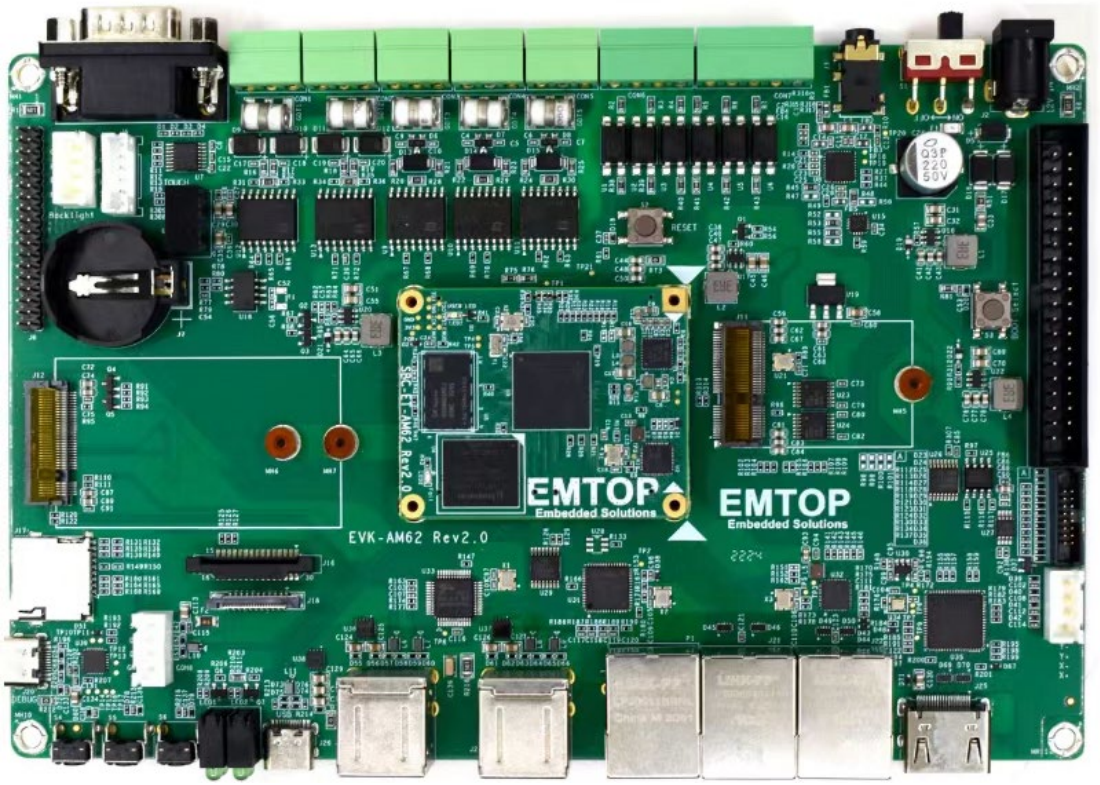
EVK-ET-AM62



SOM-ET-AM62 + EVK-ET-AM62

用户手册

Version: 0.5

2024-11-13

修订记录：

Version	Date	Description
0.1	2024-05-13	Trial Release
0.2	2024-08-21	Support M2 WiFi/BT, GSM
0.3	2024-09-19	Update and release CN
0.4	2024-10-05	Fix DI/DO operation
0.5	2024-11-13	Rename to EVK-ET-AM62

Table of Contents

1. 产品简介

2. Linux 操作系统

本章将为您全面介绍产品附带的 DVD-ROM 中包含的 Linux 软件资源，并详细介绍 Linux 系统开发的过程、驱动开发、系统更新、功能测试和应用程序开发实例。

Note：

🕮 建议提前学习 Ubuntu Linux 安装、嵌入式 Linux 开发技术。

2.1 软件资源

随板提供的 DVR-ROM 包含演示、应用示例、Linux 源代码和工具，帮助您轻松快速地开发 Linux 应用程序和系统。

2.1.1 资源目录

您可以按照下表所示的信息找到 DVD-ROM 中包含的程序、代码等软件资源；

类别	目录
应用程序	
源码	CD\Source\u-boot-ti-2023.04
	CD\Source\linux-ti-6.1.33
	CD\Source\App
工具	CD\Tools\
映像	CD\Image

2.1.2 BSP

下表列出了 BSP 中包含的文件类型和格式：

Names	Note	Formats

BOOTLOADER	U-BOOT	MMC/SD	Source Code
		FAT	Source Code
		NET	Source Code
KERNEL	LINUX-6.1.33	Support JFFS2/EXT4/FAT/NFS various of file system	Source Code
DEVICE DRIVER	PMIC	PCA9450CHN driver	Source Code
	SERIAL	Serials driver	Source Code
	RTC	Hardware RTC driver	Source Code
	NET	10/100M/1Gbps Ethernet driver	Source Code
	CAN	CAN bus driver	Source Code
	SPI	SPI driver	Source Code
	MIPI-DSI	MIPI-DSI driver	Source Code
	HDMI	SII9022ACNU HDMI driver	Source Code
	I2C	I2C driver	Source Code
	LVDS	LCD driver	Source Code
	TOUCH SCREEN	I2C touch panel driver	Source Code
	MMC/SD	MMC/SD controller driver	Source Code
	USB HOST	USB HOST driver	Source Code
	AUDIO	NAU88C22YG Audio driver(supports recording & playback)	Source Code
	BUTTON	GPIO button driver	Source Code
	LED	LED driver	Source Code
	CAMERA	CSI Camera driver	Source Code
	WIFI/BT	NXP 88W8987 driver	Source Code
ROOTFS	YOCTO	Wayland with Qt 5.15	Image

2.2 嵌入式 Linux 系统结构

EVK-ET-AM62 默认搭载的是 Linux-6.1.33 eMMC 系统，该系统由 bootloader、kernel、rootfs 组成，下表是嵌入式 Linux 系统结构。

eMMC/SD		
Partition	FAT	EXT4
Image	Bootloader, DTB, Kernel	Yocto Rootfs

1) Bootloader 是 u-boot 编译生成的程序，文件名为**tiboot3.bin**，**tispl.bin** 和**u-boot.img**。
2) 本文档所采用的内核是Linux-6.1.33，并根据硬件设计进行了定制。
3) Rootfs存储开源系统Yocto，格式为EXT4。

2.3 搭建开发环境

在开发软件之前，用户需要在 PC 上建立 Linux 交叉开发环境。本节将以 Ubuntu22.04 操作系统为例介绍如何建立交叉开发环境。

强烈建议通过以下命令为新安装的 Ubuntu 安装必要的软件包。

- **sudo apt-get update; sudo apt-get install -y build-essential git xz-utils ncurses-dev autoconf libtool automake texinfo bison flex libc6:i386 libncurses5:i386 libstdc++6:i386**

Note：

🕮 每条指令前均有“•”标记，以避免因长指令占用多行而造成混淆。

🕮 请注意每条指令内的空格；缺少任何空格都会导致执行指令失败。

2.3.1 安装交叉编译工具

我们在**Tools**目录下提供了交叉编译器：**arm-gnu-toolchain-11.3.rel1-x86_64-aarch64-none-linux-gnu.tar.xz**，**arm-gnu-toolchain-11.3.rel1-x86_64-arm-none-linux-gnueabihf.tar.xz**和**gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu.tar.xz**.。

该编译器主要用于编译u-boot和kernel。

- **sudo mkdir -p /opt/bin/arm**
- **sudo tar -xvf <YOUR_PATH>/arm-gnu-toolchain-11.3.rel1-x86_64-aarch64-none-li**

nux-gnu.tar.xz -C /opt/bin/arm

- sudo tar -xvf <YOUR_PATH>/arm-gnu-toolchain-11.3.rel1-x86_64-arm-none-linux-gnueabihf.tar.xz -C /opt/bin/arm
- sudo tar -xvf <YOUR_PATH>/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu.tar.xz -C /opt/bin/arm

它将解压并安装在**/opt/bin/arm**目录下，保留默认设置。

2.3.2 设置交叉编译环境

运行以下命令设置源代码构建环境：

- export PATH=/opt/bin/arm/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu/bin:$PATH
- export ARCH=arm64
- export CROSS_COMPILE=arm-linux-

Note：

🕮 可以在用户目录下的**.bashrc** 文件中添加指令，这样系统启动时就会自动加载添加的环境变量；

🕮 如果你想检查路径，请使用指令 **printenv PATH**

2.4 准备源代码

请参考章节《**1.2 资源下载**》获取开发资料，或者从 **Source** 目录下获取源代码。

- tar -xvf u-boot-ti-2023.04-git-xxxxxx.tar.xz
- tar -xvf linux-ti-6.1.33-git-xxxxxx.tar.xz

然后我们就可以得到源代码目录 **u-boot-ti-2023.04** 和 **linux-ti-6.1.33**。

2.5 编译

1） 编译 Bootloader

运行以下命令编译 bootloader：

- **cd u-boot-ti-2023.04**
- **git checkout .**
- **vi make.sh**

```
export PATH=/opt/bin/arm/arm-gnu-toolchain-11.3.rel1-x86_64-aarch64-none-linux-gnu/bin:$PATH
export PATH=/opt/bin/arm/arm-gnu-toolchain-11.3.rel1-x86_64-arm-none-linux-gnueabihf/bin:$PATH

DESTDIR="/dev/shm/"
```

PATH: 若安装在其它目录下，请根据您本地环境替换编译器路径。

DESTDIR: 指向存储目标映像的目录。

根据您的本地环境更改 **DESTDIR** 值以使其指向您的目标目录。

- **./make.sh setup**

该命令将安装编译过程需要调用的若干组件。

- **./make.sh**

所有命令成功完成后，您可以在 **DESTDIR** 目录下找到如下启动映像：

```
DDR1G
├── tiboot3.bin
├── tispl.bin
└── u-boot.img
DDR2G
├── tiboot3.bin
├── tispl.bin
└── u-boot.img
DDR4G
├── tiboot3.bin
├── tispl.bin
└── u-boot.img
```

如果您只需要为 DDR1G、DDR2G 或 DDR4G 编译引导程序，请运行以下命令编译其中一个：

- **./make.sh 1g**
- **./make.sh 2g**
- **./make.sh 4g**

2） 编译 Kernel

执行如下指令编译内核：

- **cd linux-ti-6.1.33**
- **git checkout .**
- **vi make.sh**

```
export PATH=/opt/bin/arm/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu/bin:$PATH
export ARCH=arm64
export CROSS_COMPILE=aarch64-linux-gnu-

DESTDIR="/dev/shm"
```

PATH: 若安装在其它目录下，请根据您本地环境替换编译器路径。

DESTDIR: 指向存储目标映像的目录。

根据您的本地环境更改 **DESTDIR** 值以使其指向您的目标目录。

- **make ARCH=arm64 distclean**
- **./make.sh modules**

如果编译成功，您可以在 **DESTDIR** 目录下找到名为**.dtb** 文件、**Image** 和 **lib/modules/6.1.33**。

Note：

The command **./make.sh**:

```
./make.sh                 # build dtbs and Image
./make.sh modules         # build dtbs, Image and driver modules
```

2.6 Yocto SDK

编译用户应用程序[Linux C/C++项目]有两种方法：

① 板上编译

② PC Ubuntu 系统用 Yocto SDK 编译

如果应用程序代码比较简单，并且不包含太多第三方库，可以尝试在板上编译。例如，让我们尝试编译 UART 程序[**Source/App/com.tar.xz**]：

- root@arm:~# **vi Makefile**

```
# CROSS_COMPILE ?= arm-linux-

all:
	$(CROSS_COMPILE)gcc -s -o com com_example.c

clean:
	rm -fr com *~
```

- root@arm:~# **make**

```
gcc -s -o com com_example.c
```

现在，我们已经得到了目标 ELF 文件 **com**。尝试运行并检查：

- root@arm:~# **./com -h**

```
Usage: ./com option [ dev... ]
	-h  --help      Display this usage information.
	-d  --device    The device ttyS[0-3] or ttyEXT[0-3]
	-s  --string    Write the device data
	-f  --flow      Flow control switch
	-b  --speed     Set speed bit/s
	-m  --mode      Set mode, rs232 or rs485
	-n  --count     Repeat times, default non-stop
```

如果应用程序代码很复杂，并且我们无法在板上成功编译它，请尝试使用 Yocto SDK 在 Ubuntu 下进行编译。

2.6.1 编译 Yocto SDK

Note：

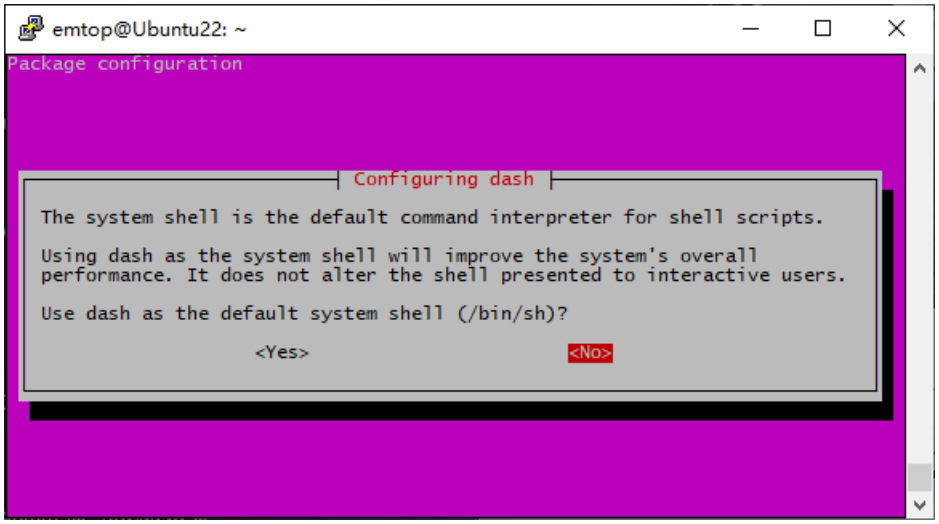
🕮 这是一个可选操作步骤。仅当您想构建自己的 SDK 时才需要用到。

请参考 TI 官方文档：**https://software-dl.ti.com/processor-sdk-linux-rt/esd/AM62X/09_00_00_03/exports/docs/linux/Overview_Building_the_SDK.html**

[HOST] Ubuntu 22.04

- **sudo apt-get update**
- **sudo apt-get -f -y install git build-essential diffstat texinfo gawk chrpath socat doxygen dos2unix python3 bison flex libssl-dev u-boot-tools mono-devel mono-complete curl python3-distutils repo pseudo python3-sphinx g++-multilib libc6-dev-i386 jq git-lfs pigz zstd liblz4-tool cpio file zstd lz4**
- **sudo dpkg-reconfigure dash**

当要求您使用 dash 作为默认系统 shell 时，请务必选择“否”：



- **git clone https://git.ti.com/git/arago-project/oe-layersetup.git tisdk**
- **cd tisdk**
- **./oe-layertool-setup.sh -f configs/processor-sdk/processor-sdk-09.00.00-config.txt**
- **cd build**

- **. conf/setenv**
- **export TOOLCHAIN_PATH_ARMV7=/opt/bin/arm/arm-gnu-toolchain-11.3.rel1-x86_64-arm-none-linux-gnueabihf**
- **export TOOLCHAIN_PATH_ARMV8=/opt/bin/arm/arm-gnu-toolchain-11.3.rel1-x86_64-aarch64-none-linux-gnu**
- **vi ../sources/meta-processor-sdk/recipes-graphics/powervr-graphics/powervr-graphics_5.10.bb**

```
DESCRIPTION = "Imagination PowerVR SDK binaries/examples"
LICENSE = "MIT"

SRC_URI = " \
    gitsm://github.com/powervr-graphics/Native_SDK.git;protocol=https;branch=${BRANCH} \
    file://0001-PATCH-use-library-so-names-for-linking.patch \
"
```

- **vi /etc/hosts**

```
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters

185.199.108.133 raw.githubusercontent.com
```

编译系统映像：

- **MACHINE=am62xx-evm ARAGO_RT_ENABLE=1 bitbake tisdk-default-image**

生成 **arago-tmp-default-glibc/deploy/images/am62xx-evm/tisdk-default-image-am62xx-evm.wic.xz**.

Note：

📖 **wic.xz** 是一个软链接，请检查它指向的真实文件。

2.6.2 安装 Yocto SDK

用如下命令安装 SDK **Tools/arago-2023.04.tar.xz**：

- **sudo tar -xvf <YOUR_PATH>/arago-2023.04.tar.xz -C /opt**

2.6.3 编译用户应用程序项目

让我们尝试编译一个 Qt 示例 **easing**，它来自 **qt-everywhere-src-6.5.0/qtbase/examples/widgets/animation/easing**。从 **Source/easing.tar.xz** 获取。

- **source /opt/arago-2023.04/environment-setup**
- **cd easing**
- **qmake**

```
Info: creating stash file easing/.qmake.stash
```

- **make**

```
.....
aarch64-oe-linux-g++ --sysroot=/opt/arago-2023.04/sysroots/aarch64-oe-linux --sysroot=/opt/arago-2023.04/sysroots/aarch64-oe-linux --sysroot=/opt/arago-2023.04/sysroots/aarch64-oe-linux -Wl,-O1 -o easing main.o window.o qrc_easing.o moc_window.o /opt/arago-2023.04/sysroots/aarch64-oe-linux/usr/lib/libQt5Widgets.so /opt/arago-2023.04/sysroots/aarch64-oe-linux/usr/lib/libQt5Gui.so /opt/arago-2023.04/sysroots/aarch64-oe-linux/usr/lib/libQt5Core.so -lGLESv2 -lpthread
```

- **file easing**

```
easing: ELF 64-bit LSB shared object, ARM aarch64, version 1 (GNU/Linux), ...
```

将目标文件 **easing** 复制到 ARM 板，运行它，您就可以看到动画界面。

2.7 Linux 系统定制

为了满足客户的不同需求，开发人员常常需要在Linux内核默认配置的基础上进行一些定制化的修改，本章将通过实例介绍系统定制的过程。

2.7.1 替换 U-BOOT LOGO

[Not supported]

Note：

2.7.2 设置配置菜单

内核源代码下提供了一个默认的配置文件：

linux-ti-6.1.33/kernel/configs/emtop-sbc-et-am62.config

请执行以下命令进入配置菜单：

- **cd linux-ti-6.1.33**
- **export PATH=/opt/bin/arm/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu/bin:$PATH**
- **export ARCH=arm64**
- **export CROSS_COMPILE=aarch64-linux-gnu-**
- **make defconfig ti_arm64_prune.config ti_rt.config emtop-sbc-et-am62.config**
- **make menuconfig**

Note：

如果执行 **make ARCH=arm64 menuconfig** 命令时出现错误，您可能需要在 Ubuntu 系统中安装 ncurse，ncurses 是生成配置菜单所需的字符图形库，请输入以下指令安装该库：
sudo apt-get install libncurses5-dev

2.7.3 菜单选项

进入配置菜单后根据定制需求配置选项，例如，访问 **Device Drivers > Input device support > Touchscreens > EDT FocalTech FT5x06 I2C Touchscreen support**

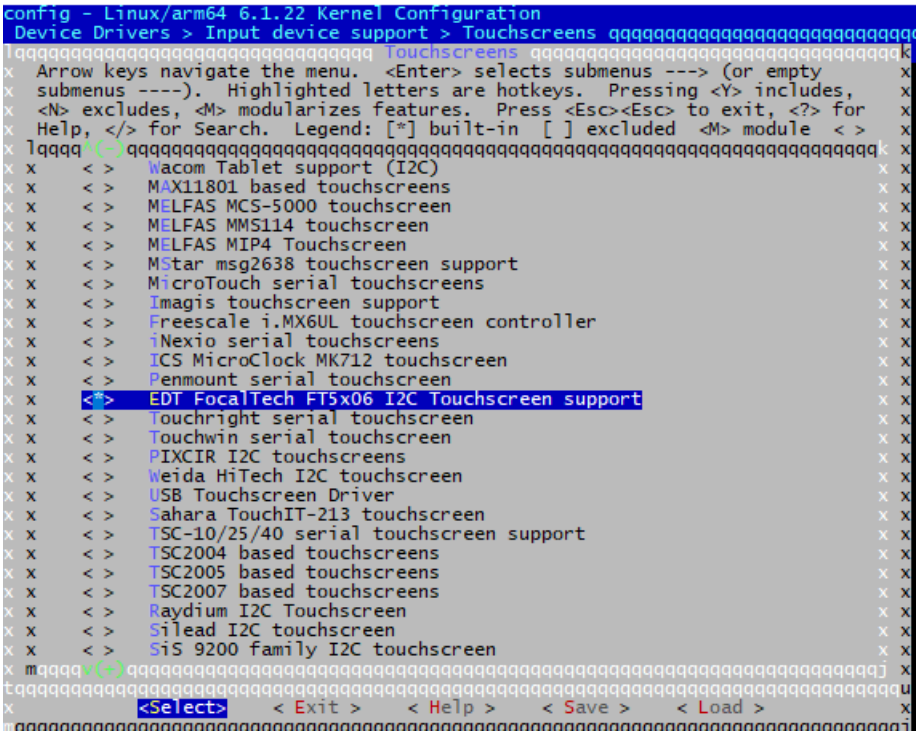
如下图所示:

-> Device Drivers

-> Input device support

-> Touchscreens

-> EDT FocalTech FT5x06 I2C Touchscreen support



开启 Goodix I2C touchscreen to **<*>**, 退出并保存。

2.7.4 编译 Kernel

请执行如下指令重新编译内核：

- **./make.sh**

该脚本不会覆盖 menuconfig 修改的配置。这意味着您修改的当前设置在目标内核映像中有效。

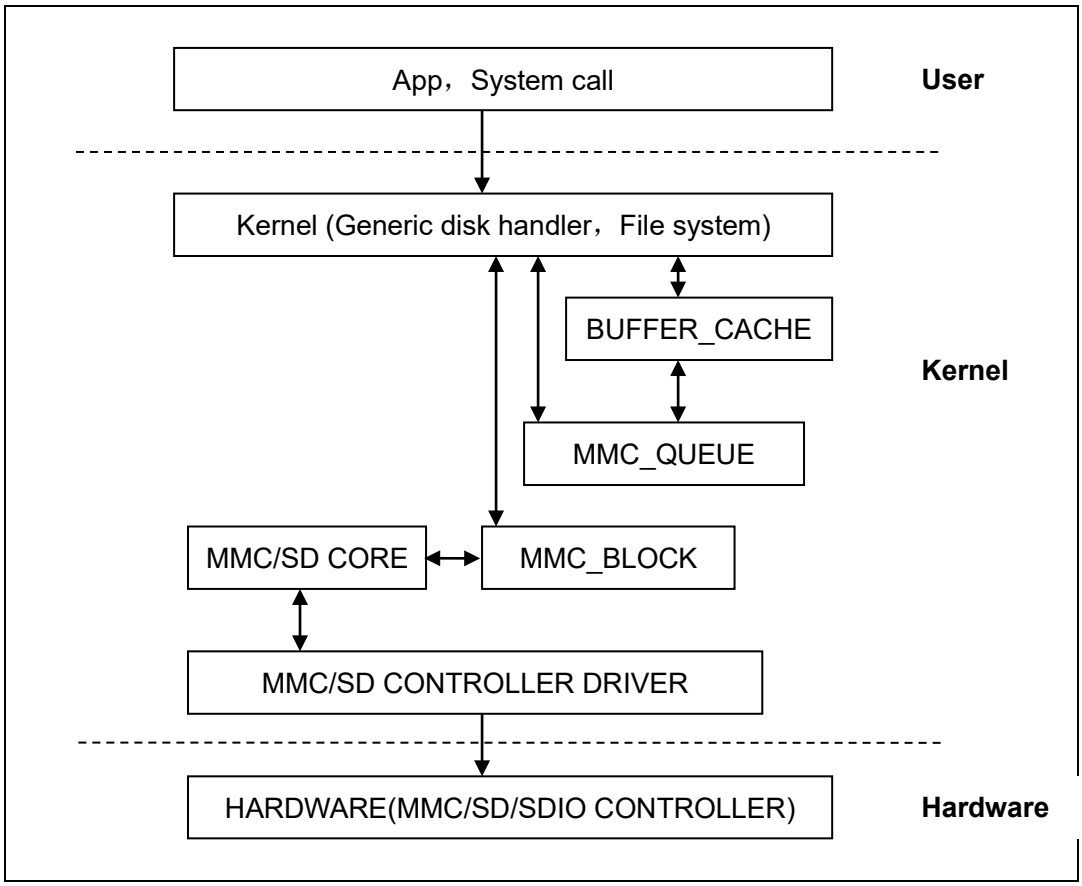
如果您想恢复默认配置，请删除文件**.config** 并运行**./make.sh**。

2.8 内核驱动介绍

下表显示了查找所有驱动程序的访问路径：

Category	Name	Description	Location
Bootloader	U-BOOT	MMC/SD	drivers/mmc/am654_sdhci.c
		FAT	fs/
		NET	drivers/net/ti/am65-cpsw-nuss.c
Kernel	Linux-6.1.33	Support JFFS2/EXT4/FAT/NFS etc.	fs/
Devices	SERIAL	Serial driver	drivers/tty/serial/8250/8250_omap.c
	RTC	Hardware RTC driver	drivers/rtc/rtc-rx8010.c
	NET	10/100M/1000M Ethernet driver	drivers/net/ethernet/ti/am65-cpsw-nuss.c
	CAN	CAN bus driver	drivers/net/can/m_can/m_can_platform.c
	SPI	SPI driver	drivers/spi/spi-omap2-mcspi.c
	DSS	DSS driver	drivers/gpu/drm/tidss/tidss_drv.c
	MIPI-DSI	MIPI-DSI driver	drivers/gpu/drm/panel/panel-simple.c
	HDMI	HDMI driver	drivers/gpu/drm/bridge/sii902x.c
	TOUCH SCREEN	I2C touch panel driver	drivers/input/touchscreen/goodix.c
	MMC/SD	MMC/SD controller driver	drivers/mmc/host/sdhci_am654.c
	USB	USB controller driver	drivers/usb/dwc3/dwc3-am62.c
	AUDIO	NAU88C22 Audio driver(supports recording & playback)	sound/soc/codecs/nau8822.c
	BUTTON	GPIO button driver	drivers/input/keyboard/gpio_keys.c
	LED	LED driver	drivers/leds/leds-gpio.c
	WIFI/BT	NXP 88W8987 driver	3rdparty/mwifiex-lf-6.1.22_2.0.0
	CAMERA	CSI Camera driver	drivers/media/i2c/ov5640.c

2.8.1 SD/MMC



Linux 下的 SD/MMC 驱动主要由 SD/MMC core、mmc_block、mmc_queue 以及 SD/MMC 驱动组成：

1） SD/MMC core 实现 SD/MMC 卡操作中与结构体无关的代码；

2） mmc_block 实现 SD/MMC 卡作为块设备时的驱动结构；

3） mmc_queue 实现请求队列的管理；

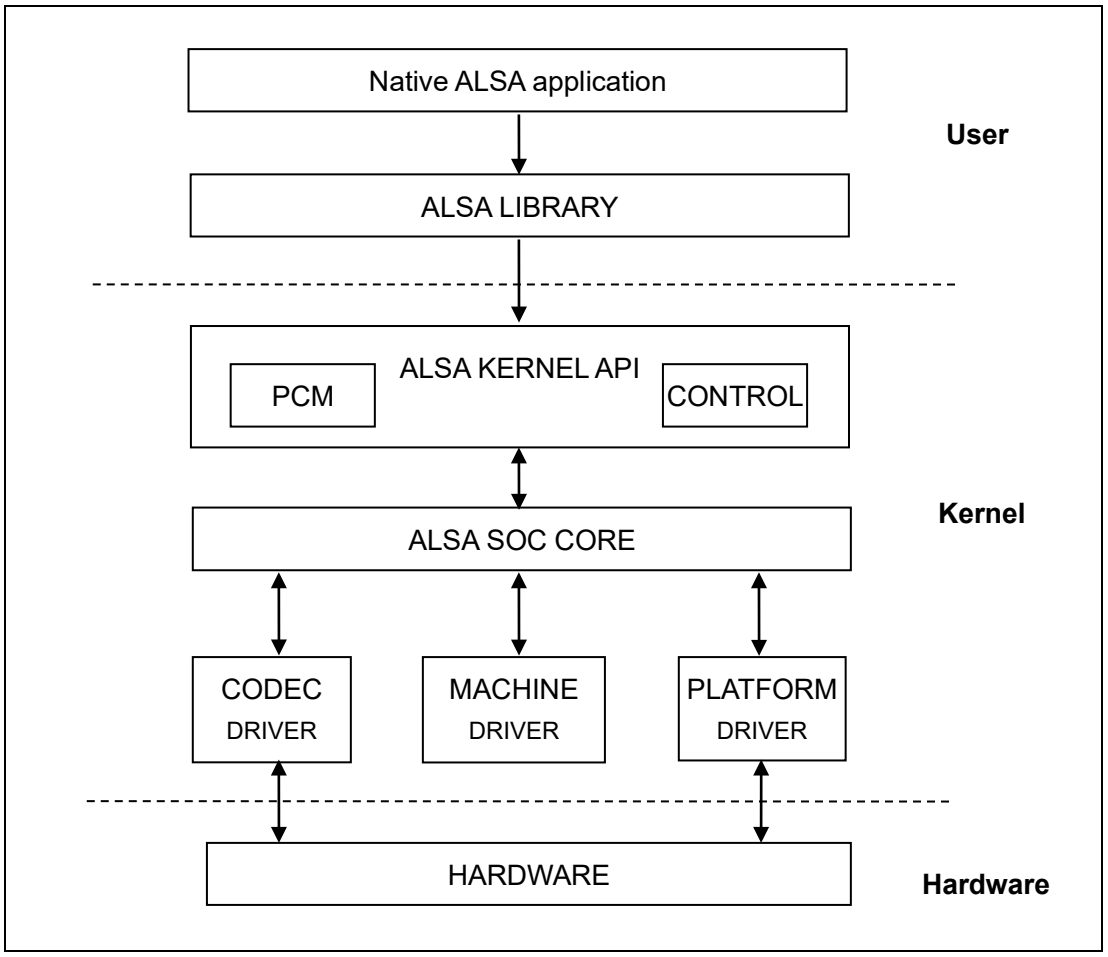
4） SD/MMC driver 实现具体的控制器驱动。

驱动及相关文件：

linux-ti-6.1.33/drivers/mmc/

linux-ti-6.1.33/drivers/mmc/host/sdhci_am654.c

2.8.2 Audio In/Out



ASoC 嵌入式音频系统基本上由三个组件组成：

1） 编解码器驱动程序：编解码器驱动程序独立于平台，包含音频控制、音频接口功能、编解码器 dapm 定义和编解码器 IO 功能；

2） 平台驱动程序：它包含该平台的音频 dma 引擎和音频接口驱动程序（例如 I2S、AC97、PCM）；

3） 板级驱动程序：板级驱动程序处理任何特定于机器的控件和音频事件，即在开始播放时打开放大器。

驱动及相关文件：

linux-ti-6.1.33/sound/soc/ti

linux-ti-6.1.33/sound/soc/codecs/nau8822.c

2.9 驱动开发

2.9.1 GPIO_LEDs 驱动

1）设备定义

linux-ti-6.1.33/arch/arm64/boot/dts/ti/emtop-evk-et-am62.dts

配置 GPIO0_12 作为系统运行状态指示灯，心跳闪烁。

```
leds {
    compatible = "gpio-leds";
    pinctrl-names = "default";
    pinctrl-0 = <&pinctrl_gpio_led>;

    sys {
        label = "sys";
        gpios = <&main_gpio0 12 GPIO_ACTIVE_HIGH>;
        linux,default-trigger = "heartbeat";
    };
```

2）GPIO pinmux 配置

linux-ti-6.1.33/arch/arm64/boot/dts/ti/emtop-evk-et-am62.dts

将 OSPI0_CSN1 配置为 GPIO0_12 功能：

```
&main_pmx0 {
    ...
    usr_led_pins_default: usr-led-pins-default {
        pinctrl-single,pins = <
            AM62X_IOPAD(0x030, PIN_OUTPUT, 7) /* (G21) OSPI0_CSN1.GPIO0
_12 */
        >;
    };
};
```

3）Driver 设计

linux-ti-6.1.33/drivers/leds/leds-gpio.c

a) 调用 platform_driver_register 注册 gpio_leds 驱动

```
static struct platform_driver gpio_led_driver = {
      .probe          = gpio_led_probe,
      .shutdown       = gpio_led_shutdown,
      .driver         = {
            .name     = "leds-gpio",
            .of_match_table = of_gpio_leds_match,
       },
};

module_platform_driver(gpio_led_driver);

MODULE_AUTHOR("Raphael Assenat <raph@8d.com>, Trent Piepho <tpiepho@freescale.com>");
MODULE_DESCRIPTION("GPIO LED driver");
MODULE_LICENSE("GPL");
MODULE_ALIAS("platform:leds-gpio");
```

b) 申请 gpio，调用 led_classdev_register 注册 led_classdev 驱动。

```
static int gpio_led_probe(struct platform_device *pdev)
{
…
      priv->num_leds = pdata->num_leds;
            for (i = 0; i < priv->num_leds; i++) {
                  const struct gpio_led *template = &pdata->leds[i];
                  struct gpio_led_data *led_dat = &priv->leds[i];

                  if (template->gpiod)
                        led_dat->gpiod = template->gpiod;
                  else
                        led_dat->gpiod =
                              gpio_led_get_gpiod(&pdev->dev,
                                          i, template);
                  if (IS_ERR(led_dat->gpiod)) {
                        dev_info(&pdev->dev, "Skipping unavailable LED gpio %d (%s)\n",
                              template->gpio, template->name);
                        continue;
                  }

                  ret = create_gpio_led(template, led_dat,
                                    &pdev->dev, NULL,
```

```
                                pdata->gpio_blink_set);
                if (ret < 0)
                    return ret;
            }
        } else {
            priv = gpio_leds_create(pdev);
            if (IS_ERR(priv))
                return PTR_ERR(priv);
        }

        platform_set_drvdata(pdev, priv);

        return 0;
}

static int create_gpio_led(const struct gpio_led *template,
        struct gpio_led_data *led_dat, struct device *parent,
        struct fwnode_handle *fwnode, gpio_blink_set_t blink_set)
{
        struct led_init_data init_data = {};
        int ret, state;

        led_dat->cdev.default_trigger = template->default_trigger;
        led_dat->can_sleep = gpiod_cansleep(led_dat->gpiod);
        if (!led_dat->can_sleep)
            led_dat->cdev.brightness_set = gpio_led_set;
        else
            led_dat->cdev.brightness_set_blocking = gpio_led_set_blocking;
        led_dat->blinking = 0;
        if (blink_set) {
            led_dat->platform_gpio_blink_set = blink_set;
            led_dat->cdev.blink_set = gpio_blink_set;
        }
        if (template->default_state == LEDS_GPIO_DEFSTATE_KEEP) {
            state = gpiod_get_value_cansleep(led_dat->gpiod);
            if (state < 0)
                return state;
        } else {
            state = (template->default_state == LEDS_GPIO_DEFSTATE_ON);
        }
```

```
    led_dat->cdev.brightness = state ? LED_FULL : LED_OFF;
    if (!template->retain_state_suspended)
        led_dat->cdev.flags |= LED_CORE_SUSPENDRESUME;
    if (template->panic_indicator)
        led_dat->cdev.flags |= LED_PANIC_INDICATOR;
    if (template->retain_state_shutdown)
        led_dat->cdev.flags |= LED_RETAIN_AT_SHUTDOWN;

    ret = gpiod_direction_output(led_dat->gpiod, state);
    if (ret < 0)
        return ret;

    if (template->name) {
        led_dat->cdev.name = template->name;
        ret = devm_led_classdev_register(parent, &led_dat->cdev);
    } else {
        init_data.fwnode = fwnode;
        ret = devm_led_classdev_register_ext(parent, &led_dat->cdev,
                                             &init_data);
    }
    return ret;
}
```

c) 用户可以访问文件**/sys/class/leds/sys/brightness**，它将调用 gpio_led_set 设置 LED 的状态。

```
static void gpio_led_set(struct led_classdev *led_cdev,
    enum led_brightness value)
{
...
                gpiod_set_value(led_dat->gpiod, level);
}
```

2.9.2 PINMUX 配置指导

AM625 有两种 GPIO：一种由 A53 控制，另一种由 MCU 控制：

A53 GPIO 命名为：GPIO0_12、GPIO1_31

MCU GPIO 命名为：MCU_GPIO0_22。

配置 A53 GPIO 引脚属性：

```
AM62X_IOPAD(0x01b0, PIN_OUTPUT, 7)  /* MCASP0_ACLKR.GPIO1_14 */
```

配置 MCU GPIO 引脚属性：

```
AM62X_MCU_IOPAD(0x0080, PIN_OUTPUT, 7) /* PMIC_LPM_EN0.MCU_GPIO0_22*/
```

函数语法：

```
AM62X_IOPAD(pa, val, muxmode)      or   AM62X_MCU_IOPAD(pa, val, muxmode)
pa: Physical Address
val: value to write
muxmode: MUXMODE[3:0]
```

它们在 **linux-ti-6.1.33/arch/arm64/boot/dts/ti/k3-pinctrl.h** 中定义：

```
#define AM62X_IOPAD(pa, val, muxmode)          (((pa) & 0x1fff)) ((val) | (muxmode))
#define AM62X_MCU_IOPAD(pa, val, muxmode)    (((pa) & 0x1fff)) ((val) | (muxmod
e))
```

现在我们来说明一下如何计算 PMIC_LPM_EN0 的参数'pa'。

打开文档《AM62x SitaraTM Processors》，找到 PMIC_LPM_EN0 引脚的物理地址为 0x04084080：

B7	C7	PMIC_LPM_EN0 PADCONFIG: MCU_PADCONFIG32 0x04084080	PMIC_LPM_EN0 MCU_GPIO0_22

- **vi linux-ti-6.1.33/arch/arm64/boot/dts/ti/k3-am62-mcu.dtsi**

```
mcu_pmx0: pinctrl@4084000 {
    compatible = "pinctrl-single";
    reg = <0x00 0x04084000 0x00 0x88>;
    #pinctrl-cells = <1>;
    pinctrl-single,register-width = <32>;
    pinctrl-single,function-mask = <0xffffffff>;
};
```

它指出 mcu_pmx0 的基物理地址是 0x04084000，那么我们只需要通过宏 AM62X_MCU_IOPAD 传递引脚 PMIC_LPM_EN0 的偏移地址就可以了：

$$offset = 0x04084080 - 0x04084000 = 0x80$$

关于参数‘val’，您可以从以下项目中选择：

- **vi linux-ti-6.1.33/arch/arm64/boot/dts/ti/k3-pinctrl.h**

```
/* Only these macros are expected be used directly in device tree files */
#define PIN_OUTPUT          (INPUT_DISABLE | PULL_DISABLE)
#define PIN_OUTPUT_PULLUP   (INPUT_DISABLE | PULL_UP)
#define PIN_OUTPUT_PULLDOWN (INPUT_DISABLE | PULL_DOWN)
#define PIN_INPUT           (INPUT_EN | PULL_DISABLE)
#define PIN_INPUT_PULLUP    (INPUT_EN | PULL_UP)
#define PIN_INPUT_PULLDOWN  (INPUT_EN | PULL_DOWN)
```

关于参数‘muxmode’，找到文档《AM62x SitaraTM Processors》的‘Pin Attributes’表：

ALW BALL NUMBER [1]	AMC BALL NUMBER [1]	BALL NAME [2] PADCONFIG Register [15] PADCONFIG Address [16]	SIGNAL NAME [3]	MUX MODE [4]	TYPE [5]
J22	J21	OSPI0_D7 PADCONFIG: PADCONFIG10 0x000F4028	OSPI0_D7	0	IO
			SPI1_D1	1	IO
			MCASP1_AFSX	2	IO
			UART6_CTSn	3	I
			GPIO0_10	7	IO
B7	C7	PMIC_LPM_EN0 PADCONFIG: MCU_PADCONFIG32 0x04084080	PMIC_LPM_EN0	0	O
			MCU_GPIO0_22	7	IO

可以看到 MCU_GPIO0_22 的 MUXMODE 是 7。

如果你的目标引脚由 A53 控制，请将其附加到 dts 文件中的 main_pmx0 节点下；否则将其放在 mcu_pmx0 节点下：

```
&mcu_pmx0 {
    usr_led_pins_default: usr-led-pins-default {
        pinctrl-single,pins = <
            AM62X_MCU_IOPAD(0x0080, PIN_OUTPUT, 7) /* (B7) PMIC_LPM_EN0.
MCU_GPIO0_22 */
```

```
            >;
        };
        ......
}
```

2.10 系统更新

EVK-ET-AM62 可以从 TF 卡和 eMMC 启动，由 **BOOT Select** 按键决定：

按下 [不松开]：从 TF 卡启动

否则：从 eMMC 启动。

2.10.1 更新 TF 卡系统镜像

1） 制作 TF 启动卡

- 从 **Image** 目录获取系统映像，命名为 **EVK-ET-AM62-SD-REVXX.img.xz**，解压并获取原始映像 **EVK-ET-AM62-SD-REVXX.img**。
- 如果您在 Windows 系统下，请运行 **Tools/win32diskimager** 将 **EVK-ET-AM62-SD-REVXX.img** 写入 TF 卡；如果您在 Linux 系统下，请使用 dd 命令将 **EVK-ET-AM62-SD-REVXX.img** 写入 TF 卡。

2） 更新 U-Boot

如果您对 u-boot 源代码进行了修改，需要将其更新到 TF 卡中，请将目标映像复制到 TF 卡 FAT 分区的根目录中：

```
├── tiboot3.bin
├── tispl.bin
└── u-boot.img
```

3） 更新 Kernel

如果您修改了内核源代码，请更新 TF 卡分区 1 [FAT32]下的 dtb 和 Image。该分区可以被 Windows 或 Linux 识别。如果更新后 **lsmod** 命令显示没有加载任何内容，则分区 2 [EXT4] **/lib/modules** 也需要更新。

4） 更新 Rootfs

由于 Windows 下无法访问 EXT4，请在 Ubuntu 下挂载 TF 卡的第 2 分区，更改目标文件后卸载该卡。

Note:

- 如果 eMMC 中已经写入系统映像，请擦除 eMMC 然后重新启动主板，因为主板将默认首先尝试从 eMMC 启动。
- 输入 u-boot 命令，擦除 eMMC：

  u-boot=> **mmc dev 0 && mmc erase 0 20000**

2.10.2 从 TF 卡启动更新 eMMC

Option 1: 将完整映像写入 eMMC

- 制作可启动的 TF 卡并启动系统；
- 选择目标镜像[在 **Image/**目录下]并将其复制到 U 盘[格式化为 NTFS 或 exFAT]。如果是**.xz** 文件，请将其解压以生成**.img** 文件；
- 在 ARM 板上安装 USB 盘，例如 USB 盘被识别为 sda；
  - root@arm:~# **mount /dev/sda /mnt**
- 运行命令开始写入 eMMC：
  - root@arm:~# **umount /dev/mmcblk0***

```
umount: /dev/mmcblk0: not mounted.
umount: /dev/mmcblk0boot0: not mounted.
umount: /dev/mmcblk0boot1: not mounted.
umount: /dev/mmcblk0p1: not mounted.
umount: /dev/mmcblk0p2: not mounted.
```

```
umount: /dev/mmcblk0rpmb: not mounted.
```

- root@arm:~# **dd if=/mnt/EVK-ET-AM62-SD-REVXX.img of=/dev/mmcblk0 status=progress bs=4M**

- 运行命令写入引导程序[必须步骤]：
  - root@arm:~# **bootloader-update.sh 1g**

bootloader-update.sh 1g	For 1GB DDR Device
bootloader-update.sh 2g	For 2GB DDR Device
bootloader-update.sh 4g	For 4GB DDR Device

Option 2: 将 TF 卡系统同步到 eMMC

- 制作可启动的 TF 卡并启动系统；
- 运行命令开始写入 eMMC：
  - root@arm:~# **system-update.sh**

```
running system update...
==============eMMC UPDATE=================
Warning: disk /dev/mmcblk0 will be formatted !
3000+0 records in
3000+0 records out
1536000 bytes (1.5 MB, 1.5 MiB) copied, 0.189324 s, 8.1 MB/s

Welcome to fdisk (util-linux 2.37.4).
Changes will remain in memory only, until you decide to write them.
Be careful before using the write command.
......
Allocating group tables: done
Writing inode tables: done
Creating journal (16384 blocks): done
Writing superblocks and filesystem accounting information: done

[   82.174125] EXT4-fs (mmcblk0p2): mounted filesystem with ordered data mode. Opts: (null). Quota mode: none.
```

```
sending incremental file list
./
bin/
bin/arping
bin/ash -> /bin/busybox.nosuid
bin/base64 -> /usr/bin/base64.coreutils
bin/bash -> /bin/bash.bash
bin/bash.bash
bin/busybox -> busybox.nosuid
......
sent 13,977,149 bytes  received 141 bytes  2,541,325.45 bytes/sec
total size is 31,423,849  speedup is 2.25
rsync error: some files/attrs were not transferred (see previous errors) (code 23) at
main.c(1336) [sender=3.2.7]
[  825.639924]  mmcblk0: p1 p2
5120+0 records in
5120+0 records out
5242880 bytes (5.2 MB, 5.0 MiB) copied, 0.203386 s, 25.8 MB/s
UPDATE  : COMPLETED
Catch a signal
[  826.153152] EXT4-fs (mmcblk0p2): mounted filesystem with ordered data mode. O
pts: (null). Quota mode: none.
```

- 关闭 ARM 板电源并取出 TF 卡。

2.11 测试与演示

本节将对外围设备运行一些测试。

电源: **12V DC**

调试串口: **UART0**, **115200 1N8**, **USB TypeC slot [J20]**

2.11.1 SSH 登录

SSH 服务器默认已经开启，请获取 ARM 板上有线或无线网络的本地 IP，然后从 PC

端使用 SSH 客户端（如 PuTTY）登录，**root** 账户，无密码。

Note:

🕮 SSH 服务器是 dropbear，而不是 openssh-server。

2.11.2 RTC

板载有一颗 RTC 芯片 RX8010SJ，并且 CPU 内置 RTC 也是默认开启的，所以系统下有两个 RTC 设备可以访问。

- root@arm:~# **cat /sys/class/rtc/rtc0/name**

```
rtc-rx8010 0-0032
```

- root@arm:~# **cat /sys/class/rtc/rtc1/name**

```
rtc-ti-k3 2b1f0000.rtc
```

即 rtc0 为 RX8010SJ，rtc1 为内置 RTC，hwclock 命令默认访问**/dev/rtc0**，若要访问**/dev/rtc1**，请附加参数：**-f /dev/rtc1**。

我们将当前时间设置为 2024-02-05 10:12：

- root@arm:~# **date -s "2024-02-05 10:12"; hwclock -f /dev/rtc0 -w**

重新启动 ARM 板，并使用以下命令检查硬件 RTC 时间：

- root@arm:~# **hwclock -f /dev/rtc0**

```
2024-02-05 10:12:07.365014+00:00
```

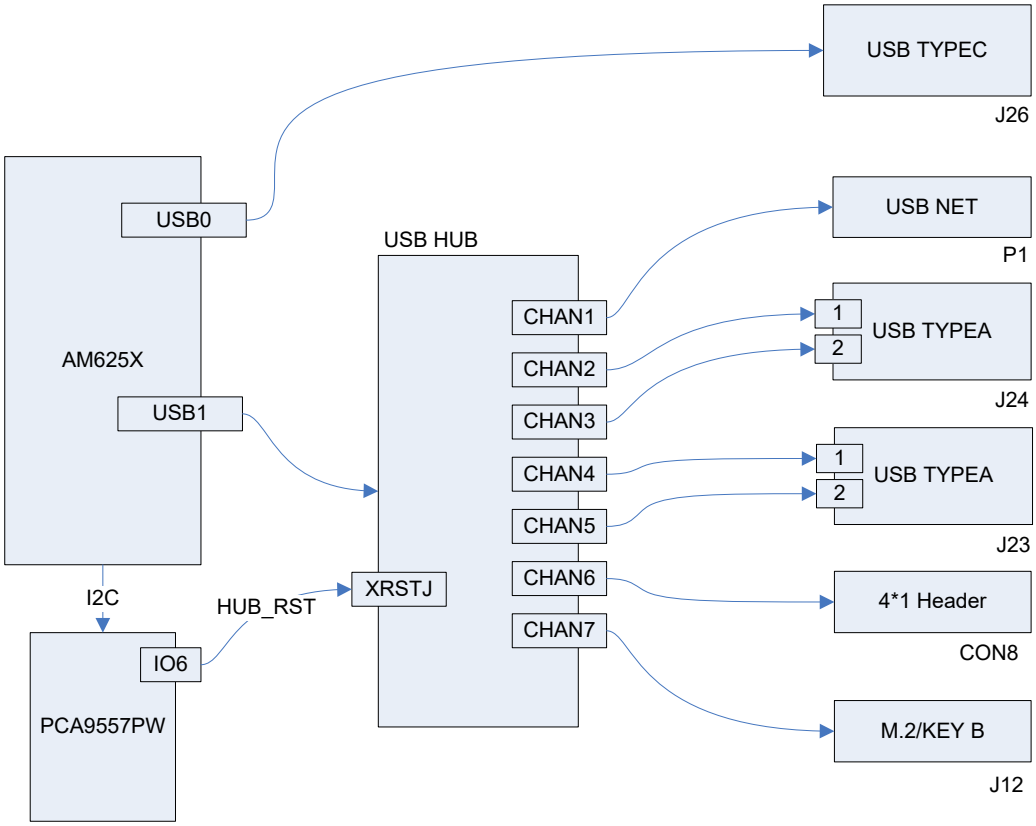
2.11.3 TIMEZONE 设置

以设置北京时间为例：

- root@arm:~# **echo "Asia/Shanghai" > /etc/timezone**
- root@arm:~# **ln -sf /usr/share/zoneinfo/Asia/Shanghai /etc/localtime**

- root@arm:~# **sync**

2.11.4 USB HOST



我们可以用 U 盘测试插槽 **J26**、**J24** 和 **J23**。在这些插槽上安装 U 盘，检查以下消息：

```
[  272.082860] usb-storage 2-1.1:1.0: USB Mass Storage device detected
[  272.098248] scsi host0: usb-storage 2-1.1:1.0
[  273.104255] scsi 0:0:0:0: Direct-Access     SanDisk  Flash Memory     0.1  PQ: 0
ANSI: 2
[  273.130158] sd 0:0:0:0: [sda] 2001888 512-byte logical blocks: (1.02 GB/977 MiB)
[  273.143825] sd 0:0:0:0: [sda] Write Protect is off
[  273.147410] sd 0:0:0:0: [sda] Mode Sense: 03 00 00 00
[  273.148611] sd 0:0:0:0: [sda] No Caching mode page found
[  273.155755] sd 0:0:0:0: [sda] Assuming drive cache: write through
```

```
[  273.176207]  sda: sda1
[  273.199625] sd 0:0:0:0: [sda] Attached SCSI removable disk
[  273.783449] FAT-fs (sda1): Volume was not properly unmounted. Some data may be corrupt. Please run fsck.
```

- root@arm:~# **mount**

```
......
/dev/sda1 on /run/media/sda1 type vfat (rw,relatime,gid=6,fmask=0007,dmask=0007,allow_utime=0020,codepage=437,iocharset=iso8859-1,shortname=mixed,errors=remount-ro)
```

U 盘被 udev 自动挂载在**/media/sda1** 下。

2.11.5 NETWORK

板上有两块 1Gbps 网络芯片 RTL8211F，一块 USB 网络 LAN9500A。

- root@arm:~# **ifconfig eth0**

```
eth0      Link encap:Ethernet  HWaddr 3a:f7:82:bc:fa:0a
          inet addr:192.168.1.81  Bcast:192.168.1.255  Mask:255.255.255.0
          inet6 addr: fe80::38f7:82ff:febc:fa0a/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:11 errors:0 dropped:4 overruns:0 frame:0
          TX packets:42 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1555 (1.5 KiB)  TX bytes:7192 (7.0 KiB)
```

DHCP 功能默认启用。主板可以从本地网络中的 DHCP 服务器请求有效的 IP 地址。此外，您可以尝试以下命令强制请求 IP 地址：

- root@arm:~# **udhcpc -i eth0**

```
udhcpc: started, v1.35.0
udhcpc: broadcasting discover
udhcpc: broadcasting select for 192.168.1.81, server 192.168.1.1
udhcpc: lease of 192.168.1.81 obtained from 192.168.1.1, lease time 86400
/etc/udhcpc.d/50default: Adding DNS 192.168.1.1
```

- root@arm:~# **ping -I eth0 www.baidu.com**

```
PING www.a.shifen.com (14.215.177.38) from 192.168.1.81 eth0: 56(84) bytes of data.
64 bytes from www.baidu.com (183.232.231.174): icmp_seq=1 ttl=56 time=12.1 ms
64 bytes from www.baidu.com (183.232.231.174): icmp_seq=2 ttl=56 time=12.2 ms
64 bytes from www.baidu.com (183.232.231.174): icmp_seq=3 ttl=56 time=12.1 ms
64 bytes from www.baidu.com (183.232.231.174): icmp_seq=4 ttl=56 time=12.5 ms
^C
--- www.a.shifen.com ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3004ms
rtt min/avg/max/mdev = 7.058/7.447/7.771/0.319 ms
```

2.11.6 TFT-LCD

已测试的设备：

MODEL	DESCRIPTION	DTB
LCD8000-70T	800 * 480, with touch panel	emtop-evk-et-am62-lcd8000-800x480.dtb

编辑 **uEnv.txt**：让 **name_fdt** 指向上表中的 DTB。

2.11.7 LVDS

已测试的设备：

MODEL	DESCRIPTION	DTB
VISLCD-101HYS145ACT02	1280 * 720, with touch panel	emtop-evk-et-am62.dtb

编辑 **uEnv.txt**：让 **name_fdt** 指向上表中的 DTB。

Figure 2-1 VISLCD-101HYS145ACT02

2.11.8 LVDS BACKLIGHT

- root@arm:~# **echo 5 > /sys/class/backlight/backlight/brightness**

Note:

🕮 背光值范围： **0 ~ 8**.

2.11.9 TOUCH PANEL

MODEL	TYPE	I2C BUS
GT9271	I2C CTP	I2C3

- root@arm:~# **evtest**

```
No device specified, trying to scan all of /dev/input/event*
Available devices:
/dev/input/event0:          30370000.snvs:snvs-powerkey
/dev/input/event1:          generic gt9271
/dev/input/event2:          gpio-keys
Select the device event number [0-2]: 1
Input driver version is 1.0.1
Input device ID: bus 0x18 vendor 0x416 product 0x38f version 0x1060
Input device name: "Goodix Capacitive TouchScreen"
Supported events:
  Event type 0 (EV_SYN)
  Event type 1 (EV_KEY)
    Event code 330 (BTN_TOUCH)
  Event type 3 (EV_ABS)
    Event code 0 (ABS_X)
      Value      799
      Min          0
      Max        799
    Event code 1 (ABS_Y)
      Value      479
      Min          0
      Max        479
    Event code 47 (ABS_MT_SLOT)
      Value        0
      Min          0
      Max          9
    Event code 53 (ABS_MT_POSITION_X)
      Value        0
      Min          0
      Max        799
    Event code 54 (ABS_MT_POSITION_Y)
```

```
        Value           0
        Min             0
        Max           479
    Event code 57 (ABS_MT_TRACKING_ID)
        Value           0
        Min             0
        Max         65535
Properties:
  Property type 1 (INPUT_PROP_DIRECT)
Testing ... (interrupt to exit)
[Touch the panel ...]
Event: time 1707131270.474572, type 3 (EV_ABS), code 53 (ABS_MT_POSITION_X), value 93
Event: time 1707131270.474572, type 3 (EV_ABS), code 54 (ABS_MT_POSITION_Y), value 93
Event: time 1707131270.474572, type 3 (EV_ABS), code 0 (ABS_X), value 93
Event: time 1707131270.474572, type 3 (EV_ABS), code 1 (ABS_Y), value 93
Event: time 1707131270.474572, ---------- SYN_REPORT ------------
Event: time 1707131270.641322, type 3 (EV_ABS), code 57 (ABS_MT_TRACKING_ID), value -1
Event: time 1707131270.641322, type 1 (EV_KEY), code 330 (BTN_TOUCH), value 0
Event: time 1707131270.641322, ---------- SYN_REPORT ------------
Event: time 1707131271.588488, type 3 (EV_ABS), code 57 (ABS_MT_TRACKING_ID), value 5
Event: time 1707131271.588488, type 3 (EV_ABS), code 53 (ABS_MT_POSITION_X), value 156
Event: time 1707131271.588488, type 3 (EV_ABS), code 54 (ABS_MT_POSITION_Y), value 114
Event: time 1707131271.588488, type 1 (EV_KEY), code 330 (BTN_TOUCH), value 1
Event: time 1707131271.588488, type 3 (EV_ABS), code 0 (ABS_X), value 156
Event: time 1707131271.588488, type 3 (EV_ABS), code 1 (ABS_Y), value 114
Event: time 1707131271.588488, ---------- SYN_REPORT ------------
Event: time 1707131271.791086, type 3 (EV_ABS), code 57 (ABS_MT_TRACKING_ID), value -1
Event: time 1707131271.791086, type 1 (EV_KEY), code 330 (BTN_TOUCH), value 0
Event: time 1707131271.791086, ---------- SYN_REPORT ------------
Event: time 1707131272.186580, type 3 (EV_ABS), code 57 (ABS_MT_TRACKING_ID), value 6
Event: time 1707131272.186580, type 3 (EV_ABS), code 53 (ABS_MT_POSITION_X), value 107
```

```
Event: time 1707131272.186580, type 3 (EV_ABS), code 54 (ABS_MT_POSITION_Y), value 84
Event: time 1707131272.186580, type 1 (EV_KEY), code 330 (BTN_TOUCH), value 1
Event: time 1707131272.186580, type 3 (EV_ABS), code 0 (ABS_X), value 107
Event: time 1707131272.186580, type 3 (EV_ABS), code 1 (ABS_Y), value 84
Event: time 1707131272.186580, ---------- SYN_REPORT ------------
Event: time 1707131272.361357, type 3 (EV_ABS), code 57 (ABS_MT_TRACKING_ID), value -1
Event: time 1707131272.361357, type 1 (EV_KEY), code 330 (BTN_TOUCH), value 0
Event: time 1707131272.361357, ---------- SYN_REPORT ------------
```

2.11.10 NAU88C22 AUDIO

- root@arm:~# **aplay -l**

```
**** List of PLAYBACK Hardware Devices ****
card 0: AM62xNAU8822 [AM62x-NAU8822], device 0: davinci-mcasp.0-nau8822-hifi nau8822-hifi-0 [davinci-mcasp.0-nau8822-hifi nau8822-hifi-0]
  Subdevices: 1/1
  Subdevice #0: subdevice #0
```

播放：

- root@arm:~# **for wav in `ls /usr/share/sounds/alsa/*.wav`; do aplay $wav; done**

2.11.11 HDMI

MODEL	DESCRIPTION	DTB
HDMI Display		emtop-evk-et-am62.dtb emtop-evk-et-am62-hdmi.dtb

emtop-evk-et-am62.dtb：支持 LVDS 和 HDMI 双显示

emtop-evk-et-am62-hdmi.dtb：仅支持 HDMI 显示。

编辑 **uEnv.txt**：让 **name_fdt** 指向上表中的 DTB。

2.11.12 HDMI AUDIO

MODEL	DESCRIPTION	DTB
HDMI Display	支持音频播放	emtop-evk-et-am62-hdmi.dtb

编辑 **uEnv.txt**：让 **name_fdt** 指向上表中的 DTB。

- root@arm:~# **aplay -l**

```
**** List of PLAYBACK Hardware Devices ****
card 0: AM62xSil9022HDM [AM62x-Sil9022-HDMI], device 0: davinci-mcasp.0-i2s-hifi i2s-hifi-0 [davinci-mcasp.0-i2s-hifi i2s-hifi-0]
  Subdevices: 1/1
  Subdevice #0: subdevice #0
```

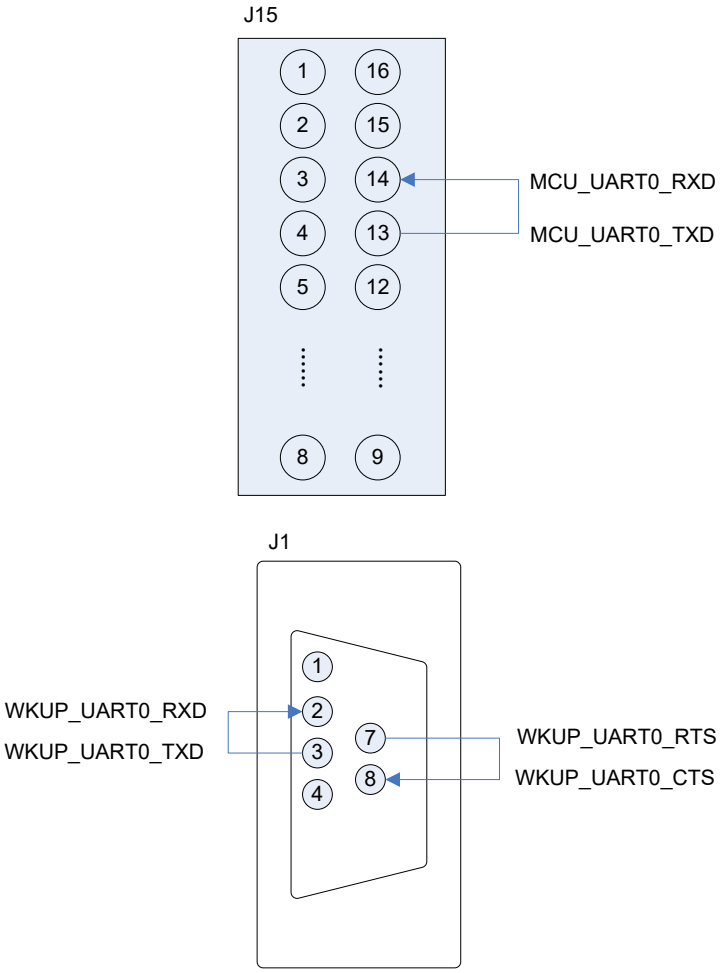
播放：

- root@arm:~# **for wav in `ls /usr/share/sounds/alsa/*.wav`; do aplay $wav; done**

2.11.13 UART

DEVICE NODE	HARDWARE	USAGE
/dev/ttyS2	UART0	DEBUG PORT
/dev/ttyS3	UART1	RS485
/dev/ttyS7	UART5	RS485
/dev/ttyS8	UART6	BLUETOOTH
/dev/ttyS9	MCU_UART0	HEADER J15
/dev/ttyS10	WKUP_UART0	DB9 J1

这里先不要测试 UART0、UART1、UART5 和 UART6。我们来测试其他的 [MCU_UART0 和 WKUP_UART0]。连接它们的 RXD 和 TXD 引脚：



并运行以下命令：

- root@arm:~# **/test/app/com -d /dev/ttyS9**

```
SEND: 1234567890
RECV: 1234567890
SEND: 1234567890
RECV: 1234567890
```

默认波特率为 **115200**。如果要指定其他特定波特率：

- root@arm:~# **/test/app/com -d /dev/ttyS9 -b 9600**

所有支持的波特率请参阅源代码 **com.tar.xz**。

- root@arm:~# **/test/app/com -d /dev/ttyS10 -f**

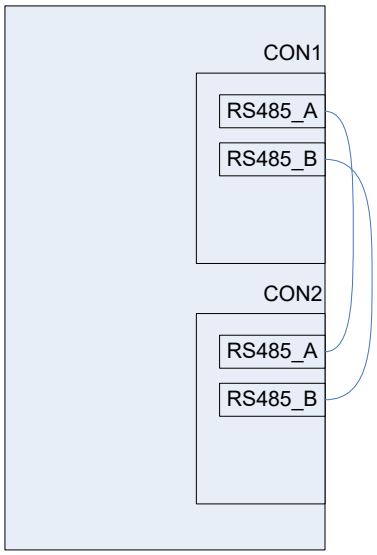
```
SEND: 1234567890
RECV: 1234567890
SEND: 1234567890
RECV: 1234567890
```

参数**-f**：启用硬件流控制[RTS/CTS]功能。

2.11.14 RS485

DEVICE NODE	HARDWARE	USAGE	REMARK
/dev/ttyS3	UART1	RS485	
/dev/ttyS7	UART5	RS485	with RTS

There are 2 RS485 bus on board, lets connect them together.



- root@arm:~# **/test/app/com -d /dev/ttyS3 -s "Hello world" &**
- root@arm:~# **/test/app/com -d /dev/ttyS7 -m rs485**

```
SEND: 1234567890
SEND: Hello world
RECV: 1234567890
RECV: Hello world
SEND: 1234567890
```

```
SEND: Hello world
RECV: 1234567890
RECV: Hello world
```

2.11.15 EEPROM

核心板上有一个 AT24LC32A，并启用了写保护。

- root@arm:~# **hexdump -Cv /sys/bus/i2c/devices/0-0050/eeprom**

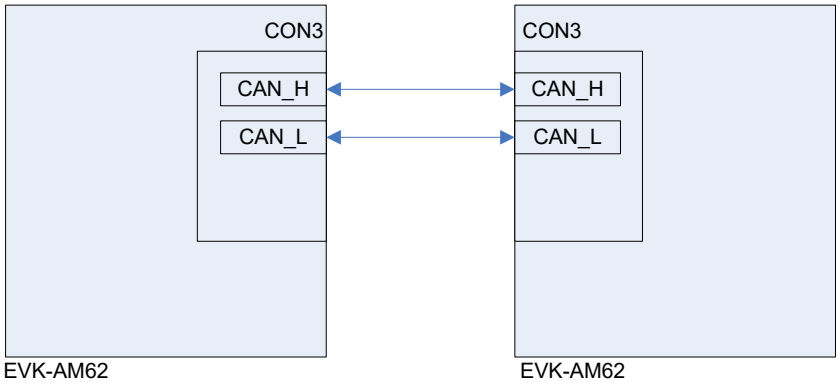
```
00000000  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff  |................|
00000010  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff  |................|
00000020  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff  |................|
00000030  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff  |................|
00000040  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff  |................|
00000050  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff  |................|
*
```

2.11.16 CAN BUS

板上有 3 条 CAN 总线。

ITEM	HW INTERFACE	REGISTER BASEADDR	LINUX INTERFACE	SLOT
1	MCAN0	0x20701000	can2	CON3
2	MCU_MCAN0	0x4e00000	can0	CON4
3	MCU_MCAN1	0x4e10000	can1	CON5

将 2 个 CAN 总线与 2 个 EVK-ET-AM62 连接：



- root@arm:~# **ifconfig can0**

```
can0: flags=128<NOARP>  mtu 16
        unspec 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00  txqueuelen 10  (U
NSPEC)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

配置参数[双方]：

- root@arm:~# **ifconfig can0 down**
- root@arm:~# **ip link set can0 type can bitrate 125000**
- root@arm:~# **ip link set can0 type can restart-ms 100**
- root@arm:~# **ifconfig can0 up**

开始在一个板上监听：

- root@arm:~# **candump can0 &**

另一块板上发送：

- root@arm:~# **cansend can0 "5A1#1122334455667788"**

更多信息请参考项目 can-utils。

2.11.17 BUTTON

PMIC_PBn [S4] 按键：默认行为是关闭电源。

用户按键[**S5, S6**]:

- root@arm:~# **evtest**

```
No device specified, trying to scan all of /dev/input/event*
Available devices:
/dev/input/event0:      keys
/dev/input/event1:      tps65219-pwrbutton
/dev/input/event2:      ADS7846 Touchscreen
```

```
Select the device event number [0-2]: 0
Input driver version is 1.0.1
Input device ID: bus 0x19 vendor 0x1 product 0x1 version 0x100
Input device name: "gpio-keys"
Supported events:
  Event type 0 (EV_SYN)
  Event type 1 (EV_KEY)
    Event code 102 (KEY_HOME)
    Event code 105 (KEY_LEFT)
Properties:
Testing ... (interrupt to exit)
Event: time 1707132374.777133, type 1 (EV_KEY), code 102 (KEY_HOME), value 1
Event: time 1707132374.777133, ---------- SYN_REPORT ------------
Event: time 1707132374.904456, type 1 (EV_KEY), code 102 (KEY_HOME), value 0
Event: time 1707132374.904456, ---------- SYN_REPORT ------------
Event: time 1707132375.518704, type 1 (EV_KEY), code 105 (KEY_LEFT), value 1
Event: time 1707132375.518704, ---------- SYN_REPORT ------------
Event: time 1707132375.615938, type 1 (EV_KEY), code 105 (KEY_LEFT), value 0
Event: time 1707132375.615938, ---------- SYN_REPORT ------------
```

2.11.18 LED

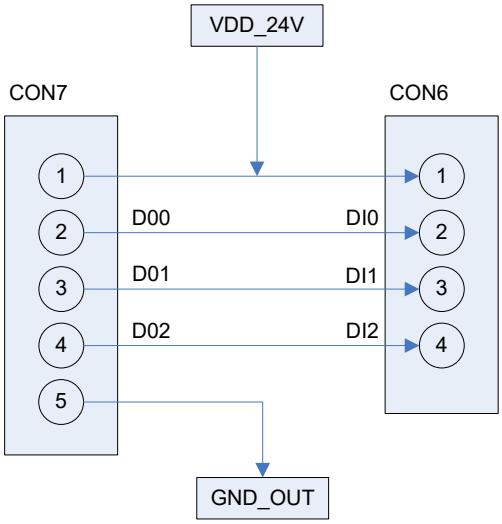
LED	GPIO	LINUX DEVICE
SYS_nLED	GPIO0_12	/sys/class/leds/sys

板上可控制的 LED 只有一个，SYS_nLED 持续闪烁以指示系统运行状态。但我们可以让它像普通 LED 一样工作：

- root@arm:~# **echo none > /sys/class/leds/sys/trigger**
- root@arm:~# **while test 1; do echo 1 > /sys/class/leds/sys/brightness;sleep 1;echo 0 > /sys/class/leds/sys/brightness;sleep 1;done**

您可以看到 **SYS_nLED** 以 2Hz 的频率闪烁。

2.11.19 DI/DO



DI/DO	GPIO	BASEADDR[HEX]	IO OFFSET
DO0	GPIO0_0	600000	0
DO1	GPIO0_3	600000	3
DO2	GPIO0_4	600000	4
DI0	GPIO0_5	600000	5
DI1	GPIO0_2	600000	2
DI2	GPIO0_6	600000	6

我们可以使用以下命令获取 GPIOCHIP 编号：

- root@arm:~# **gpiochip=`gpiodetect | awk '/600000/ {print $1}'`**

Note:

📖 **600000** 为对应 GPIO 的 **BASEADDR** 十六进制数值。

DO0 输出低电平：

- root@arm:~# **gpioset $gpiochip 0=0**

DO0 输出高电平：

- root@arm:~# **gpioset $gpiochip 0=1**

DO1 输出低电平：

- root@arm:~# **gpioset $gpiochip 3=0**

Note:

🕮 **gpioset <GPIOCHIP> <IO OFFSET>=<output value>**

读取 DI0 输入：

- root@arm:~# **gpioget $gpiochip 5**

```
1 or 0
```

Note:

🕮 **gpioget <GPIOCHIP> <IO OFFSET>**

或者监控 IO 状态改变事件：

- root@arm:~# **gpiomon $gpiochip 5**

```
event:   RISING EDGE offset: 5 timestamp: [      1151.814356387]
event:   FALLING EDGE offset: 5 timestamp: [      1151.815449803]
event:   RISING EDGE offset: 5 timestamp: [      1152.091556803]
```

Note:

🕮 **libgpiod version is 1.6.3.**

2.11.20 SPI ADC

底板上有一个 SPI ADC 芯片 ADC102S051。

- root@arm:~# **cat /sys/bus/iio/devices/iio:device0/name**

```
adc102s051
```

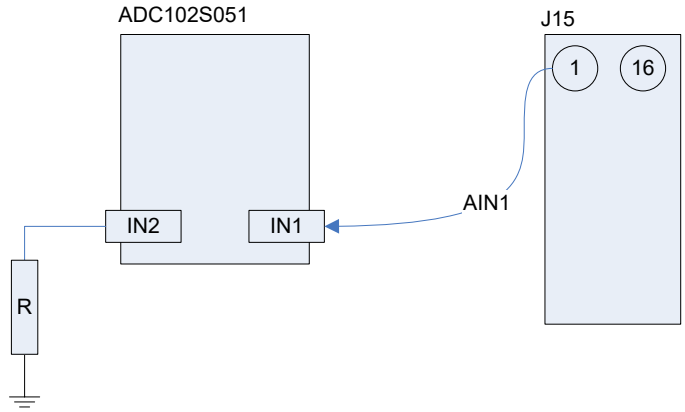


Figure 2-2 SPI ADC 示意图

读取 IN1 通道输入：

- root@arm:~# **cat /sys/bus/iio/devices/iio:device0/in_voltage0_raw**

```
1884
```

- root@arm:~# **cat /sys/bus/iio/devices/iio:device0/in_voltage0_scale**

```
0.805664062
```

公式：

Voltage = **raw** * **scale** (V)

读取 IN2 通道输入：

- root@arm:~# **cat /sys/bus/iio/devices/iio:device0/in_voltage1_raw**

```
3
```

通道 IN2 连接到 GND，因此其读数始终近似为 0。

2.11.21 PWM

底板接头[J15]上的 MCU_GPIO0_8 默认配置为 PWM 输出。

- root@arm:~# **/test/app/mcu_timer1 1000**

上述命令可以设置其输出 1KHz，占空比为 50%。

- root@arm:~# **/test/app/mcu_timer1 1000 80**

上述命令可以设置其输出 1KHz，占空比为 80%。

- root@arm:~# **/test/app/mcu_timer1 -h**

```
Usage:
    /test/app/mcu_timer1 frequency [duty_circle] - Configure MCU_TIMER1 output under
PWM mode

    frequency                   unit: Hz, maximum 17000000Hz[17MHz]
    duty_circle                 percentage, valid value: 0,10,20,...,90,100, 50 as default

Example:
    /test/app/mcu_timer1 1000           output 1KHz with 50% duty circle
    /test/app/mcu_timer1 1000 80        output 1KHz with 80% duty circle
    -h                                  display help info
```

2.11.22 eMMC

eMMC 主要用于保存系统镜像，无需手动测试。

2.11.23 SPIFLASH

底板上配备了 SPIFlash XT25F64BSOIGT。

- root@arm:~# **dmesg |grep -i spi**

```
[    7.035063] spi-nor spi0.1: unrecognized JEDEC id bytes: 0b fb 7f ff ff ff
```

- root@arm:~# **cat /proc/mtd**

```
dev:    size   erasesize  name
mtd0: 00400000 00010000 "30bb0000.spi"
```

擦除格式化：

- root@arm:~# **flash_erase /dev/mtd0 0 0**

```
Erasing 8192 Kibyte @ 0 -- 100 % complete
```

- root@arm:~# **mount -t jffs2 /dev/mtdblock0 /mnt**

在**/mnt** 目录下进行写入和读取，内容将保留在 QSPIFlash 存储器中。

- root@arm:~# **umount /mnt**

下次启动时挂载此 FLASH，就可以看到之前写入的内容。

2.11.24 M.2/KEY B [WIFI and BLUETOOTH]

已测试的设备：

MODEL	CHIPSET	RESOLUTION
1ZM M.2 Module	NXP 88W8987	Support Wi-Fi and Bluetooth 5.1

Figure 2-3 1ZM M.2 Module

2.11.25 M.2 WIFI

- root@arm:~# **modprobe moal sta_name=wlan uap_name=wlan wfd_name=p2p max_vir_bss=1 cfg80211_wext=0xf cal_data_cfg=none fw_name=sdiouart8987_combo_v0.bin**

```
[    27.300912] mlan: loading out-of-tree module taints kernel.
[    27.391413] wlan: Loading MWLAN driver
[    27.392160] wlan: Register to Bus Driver...
[    27.478548] vendor=0x02DF device=0x9149 class=0 function=1
[    27.478688] Attach moal handle ops, card interface type: 0x105
[    27.478716] rps set to 0 from module param
[    27.478721] No module param cfg file specified
[    27.478736] SDIO: max_segs=128 max_seg_size=65536
[    27.478750] rx_work=1 cpu_num=4
[    27.478806] Attach mlan adapter operations.card_type is 0x105.
[    27.479449] wlan: Enable TX SG mode
[    27.479455] wlan: Enable RX SG mode
[    27.486150] Request firmware: sdiouart8987_combo_v0.bin
[    27.791167] Wlan: FW download over, firmwarelen=612304 downloaded 612304
[    28.662012] WLAN FW is active
[    28.662030] on_time is 28660259810
[    28.721744] fw_cap_info=0x181d7f03, dev_cap_mask=0xffffffff
[    28.721921] max_p2p_conn = 8, max_sta_conn = 8
[    28.722567] SDIO rx aggr: 1 block_size=512
[    28.722648] wlan: Enable RX SG mode
[    28.722651] mpa_rx_buf_size=65280
[    28.750785] Register NXP 802.11 Adapter wlan0
[    28.762135] Register NXP 802.11 Adapter wlan1
[    28.774227] Register NXP 802.11 Adapter p2p0
[    28.774334] wlan: version = SD8987----16.92.21.p76.5-MM5X16391.p3-GPL-(FP92)
[    28.775489] wlan: Register to Bus Driver Done
[    28.775511] wlan: Driver loaded successfully
```

- root@arm:~# **ifconfig wlan0 up**
- root@arm:~# **iw wlan0 scan | grep SSID**

```
[   106.018542] wlan: wlan0 START SCAN
[   111.007459] wlan: SCAN COMPLETED: scanned AP count=23
            SSID: EMTOP
......
```

- root@arm:~# **wpa_passphrase EMTOP 12345678 >> /etc/wpa_supplicant.conf**

File: /etc/wpa_supplicant.conf

```
ctrl_interface=/var/run/wpa_supplicant
ctrl_interface_group=0
update_config=1

network={
            key_mgmt=NONE
}
network={
            ssid="EMTOP"
            #psk="12345678"

psk=c238e09ef54285daf31c8f6833efab9fb8ff55632f7b9a7d94c117711de27822
}
```

- root@arm:~# **wpa_supplicant -B -iwlan0 -c/etc/wpa_supplicant.conf**

```
Successfully initialized wpa_supplicant
[   254.521484] wlan: wlan0 START SCAN
[   259.510371] wlan: SCAN COMPLETED: scanned AP count=21
[   259.516932] wlan: HostMlme wlan0 send auth to bssid dc:XX:XX:XX:53:70
[   259.517747] wlan0:
[   259.517755] wlan: HostMlme Auth received from dc:XX:XX:XX:53:70
[   259.522576] CMD_RESP: cmd 0x121 error, result=0x2
[    259.522608] IOCTL failed: 000000005a18a418 id=0x200000, sub_id=0x200024
action=2, status_code=0x3
[    259.528757] wlan: HostMlme wlan0 Connected to bssid dc:XX:XX:XX:53:70
successfully
[   259.531799] wlan0:
[   259.531820] wlan: Send EAPOL pkt to dc:XX:XX:XX:53:70
[   259.539604] wlan0:
[   259.539632] wlan: Send EAPOL pkt to dc:XX:XX:XX:53:70
```

```
[  259.548222] IPv6: ADDRCONF(NETDEV_CHANGE): wlan0: link becomes ready
[  259.548858] woal_cfg80211_set_rekey_data return: gtk_rekey_offload is DISABLE
```

- root@arm:~# **udhcpc -i wlan0**

```
udhcpc: started, v1.35.0
udhcpc: broadcasting discover
udhcpc: broadcasting discover
udhcpc: broadcasting select for 192.168.1.100, server 192.168.1.1
udhcpc: lease of 192.168.1.100 obtained from 192.168.1.1, lease time 7200
RTNETLINK answers: File exists
/etc/udhcpc.d/50default: Adding DNS 192.168.1.1
```

2.11.26 M.2 BLUETOOTH

- root@arm:~# **hciattach /dev/ttyS8 any 115200 flow**

```
[  447.897177] Bluetooth: Core ver 2.22
[  447.897924] NET: Registered PF_BLUETOOTH protocol family
[  447.897942] Bluetooth: HCI device and connection manager initialized
[  447.897977] Bluetooth: HCI socket layer initialized
[  447.897988] Bluetooth: L2CAP socket layer initialized
[  447.898038] Bluetooth: SCO socket layer initialized
[  447.920896] Bluetooth: HCI UART driver ver 2.3
[  447.920929] Bluetooth: HCI UART protocol H4 registered
Device setup complete
[  447.921092] Bluetooth: HCI UART protocol LL registered
[  447.921141] Bluetooth: HCI UART protocol Three-wire (H5) registered
[  447.922183] Bluetooth: HCI UART protocol Broadcom registered
[  447.922241] Bluetooth: HCI UART protocol QCA registered
[  447.922286] Bluetooth: HCI UART protocol Marvell registered
[  448.433149] Bluetooth: MGMT ver 1.22
[  448.446176] NET: Registered PF_ALG protocol family
```

- root@arm:~# **bluetoothctl**

```
Agent registered
[bluetooth]# power on
Changing power on succeeded
[bluetooth]# scan on
Discovery started
[CHG] Controller D0:C5:D3:F9:60:06 Discovering: yes
```

```
[NEW] Device 78:C5:28:67:88:03 78-C5-28-67-88-03
[NEW] Device 7B:A2:1E:1D:15:60 7B-A2-1E-1D-15-60
.. ..
[bluetooth]# scan off
```

请在网上搜索 **bluetoothctl** 用法以获取更多信息。

Note:

📖 **hciattach 操作之前必须加载 moal.ko，否则会报错：** **Bluetooth: hci0: Frame reassembly failed (-84)**.

2.11.27 M.2 4G/5G MODULE

已测试的设备：

MODEL	DESCRIPTION
QUECTEL EM05-CE	4G module
QUECTEL RM500Q-GL	5G module

安装 GSM 模块、天线、SIM 卡，然后给 ARM 板通电。

- root@arm:~# **lsusb**

```
Bus 002 Device 004: ID 2c7c:0800 Quectel Wireless Solutions Co., Ltd. RM500Q-GL
Bus 002 Device 003: ID 0424:9e00 Microchip Technology, Inc. (formerly SMSC) LAN9500A/LAN9500Ai
Bus 002 Device 002: ID 1a40:0201 Terminus Technology Inc. FE 2.1 7-port Hub
Bus 002 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
```

终止可能在后台运行的 **pppd** 程序：

- root@arm:~# **killall -q pppd && sleep 3**

- root@arm:~# **pppd call quectel-ppp &**

```
.....
```

```
Serial connection established.
using channel 1
Using interface ppp0
Connect: ppp0 <--> /dev/ttyGSM03
sent [LCP ConfReq id=0x1 <asyncmap 0x0> <magic 0x6586363d> <pcomp> <accomp>]
rcvd [LCP ConfReq id=0x0 <asyncmap 0x0> <auth chap MD5> <magic 0xafb6e7ff>
<pcomp> <accomp>]
sent [LCP ConfAck id=0x0 <asyncmap 0x0> <auth chap MD5> <magic 0xafb6e7ff>
<pcomp> <accomp>]
rcvd [LCP ConfAck id=0x1 <asyncmap 0x0> <magic 0x6586363d> <pcomp> <accomp>]
rcvd [LCP DiscReq id=0x1 magic=0xafb6e7ff]
rcvd [CHAP Challenge id=0x1 <5d8494ff9ffeb38c9d39b711e1dc3f38>, name =
"UMTS_CHAP_SRVR"]
sent [CHAP Response id=0x1 <b8f94ab38da425eb339f548b11d591c9>, name =
"$LTE_USERNAME"]
rcvd [CHAP Success id=0x1 ""]
CHAP authentication succeeded
CHAP authentication succeeded
sent [IPCP ConfReq id=0x1 <addr 0.0.0.0> <ms-dns1 0.0.0.0> <ms-dns2 0.0.0.0>]
sent [IPV6CP ConfReq id=0x1 <addr fe80::2052:fff9:f87b:4287>]
rcvd [IPCP ConfReq id=0x0]
sent [IPCP ConfNak id=0x0 <addr 0.0.0.0>]
rcvd [IPCP ConfNak id=0x1 <addr 10.23.13.247> <ms-dns1 120.196.165.7> <ms-dns2
221.179.38.7>]
sent [IPCP ConfReq id=0x2 <addr 10.23.13.247> <ms-dns1 120.196.165.7> <ms-dns2
221.179.38.7>]
rcvd [IPCP ConfReq id=0x1]
sent [IPCP ConfAck id=0x1]
rcvd [IPCP ConfAck id=0x2 <addr 10.23.13.247> <ms-dns1 120.196.165.7> <ms-dns2
221.179.38.7>]
Could not determine remote IP address: defaulting to 10.64.64.64
not replacing default route to eth2 [192.168.3.1]
local  IP address 10.23.13.247
remote IP address 10.64.64.64
primary  DNS address 120.196.165.7
secondary DNS address 221.179.38.7
```

Note:

🕮 如果 **pppd** 命令报告错误，请尝试再次运行。

配置默认网关：

- root@arm:~# **route del default; route add default ppp0**

配置 **resolv.conf**:

- root@arm:~# **cat /etc/ppp/resolv.conf > /etc/resolv.conf**

Note:

🕮 **resolv.conf** 非常重要，如果它不正确，带 URL 的 ping 命令会报错，类似：Temporary failure in name resolution。

连通性测试：

- root@arm:~# **ping -I ppp0 www.baidu.com**

```
PING www.a.shifen.com (14.215.177.38) from 10.32.232.200 ppp0: 56(84) bytes of data.
64 bytes from 14.215.177.38: icmp_seq=1 ttl=54 time=37.0 ms
64 bytes from 14.215.177.38: icmp_seq=2 ttl=54 time=43.5 ms
64 bytes from 14.215.177.38: icmp_seq=3 ttl=54 time=51.8 ms
64 bytes from 14.215.177.38: icmp_seq=4 ttl=54 time=41.4 ms
^C64 bytes from 14.215.177.38: icmp_seq=5 ttl=54 time=33.4 ms

--- www.a.shifen.com ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 20329ms
rtt min/avg/max/mdev = 33.408/41.456/51.856/6.272 ms
```

禁用 GSM

它通常被称为“飞行模式”，禁用无线传输。

- root@arm:~# **echo 0 > /sys/class/leds/lte_on/brightness**

使能 GSM

- root@arm:~# **echo 1 > /sys/class/leds/lte_on/brightness**

GSM 复位:

root@arm:~# **echo 0 > /sys/class/leds/lte_reset/brightness; sleep 3; echo 1 > /sys/class/leds/lte_reset/brightness**

2.11.28 MIPI-CSI CAMERA

已测试的设备：

MODEL	CORE	RESOLUTION
ALINX AN5641	OV5640	QSXGA (2592x1944), 1080p, 1280x960, VGA (640x480)

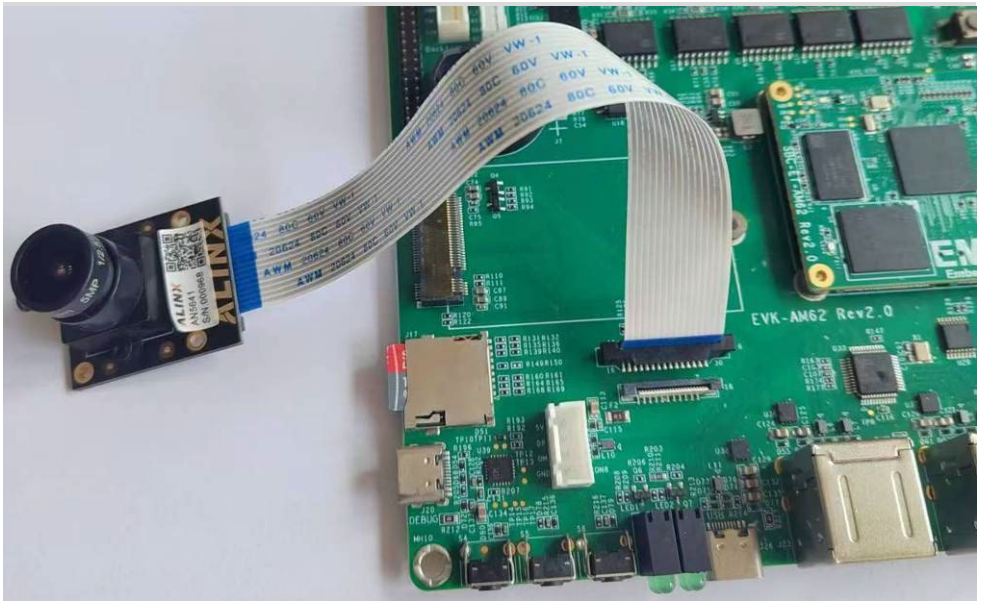


Figure 2-4 AN5641

- root@arm:~# **media-ctl -p**

```
.....
- entity 13: ov5640 0-003c (1 pad, 1 link, 0 route)
                type V4L2 subdev subtype Sensor flags 0
                device node name /dev/v4l-subdev2
        pad0: Source
                [stream:0 fmt:UYVY8_1X16/640x480@1/30 field:none colorspace:srgb
xfer:srgb ycbcr:601 quantization:full-range
```

```
                    crop.bounds:(0,0)/2624x1964
                    crop:(16,14)/2592x1944]
                   -> "cdns_csi2rx.30101000.csi-bridge":0 [ENABLED,IMMUTABLE]
......
```

相机设备节点是**/dev/video0**.

相机测试：

- root@arm:~# **media-ctl -V '"30102000.ticsi2rx":0/0 [fmt:UYVY8_1X16/640x480 field:none]'**
- root@arm:~# **media-ctl -V '"cdns_csi2rx.30101000.csi-bridge":0/0 [fmt:UYVY8_1X16/640x480 field:none]'**
- root@arm:~# **media-ctl --set-v4l2 '"ov5640 0-003c':0[fmt:UYVY8_1X16/640x480 field:none]"**
- root@arm:~# **gst-launch-1.0 v4l2src device="/dev/video0" ! video/x-raw, width=640, height=480, format=UYVY ! autovideosink**

```
Setting pipeline to PAUSED ...
Pipeline is live and does not need PREROLL ...
Pipeline is PREROLLED ...
Setting pipeline to PLAYING ...
New clock: GstSystemClock
Redistribute latency...
0:00:02.4 / 99:99:99.
```

现在我们可以看到摄像机捕获的实时图像流显示在屏幕上。

2.11.29 WAYLAND GPU

- root@arm:~# **glmark2-es2-wayland --run-foreve**

```
libEGL warning: egl: failed to create dri2 screen
=======================================================
    glmark2 2021.12
=======================================================
    OpenGL Information
    GL_VENDOR:      Mesa/X.org
    GL_RENDERER:    softpipe
```

```
    GL_VERSION:       OpenGL ES 3.1 Mesa 22.3.5 (git-54fd9d7dea)
=======================================================
[build] use-vbo=false: FPS: 1 FrameTime: 1000.000 ms
[build] use-vbo=true: FPS: 1 FrameTime: 1000.000 ms
......
```

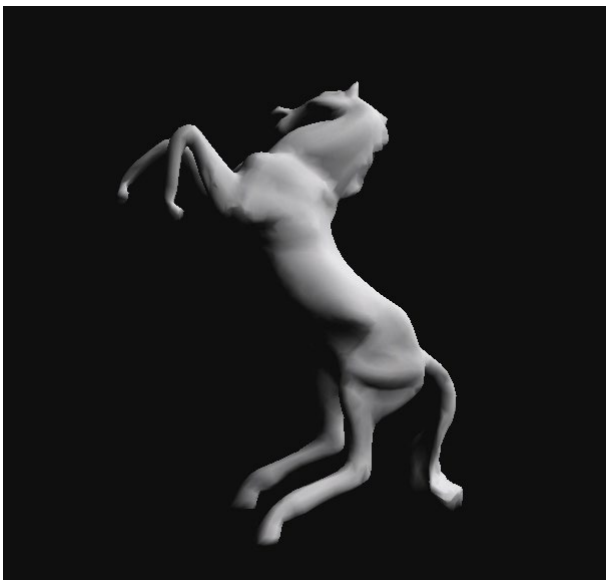


Figure 2-5 glmark2-es2-wayland