AN14184

在MCX N系列MCU上使用SmartDMA进行按键扫描

第1版 — 2024年1月20日 **应用笔记**

文档信息

信息	内容
关键词	按键扫描、FRDM-MCXN947、SmartDMA
摘要	本应用笔记介绍了针对MCX N系列MCU的按键扫描解决方案。

1 介绍

本应用笔记主要介绍了针对MCX N系列MCU的按键扫描解决方案，包括按键扫描解决方案的介绍、其特点和API例程以及一个演示。

所有的MCX N系列MCU均包含一个SmartDMA协处理器，可有效减轻Arm内核的负载，并进行快速的I/O操作。

2 目标应用

顾名思义，按键扫描解决方案常用于按键扫描应用，例如计算机键盘。不过，它也可以用于其他场景，例如一种需要连续扫描IO端口输入的需求。

3 按键扫描接口

按键扫描方案没有固定的接口。它既可用于矩阵扫描，也可用于行或列扫描。 扫描的键数可以是一个，也可以是从一到两百个。

如果是一个常用的电脑键盘，一般是101键、104键、或者87键。如果是小键盘，一般是4x4布局，共16个键。也可用于不规则的按键矩阵。简而言之，按钮布局和按钮数量都是可以自定义的。

本应用笔记使用的是一个4x4的矩阵键盘，但由于接口并不完全兼容，它仅支持2x4布局的共8键的形式。为了实现16键的形式，需要用飞线来改造硬件。

4 按键扫描方案的特点

此按键扫描方案的特点有：

- 4x4按键扫描
- 超快按键扫描，无需Arm内核的干预（>= 8kHz的报告速率）
- 可编程的消抖时间
- 易于支持8x16布局及其他尺寸
- 易于移植到其他平台

5 功能说明

本节介绍了按键扫描方案的功能描述。

5.1 按键扫描引擎

SmartDMA作为MCX N系列MCU的一个协处理器，其特点是指令执行的效率高。它可以快速高效地完成按键扫描操作。在按钮操作的扫描过程中，无需Arm内核的介入。只有当键值发生变化时才会向Arm内核发送一个中断。Arm内核只需要从RAM中读取这个按键的值。

5.2 按键扫描驱动库

SmartDMA的指令使用机器码的类型。这些代码实现了按键扫描方案的功能，并以C数组的形式发布。此应用程序中提供了一些API例程。可以使用这些API例程来初始化引擎、配置引脚、启动或停止按键扫描。

5.3 系统时钟

按键扫描引擎与Arm内核共享系统时钟。 降低系统时钟频率会降低 SmartDMA执行代码的速度。

5.4 内存使用

SmartDMA的代码必须在固定的位置加载和执行，在本应用中为0x04000000。更改执行指令的位置需要重新生成指令代码数组。

5.5 硬件说明

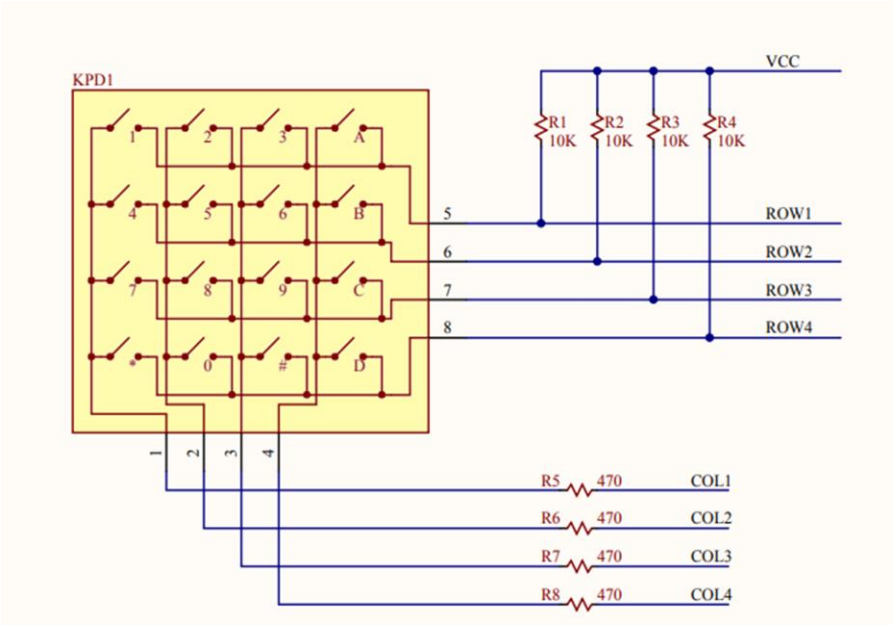
将PmodKYPD板与FRDM-MCXN947板连接，如图1所示。

图1. 演示的硬件

注：*可通过以下网站购买PmodKYPD板：*

https://store.digilentinc.com/pmod-kypd-16-button-keypad

图2所示为PmodKYPD的原理图。



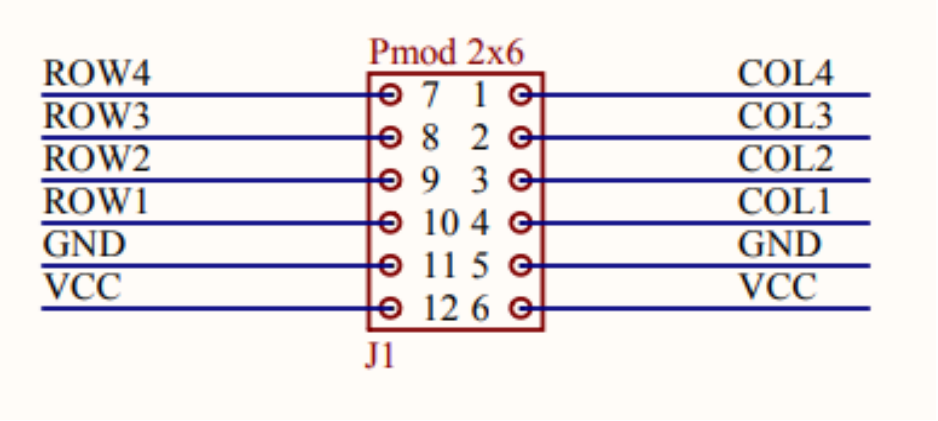


图2. 按键扫描的原理图

图3所示为FRDM-MCXN947板上Pmod接头的原理图。

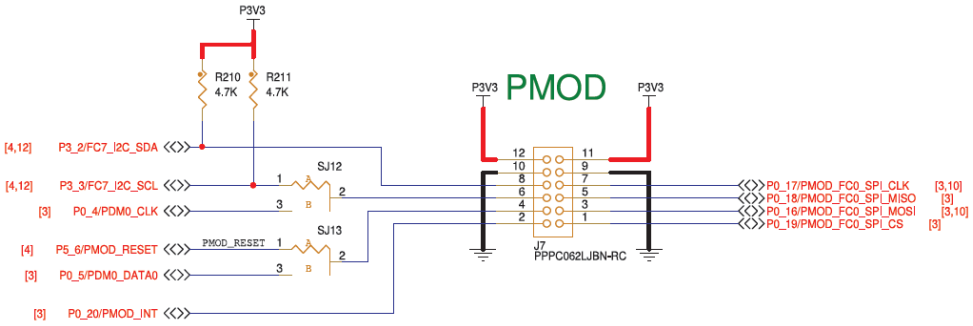


图3. Pmod接头的原理图

5.6 引脚说明

图4显示了如何连接PmodKYPD板和FRDM-MCXN947板。

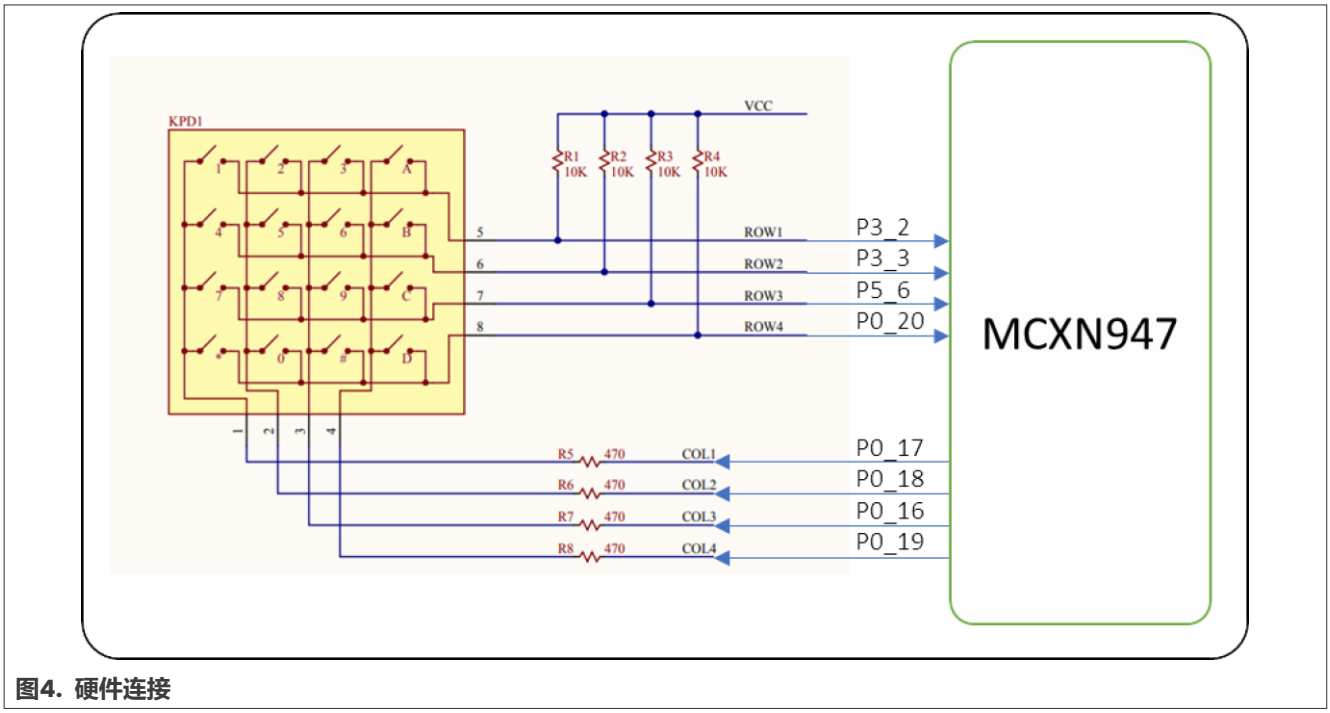


图4. 硬件连接

5.7 按键扫描的时序

当按键未被按下时，SmartDMA会在每一列上连续输出波形。然而，当某个按键被按下时，该键所在行的波形就会与其所在列的波形相同。这样就可以确定是哪个键被按下了。

6 软件说明

本节介绍了SmartDMA按键扫描示例及其实现的功能。

6.1 演示示例说明

本示例中的演示代码是作为一个独立的“Hello World”工程由配置工具生成的。在此工程的基础上添加了I/O初始化代码和SmartDMA驱动程序代码。

6.2 SmartDMA的函数数组

SmartDMA按键扫描的API位于fsl_smartdma_mcxn.h文件中。

```
/*!
* @brief The API index when using s_smartdmaKeyscanFirmware
*/
enum _smartdma_keyscan_api
{
/*!using Smartdma to control GPIO . */
kSMARTDMA_Keyscan_4x4 = 0U,
};
```

在fsl_smartdma_mcxn.c文件中，有个一名为s_smartdmaKeyscanFirmware的数组，其中包含SmartDMA按键扫描函数的实现。将SmartDMA函数封装成一个数组中的目的是降低用户对SmartDMA的研究成本，并支持用户直接使用已实现的模块功能，从而更快地实现应用的功能。

6.3 SmartDMA的初始化

以下函数实现了SmartDMA的初始化。

表1. API例程

例程	说明
SMARTDMA_InitWithoutFirmware	初始化SmartDMA
SMARTDMA_InstallFirmware	安装固件
SMARTDMA_InstallCallback	安装完整的回调函数
SMARTDMA_Boot	启动SmartDMA来运行程序
SMARTDMA_Deinit	取消初始化SmartDMA
SMARTDMA_Reset	重置SmartDMA
SMARTDMA_HandleIRQ	SmartDMA中断请求
SmartDMA_keyscan_callback	SmartDMA中断回调

6.3.1 初始化SmartDMA

要启用SmartDMA，请执行以下操作。

- 清除SmartDMA的复位信号
- 启用SmartDMA的时钟
- 启用SmartDMA的IRQ

6.3.2 安装SmartDMA固件

SmartDMA的功能模块必须放置在固定的内存地址上才能正常工作。在本应用程序中，必须将其置于0x04000000处。

例如：

```
/*! @brief The firmware used for keyscan. */
extern const uint8_t s_smartdmaKeyscanFirmware[];
/*! @brief The s_smartdmaKeyscanFirmware firmware memory address. */
#define SMARTDMA_KEYSCAN_MEM_ADDR 0x04000000U
/*! @brief Size of s_smartdmacameraFirmware */
#define SMARTDMA_KEYSCAN_FIRMWARE_SIZE (s_smartdmaKeyscanFirmwareSize)
/*! @brief Size of s_smartdmacameraFirmware */
extern const uint32_t s_smartdmaKeyscanFirmwareSize;
```

安装SmartDMA固件的过程本质上是将SmartDMA功能模块的代码数组复制到一个指定的RAM地址上。

代码片段如下所示：

```
SMARTDMA_InitWithoutFirmware();
SMARTDMA_InstallFirmware(SMARTDMA_KEYSCAN_MEM_ADDR,s_smartdmaKeyscanFirmware,
SMARTDMA_KEYSCAN_FIRMWARE_SIZE);
```

6.3.3 SmartDMA回调例程

SmartDMA可以主动触发Arm内核的中断，如在数据传输结束后进行触发。

SmartDMA在Arm矢量表中有一个相关的中断号（SMARTDMA_IRQHandler）。在SmartDMA的配置阶段，可以安装一个回调函数。

代码片段如下所示：

```
SMARTDMA_InstallCallback(SmartDMA_keyscan_callback, NULL);
```

在回调函数中，Arm内核可以读取按下的键值并打印日志。

6.3.4 启动SmartDMA API

在应用程序中，定义一个结构体来设置与SmartDMA相关的参数。这些参数包括数据缓冲区的地址、数据传输的长度以及SmartDMA协议栈空间的地址。最重要的是找到一个必须从SmartDMA功能块代码执行的API。

代码片段如下所示：

```
smartdmaParam.smartdma_stack = (uint32_t*)g_samrtdma_stack;
smartdmaParam.p_gpio_reg = (uint32_t*)g_keyscan_gpio_register;
smartdmaParam.p_keyvalue = (uint32_t*)KeyValue;
smartdmaParam.p_keycan_interval = (uint32_t*)&g_keyscan_interval;
SMARTDMA_Boot(kSMARTDMA_Keyscan_4x4, &smartdmaParam, 0x2);
```

启动的过程是将相应API的地址赋给SmartDMA的程序计数器，然后再开始执行函数块。

7 演示的下载和运行

本节介绍了如何准备和运行演示。

7.1 准备演示

1. 在PC主机和开发板上的USB端口之间将USB Type-C连接到micro-USB线。
2. 在PC上为串行设备打开一个串行终端，并进行以下设置：
   - 115200波特率
   - 8个数据位
   - 无奇偶校验
   - 1个停止位
   - 无流量控制
3. 将程序下载到目标板。

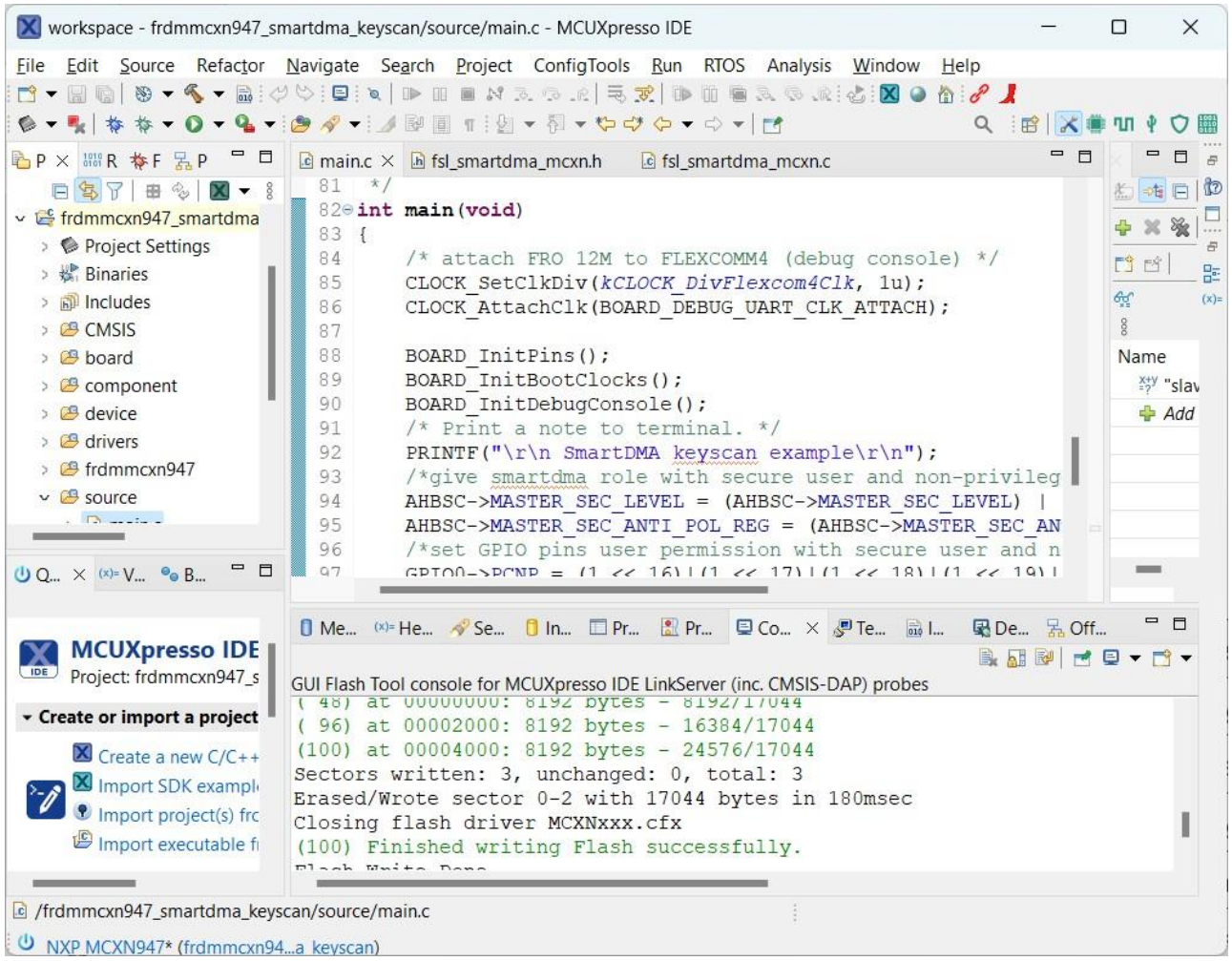


图5. 工程

4. 按下板上的复位按钮或在集成开发环境（IDE）中启动调试器，开始运行演示。

7.2 运行演示

1. 执行演示程序时，串行终端上将显示以下几行。

```
SmartDMA keyscan example
```

2. 按下PmodKYPD上的某个按钮，串行终端上将显示以下几行：

```
Button 2 is pressed
Button 1 is pressed
Button B is pressed
Button 6 is pressed
Button 5 is pressed
```

8 关于本文中源代码的说明

本文中所示的示例代码具有以下版权和BSD-3-Clause许可：

9 修订历史

表2总结了本文的修订情况。

表2. 修订历史

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