

1 Description

This [subsystem software example](#) creates a two OPA instrumentation amplifier (INA) using an MSPM0 and external resistors. In this configuration, the difference between V_{i1} and V_{i2} is amplified, and outputs a single-ended signal with high common-mode rejection. The output of the integrated INA can be sampled using an internal ADC channel of the device.

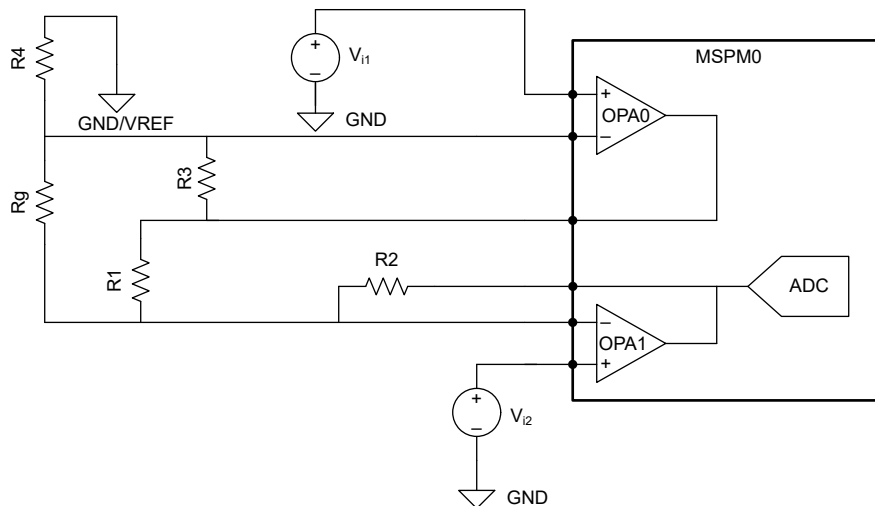


Figure 1-1. Subsystem Functional Block Diagram

2 Required Peripherals

This application requires the two OPAs integrated in the MSPM0, and an ADC for sampling the results

Table 2-1. Required Peripherals

Subblock Functionality	Peripheral Use	Notes
OPA	OPA0	Pins are configured in SysConfig based on what input sources are selected
OPA	OPA1	
ADC	ADC0	Used to measure the output voltage of the INA

3 Compatible Devices

Based on the requirements in [Table 2-1](#), this example is compatible with the devices in [Table 3-1](#). The corresponding EVM can be used for prototyping.

Table 3-1. Compatible Devices

Compatible Devices	EVM
MSPM0Lx	LP-MSPM0L1306
MSPM0Gx	LP-MSPM0G3507

4 Design Notes

The design of the two op amp instrumentation amplifier using the integrated amplifiers of the MSPM0 is not different from the design using discrete op amps. The [Two op amp instrumentation amplifier circuit](#) application note covers the design notes for this circuit. These are paraphrased in the following list for convenience:

1. R_g sets the gain of the circuit.
2. High-value resistors can degrade the phase margin of the circuit and introduce additional noise in the circuit.
3. The ratio of R_4 and R_3 set the minimum gain when R_g is removed.
4. Ratios of R_2 / R_1 and R_4 / R_3 must be matched to avoid degrading the DC CMRR of the instrumentation amplifier and to make sure the V_{ref} gain is 1V/V.
5. Linear operation is contingent upon the input common-mode and output swing ranges of the discrete op amps used. The linear output swing ranges are specific under the A_{OL} test conditions in the device data sheet.

5 Design Steps

Similar to [Design Notes](#), the steps for designing the external circuitry of the two op amp INA is not different from the discrete method. The following list describes the steps in the document covering the discrete design:

1. Calculate the transfer function of the circuit.

$$V_o = V_{iDiff} \times G + V_{ref} = (V_{i2} - V_{i1}) \times G + V_{ref} \quad (1)$$

when $V_{ref} = 0$, the transfer function simplifies to the following equation:

$$V_o = (V_{i2} - V_{i1}) \times G$$

where G is the gain of the instrumentation amplifier and $G = 1 + \frac{R_4}{R_3} + \frac{2R_2}{R_g}$

2. Select R_4 and R_3 to set the minimum gain.

$$G_{min} = 1 + \frac{R_4}{R_3} = 5 \frac{V}{V} \quad (2)$$

Choose $R_4 = 20k\Omega$

$$G_{min} = 1 + \frac{20k\Omega}{R_3} = 5 \frac{V}{V}$$

$$R_3 = \frac{R_4}{5-1} = \frac{20k\Omega}{4} = 5k\Omega \rightarrow R_3 = 5.1k\Omega \quad (\text{Standard Value})$$

3. Select R_1 and R_2 . Make sure that R_1 / R_2 and R_3 / R_4 ratios are matched to set the gain applied to the reference voltage at 1V/V.

$$\frac{V_{o_ref}}{V_{ref}} = \left(-\frac{R_3}{R_4}\right) \times \left(-\frac{R_2}{R_1}\right) = \frac{R_3 \times R_2}{R_4 \times R_1} = 1 \frac{V}{V} \quad (3)$$

$$\frac{R_2}{R_1} = \frac{R_4}{R_3} \rightarrow R_1 = R_3 = 5.1k\Omega \text{ and } R_2 = R_4 = 20k\Omega \quad (\text{Standard Value})$$

4. Select R_g to meet the desired maximum gain $G = 10V/V$.

$$G = 1 + \frac{R_4}{R_3} + \frac{2R_2}{R_g} = 1 + \frac{20k\Omega}{5.1k\Omega} + \frac{2 \times 20k\Omega}{R_g} = 10 \frac{V}{V} \quad (4)$$

$$R_g = 8k\Omega \rightarrow R_g = 7.87k\Omega \quad (\text{Standard Value})$$

6 Device Configuration

1. Configure SysConfig:
 - a. Select the inverting and non-inverting inputs for the OPAs.
 - b. Enable the output for both OPAs.
2. Build the external circuit with connections to the correlating pins from SysConfig.
3. Determine two input voltages and gain, details are in [Design Considerations](#).

7 Design Considerations

1. Voltage reference:
 - V_{ref} is set to GND in this example but a voltage can be connected to R_4 to change the DC level.
2. Output limitation:
 - For the MSPM0 family, the output signal cannot be greater than VDD.
3. The PGA built into the OPA module can be used as well, but the external resistor values need to be adjusted. The ratios are not necessarily going to be equal; therefore, matching can be imperfect.
4. The ADC can be set for different sampling speeds and conversion resolutions as described. These configurations can be done in SysConfig and more details on the capabilities of the ADC and OPA are found in the device TRM and data sheet.
5. LaunchPad Configuration: On the LaunchPad, the OPA inputs and outputs can be connected to different circuitry such as the onboard photodiode or thermistor circuits. Check the associated LaunchPad user guide to determine which jumpers to remove.

8 Reference

- Texas Instruments, [Download the MSPM0 SDK](#)
- Texas Instruments, [Learn more about SysConfig](#)
- Texas Instruments, [MSPM0L LaunchPad™](#)
- Texas Instruments, [MSPM0G LaunchPad™](#)
- Texas Instruments, [MSPM0 Academy](#)
- Texas Instruments, [Two op amp instrumentation amplifier circuit](#) for discrete implementation of this circuit

9 E2E

See TI's [E2E™](#) support forums to view discussions and post new threads to get technical support for utilizing MSPM0 devices in designs.

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