AN14190

如何在MCXN947上使用OPAMP

第1.0版 — 2024年1月20日 **应用笔记**

文档信息

信息	内容
关键词	AN14190、OPAMP、电机控制、电源管理、放大
摘要	本应用笔记介绍了OPAMP模块的功能以及如何在MCXN947上使用OPAMP的功能。

1 MCX OPAMP的简介

OPAMP被广泛应用于电机控制、电源管理应用中，可用于电流和电压检测、小信号放大等。MCXN947微控制器集成了三个独立的OPAMP模块。MCXN947中的OPAMP模块可以配置为低噪模式或高速模式。正负增益都是可编程的。此外，正负增益均可配置为缓冲模式，以便用户能够连接外部电阻来配置增益和功能。MCXN947的OPAMP模块提供了两个正输入引脚。触发控制器可以切换这两个引脚。且OPAMP的正参考电压、负增益电阻、阶梯电压输出及OPAMP输出都可以连接到ADC。正参考电压可以在其内部连接到VDDA2/2、DAC、VERF0和VERF1V。图1所示为MCX N947的OPAMP模块的框图。

本应用笔记介绍了OPAMP模块的功能以及如何在MCXN947上使用OPAMP的功能。

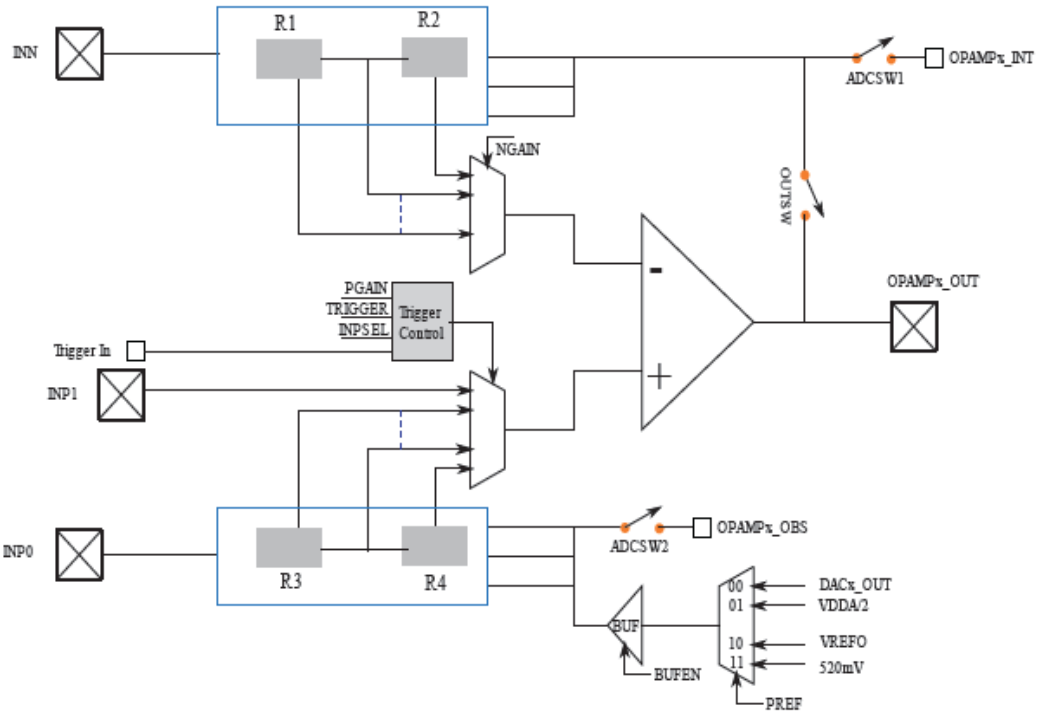

图1. MCXN947的OPAMP模块框图

2 典型的OPAMP类型

OPAMP是一种电子集成电路，包含一个多级放大电路。其输入级是一个差分放大电路，具有高输入电阻和抑制零漂的能力。

理想的OPAMP具有以下特性：

- 输入偏置电流I_B = 0
- 输入偏移电压V_E = 0
- 输入阻抗Z_{IN} = ∞
- 输出阻抗Z_{OUT} = 0
- 增益a = ∞

为了简化分析，请参见图2中的理想OPAMP。

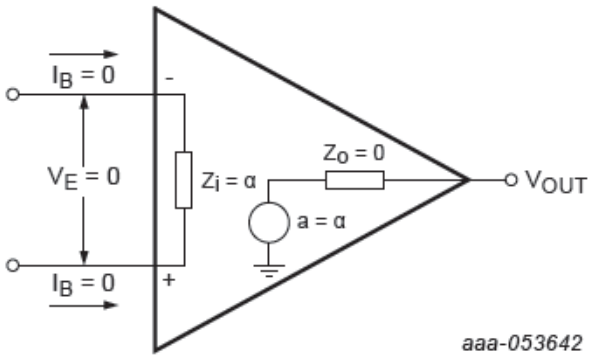

图2. 理想OPAMP

2.1 电压跟随器OPAMP

图3所示为电压跟随器OPAMP的连接图。

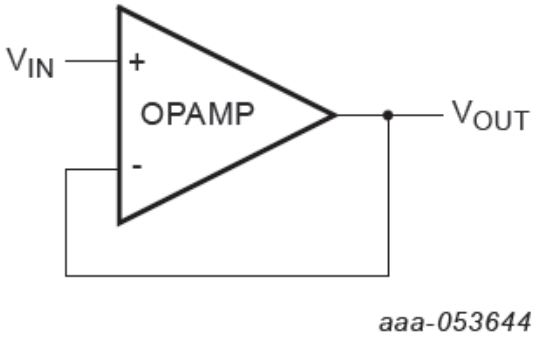

图3. 电压跟随器OPAMP

在同相OPAMP中，如果令R2 = 0并移除R1，可以得到等式(1)如下：

$$V_{OUT} = V_{IN} \tag{1}$$

为了对输入信号进行阻抗适配，该电路使用OPAMP作为跟随缓冲器。

2.2 同相OPAMP

图4所示为同相OPAMP的连接图。

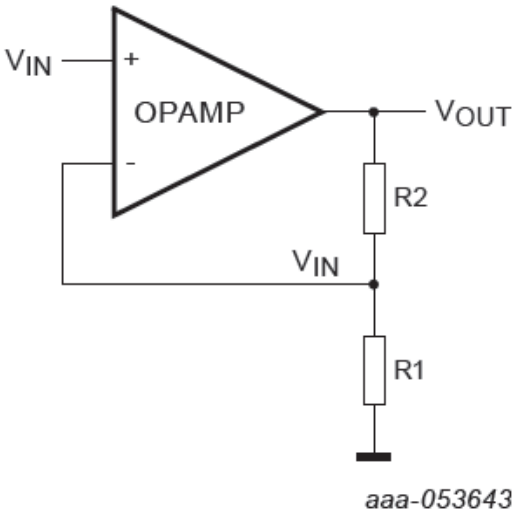

图4. 同相OPAMP

同相OPAMP将输入信号连接到其正输入端。根据理想OPAMP的假设，当输入电流I_B = 0且输入偏移电压V_E = 0时，可以得到如下等式：

$$V_{IN} = V_{OUT} \frac{R_1}{R_1+R_2} \tag{2}$$

则：

$$V_{OUT} = V_{IN} \left(1 + \frac{R_2}{R_1}\right) \tag{3}$$

输出信号是一个放大信号，并且与输入信号同相。电路输入阻抗为无穷大阻抗。

2.3 反相OPAMP

图5所示为反相OPAMP的连接图。

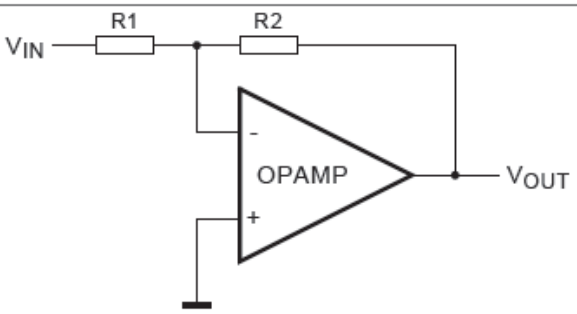

图5. 反相OPAMP

反相OPAMP将输入信号连接到其负输入端。根据理想OPAMP的假设，如果输入电流IB = 0且输入偏移电压VE = 0，可以得到如下等式：

$$\frac{V_{IN}}{R_1} = -\frac{V_{OUT}}{R_2} \tag{4}$$

则：

$$V_{OUT} = \left(-\frac{R_2}{R_1}\right)V_{IN} \quad (5)$$

输出信号为一个放大信号，并且与输入信号反相。

2.4 差分OPAMP

图6所示为差分OPAMP的连接图。

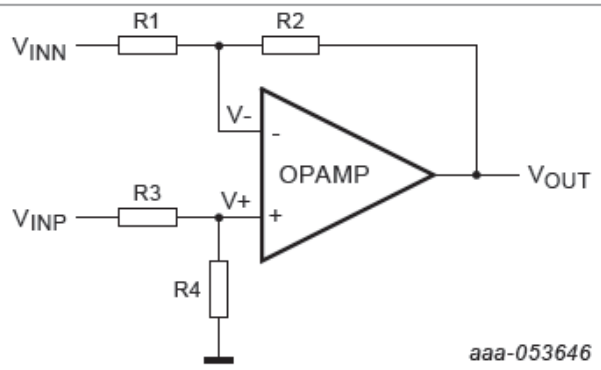

图6. 差分OPAMP

差分OPAMP放大了输入信号之间的电压差。根据理想OPAMP的假设，如果输入电流I_B = 0且输入偏移电压V_E = 0，则可以得到如下等式：

从：

$$\frac{V_{INP}-V_+}{R_3} = \frac{V_+}{R_4} \quad (6)$$

可以得到：

$$V_+ = \frac{R_4}{R_3+R_4} V_{INP} \quad (7)$$

从：

$$\frac{V_- - V_{INN}}{R_1} = \frac{V_{OUT}-V_-}{R_2} \quad (8)$$

可以得到：

$$V_{OUT} = \frac{R_1+R_2}{R_1}V_- - \frac{R_2}{R_1}V_{INN} \quad (9)$$

根据 V+ = V-，从等式7和等式9，可以得到：

$$V_{OUT} = \frac{R_1+R_2}{R_1} * \frac{R_4}{R_3+R_4}V_{INP} - \frac{R_2}{R_1}V_{INN} \quad (10)$$

如R1=R3、R2=R4，则：

$$V_{OUT} = \frac{R_2}{R_1}\left(V_{INP} - V_{INN}\right) \quad (11)$$

在该电路中，差分信号(V_{INP} – V_{INN})会乘以级增益。该电路是一个差分放大器。它仅放大输入信号的差分部分，并抑制输入信号的共模部分。

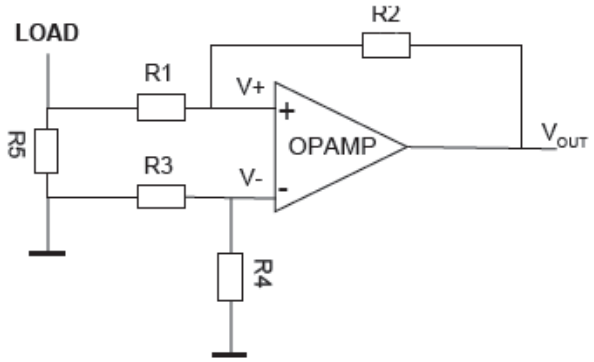

图7. 电流检测电路

图7所示为一个差分OPAMP的用例。它可以用于检测和计算负载电流。

2.5 OPAMP积分电路

图8所示为积分电路中使用的OPAMP。

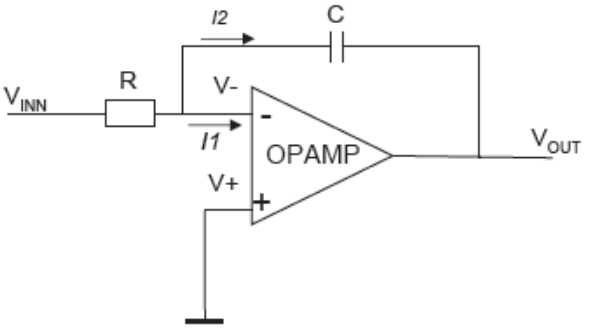

图8. OPAMP积分电路

基于虚短和虚断原理得到等式（12）和（13）如下所示：

$$V_+ = V_- \tag{12}$$

$$I_1 = 0 \tag{13}$$

可得下面的等式（14）：

$$I_2 = I_1 = \frac{V_{INN}}{R} \tag{14}$$

假设电容的初始电压为零，得到等式（15）：

$$V_- - V_{OUT} = \frac{1}{C}\int I_2 d_t = \frac{1}{C}\int \frac{V_{INN}}{R} d_t \tag{15}$$

等式（16）所示为OPAMP输出引脚的VOUT值：

$$V_{OUT} = -\frac{1}{RC}\int V_{INN} d_t \tag{16}$$

2.6 OPAMP微分电路

图9所示为微分电路中使用的OPAMP。

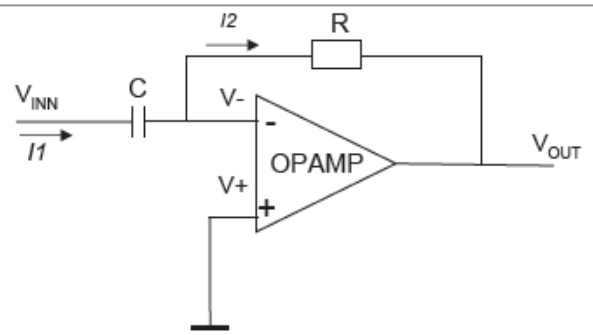

图9. OPAMP微分电路

基于虚短和虚断原理，得到等式：

$$V_{OUT} = -I_2 * R = -I_1 * R = -RC\frac{dV_{INN}}{d_t} \tag{17}$$

等式（18）所示为OPAMP输出引脚的V_{OUT}值：

$$V_{OUT} = -RC\frac{dV_{INN}}{d_t} \tag{18}$$

3 MCXN947上的OPAMP演示

在本节中，使用FRDM-MCXN947电路板进行OPAMP功能测试，并基于SDK_2_14_0_FRDM-MCXN947进行测试演示。

3.1 演示平台

本节介绍了硬件和软件的要求。

3.1.1 硬件

该演示是在FRDM-MCXN947电路板上开发的。图10所示为MCXN947 FRDM电路板。

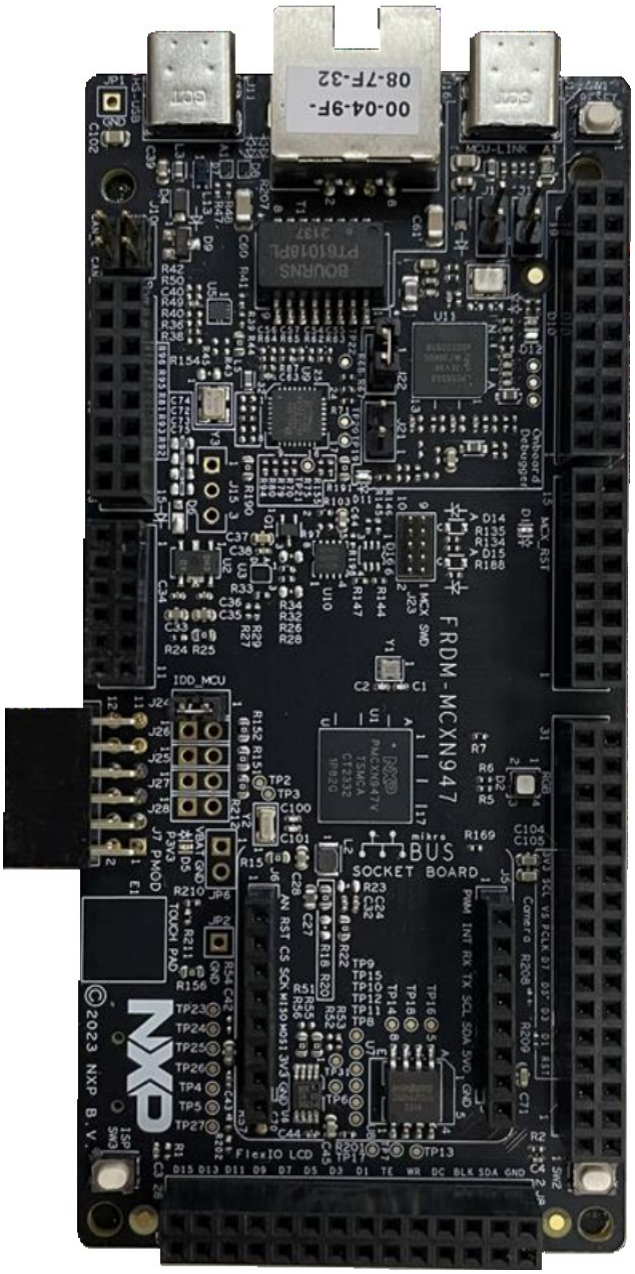

图10. FRDM-MCXN947电路板

3.1.2 软件

- 软件包：SDK_2_14_0_FRDM-MCXN947
- IDE：MDK5.37

4 OPAMP的模块测试

OPAMP模块具有多种功能，如电压跟随器、同相、反相、差分等。本节介绍了如何设置OPAMP的功能。

4.1 跟随器的测试

图11所示为跟随器测试的硬件设置。要测试此功能，请将MCXN947-FRDM电路板上的J1-4与J4-1连接起来，从而将DAC0_OUT与OPAMP0_INP0相连，以测量OPAMP0_OUT引脚的J8-20电压。

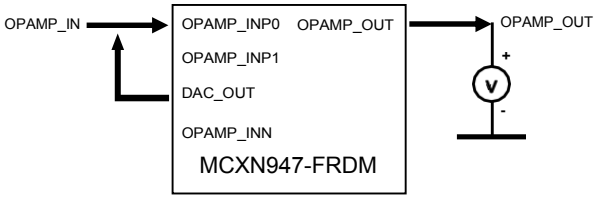

图11. MCXN947-FRDM的硬件设置

以下为电压跟随器OPAMP的测试代码。

```
void OPAMP_Configuration(void)
{
    opamp_config_t config;
    OPAMP_GetDefaultConfig(&config);
    config.PosInputChannelSelection = kOPAMP_PosInputChannel0;
    config.posGain =  kOPAMP_PosGainNonInvert2X;
    config.negGain = kOPAMP_NegGainBufferMode;
    config.enable = true;
    config.enableRefBuffer = false;
    OPAMP_Init(DEMO_OPAMP_BASEADDR, &config);
}
```

4.2 同相测试

此硬件设置与图11所示相同。将FRDM-MCXN947电路板上的J1-4与J4-1连接起来，从而将DAC0_OUT与OPAMP0_INP0相连，以测量OPAMP0_OUT引脚的J8-20电压。

以下为非反相OPAMP的测试代码。

```
void OPAMP_Configuration(void)
{
    opamp_config_t config;
    OPAMP_GetDefaultConfig(&config);
    config.PosInputChannelSelection = kOPAMP_PosInputChannel0;
    config.posGain = kOPAMP_PosGainNonInvertDisableBuffer2X;
    config.negGain = kOPAMP_NegGainInvert1X;
    config.enable = true;
    config.enableRefBuffer = false;
    OPAMP_Init(DEMO_OPAMP_BASEADDR, &config);
}
```

4.3 差分测试

此硬件设置与图11所示相同。将MCXN947-FRDM电路板上的J1-4与J4-1连接，从而将DAC0_OUT与OPAMP0_INP0相连，以测量OPAMP0_OUT引脚的J8-20电压。

以下为差分OPAMP的测试代码。

```
void OPAMP_Configuration(void)
{
    opamp_config_t config;
```

```
    OPAMP_GetDefaultConfig(&config);
    config.PosInputChannelSelection = kOPAMP_PosInputChannel0;
    config.posGain =  kOPAMP_PosGainNonInvert1X;
    config.negGain = kOPAMP_NegGainInvert1X;
    config.posRefVoltage = kOPAMP_PosRefVoltVrefh3;
    config.enable = true;
    config.enableRefBuffer = true;
    OPAMP_Init(DEMO_OPAMP_BASEADDR, &config);
}
```

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6 修订历史

表1汇总了对本文档所做的修订。

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