

AN13970

在 Cadence Tensilica HiFi 4 DSP 上运行 Zephyr RTOS

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应用笔记

文档信息

信息	内容
关键词	AN13970_ZH , i.MX 8M Plus, HiFi 4 DSP, Zephyr, IPC, OpenAMP, remoteproc
摘要	本文介绍了如何在 HiFi 4 DSP 上启动示例应用、HiFi 4 DSP 与主核如何通信，以及如何获取示例应用的输出。



1 介绍

业内广泛讨论如何在 Arm Cortex-A 或 Cortex-M 核上运行 Zephyr，并且已经产生了许多实例。然而，许多基于 Cortex 的 MCU 和 MPU 也选择集成片上 DSP 来分流计算密集型任务。

Cadence Tensilica HiFi 4 DSP 就是这类高性能嵌入式数字信号处理器（DSP）的示例之一，它针对音频、语音或神经网络处理进行了优化。本应用笔记重点介绍了：如何在主 Cortex-A 核上运行 Linux 操作系统的同时，在 DSP 上运行 Zephyr 实时操作系统，从而利用 DSP 的强大处理能力。

本文档包含一个简单的示例应用 `hello_world`，但也可以使用其他示例。本文档将解释如下问题：

- 如何在 HiFi 4 DSP 上启动示例应用
- HiFi 4 DSP 和主核如何通信
- 如何获取示例应用的输出

在本文档中，所有示例均使用 Linux 操作系统和 Zephyr 实时操作系统的现有驱动程序和/或框架进行说明。

2 硬件平台

i.MX 8M Plus EVK 板基于 NXP i.MX 8M Plus 应用处理器，由以下部分组成：

- 四个 Arm Cortex-A53，频率高达 1.8 GHz
- 一个 Arm Cortex-M7，频率高达 800 MHz
- Cadence Tensilica HiFi 4 DSP，频率高达 800 MHz

[图 1](#) 显示了 i.MX 8M Plus EVK 板的俯视图。

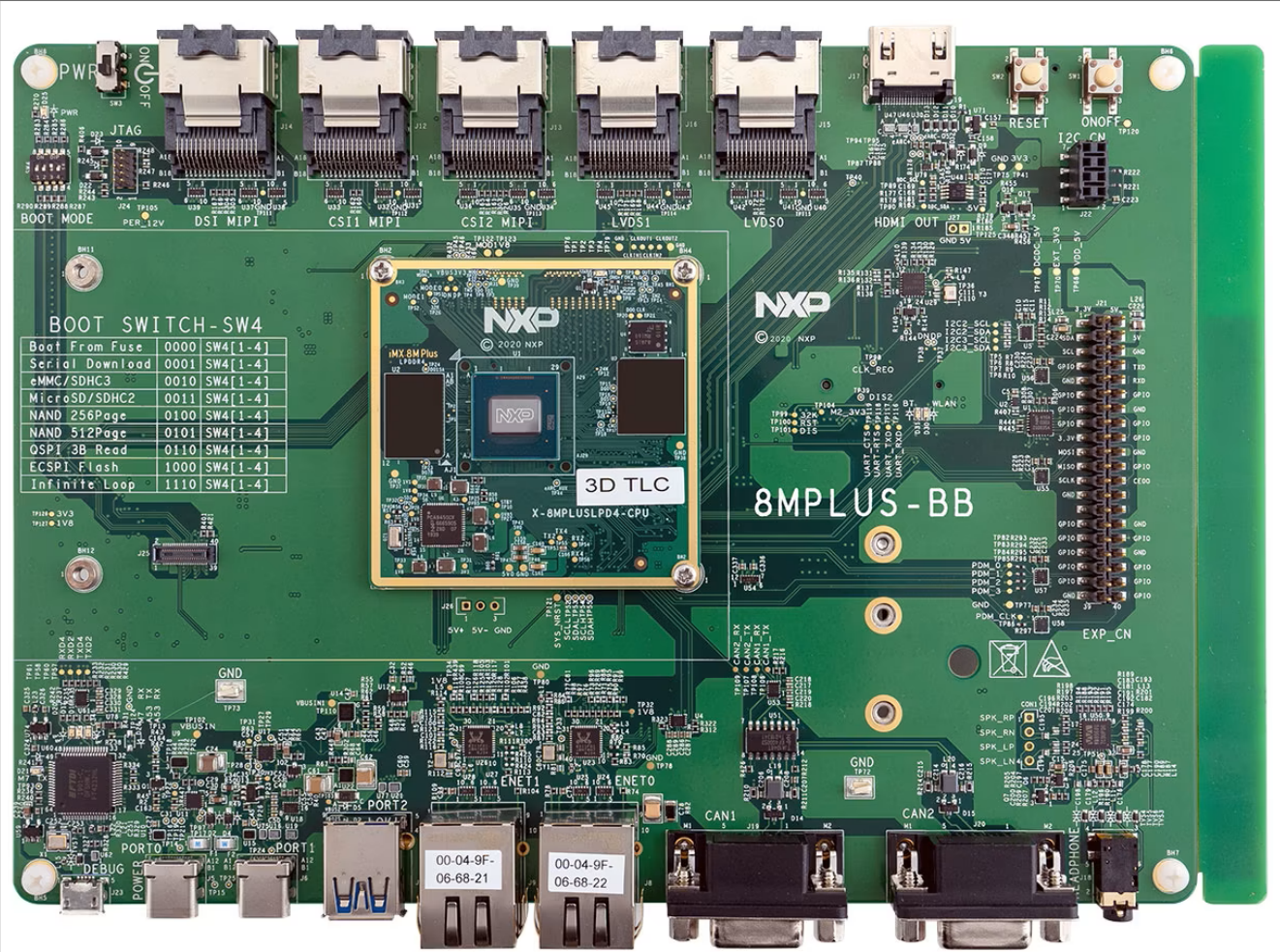


图 1. i.MX 8M Plus EVK 板俯视图

如需了解详情，请参阅 [i.MX 8M Plus EVK](#) 上的电路板信息。

3 Zephyr 操作系统

[Zephyr Project](#) 是一个可扩展的实时操作系统（RTOS），支持多种硬件架构，针对资源受限的器件进行了优化，并在构建时考虑了安全性。它基于小内核，专为在资源受限的系统上使用而设计。

NXP 提供 Zephyr 操作系统支持的各种评估和原型平台。开发人员能够使用包含硬件、开发工具以及传感器和器件驱动程序的真实开源项目，轻松定制符合自身需求的解决方案。Zephyr 操作系统的安全增强功能使设备管理、连接栈和文件系统的实施变得简单。

有关 Zephyr RTOS 的更多信息，请访问 www.zephyrproject.org/。

4 HiFi 四音频数字信号处理器 DSP

HiFi 四音频引擎是一款高度优化的音频处理器，可实现音频和语音编解码器以及前处理和后处理模块的高效执行。

在 Zephyr 中，支持 i.MX 8M Plus 音频 DSP 的板是 `imx8mp_evk/mimx8ml8/adsp`。

4.1 支持的功能

Zephyr `imx8mp_evk/mimx8ml8/adsp` 板的配置支持 [表 1](#) 中的硬件功能。

表 1. 支持的硬件功能

接口	控制器	驱动程序/组件
SYSTICK	On-chip	systick
CLOCK	On-chip	clock_control
PINMUX	On-chip	pinmux
UART	On-chip	serial port-polling

注：该端口目前不支持其他硬件功能。

默认配置可在 `defconfig` 文件中找到：[zephyr/boards/nxp/imx8mp_evk/imx8mp_evk_mimx8ml8_adsp_defconfig](#)。

4.2 连接和 I/Os

i.MX 8M Plus EVK 板使用以下 `pinmux` 控制器配置进行测试，如 [表 2](#) 所示。

表 2. 连接

电路板名称	SoC 名称	用途
UART4 RXD	UART4_TXD	UART 控制台
UART4 TXD	UART4_RXD	UART 控制台

4.3 系统时钟

HiFi 4 DSP 内核配置为以 800 MHz 时钟速度运行。.

4.4 串行端口

i.MX 8M Plus SoC 有四个 UART。仅 `UART_4` 配置给了 DSP 控制台，其余 UART 没有被使用/测试。

5 在 HiFi 4 DSP 上构建和运行 Zephyr 示例

本节介绍在 HiFi 4 DSP 上构建和运行 Zephyr 示例的步骤:

- [章节 5.1 "hello_world 应用"](#)
- [章节 5.2 "openamp_rsc_table 应用"](#)

5.1 hello_world 应用

[Zephyr's hello_world](#) 应用是一个简单的示例, 支持用于多种 [Supported boards](#), 并在控制台中打印 Hello World。

5.1.1 在 DSP 上加载 hello_world 应用

要在 DSP 上加载应用, 请使用 Linux [remoteproc](#) 驱动程序。

在 Linux 中, 可以使用 [i.MX remoteproc](#) 驱动程序和 DSP 特定驱动程序 ([imx_dsp_rproc](#))。

由于应用是在 DSP 上运行, 因此要使用 `imx_dsp_rproc` 驱动程序。为此, 请启用 Linux 内核中的 `CONFIG_IMX_DSP_REMOTEPROC`。

5.1.2 编译 hello_world application

在 Zephyr 中为 i.MX 8M Plus DSP (即 Zephyr 中的 `imx8mp_evk/mimx8ml8/adsp` 板) 编译 `hello_world` 应用。

进入 `zephyrproject` 中的 `zephyr/` 文件夹并运行:

```
~/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
...
-rw-r--r--  1 user nxp   2275 Oct 17 17:05 zephyr.dts
-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
```

`zephyr.elf` 文件将作为固件加载到 DSP 上。

5.1.3 在 DSP 上运行 hello_world 应用的步骤

以下是在 i.MX 8M Plus 的 HiFi 4 DSP 上运行 hello_world 应用的步骤。

5.1.3.1 启动 i.MX 8M Plus EVK 板

使用特定 DTS 启动 i.MX 8M Plus EVK 板。

使用 imx8mp-evk-dsp.dtb，插入 imx_dsp_rproc.ko 内核模块后，您就可以看到如下脚本：

```
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:~#
```

由于 remoteproc1 用于 DSP，因此使用此模块。

5.1.3.2 检查电路板上的固件

检查电路板上的固件镜像：

```
root@imx8mpevk:~# ls -la /lib/firmware/imx/zephyr/
total 472
drwxr-xr-x  2 root root  4096 Mar  9 2018 .
drwxr-xr-x 12 root root  4096 Mar  9 2018 ..
-rwxr-xr-x  1 root root 58068 Mar  9 2018 imx8mp_evk-hello_world-zephyr.elf
-rwxr-xr-x  1 root root 139300 Mar  9 2018 imx8mp_evk-openamp_rsc_table-
zephyr.elf
-rwxr-xr-x  1 root root  72460 Mar  9 2018 imx8mp_evk-philosophers-zephyr.elf
-rwxr-xr-x  1 root root  63252 Mar  9 2018 imx8mp_evk-synchronization-
zephyr.elf
-rwxr-xr-x  1 root root  64212 Mar  9 2018 imx8qm_mek-hello_world-zephyr.elf
-rwxr-xr-x  1 root root  64212 Mar  9 2018 imx8qxp_mek-hello_world-zephyr.elf
root@imx8mpevk:~#
```

在检测 remoteproc 驱动程序之前，固件必须存在于 /lib/firmware 中，但也可以使用绝对路径。

5.1.3.3 插入 imx_dsp_rproc.ko 内核模块

默认情况下，i.MX DSP remoteproc 协议等待远程处理器的 **READY** 回复。由于不是所有 Zephyr 示例应用（特别是不使用 mailbox 的简单应用）会发送 **READY** 回复，因此必须使用 remoteproc 模块，无需等待回复。这需要使用 no_maiboxes 内核模块参数来实现：

```
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
license:        GPL v2
...
depends:
```

```
intree: Y
name: imx_dsp_rproc
vermagic: 6.6.23-lts-next-06224-ga6e188bee815 SMP preempt mod_unload
modversions aarch64
parm: no_mailboxes:There is no mailbox between cores, so ignore remote
proc reply after start, default is 0 (off). (int)
root@imx8mpevk:~#
```

默认情况下，no_mailboxes 参数是 off，即不忽略来自 rproc 的回复。

因此，首先检查 imx_dsp_rproc 参数。如果是 off，请删除模块，然后插入正确参数的模块。

```
root@imx8mpevk:~# grep -H ' ' /sys/module/imx_dsp_rproc/parameters/*
/sys/module/imx_dsp_rproc/parameters/no_mailboxes:0 /* no_mailboxes param
is off */
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 */
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:~#
```

5.1.3.4 在 DSP 上加载并运行固件

要在 DSP 上加载固件并运行，请执行以下命令：

```
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
```

5.1.3.5 停止固件

要停止固件，请执行以下命令：

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

5.1.4 获取 hello_world 应用输出

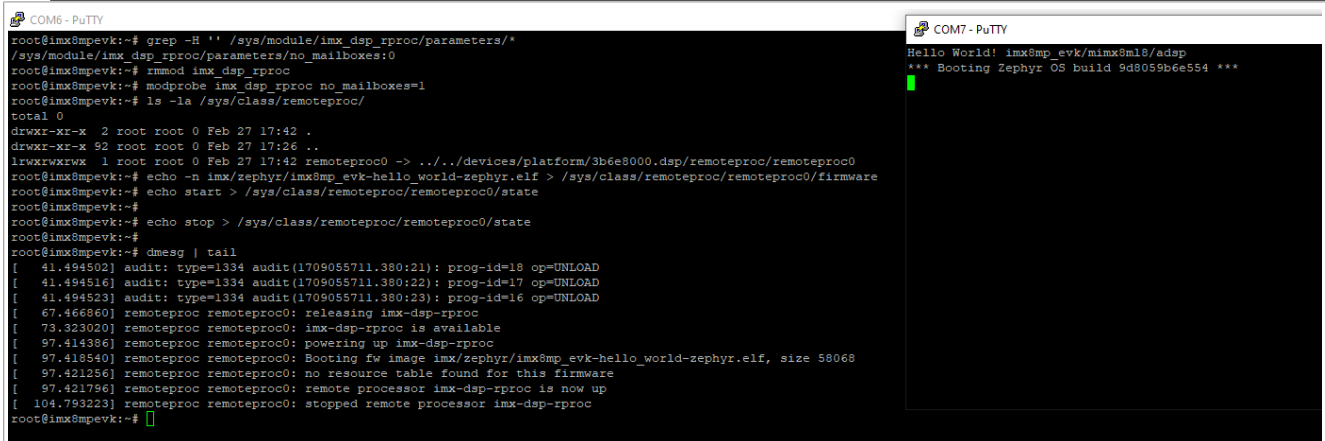
为了获取 hello_world 应用输出，请遵循以下步骤：

1. 通过 UART 获取控制台。
2. 在第四串口上打开串口终端：

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

您将在终端上看到以下信息（也可在 [图 2](#) 中查询）：

```
Hello World! imx8mp_evk/mimx8ml8/adsp
*** Booting Zephyr OS build 9d8059b6e554 ***
```



```
COM6 - PuTTY
root@imx8mp-evk:~# grep -H '' /sys/module/imx_dsp_rproc/parameters/*
/sys/module/imx_dsp_rproc/parameters/no_mailboxes:0
root@imx8mp-evk:~# rmmod imx_dsp_rproc
root@imx8mp-evk:~# modprobe imx_dsp_rproc no_mailboxes=1
root@imx8mp-evk:~# ls -la /sys/class/remoteproc/
total 0
drwxr-xr-x  2 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 remoteproc0 -> ../../devices/platform/3b6e8000.dsp/remoteproc/remoteproc0
root@imx8mp-evk:~# echo -n imx/zephyr/imx8mp_evk-hello_world-zephyr.elf > /sys/class/remoteproc/remoteproc0/firmware
root@imx8mp-evk:~# echo start > /sys/class/remoteproc/remoteproc0/state
root@imx8mp-evk:~#
root@imx8mp-evk:~# echo stop > /sys/class/remoteproc/remoteproc0/state
root@imx8mp-evk:~#
root@imx8mp-evk:~# dmesg | tail
[ 41.494502] audit: type=1334 audit(1709055711.380:21): prog-id=18 op=UNLOAD
[ 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@imx8mp-evk:~#
```

图 2. `hello_world` 应用输出

您可以使用上述步骤来构建和测试任何其他示例，例如 [synchronization](#) 或 [philosophers](#)。

您还可以运行更复杂的示例来演示 Linux 和 Zephyr 如何协同工作。下一节举例说明了 `openamp_rsc_table` 应用程序。

5.2 `openamp_rsc_table` 应用

[Zephyr's openamp_rsc_table](#) 应用演示了如何在 Zephyr 中基于资源表使用开放式非对称多处理（OpenAMP）。它旨在响应：

- [Linux rpmsg client sample](#)
- [Linux rpmsg tty driver](#)

此示例实现与在主处理器上嵌入 Linux 内核操作系统和在协处理器上嵌入 Zephyr 应用程序的平台兼容。

5.2.1 在 DSP 上加载 `openamp_rsc_table` 应用

如 [章节 5.1.1](#) 中所描述，要在 DSP 上加载 `openamp_rsc_table` 应用，请在 Linux 内核中启用 `CONFIG_IMX_DSP_REMOTEPROC` 后使用 `imx_dsp_rproc` 驱动程序。

5.2.2 在 Zephyr 中编译 `openamp_rsc_table` 应用

在 Zephyr 中为 i.MX 8M Plus DSP 编译 `openamp_rsc_table` 应用意味着为 `imx8mp_evk/mimx8ml8/adsp` 板编译应用。

进入 `zephyrproject` 中的 `zephyr/` 文件夹并运行：

```
~/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
```

```
drwxr-xr-x 3 nxa06898 nxp 4096 Sep 27 17:42 boards
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 4096 Sep 27 17:42 soc
drwxr-xr-x 23 nxa06898 nxp 4096 Sep 27 17:42 subsys
-rw-r--r-- 1 nxa06898 nxp 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
...
```

zephyr_openamp_rsc_table.elf 文件用作要加载到 DSP 上的固件。

5.2.3 在 Linux 中的 DSP 上运行 openamp_rsc_table 应用

以下小节介绍了如何在 Linux 中的 i.MX 8M Plus 板上的 HiFi 4 DSP 运行 openamp_rsc_table 应用。

rpmsg_client_sample.ko 和 rpmsg_tty.ko 模块用于与 DSP 上运行的 openamp_rsc_table 应用进行通信。这些是在主处理器（Cortex A 内核）上运行的示例模块。

要构建 rpmsg_client_sample.ko 和 rpmsg_tty.ko 模块，请分别在 Linux 内核中启用 CONFIG_SAMPLE_RPMSG_CLIENT and CONFIG_RPMSG_TTY 配置。

5.2.3.1 启动 i.MX 8M Plus EVK 板

使用特定的 DTS 启动 i.MX 8M Plus EVK 板。

使用 imx8mp-evk-dsp.dtb，插入 imx_dsp_rproc.ko 内核模块后得到：

```
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:~#
```

这里使用的是用于 DSP 的 remoteproc0。

5.2.3.2 检查板上固件

如要检查板上的固件镜像，请使用以下命令：

```
root@imx8mpevk:~# ls -la /lib/firmware/imx/zephyr/
total 472
drwxr-xr-x 2 root root 4096 Mar 9 2018 .
```

```
drwxr-xr-x 12 root root 4096 Mar 9 2018 ..
-rwxr-xr-x 1 root root 58068 Mar 9 2018 imx8mp_evk-hello_world-zephyr.elf
-rwxr-xr-x 1 root root 139300 Mar 9 2018 imx8mp_evk-openamp_rsc_table-
zephyr.elf
-rwxr-xr-x 1 root root 72460 Mar 9 2018 imx8mp_evk-philosophers-zephyr.elf
-rwxr-xr-x 1 root root 63252 Mar 9 2018 imx8mp_evk-synchronization-
zephyr.elf
-rwxr-xr-x 1 root root 64212 Mar 9 2018 imx8qm_mek-hello_world-zephyr.elf
-rwxr-xr-x 1 root root 64212 Mar 9 2018 imx8qxp_mek-hello_world-zephyr.elf
root@imx8mpevk:~#
```

在探测 remoteproc 驱动程序之前，固件必须存在于 `/lib/firmware` 中；然而，它也可以用绝对路径给出。

5.2.3.3 插入 `imx_dsp_rproc.ko` 内核模块

如要插入 `imx_dsp_rproc` 内核模块，请使用以下命令：

```
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:~#
```

5.2.3.4 插入 `rpmsg Linux` 客户端示例

如要插入 `rpmsg Linux` 客户端示例，请使用以下命令：

```
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/ttyRMSGx */
```

5.2.3.5 在 DSP 上加载并运行固件

5.2.3.5.1 `rpmsg` 客户端示例

从 Linux 向 Zephyr 发送一百条带有 `hello world` 的消息。

Linux 控制台：

```
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 -> 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: 0x401)
[ 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:~#
```

默认情况下，Zephyr 控制台仅打印：

```
*** Booting Zephyr OS build v3.6.0-4997-gl3a33fe368c2 ***
```

如果从工程配置中禁用 CONFIG_SHELL，我们会得到：

```
*** Booting Zephyr OS build v3.6.0-4997-gl3a33fe368c2 ***
[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
```

5.2.3.5.2 rpmsg TTY 演示

在 Linux 控制台上，向 Zephyr 发送信息，其使用 TTY <add> 前缀进行回复。<add> 为 Zephyr rpmsg-tty 的地址。

Linux 控制台：

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

5.2.3.6 停止固件

要停止固件，请使用以下命令：

```
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 获取 openamp_rsc_table 应用输出

要获取 openamp_rsc_table 应用输出，请执行以下步骤：

- 通过 UART 获取控制台。
- 在第四个串行端口上打开串行终端：

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

您在终端中看到以下消息（也显示在 [图 3](#)）：

```
*** Booting Zephyr OS build v3.6.0-4997-gl3a33fe368c2 ***
```

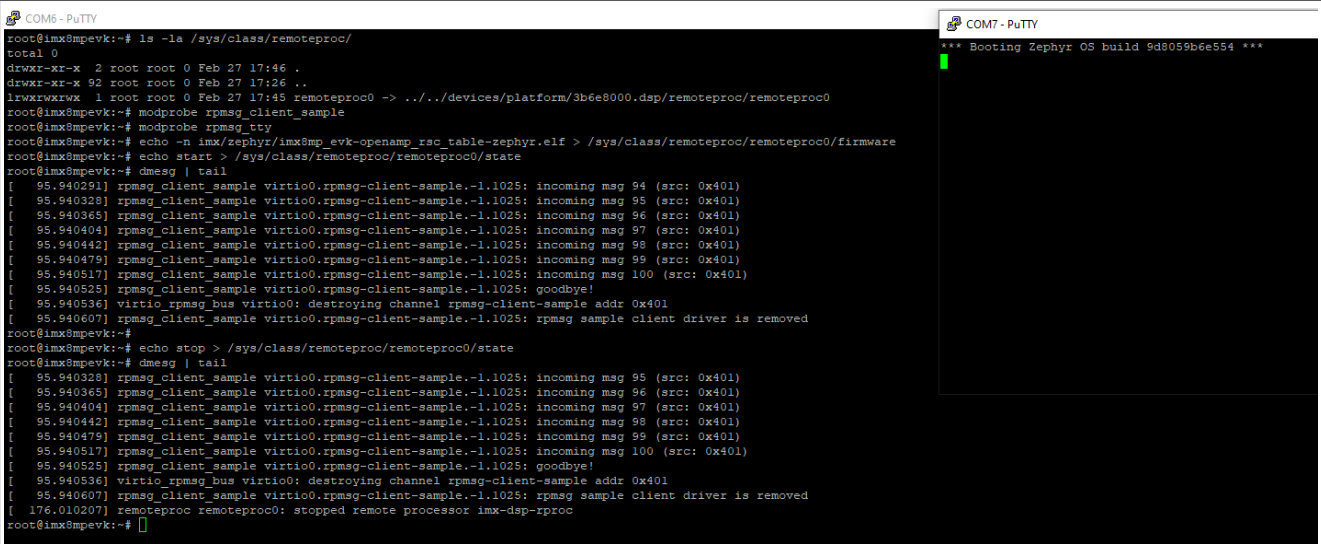


图 3. openamp_rsc_table 应用输出

6 缩略语

[Table 3](#) 列出了本文档中使用的缩略语。

Table 3. 缩略语

缩略语	全称
DSP	Digital signal processor
DTS	Device tree source
IPC	Inter-process communication
MCU	Microcontroller unit
MPU	Microprocessor unit
OpenAMP	Open Asymmetric Multi-Processing
OS	Operating system
rproc	Remote processor
rsc_table	Resource table

Table 3. 缩略语...continued

缩略语	全称
RTOS	Real-time operating system
UART	Universal Asynchronous Receiver/Transmitter

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8 修订记录

表 4 汇总了自初始版以来对本文档所做的更改。

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文档号	日期	说明
AN13970_ZH v.3	2024 年 6 月 14 日	• Changed nxp_adsp_imx8m board to imx8mp_evk/mimx8m18/adsp • 更新以下图： - 图 2 - 图 3 • 更新下列章节中的代码： - 章节 5.1.3.2 - 章节 5.1.3.3 - 章节 5.1.3.4 - 章节 5.1.3.5 - 章节 5.1.4 - 章节 5.1.3.1 - 章节 5.1.3.2 - 章节 5.2.3.3

表 4. 修订记录...续上页

文档号	日期	说明
		- 章节 5.2.3.4 - 章节 5.2.3.5.1 - 章节 5.2.3.5.2 - 章节 5.1.3.5 - 章节 5.2.4
AN13970_ZH v.2	2023 年 11 月 28 日	• 更新以下章节： - 章节 5.1.2 - 章节 5.1.3.1 - 章节 5.1.3.2 - 章节 5.1.3.3 - 章节 5.1.3.4 - 章节 5.1.3.5 - 章节 5.1.4 • 增加新章节: 章节 5.2
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内容

1 介绍2

2 硬件平台2

3 Zephyr 操作系统 3

4 HiFi 四音频数字信号处理器 DSP4

4.1 支持的功能4

4.2 连接和 I/Os 4

4.3 系统时钟4

4.4 串行端口4

5 在 HiFi 4 DSP 上构建和运行 Zephyr 示例 5

5.1 hello_world 应用 5

5.1.1 在 DSP 上加载 hello_world 应用 5

5.1.2 编译 hello_world application 5

5.1.3 在 DSP 上运行 hello_world 应用的步骤6

5.1.3.1 启动 i.MX 8M Plus EVK 板6

5.1.3.2 检查电路板上的固件6

5.1.3.3 插入 imx_dsp_rproc.ko 内核模块6

5.1.3.4 在 DSP 上加载并运行固件7

5.1.3.5 停止固件7

5.1.4 获取 hello_world 应用输出7

5.2 openamp_rsc_table 应用 8

5.2.1 在 DSP 上加载 openamp_rsc_table 应用 8

5.2.2 在 Zephyr 中编译 openamp_rsc_table 应用8

5.2.3 在 Linux 中的 DSP 上运行 openamp_rsc_table 应用9

5.2.3.1 启动 i.MX 8M Plus EVK 板 9

5.2.3.2 检查板上固件 9

5.2.3.3 插入 imx_dsp_rproc.ko 内核模块 10

5.2.3.4 插入 rpmsg Linux 客户端示例 10

5.2.3.5 在 DSP 上加载并运行固件 10

5.2.3.6 停止固件12

5.2.4 获取 openamp_rsc_table 应用输出 13

6 缩略语 13

7 Note about the source code in the document14

8 修订记录14

Legal information16

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