AN13970 Running Zephyr RTOS on Cadence Tensilica HiFi 4 DSP Rev. 4.0 — 28 January 2025

Application note

Document information

Information	Content
Keywords	AN13970, i.MX 8M Plus, i.MX 8ULP, i.MX 8 QuadMax, i.MX 8 QuadXPlus, HiFi 4 DSP, Zephyr, IPC, OpenAMP, remoteproc
Abstract	This document explains how to harness the power processing of HiFi 4 DSP available in the NXP i.MX 8, i.MX 8M Plus,i.MX 8ULP, and i.MX 8X product family processor by running Zephyr RTOS on the DSP.



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 microcontroller units (MCUs) and microprocessor units (MPUs) have on-chip digital signal processors (DSPs) incorporated to offload compute-intensive tasks.

The Cadence Tensilica HiFi 4 DSP is one such example of a high-performance embedded DSP optimized for audio, voice, or neural network processing. This application note explains how to harness the power processing of the HiFi 4 DSP available in the NXP i.MX 8, i.MX 8M Plus and i.MX 8X product family, by running Zephyr Real-Time Operating System (RTOS) on the DSP; while Linux Operating System (OS) runs on the main Cortex-A core.

Using example applications, this document explains:

- · How to launch the applications on the HiFi 4 DSP
- · How the HiFi 4 DSP and the main processor core communicate with each other
- How to get the output of the applications

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

2 Hardware platform

This document exemplifies on i.MX 8M Plus processor, but the same is available on other platforms: i.MX 8ULP, i.MX 8QuadMax, i.MX 8QuadXPlus.

The 8MPLUSLPD4-EVK board is based on the NXP i.MX 8M Plus applications processor, which is composed of the following:

• 4 × Arm Cortex-A53 up to 1.8 GHz

- 1 × Arm Cortex-M7 up to 800 MHz
- · Cadence Tensilica HiFi 4 DSP up to 800 MHz

Figure 1 shows the top view of the 8MPLUSLPD4-EVK board.



Figure 1. 8MPLUSLPD4-EVK board top view

For more details on the 8MPLUSLPD4-EVK board, see 8MPLUSLPD4-EVK.

3 Zephyr OS

The <u>Zephyr Project</u> is a scalable RTOS, which supports multiple hardware architectures, optimized for resourceconstrained 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 tailor a solution easily 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 easy implementation of device management, connectivity stacks, and file systems.

For more details on the Zephyr RTOS, visit www.zephyrproject.org/.

Running Zephyr RTOS on Cadence Tensilica HiFi 4 DSP

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 boards that support the audio DSP are as follows:

- For i.MX 8M Plus: imx8mp_evk/mimx8ml8/adsp
- For i.MX 8ULP: imx8ulp_evk/mimx8ud7/adsp
- For i.MX 8QuadMax: imx8qm_mek/mimx8qm6/adsp
- For i.MX 8QuadXPlus: imx8qxp_mek/mimx8qx6/adsp

4.1 Supported features

The imx8mp evk/mimx8ml8/adsp board configuration supports the hardware features shown in Table 1.

Interface	Controller	Driver/component
SYSTICK	On-chip	systick
CLOCK	On-chip	clock_control
PINMUX	On-chip	pinmux
UART	On-chip	serial port-polling

Table 1. Supported hardware features

Note: The port does not support other hardware features currently.

The default configuration can be found in the <u>defconfig</u> file.

4.2 Connections and I/Os

The i.MX 8M Plus EVK board is tested with the pinmux controller configuration shown in Table 2.

Table 2. Connections		
Board name	SoC name	Usage
UART4 RXD	UART4_TXD	UART console
UART4 TXD	UART4_RXD	UART console

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 Universal Asynchronous Receiver/Transmitters (UARTs). Only UART_4 is configured for the DSP console and the remaining UARTs are not used/tested.

5 Building and running Zephyr samples on HiFi 4 DSP

This section describes how to build and run Zephyr samples on HiFi 4 DSP using the following three applications:

- Section 5.1 "hello_world application"
- <u>Section 5.2 "openamp_rsc_table application"</u>
- <u>Section 5.3 "number_crunching application"</u>

5.1 hello_world application

The <u>Zephyr's hello_world</u> application is a simple sample that can be used with one of the <u>Supported boards</u> and prints Hello World to the console.

5.1.1 Load hello_world application on DSP

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

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

Because the application is running on the DSP, use the <code>imx_dsp_rproc</code> driver. To use the driver, enable <code>CONFIG_IMX_DSP_REMOTEPROC</code> in the Linux kernel.

5.1.2 Compile hello_world application

Compile the hello_world application in Zephyr for the i.MX 8M Plus DSP, that is, compile the application for the imx8mp evk/mimx8ml8/adsp board.

Go to the <code>zephyr/</code> folder from <code>zephyrproject</code> and run the following:

```
~/zephyrproject/zephyr$ west build -p always -b imx8mp evk/mimx8ml8/adsp
samples/hello world/
~/zephyrproject/zephyr$
~/zephyrproject/zephyr$ ls -la build/zephyr
total 4288
drwxr-xr-x 14 user nxp 4096 Oct 17 17:05 .
drwxr-xr-x 7 user nxp 4096 Oct 17 17:05 .
drwxr-xr-x 5 user nxp 4096 Oct 17 17:05 arch
drwxr-xr-x 3 user nxp 4096 Oct 17 17:05 boards
drwxr-xr-x 5 user nxp 4096 Oct 17 17:05 cmake
-rw-r--r-- 1 user nxp
                              64 Oct 17 17:05 .cmake.dotconfig.checksum
drwxr-xr-x 6 user nxp 4096 Oct 17 17:05 CMakeFiles
-rw-r--r-- 1 user nxp 12355 Oct 17 17:05 cmake_install.cmake
-rw-r--r-- 1 user nxp 39648 Oct 17 17:05 .config
. . .
                           2275 Oct 17 17:05 zephyr.dts
-rw-r--r-- 1 user nxp
-rw-r--r-- 1 user nxp
                             619 Oct 17 17:05 zephyr.dts.d
-rw-r--r-- 1 user nxp 124460 Oct 17 17:05 zephyr.dts.pre
-rwxr-xr-x 1 user nxp 715896 Oct 17 17:05 zephyr.elf
-rw-r--r-- 1 user nxp 408374 Oct 17 17:05 zephyr final.map
-rw-r--r-- 1 user nxp 408374 Oct 17 17:05 zephyr.map
-rwxr-xr-x 1 user nxp 717052 Oct 17 17:05 zephyr pre0.elf
-rw-r--r-- 1 user nxp 408886 Oct 17 17:05 zephyr_pre0.map
-rw-r--r-- 1 user nxp 7273 Oct 17 17:05 zephyr.stat
```

The *zephyr.elf* file is used as the firmware to be loaded on the DSP.

The same command is used to compile the hello_world sample on i.MX 8ULP, i.MX 8QuadMax, i.MX 8QuadXPlus, only the board name is different. For example, for i.MX 8QuadMax uses the following board with the same command:

west build -p always -b imx8qm_mek/mimx8qm6/adsp samples/hello_world/

5.1.3 Run hello_world application on DSP

To run the hello world application on HiFi 4 DSP from i.MX 8M Plus, perform the following steps:

1. Start the board with a specific device tree source (DTS).

For i.MX 8M Plus use imx8mp-evk-dsp.dtb, for i.MX 8ULP use imx8ulp-evk.dtb, for i.MX 8QuadMax use imx8qm-mek-rpmsg.dtb, and for i.MX 8QuadXPlus use imx8qxp-mek-rpmsg.dtb. After inserting imx_dsp_rproc kernel module, check in the remoteproc id /sys/class/remoteproc/ for the DSP:

```
root@imx8mpevk:~# ls -la /sys/class/remoteproc/
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 09:54 remoteproc0 -> ../../devices/
platform/3b6e8000.dsp/remoteproc/remoteproc0
root@imx8mpevk:~# cat /sys/class/remoteproc/remoteproc0/firmware
imx/dsp/hifi4.bin
root@imx8mpevk:~#
```

Here, remoteproc0, which is for DSP, is used.

2. Check the firmware image on the board:

```
root@imx8mpevk:~# ls -la /lib/firmware/imx/zephyr/
total 1000
                         4096 Mar
                                   9
drwxr-xr-x
           2 root root
                                      2018 .
                                  9
                                      2018 ..
drwxr-xr-x 10 root root
                         4096 Mar
-rwxr-xr-x 1 root root 65424 Mar 9 2018 imx8mp evk-hello world-zephyr.elf
-rwxr-xr-x 1 root root 221072 Mar 9 2018 imx8mp evk-
number crunching cmsisDSP-zephyr.elf
-rwxr-xr-x 1 root root 147740 Mar 9 2018 imx8mp evk-openamp rsc table-
zephyr.elf
-rwxr-xr-x 1 root root 78792 Mar 9 2018 imx8mp evk-philosophers-
zephyr.elf
          1 root root 67536 Mar 9 2018 imx8mp evk-synchronization-
-rwxr-xr-x
zephyr.elf
-rwxr-xr-x 1 root root 76688 Mar 9
                                     2018 imx8qm mek-hello world-zephyr.elf
-rwxr-xr-x 1 root root 97336 Mar
                                     2018 imx8qm mek-openamp rsc table-
                                  9
zephyr.elf
-rwxr-xr-x 1 root root 76688 Mar 9
                                     2018 imx8qxp mek-hello world-
zephyr.elf
-rwxr-xr-x 1 root root 97336 Mar 9 2018 imx8qxp mek-openamp rsc table-
zephyr.elf
-rwxr-xr-x 1 root root 72536 Mar 9 2018 imx8ulp evk-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 an absolute path.

3. Insert imx dsp rproc kernel module:

By default, the i.MX DSP remoteproc protocol waits for a "READY" reply from the remote processor. Because not all Zephyr sample applications (especially simple applications that do not use the mailbox)

send a "READY" reply, you must use the remoteproc module <code>imx_dsp_rproc</code> without waiting for a reply. The <code>imx_dsp_rproc</code> module is implemented using the kernel module parameter <code>no_maiboxes</code>, as shown below:

```
root@imx8mpevk:~# modinfo imx dsp rproc
filename: /lib/modules/6.6.23-lts-next-06224-ga6e188bee815/kernel/
drivers/remoteproc/imx dsp rproc.ko
author: Shengjiu Wang <shengjiu.wang@nxp.com>
description:
              i.MX HiFi Core Remote Processor Control Driver
           GPL v2
license:
. . .
depends:
              Y
intree:
              imx dsp rproc
name:
vermagic: 6.6.23-lts-next-06224-ga6e188bee815 SMP preempt mod_unload
modversions aarch64
              no mailboxes: There is no mailbox between cores, so ignore
parm:
remote proc reply after start, default is 0 (off). (int)
root@imx8mpevk:~#
```

By default, the no_maiboxes parameter is off; do not ignore the reply from the remote processor. 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/*
/sys/module/imx_dsp_rproc/parameters/no_mailboxes:0 /* no mailboxes
param is off *7
root@imx8mpevk:~#
root@imx8mpevk:~# rmmod imx dsp rproc /* remove kernel module */
root@imx8mpevk:~#
root@imx8mpevk:~# modprobe imx_dsp_rproc no_mailboxes=1 /* insert kernel
module with the right parameter *7
root@imx8mpevk:~#
root@imx8mpevk:~# ls -la /sys/class/remoteproc/ /* insert kernel module
with the right parameter */
total 0
drwxr-xr-x 2 root root 0 Feb 27 17:37 .
drwxr-xr-x 92 root root 0 Feb 27 17:27 ..
lrwxrwxrwx 1 root root 0 Feb 27 17:37 remoteproc0 -> ../../devices/
platform/3b6e8000.dsp/remoteproc/remoteproc0
root@imx8mpevk:~#
```

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

```
root@imx8mpevk:~# echo -n /lib/firmware/imx/zephyr/imx8mp_evk-hello_world-
zephyr.elf > /sys/class/remoteproc/remoteproc0/firmware
root@imx8mpevk:~# echo start > /sys/class/remoteproc/remoteproc0/state
```

5. To stop the firmware, use the following command:

```
root@imx8mpevk:~# echo stop > /sys/class/remoteproc/remoteproc0/state
root@imx8mpevk:~#
```

5.1.4 hello_world application output

To get the hello_world application output, perform the following steps:

1. Get the console through the UART.

2. Open a serial terminal on the fourth serial port:

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

Note: Check the serial port number for the other targets.

The terminal displays the following message (also shown in Figure 2):

```
Hello World! imx8mp_evk/mimx8ml8/adsp
*** Booting Zephyr OS build v4.0.0-3025-g52fd016274f3 ****
```

<pre>@* COMd- PullY / grys/module/imx_dsp_rproc/parameters/* / ary/module/imx_dsp_rproc/parameters/no_pailboxes:0 root&inx&mpevk:-# funnod imx_dsp_rproc no_mailboxes:0 root&inx&mpevk:-# imodprobe imx_dsp_rproc no_mailboxes=1 root&inx&mpevk:-# is -la /sys/class/remoteproc/ dix&x-xr-x 2 root root 0 Feb 27 17:42 . dix&x-xr-x 2 root root 0 Feb 27 17:42 . lix&xrwrxx 1 root root 0 Feb 27 17:42 . lix&xrwrxx 1 root root 0 Feb 27 17:42 . lix&xrwrxx 1 root root 0 Feb 27 17:42 . lix&xrwrxx 1 cont root 0 Feb 27 17:42 . lix&xrwrxx 4 cho start > /sys/class/remoteproc/ ->//devices/platform/3b6e8000.dsp/remoteproc/remoteproc0 root&inx&mpevk:-# echo start > /sys/class/remoteproc//remoteproc//firmware root&inx&mpevk:-# echo start > /sys/class/remoteproc//remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//remoteproc//state root&inx&mpevk:-# root&inx&mpevk:-# echo start > /sys/class/remoteproc//remoteproc//state root&inx&mpevk:-# echo start > /sys/class/remoteproc//state root&inx&mpevk:-# root&inx&mpevk:-# echo start > /sys/class/remoteproc//state root&inx&mpevk:-</pre>
<pre>root@imx8mpevk:-# grep -H '' /gyg/module/imx dsp_proc/parameters/* /gyg/module/imx dsp_proc/parameters/no_mailboxes:0 root@imx8mpevk:-# modiorDof/parameters/no_mailboxes:1 root@imx8mpevk:-# modiorDof nax dsp_proc no_mailboxes=1 root@imx8mpevk:-# is _la /gyg/class/remoteproc/ total 0 diwxx-xxr-x 2 root root 0 Feb 27 17:42 . diwxx-xxr-x 22 root root 0 Feb 27 17:42 . liwxrwxrwx 1 root root 0 Feb 27 17:42 remoteproc0 ->//devices/platform/3b6e8000.dsp/remoteproc/remoteproc0 root@imx8mpevk:-# echo -n imx/zephyr/imx8mm_evk-hello world-zephyr.elf > /gyg/class/remoteproc/firmware root@imx8mpevk:-# echo stat > /gyg/class/remoteproc//remoteproc//remoteproc0/firmware root@imx8mpevk:+# echo stat > /gyg/class/remoteproc//remoteproc//state root@imx8mpevk:+# echo stat > /gyg/class/remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc//remoteproc0//remoteproc/</pre>
<pre>/yyy/module/img/dsp_rproc/parameters/no_mailEoxes:0 /yyy/module/img/dsp_rproc/parameters/no_mailEoxes:0 root@imx@mpevk:-# modprobe img/dsp_rproc root@imx@mpevk:-# modprobe img/dsp_remoteproc/ root@imx@mpevk:-# is -la /ysy/class/remoteproc/ total drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 4 cho stort > /sys/class/remoteproc/ ->//devices/platform/3b6e8000.dsp/remoteproc/remoteproc0 root@imx@mpevk:-# cho stort > /sys/class/remoteproc/remoteproc/firmware root@imx@mpevk:-# cho stort > /sys/class/remoteproc/remoteproc/state root@imx@mpevk:-# cho stort > /sys/class/remoteproc/remoteproc/state root@imx@mpevk:-# dmesg til root@imx@mpevk:-# dmesg til </pre>
<pre>root@imx@mpevk:-# cho start > /sys/class/remoteproc/semoteproc/semoteproc/remoteproc/firmware root@imx@mpevk:-# e cho start > /sys/class/remoteproc/semoteproc/semoteproc/firmware root@imx@mpevk:-# e cho start > /sys/class/remoteproc/semoteproc/state root@imx@mpevk:-# e cho start > /sys/class/remoteproc/state root@imx@mpevk:-# e cho start = /sys/class/remoteproc/state root@imx@mpevk:-# e dmes = tail</pre>
<pre>root@imx@mpevk:-# dmsg tail root@imx@mpevk:-# dmsg tail</pre>
<pre>root@imxBmpevk:~# 1s -la /sys/class/remoteproc/ total 0 drwar-xr-x 2 root root 0 Feb 27 17:42 . drwar-xr-x 92 root root 0 Feb 27 17:42 . drwar-xr-x 1 root root 0 Feb 27 17:42 . mixBmpevk:~# echo -n imx/zephyr/imxBmp_evk-hello world-zephyr.elf > /sys/class/remoteproc/remoteproc0 root@imxBmpevk:~# echo -n imx/zephyr/imxBmp_evk-hello world-zephyr.elf > /sys/class/remoteproc/remoteproc0/firmware root@imxBmpevk:~# echo start > /sys/class/remoteproc/remoteproc0/state root@imxBmpevk:~# echo stop > /sys/class/remoteproc/remoteproc0/state root@imxBmpevk:~# echo stop > /sys/class/remoteproc/remoteproc0/state root@imxBmpevk:~# echo stop > /sys/class/remoteproc/remoteproc0/state root@imxBmpevk:~# dmesg tail</pre>
<pre>total 0 drwxr-xr-x 2 root root 0 Feb 27 17:42 . drwxr-xr-x 92 root root 0 Feb 27 17:42 . drwxr-xr-x 92 root root 0 Feb 27 17:42 . lrwxrwxrwx 1 root root 0 Feb 27 17:42 . lrwxrwxrwx 1 root root 0 Feb 27 17:42 . coot@anx@mpevk:-4 echo -1 imx/zephyr/anx@mp_evk-hello_world-zephyr.elf > /sys/class/remoteproc0 root@anx@mpevk:-4 echo stat > /sys/class/remoteproc0/state root@anx@mpevk:-4 echo stop > root@anx@mpevk:-4 e</pre>
<pre>drwxr=xr=x 2 root root 0 Feb 27 17:42 . drwxr=xr=x 92 root root 0 Feb 27 17:26 lrwxrwxrwx 1 root root 0 Feb 27 17:42 remoteproc0 ->//devices/platform/3b6e8000.dsp/remoteproc/remoteproc0 root@imxRimpevkt=4 echo -n imx/zephyr/imxRim_evk-hello world=zephyr.elf > /sys/class/remoteproc/remoteproc0/firmware root@imxRimpevkt=4 echo start > /sys/class/remoteproc/remoteproc0/state root@imxRimpevkt=4 echo stop > /sys/class/remoteproc0/state root@imxRimpevkt=4 echo stop > /sys/class/remoteproc0/state root@imxRimpevkt=4 dnesg tail</pre>
<pre>dimmar.xr.=x 92 root root 0 Feb 27 17:26 Inwarwarwa 1 root root 0 Feb 27 17:36 remoteproc0 ->//devices/platform/3b6e8000.dsp/remoteproc/remoteproc0 root@imm&mpevk:-\$ echo -n imm/zephyr/imm∓_evk-hello_world-zephyr.elf > /sys/class/remoteproc/remoteproc0/firmware root@imm&mpevk:-\$ echo start > /sys/class/remoteproc0/state root@imm&mpevk:-\$ echo stop > /sys/class/remoteproc0/state root@imm&mpevk:-\$ echo stop > /sys/class/remoteproc0/state root@imm&mpevk:-\$ echo stop > /sys/class/remoteproc0/state root@imm&mpevk:-\$ dimedg tail</pre>
<pre>lrwxrwxrwx l root root 0 0 Feb 27 17:42 remoteproo0 ->//devices/platform/3b6e8000.dsp/remoteproc/remoteproo0 root@inx8mpevk:+# echo -n inx/zephyr/inx8mp_evk-hello_world-zephyr.elf > /sys/class/remoteproc/remoteproc0/firmware root@inx8mpevk:+# echo start > /sys/class/remoteproc0/state root@inx8mpevk:+# echo stop > /sys/class/remoteproc0/state root@inx8mpevk:+# echo stop > /sys/class/remoteproc0/state root@inx8mpevk:+# echo stop > /sys/class/remoteproc0/state root@inx8mpevk:+# dmesg tail root@inx8mpevk:+# dmesg tail</pre>
root8imx8mpevk:~# ccho -n imx/zephyr/imx8mp_evk-hello_world-zephyr.elf > /sys/class/remoteproc0/firmware root8imx8mpevk:~# root8imx8mpevk:~# root8imx8mpevk:~# root8imx8mpevk:~# root8imx8mpevk:~# root8imx8mpevk:~# coot8imx8mpevk:~# root8imx8mpevk:~#
<pre>root@imx@mpevk:-# echo start > /sys/class/remoteproc/remoteproc0/state root@imx@mpevk:-# echo stop > /sys/class/remoteproc/remoteproc0/state root@imx@mpevk:-# echo stop > /sys/class/remoteproc0/state root@imx@mpevk:-# dmesg till root@imx@mpevk:-# dmesg till</pre>
root@imx8mpevk:~# root@imx8mpevk:~# root@imx8mpevk:~# root@imx8mpevk:~#
root@immRimpevk:~# echo stop > /sys/class/remoteproc/remoteproc0/state root@immRimpevk:~# dmesg tall root@immRimpevk:~# dmesg tall
root@imx8mpevk:~# root@imx8mpevk:~#
5 41 4045021 multiple processing (1200055711 200.21), processing (1200
[41.494502] audit: type=1534 audit(1/09055/11.580:21): prog-1d-18 op-0NLOAD
[41.494516] audit: type=1334 audit(1709055711.380:22): prog-id=17 op=UNLOAD
[41.494523] audit: type=1334 audit(1709055711.380:23): prog-id=16 op=UNLOAD
[67.466860] remoteproc remoteproc0: releasing imx-dsp-rproc
[73.323020] remoteproc remoteproc0: imx-dsp-rproc is available
[97.414386] remoteproc remoteproc0: powering up imx-dsp-rproc
[97.418540] remoteproc remoteproc0: Booting fw image imx/zephyr/imx8mp_evk-hello_world-zephyr.elf, size 58068
[97.421256] remoteproc remoteproc0: no resource table found for this firmware
[97.421796] remoteproc remoteproc0: remote processor imx-dsp-rproc is now up
[104.793223] remoteproc remoteproc0: stopped remote processor imx-dsp-rproc
root@imx8mpevk:~#

Figure 2. hello_world application output

To build and test any other sample, such as <u>synchronization</u> or <u>philosophers</u>, for any of the targets i.MX 8M Plus, i.MX 8ULP, i.MX 8QuadMax, and i.MX 8QuadXPlus, use the above steps.

You can also run more complex samples that demonstrate how Linux and Zephyr can work in unison.

The next section exemplifies the openamp rsc table application.

5.2 openamp_rsc_table application

The <u>Zephyr's openamp_rsc_table</u> application demonstrates how to use Open Asymmetric Multi-Processing (OpenAMP) with Zephyr based on a resource table. It is designed to respond to the:

- Linux rpmsg client sample
- Linux rpmsg tty driver

This sample implementation is compatible with platforms that embed a Linux kernel OS on the main processor and a Zephyr application on the coprocessor.

5.2.1 Load openamp_rsc_table application on DSP

As mentioned in <u>Section 5.1.1 "Load hello_world application on DSP"</u>, to load the <code>openamp_rsc_table</code> application on the DSP, use the <code>imx_dsp_rproc</code> driver, after enabling <code>CONFIG_IMX_DSP_REMOTEPROC</code> in the Linux kernel.

5.2.2 Compile openamp_rsc_table application in Zephyr

Compile the <code>openamp_rsc_table</code> application in Zephyr for the i.MX 8M Plus DSP, that is, compile the application for the <code>imx8mp_evk/mimx8ml8/adsp</code> board.

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Go to the zephyr/ folder from zephyrproject and run the following:

```
~/zephyrproject/zephyr$ west build -p always -b imx8mp evk//adsp samples/subsys/
ipc/openamp rsc table
~/zephyrproject/zephyr$
~/zephyrproject/zephyr$ ls -la build/zephyr total 5284
drwxr-xr-x 14 nxa06898 nxp 4096 Sep 27 17:42 .
drwxr-xr-x
             7 nxa06898 nxp
                                 4096 Sep 27 17:42 ..
drwxr-xr-x 5 nxa06898 nxp
                                4096 Sep 27 17:42 arch
                               4096 Sep 27 17:42 boards
drwxr-xr-x 3 nxa06898 nxp
drwxr-xr-x 5 nxa06898 nxp 4096 Sep 27 17:42 cmake
-rw-r--r-- 1 nxa06898 nxp
                                  96 Sep 27 17:42 .cmake.dotconfig.checksum
drwxr-xr-x 6 nxa06898 nxp 4096 Sep 27 17:42 CMakeFiles
-rw-r--r-- 1 nxa06898 nxp 13684 Sep 27 17:42 cmake_install.cmake
-rw-r--r-- 1 nxa06898 nxp 41787 Sep 27 17:42 .config
drwxr-xr-x 16 nxa06898 nxp 4096 Sep 27 17:42 drivers
. . .
drwxr-xr-x 4 nxa06898 nxp
drwxr-xr-x 23 nxa06898 nxp
-rw-r--r-- 1 nxa06898 nxp
2421 Sep 27 17:42 subsys
2421 Sep 27 17:42 zephyr.dts
-rw-r--r-- 1 nxa06898 nxp 730 Sep 27 17:42 zephyr.dts.d
-rw-r--r-- 1 nxa06898 nxp 124812 Sep 27 17:42 zephyr.dts.pre
-rw-r--r- 1 nxa06898 nxp 550701 Sep 27 17:42 zephyr_final.map
-rwxr-xr-x 1 nxa06898 nxp 998304 Sep 27 17:42 zephyr_openamp_rsc_table.elf
-rw-r--r-- 1 nxa06898 nxp 550701 Sep 27 17:42 zephyr_openamp_rsc_table.map
-rw-r--r-- 1 nxa06898 nxp 7463 Sep 27 17:42 zephyr_openamp_rsc_table.stat
-rwxr-xr-x 1 nxa06898 nxp 998476 Sep 27 17:42 zephyr pre0.elf
-rw-r--r-- 1 nxa06898 nxp 551293 Sep 27 17:42 zephyr pre0.map
. . .
```

The zephyr openamp rsc table.elf file is used as the firmware to be loaded on the DSP.

For i.MX 8ULP (imx8ulp evk/mimx8ud7/adsp board), the above command can be used.

For i.MX 8QuadMax and i.MX 8QuadXPlus, to compile the sample, use the following command:

west build -p -b imx8qm_mek/mimx8qm6/adsp -S nxp-openamp-imx8-adsp -s samples/ subsys/ipc/openamp rsc table

For these two targets, use a <u>snippet</u> for the device tree and configuration overlay.

5.2.3 Run openamp_rsc_table application on DSP in Linux

To run the <code>openamp_rsc_table</code> application on HiFi 4 DSP from i.MX 8M Plus in Linux, perform the following steps:

Note: The <code>rpmsg_client_sample</code> and <code>rpmsg_tty</code> modules are used to communicate with the <code>openamp_rsc_table</code> application that runs on the DSP. These modules are the sample modules that run on the main processor (Cortex A core).

Note: To build the <code>rpmsg_client_sample</code> and <code>rpmsg_tty</code> modules, enable the <code>CONFIG_SAMPLE_RPMSG_CLIENT</code> and <code>CONFIG_RPMSG_TTY</code> configurations, respectively, in the Linux kernel.

 Start the i.MX 8M Plus EVK board with a specific DTS. For i.MX 8M Plus use imx8mp-evk-dsp.dtb, for i.MX 8ULP use imx8ulp-evk.dtb, for i.MX 8QuadMax use imx8qm-mek-rpmsg.dtb, and for i.MX 8QuadXPlus use imx8qxp-mek-rpmsg.dtb.

After inserting imx_dsp_rproc kernel module, check in the remoteproc id /sys/class/remoteproc/ for the DSP:

```
root@imx8mpevk:~# ls -la /sys/class/remoteproc/
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 09:54 remoteproc0 -> ../../devices/
platform/3b6e8000.dsp/remoteproc/remoteproc0
root@imx8mpevk:~# cat /sys/class/remoteproc/remoteproc0/firmware
imx/dsp/hifi4.bin
root@imx8mpevk:~#
```

Here, remoteproc0, which is for DSP, is used.

2. Check the firmware image on the board:

```
root@imx8mpevk:~# ls -la /lib/firmware/imx/zephyr/
total 1000
drwxr-xr-x 2 root root
                           4096 Mar 9 2018 .
drwxr-xr-x 10 root root 4096 Mar 9 2018 ..
-rwxr-xr-x 1 root root 65424 Mar 9 2018 imx8mp_evk-
-rwxr-xr-x 1 root root 221072 Mar 9 2018 imx8mp_evk-
                                         2018 imx8mp_evk-hello world-zephyr.elf
number_crunching_cmsisDSP-zephyr.elf
-rwxr-xr-x 1 root root 147740 Mar 9 2018 imx8mp evk-openamp rsc table-
zephyr.elf
-rwxr-xr-x 1 root root 78792 Mar 9 2018 imx8mp evk-philosophers-
zephyr.elf
-rwxr-xr-x 1 root root 67536 Mar 9 2018 imx8mp evk-synchronization-
zephyr.elf
-rwxr-xr-x 1 root root 76688 Mar
                                       9
                                          2018 imx8qm mek-hello world-zephyr.elf
-rwxr-xr-x 1 root root 97336 Mar
                                     9
                                          2018 imx8qm mek-openamp rsc table-
zephyr.elf
-rwxr-xr-x 1 root root 76688 Mar 9 2018 imx8qxp mek-hello world-
zephyr.elf
-rwxr-xr-x 1 root root 97336 Mar 9 2018 imx8qxp mek-openamp rsc table-
zephyr.elf
-rwxr-xr-x 1 root root 72536 Mar 9 2018 imx8ulp evk-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 an absolute path.

3. Insert the imx_dsp_rproc kernel module as shown below:

```
root@imx8mpevk:~# modprobe imx_dsp_rproc
root@imx8mpevk:~# ls -la /sys/class/remoteproc
total 0
drwxr-xr-x 2 root root 0 Feb 27 17:54 .
drwxr-xr-x 92 root root 0 Feb 27 17:27 ..
lrwxrwxrwx 1 root root 0 Feb 27 17:54 remoteproc0 -> ../../devices/
platform/3b6e8000.dsp/remoteproc/remoteproc0
root@imx8mpevk:~#
```

4. Insert rpmsg Linux client samples as follows:

```
root@imx8mpevk:~# modprobe rpmsg_client_sample /* rpmsg client sample driver
used to communicate with remote processor over the rpmsg bus */
root@imx8mpevk:~# modprobe rpmsg_tty /* export rpmsg endpoints as tty
devices, usually found as /dev/ttyRPMSGx */
```

5. Load firmware on DSP and run it:

```
root@imx8mpevk:~# echo -n imx/zephyr/imx8mp evk-openamp rsc table-zephyr.elf
> /sys/class/remoteproc/remoteproc0/firmware
root@imx8mpevk:~# echo start > /sys/class/remoteproc/remoteproc0/state
root@imx8mpevk:~# dmesg
  979.299090] remoteproc remoteproc0: powering up imx-dsp-rproc
979.306290] remoteproc remoteproc0: Direct firmware load for /lib/
firmware/imx/zephyr/imx8mp evk-hello world-zephyr.elf failed with error -2
[ 979.306308] remoteproc remoteproc0: Falling back to sysfs fallback for: /
lib/firmware/imx/zephyr/imx8mp evk-hello world-zephyr.elf
[ 979.329548] remoteproc remoteproc0: Booting fw image /lib/firmware/imx/
zephyr/imx8mp_evk-hello world-zephyr.elf, size 58068
[ 979.332297] remoteproc remoteproc0: no resource table found for this
firmware
[ 979.332841] remoteproc remoteproc0: remote processor imx-dsp-rproc is now
up
[ 1033.463449] remoteproc remoteproc0: stopped remote processor imx-dsp-rproc
[ 1675.323618] remoteproc remoteproc0: releasing imx-dsp-rproc
[ 1698.645763] remoteproc remoteproc0: imx-dsp-rproc is available
[ 2198.083754] remoteproc remoteproc0: powering up imx-dsp-rproc
[ 2198.095763] remoteproc remoteproc0: Booting fw image imx/zephyr/
imx8mp_evk-openamp_rsc_table-zephyr.elf, size 139300
[ 2198.101399] rproc-virtio rproc-virtio.2.auto: assigned reserved memory
node vdev0buffer@94300000
[ 2198.104977] virtio rpmsg bus virtio0: rpmsg host is online
[ 2198.105061] rproc-virtio rproc-virtio.2.auto: registered virtio0 (type 7)
[ 2198.105068] remoteproc remoteproc0: remote processor imx-dsp-rproc is now
up
[ 2198.105117] virtio rpmsg bus virtio0: creating channel rpmsg-tty addr
0x400
[ 2198.105489] virtio rpmsg bus virtio0: creating channel rpmsg-client-sample
addr 0x401
[ 2198.105731] rpmsg client sample virtio0.rpmsg-client-sample.-1.1025: new
channel: 0x401 \rightarrow 0x401!
[ 2198.105815] virtio rpmsg bus virtio0: creating channel rpmsg-tty addr
0x402
[ 2198.106153] rpmsg client sample virtio0.rpmsg-client-sample.-1.1025:
incoming msg 1 (src: 0x401)
[ 2198.106207] rpmsg_client_sample virtio0.rpmsg-client-sample.-1.1025:
incoming msg 2 (src: 0x401)
[ 2198.106246] rpmsg_client_sample virtio0.rpmsg-client-sample.-1.1025:
incoming msg 3 (src: 0x401)
[ 2198.111203] rpmsg client sample virtio0.rpmsg-client-sample.-1.1025:
incoming msg 97 (src: 0x401)
[ 2198.111242] rpmsg client sample virtio0.rpmsg-client-sample.-1.1025:
incoming msg 98 (src: 0x401)
[ 2198.111282] rpmsg_client_sample virtio0.rpmsg-client-sample.-1.1025:
incoming msg 99 (src: 0x401)
[ 2198.111323] rpmsg client sample virtio0.rpmsg-client-sample.-1.1025:
 incoming msg 100 (src: 0x4\overline{0}1)
[ 2198.111329] rpmsg client sample virtio0.rpmsg-client-sample.-1.1025:
goodbye!
[2198.111341] virtio rpmsg bus virtio0: destroying channel rpmsg-client-
sample addr 0x401
[ 2198.111413] rpmsg client sample virtio0.rpmsg-client-sample.-1.1025: rpmsg
 sample client driver is removed
root@imx8mpevk:~#
```

By default, the Zephyr console only prints:

*** Booting Zephyr OS build v4.0.0-3025-g52fd016274f3 ***

If CONFIG SHELL is disabled from the project configuration, we get:

*** Booting Zephyr OS build v4.0.0-3025-g52fd016274f3 *** [00:00:00.007,000] <inf> openamp_rsc_table: Starting application threads! [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received --- 287 messages dropped ---[00:00:00.012,000] <dbg> openamp rsc table: platform ipm callback: platform_ipm_callback: msg received from mb 0 [00:00:00.012,000] <inf> openamp rsc table: [Linux sample client] incoming msg 95: hello world! [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received [00:00:00.012,000] <dbg> openamp rsc table: platform ipm callback: platform ipm callback: msg received from mb 0 [00:00:00.012,000] <inf> openamp rsc table: [Linux sample client] incoming msg 96: hello world! [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received [00:00:00.012,000] <dbg> openamp_rsc_table: platform_ipm_callback: platform ipm callback: msg received from mb 0 [00:00:00.012,000] <inf> openamp rsc table: [Linux sample client] incoming msg 97: hello world! [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received [00:00:00.012,000] <dbg> openamp_rsc_table: platform_ipm_callback: platform_ipm_callback: msg received from mb 0 [00:00:00.012,000] <inf> openamp rsc table: [Linux sample client] incoming msg 98: hello world! [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received [00:00:00.012,000] <dbg> openamp rsc table: platform ipm callback: platform ipm callback: msg received from mb 0 [00:00:00.012,000] <inf> openamp rsc table: [Linux sample client] incoming msg 99: hello world! [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received [00:00:00.012,000] <dbg> openamp_rsc_table: platform_ipm_callback: platform ipm callback: msg received from mb 0 [00:00:00.012,000] <inf> openamp rsc table: [Linux sample client] incoming msg 100: hello world! [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received [00:00:00.012,000] <dbg> openamp rsc table: mailbox notify: mailbox notify: msg received [00:00:00.012,000] <inf> openamp rsc table: OpenAMP Linux sample client responder ended

 On the Linux console, send a message to Zephyr, which replies with the "TTY <add>" prefix. <addr> corresponds to the Zephyr rpmsg-tty endpoint address. Linux console:

root@imx8mpevk:~# cat /dev/ttyRPMSG1 &
[1] 1657
root@imx8mpevk:~# echo "Hello Zephyr" >/dev/ttyRPMSG1
TTY 0x0402: Hello Zephyr

If <code>CONFIG_SHELL</code> option is enabled use the <code>ttyRPMSG1</code> for rpmsg TTY demo, as <code>ttyRPMSG0</code> is used for shell.

Otherwise, use ttyRPMSG0.

7. To stop the firmware, use the following command:

```
root@imx8mpevk:~# echo stop > /sys/class/remoteproc/remoteproc0/state
root@imx8mpevk:~#
root@imx8mpevk:~# dmesg | tail
...
[ 2758.000796] remoteproc remoteproc0: stopped remote processor imx-dsp-rproc
root@imx8mpevk:~#
```

5.2.4 openamp_rsc_table application output

To get the <code>openamp_rsc_table</code> application output, perform the following steps:

- 1. Get the console through the UART.
- 2. Open a serial terminal on the fourth serial port, for i.MX 8M Plus:

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

Note: Check the serial port number for the other targets.

The terminal displays the following messages (also shown in Figure 3):

*** Booting Zephyr OS build v4.0.0-3025-g52fd016274f3 ***



Figure 3. openamp_rsc_table application output

5.3 number_crunching application

This section demonstrates how to include a proprietary static library into the Zephyr build system. The library is in an out-of-tree location.

Number crunching sample does vector operations, Fast Fourier transformation (FFT), and filtering.

To demonstrate how to integrate a proprietary code, the NatureDSP library from Cadence has been used, which is in an out-of-tree location as it has a proprietary license.

By default, the sample is using the CMSIS-DSP backend which is in Zephyr as a module.

To use this sample, with an out-of-tree library, define an environment variable LIB_LOCATION. In the location, ensure to have a CMakeLists.txt that defines the following:

```
# Link with the external 3rd party library.
set(LIB_DIR "lib" CACHE STRING "")
set(INCLUDE_DIR "include" CACHE STRING "")
set(LIB_NAME "proprietary_lib.a" CACHE STRING "")
```

If the environment variable LIB LOCATION is not defined, a default Zephyr API is used instead.

This sample executes some mathematical functions that can be used for audio processing like filtering (FFT) or echo cancellation (Least Mean Square (LMS) filter algorithm).

The sample has the following:

- main.c: Calls the generic math functions;
- math ops.c: Executes the math functions, computes the cycles it took to execute, and checks the output.
- cmsis_dsp_wrapper.c: Calls the exact math functions from CMSIS-DSP when CONFIG_CMSIS_DSP is defined and LIB_LOCATION is not defined.
- nature_dsp_wrapper: If LIB_LOCATION is defined and points to an out-of-tree location where the NatureDSP library and headers can be found, calls the exact math functions from the NatureDSP library.

To include a new backend, create a new wrapper for that library or backend.

5.3.1 Load number_crunching application on DSP

To load the number crunching application on the DSP, use the Linux DSP-specific remoteproc driver.

To use the driver, enable CONFIG IMX DSP REMOTEPROC in the Linux kernel.

5.3.2 Compile number_crunching application

CMSIS-DSP is an optional module and must be added explicitly to the Zephyr workspace:

```
west config manifest.project-filter -- +cmsis-dsp
west update cmsis-dsp
```

NatureDSP is available on GitHub: <u>https://github.com/foss-xtensa/ndsplib-hifi4/tree/main</u>. To compile it, use the steps described in the repository.

5.3.2.1 Compilation

Go to the <code>zephyr/</code> folder from <code>zephyrproject</code> and run the following:

```
~/zephyrproject/zephyr$ west build -p -b imx8mp_evk/mimx8ml8/adsp -s samples/
boards/nxp/adsp/number crunching/
```

This links the application with the default backend, CMSIS_DSP.

If you have a proprietary library, define an environment variable LIB_LOCATION and export it, before compiling the application:

```
~/zephyrproject/zephyr$ export LIB_LOCATION=/home/external_lib_location
~/zephyrproject/zephyr$
```

```
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```

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```
~/zephyrproject/zephyr$ west build -p always -b imx8mp_evk/mimx8ml8/adsp -s
samples/boards/nxp/adsp/number_crunching/
~/zephyrproject/zephyr$
```

Or use LIB LOCATION as simple variable and compile with the following:

```
~/zephyrproject/zephyr$ west build -p always -b imx8mp_evk/mimx8ml8/
adsp -s samples/boards/nxp/adsp/number_crunching/ -DLIB_LOCATION=/home/
external_lib_location
```

After compilation you have the following result:

```
~/zephyrproject/zephyr$
~/zephyrproject/zephyr$ ls -la build/zephyr
total 8216
drwxr-xr-x 14 user nxp 4096 Jan 10 13:56 .
                                4096 Jan 10 13:56 ..
drwxr-xr-x 7 user nxp
                                4096 Jan 10 13:56 arch
drwxr-xr-x 5 user nxp
drwxr-xr-x 5 user nxp
drwxr-xr-x 5 user nxp
                                   4096 Jan 10 13:56 boards
                                4096 Jan 10 13:56 board
4096 Jan 10 13:56 cmake
64 Jan 10 13:56 cmake
-rw-r--r-- 1 user nxp
                                    64 Jan 10 13:56 .cmake.dotconfig.checksum
-rw-r--r-- 1 user nxp 125981 Jan 10 13:56 zephyr.dts.pre
-rwxr-xr-x 1 user nxp 1087796 Jan 10 13:56 zephyr.elf
-rw-r--r-- 1 user nxp 1446150 Jan 10 13:56 zephyr_final.map
-rw-r--r-- 1 user nxp 1446150 Jan 10 13:56 zephyr.map
-rwxr-xr-x 1 user nxp 1088088 Jan 10 13:56 zephyr_pre0.elf
-rw-r--r-- 1 user nxp 1446801 Jan 10 13:56 zephyr_pre0.map
-rw-r--r-- 1 user nxp 7584 Jan 10 13:56 zephyr.stat
```

The *zephyr.elf* file is used as the firmware to be loaded on the DSP.

5.3.3 Run number_crunching application on DSP

To run the number crunching application on HiFi 4 DSP from i.MX 8M Plus, perform the following steps:

- 1. Start the board with a specific DTS, see Section 5.1.3 "Run hello_world application on DSP".
- 2. Check the firmware image on the board:

```
root@imx8mpevk:~# ls -la /lib/firmware/imx/zephyr/
total 1000
drwxr-xr-x 2 root root 4096 Mar 9
                                      2018 .
drwxr-xr-x 10 root root 4096 Mar 9
-rwxr-xr-x 1 root root 65424 Mar 9
drwxr-xr-x 10 root root
                                       2018 ..
                                       2018 imx8mp evk-hello world-zephyr.elf
-rwxr-xr-x 1 root root 221072 Mar 9 2018 imx8mp evk-
number crunching cmsisDSP-zephyr.elf
-rwxr-xr-x 1 root root 147740 Mar 9 2018 imx8mp_evk-openamp_rsc_table-
zephyr.elf
-rwxr-xr-x 1 root root 78792 Mar 9 2018 imx8mp evk-philosophers-
zephyr.elf
-rwxr-xr-x 1 root root 67536 Mar 9 2018 imx8mp evk-synchronization-
zephyr.elf
           1 root root 76688 Mar
                                   9 2018 imx8qm mek-hello world-zephyr.elf
-rwxr-xr-x
-rwxr-xr-x 1 root root 97336 Mar 9 2018 imx8qm mek-openamp rsc table-
zephyr.elf
-rwxr-xr-x 1 root root 76688 Mar 9 2018 imx8qxp mek-hello world-
zephyr.elf
-rwxr-xr-x 1 root root 97336 Mar 9 2018 imx8qxp mek-openamp rsc table-
zephyr.elf
```

```
-rwxr-xr-x 1 root root 72536 Mar 9 2018 imx8ulp_evk-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 an absolute path.

3. Insert the imx dsp rproc kernel module with default parameters as shown below:

root@imx8mpevk:~# modprobe imx_dsp_rproc

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

```
root@imx8mpevk:~# echo -n /lib/firmware/imx/zephyr/imx8mp_evk-
number_crunching_cmsisDSP-zephyr.elf > /sys/class/remoteproc/remoteproc0/
firmware
root@imx8mpevk:~# echo start > /sys/class/remoteproc/remoteproc0/state
```

5. To stop the firmware, use the following command:

root@imx8mpevk:~# echo stop > /sys/class/remoteproc/remoteproc0/state

5.3.4 number_crunching application output

To get the number_crunching application output, perform the following steps:

- 1. Get the console through the UART.
- 2. Open a serial terminal on the fourth serial port:

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

The terminal displays the following message:

```
*** Booting Zephyr OS build v4.0.0-3164-g5faf471ce00d ***
Number crunching example!
[Library Test] == Vector Sum test ==
[Backend] CMSIS-DSP module
[Library Test] Vector Sum takes 6614 cycles
[Library Test] == Vector Sum test end with 1 ==
[Library Test] == Vector power sum test ==
[Backend] CMSIS-DSP module
[Library Test] Vector power sum takes 6669 cycles
[Library Test] == Vector power sum test end with 1 ==
[Library Test] == Vector power sum test ==
[Backend] CMSIS-DSP module
[Library Test] Vector power sum takes 3762 cycles
[Library Test] == Vector power sum test end ==
[Library Test] == Fast Fourier Transform on Real Data test ==
[Backend] CMSIS-DSP module
[Library Test] Fast Fourier Transform on Real Data takes 66870 cycles
[Library Test] == Fast Fourier Transform on Real Data test end ==
[Library Test] == Bi-quad Real Block IIR test ==
[Backend] CMSIS-DSP module
[Library Test] Bi-quad Real Block IIR takes 506486 cycles
[Library Test] == Bi-quad Real Block IIR end ==
```

Running Zephyr RTOS on Cadence Tensilica HiFi 4 DSP

[Library Test] == Least Mean Square (LMS) Filter for Real Data test == [Backend] CMSIS-DSP module [Library Test] Least Mean Square (LMS) Filter for Real Data test takes 184792 cycles [Library Test] == Least Mean Square (LMS) Filter for Real Data test end ==

For NatureDSP, the output looks as follows:

*** Booting Zephyr OS build v4.0.0-3164-g5faf471ce00d *** Proprietary library example! [Library Test] == Vector Sum test == [Backend] NatureDSP library [Library Test] Vector Sum takes 3829 cycles [Library Test] == Vector Sum test end with 1 == [Library Test] == Vector power sum test == [Backend] NatureDSP library [Library Test] Vector power sum takes 2432 cycles [Library Test] == Vector power sum test end with 1 == [Library Test] == Vector power sum test == [Backend] NatureDSP library [Library Test] Vector power sum takes 2594 cycles [Library Test] == Vector power sum test end == [Library Test] == Fast Fourier Transform on Real Data test == [Backend] NatureDSP library [Library Test] Fast Fourier Transform on Real Data takes 3338 cycles [Library Test] == Fast Fourier Transform on Real Data test end == [Library Test] == Bi-quad Real Block IIR test == [Backend] NatureDSP library [Library Test] Bi-quad Real Block IIR takes 13501 cycles [Library Test] == Bi-quad Real Block IIR end == [Library Test] == Least Mean Square (LMS) Filter for Real Data test == [Backend] NatureDSP library [Backend] NatureDSP library [Library Test] Least Mean Square (LMS) Filter for Real Data test takes 7724 cvcles [Library Test] == Least Mean Square (LMS) Filter for Real Data test end ==

6 Acronyms

Table 3 lists the acronyms used in this document.

 Description

 DTS
 Device tree source

 IPC
 Inter-process communication

 MCU
 Microcontroller unit

 MPU
 Microprocessor unit

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Table 3. Acronymscontinued		
Acronym	Description	
OpenAMP	Open Asymmetric Multi-Processing	
OS	Operating system	
rproc	Remote processor	
rsc_table	Resource table	
RTOS	Real-time operating system	
UART	Universal Asynchronous Receiver/Transmitter	

7 Note about the source code in the document

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8 Revision history

Table 4 summarizes the revisions to this document.

Document ID	Release date	Description
AN13970 v.4.0	28 January 2025	 Updated the document for i.MX 8, i.MX 8M Plus, i.MX 8ULP, and i.MX 8X product family Updated Section 5.1 "hello_world application" Updated Section 5.2 "openamp_rsc_table application" Added Section 5.3 "number_crunching application" Updated Section 6 "Acronyms"
AN13970 v.3.0	05 June 2024	 Changed nxp_adsp_imx8m board to imx8mp_evk/ mimx8ml8/adsp Updated these images: – Figure 2
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 Table 4. Revision history

Table 4.	Revision	historycontinued
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Document ID	Release date	Description
		 Figure 3 Updated the code in these sections: Check firmware on board Load firmware on DSP and run it Stop firmware Section 5.1.4 Start i.MX 8M Plus EVK board Check firmware on board Insert imx_dsp_rproc kernel module Insert rpmsg Linux client samples rp rpmsg TTY demo Stop firmware Section 5.2.4
AN13970 v.2.0	28 November 2023	 Updated these sections: <u>Section 5.1.2</u> <u>Start i.MX 8M Plus EVK board</u> <u>Check firmware on board</u> <u>Load firmware on DSP and run it</u> <u>Stop firmware</u> <u>Section 5.1.4</u> Added <u>Section 5.2</u>
AN13970 v.1.0	1 June 2023	Initial public release

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