file.

Go to zephyr/ folder from zephyrproject and run:

```bash
~/zephyrproject/zephyr$ west build -p always -b nxp_adsp.imx8m samples/hello_world/ -DDTC_OVERLAY_FILE="~/zephyrproject/zephyr/boards/xtensa/nxp_adsp.imx8m/nxp_adsp.imx8m_uart.overlay" -DCONF_FILE="~/zephyrproject/zephyr/boards/xtensa/nxp_adsp.imx8m/nxp_adsp.imx8m_uart.conf"
~/zephyrproject/zephyr$ ~/zephyrproject/zephyr$ ls -la build/zephyr
```

```
total 4504
drwxr-xr-x 14 user nxp  4096 Apr 28 17:23 .
drwxr-xr-x  7 user nxp  4096 Apr 28 17:23 ..
drwxr-xr-x  5 user nxp  4096 Apr 28 17:23 arch
drwxr-xr-x  3 user nxp  4096 Apr 28 17:23 boards
drwxr-xr-x  5 user nxp  4096 Apr 28 17:23 cmake
-rw-r-r--  1 user nxp   64 Apr 28 17:23 .cmake.dotconfig.checksum
-dw-r--r--  7 user nxp  4096 Apr 28 17:23 CMakeFiles
-rw-r--r--  1 user nxp 12735 Apr 28 17:23 cmake_install.cmake
-rw-r--r--  1 user nxp 28421 Apr 28 17:23 .config
  ...
-rw-r--r--  1 user nxp  1909 Apr 28 17:23 zephyr.dts
-rw-r--r--  1 user nxp   537 Apr 28 17:23 zephyr.dts.d
-rw-r--r--  1 user nxp  3098 Apr 28 17:23 zephyr.dts.pre
-rw-r--r--  1 user nxp  699020 Apr 28 17:23 zephyr.elf
-rw-r--r--  1 user nxp  437808 Apr 28 17:23 zephyr_final.map
```
The `zephyr.elf` file is used as the firmware to be loaded on DSP.

### 5.2.1.2 Start i.MX 8M Plus board

Start i.MX 8M Plus board with specific DTS.

Use `imx8mp-evk-rpmsg.dtb` and after inserting the `imx_dsp_rproc` kernel module, you will have:

```
root@imx8mpevk:~# ls -la /sys/class/remoteproc/
total 0
  drwxr-xr-x  2 root root 0 Nov  8 14:00 .
  drwxr-xr-x  90 root root 0 Nov  8 14:00 ..
  lrwxrwxrwx  1 root root 0 Nov  8 14:00 remoteproc0 -> ../devices/platform/imx8mp-cm7/remoteproc/remoteproc0
  lrwxrwxrwx  1 root root 0 Nov  8 20:28 remoteproc1 -> ../devices/platform/3b6e8000.dsp/remoteproc/remoteproc1
root@imx8mpevk:~# cat /sys/class/remoteproc/remoteproc0/firmware
rproc-imx-rproc-fw
root@imx8mpevk:~# cat /sys/class/remoteproc/remoteproc1/firmware
imx/dsp/hifi4.bin
root@imx8mpevk:~#
```

Since `remoteproc1` is for DSP, this one is used.

### 5.2.1.3 Check firmware on board

Check firmware image on board:

```
root@imx8mpevk:~# ls -la /lib/firmware/imx/zephyr/
total 148
  drwxr-xr-x  2 root root 4096 Mar  9  2018 .
  drwxr-xr-x 11 root root 4096 Mar  9  2018 ..
  -rwxr-xr-x  1 root root 41524 Mar  9  2018 imx8-hello-world-zephyr.elf
  -rwxr-xr-x  1 root root 57100 Mar  9  2018 imx8m-hello-world-zephyr.elf
  -rwxr-xr-x  1 root root 41524 Mar  9  2018 imx8x-hello-world-zephyr.elf
root@imx8mpevk:~#
```

The firmware must be present in `/lib/firmware` before the `remoteproc` driver is probed, however, it can also be given with absolute path.

### 5.2.1.4 Insert `imx_dsp_rproc.ko` kernel module

By default, i.MX DSP remoteproc protocol waits for a READY reply from remote processor. Since, Zephyr sample applications do not send a READY reply, you must use `remoteproc` module without waiting for a reply. This is implemented using `no_maiboxes` kernel module parameter.

```
root@imx8mpevk:~# modinfo imx_dsp_rproc
filename:       /lib/modules/6.1.22+ge708cbe250ef/kernel/drivers/remoteproc/imx_dsp_rproc.ko
author:         Shengjiu Wang <shengjiu.wang@nxp.com>
description:    i.MX HiFi Core Remote Processor Control Driver
license:        GPL v2
```
... depends:
intree: Y
name: imx_dsp_rproc
parm: no_mailboxes: There is no mailbox between cores, so ignore remote proc reply after start, default is 0 (off). (int)

By default, no_mailboxes parameter is off - do not ignore reply from rproc.
Therefore, first check the imx_dsp_rproc parameter. If it is off, remove the module and insert it with the right parameter.

root@imx8mpevk:~# grep -H '' /sys/module/imx_dsp_rproc/parameters/* /*
no_mailboxes param is off */
/root/imx8mpevk:~# rmod imx_dsp_rproc /* remove kernel module */
[ 797.929292] remoteproc remoteproc1: releasing imx-dsp-rproc
/root/imx8mpevk:~# modprobe imx_dsp_rproc no_mailboxes=1 /* insert kernel module with the right parameter */
[ 819.930792] remoteproc remoteproc1: imx-dsp-rproc is available
[ 819.938640] imx-audio-rpmsg imx-audio-rpmsg.2.auto: assigned reserved memory node audio@81000000
[ 819.947491] imx-audio-rpmsg imx-audio-rpmsg.2.auto: Unable to get codec_dai_name
[ 819.955513] imx-audio-rpmsg imx-audio-rpmsg.3.auto: assigned reserved memory node mic_rpmsg@91000000
/root/imx8mpevk:~#

ls -la /sys/class/remoteproc/ /* now, we have remoteproc1, for DSP */
total 0
drwxr-xr-x  2 root root 0 Mar  3 09:49 .
drwxr-xr-x 90 root root 0 Mar  3 09:49 ..
lrwxrwxrwx  1 root root 0 Mar  3 09:49 remoteproc0 -> ../../devices/platform/imx8mp-cm7/remoteproc/remoteproc0
lrwxrwxrwx  1 root root 0 Mar  3 10:12 remoteproc1 -> ../../devices/platform/3b6e8000 dsp/remoteproc/remoteproc1
/root/imx8mpevk:~#

5.2.1.5 Load firmware on DSP and run it

To load firmware on DSP and run it, execute the following commands.

root@imx8mpevk:~# echo -n /lib/firmware/imx/zephyr/imx8m-hello-world-zephyr.elf
> /sys/class/remoteproc/remoteproc1/firmware
root@imx8mpevk:~# echo start > /sys/class/remoteproc/remoteproc1/state
[ 1900.189075] remoteproc remoteproc1: powering up imx-dsp-rproc
[ 1900.207094] remoteproc remoteproc1: Falling back to sysfs fallback for: /lib/firmware/imx/zephyr/imx8m-hello-world-zephyr.elf
[ 1900.219192] remoteproc remoteproc1: Booting fw image /lib/firmware/imx/zephyr/imx8m-hello-world-zephyr.elf, size 57100
[ 1900.231682] remoteproc remoteproc1: no resource table found for this firmware
[ 1900.239310] remoteproc remoteproc1: remote processor imx-dsp-rproc is now up
/root/imx8mpevk:~#
5.2.1.6 Stop firmware

To stop the firmware, use the following command:

```bash
root@imx8mpevk:~# echo stop > /sys/class/remoteproc/remoteproc1/state
[ 1993.965208] remoteproc remoteproc1: stopped remote processor imx-dsp-rproc
root@imx8mpevk:~#
```

5.3 Get the application output

1. Get console and shell through UART.
2. Open a serial terminal on the fourth serial:

```bash
user@developerpc:~# minicom -D /dev/ttyUSB3
```

You see the following message in the terminal:

```text
*** Booting Zephyr OS build v2.7.0-rc1-19112-g5ed35400036b ***
Hello World! nxp_adsp_imx8m
```

You can use the above steps to build and test any other sample, such as synchronization or philosophers.

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7 Revision history

Table 3 summarizes the revisions to this document.

Table 3. Revision history

<table>
<thead>
<tr>
<th>Revision number</th>
<th>Date</th>
<th>Substantive changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 June 2023</td>
<td>Initial public release</td>
</tr>
</tbody>
</table>
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