

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 |
|-----|--|
| 关键字 | i.MX 8M Plus、HiFi 4 DSP、Zephyr、Linux |
| 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板基于恩智浦i.MX 8M Plus应用处理器，由以下部分组成：

- 4个Arm Cortex-A53，频率高达1.8 GHz
- 1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。

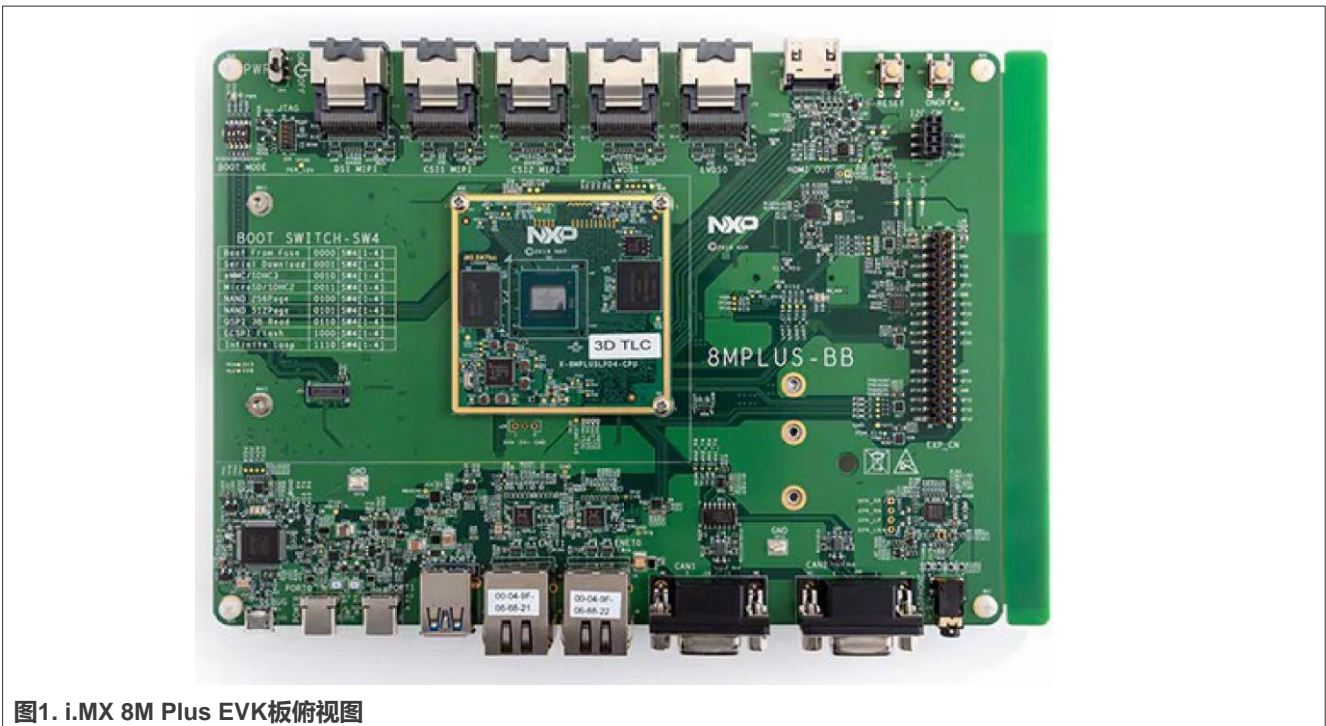


图1. i.MX 8M Plus EVK板俯视图

如需了解详情，请参阅[恩智浦网站](#)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。

恩智浦提供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 4音频数字信号处理器（DSP）

HiFi 4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npx_adsp_imx8m。

4.1 支持的功能

Zephyr npx_adsp_imx8m板的配置支持以下硬件功能。

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; serial port-interrupt |

默认配置可在defconfig文件中找到：[boards/xtensa/npx_adsp_imx8m/npx_adsp_imx8m_defconfig](#)。

该端口目前不支持其他硬件功能。

4.2 连接和IO

i.MX 8M Plus EVK板使用以下pinmux控制器配置进行测试。

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800MHz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。

5.1 hello_world应用

[Zephyr的hello_world](#)应用是一个简单的示例，支持用于多种[电路板](#)，并在控制台中打印“Hello World”。

5.2 在DSP上加载应用

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

在Linux中，可以使用[通用的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。

5.2.1 在DSP上运行hello_world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。

5.2.1.1 编译hello_world应用

在Zephyr中为i.MX 8M Plus DSP（即Zephyr中的nxp_adsp_imx8m板）编译hello_world应用。要启用UART，请使用nxp_adsp_imx8m_uart.overlay DTC覆盖文件和nxp_adsp_imx8m_uart.conf配置片段文件。

从zephyrproject转到zephyr/文件夹并运行：

```
~/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
drwxr-xr-x  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
-rwxr-xr-x  1 user nxp   699020 Apr 28 17:23 zephyr.elf
-rw-r--r--  1 user nxp   437808 Apr 28 17:23 zephyr_final.map
```

```
-rw-r--r-- 1 user nxp 646830 Apr 28 17:23 zephyr.lst
-rw-r--r-- 1 user nxp 437808 Apr 28 17:23 zephyr.map
...
```

zephyr.elf文件将作为固件加载到DSP上。

5.2.1.2 启动i.MX 8M Plus板

使用特定DTS启动i.MX 8M Plus板。

使用imx8mp-evk-rpmsg.dtb, 插入imx_dsp_rproc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 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:~#
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:~#
```

由于remoteproc1用于DSP, 因此使用此模块。

5.2.1.3 检查电路板上的固件

检查电路板上的固件映像:

```
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:~#
```

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。

5.2.1.4 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Zephyr示例应用不会发送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/6.1.22+ge708cbc250ef/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)
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/* /*
no_mailboxes param is off */
/sys/module/imx_dsp_rproc/parameters/no_mailboxes:0
root@imx8mpevk:~#
root@imx8mpevk:~# rmmod imx_dsp_rproc /* remove kernel module */
[ 797.922929] remoteproc remoteproc1: releasing imx-dsp-rproc
root@imx8mpevk:~#
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:~#
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 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/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
[ 1900.194904] remoteproc remoteproc1: Direct firmware load for /lib/firmware/
imx/zephyr/imx8m-hello-world-zephyr.elf failed with error -2
[ 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 停止固件

要停止固件，请执行以下命令：

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

5.3 获取应用输出

1. 通过UART获取控制台和shell。
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：

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

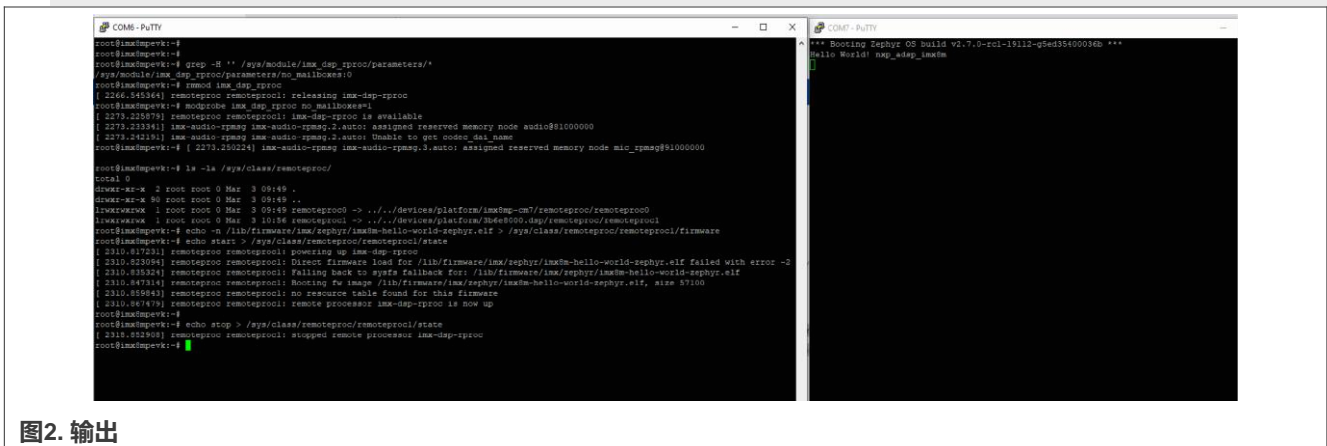


图2. 输出

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

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7 修订历史

[表3](#)总结了对本文所做的修订。

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目录

| | | |
|-------|---------------------------------|---|
| 1 | 介绍 | 2 |
| 2 | 硬件平台 | 2 |
| 3 | Zephyr操作系统 | 3 |
| 4 | HiFi 4音频数字信号处理器 (DSP) | 3 |
| 4.1 | 支持的功能 | 3 |
| 4.2 | 连接和IO..... | 3 |
| 4.3 | 系统时钟..... | 3 |
| 4.4 | 串行端口..... | 4 |
| 5 | 在HiFi 4 DSP上构建和运行Zephyr示例 | 4 |
| 5.1 | hello_world应用..... | 4 |
| 5.2 | 在DSP上加载应用 | 4 |
| 5.2.1 | 在DSP上运行hello_world的步骤 | 4 |
| 5.3 | 获取应用输出 | 7 |
| 6 | 关于本文中源代码的说明 | 7 |
| 7 | 修订历史 | 8 |
| 8 | 法律声明 | 9 |

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