Application Report
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How to Optimize Performance of AMC1204 in Voltage Sensing

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ABSTRACT

Many applications, such as motor drives and power inverters, require measurements of both current and voltage to obtain motor information, for example, speed, torque and power, to control, monitor and protect system. Meanwhile, these applications will be operated in harsh, noisy environments and high voltage difference between power stage and control stage. Therefore, this is very important that the device have precise performance and isolation functions simultaneously. In this case, AMC1204 can satisfy these criteria. The AMC1204 is optimized for use in current-sensing applications using low-impedance shunts. However, the device can also be used in isolated voltage sensing. In terms of that, this application note will give you an idea of how large shunt resistor that you could use will not influence device performance and how to optimize the system performance if you want to use large shunt resistors.

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1 Design Consideration of AMC1204

The differential analog input of the AMC1204 is implemented with a switched-capacitor circuit. Figure 1 shows the simplified schematic of the ADC input circuitry; the right side of Figure 1 illustrates the input circuitry with the capacitors and switches replaced by an equivalent circuit.

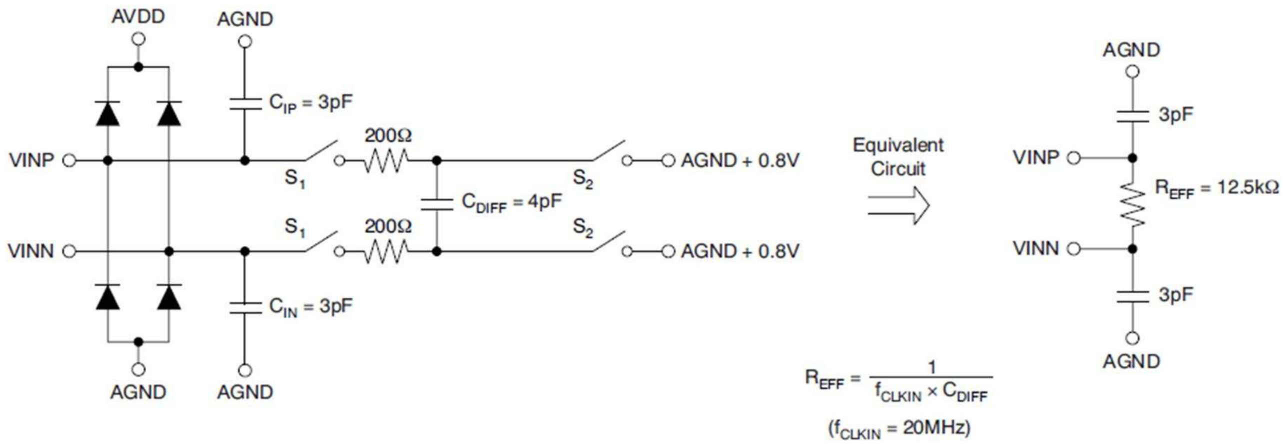

Figure 1. Equivalent Analog Input Circuit

Consider the input impedance of the AMC1204 (R_{ID}: 12.5 kΩ) in designs with high-impedance shunt resistors that can cause degradation of specifications. However, the bias current of the AMC1204 is very small, so it just will cause gain error and not have a big impact in offset error as occurs in the AMC1305. Therefore, if AMC1204 is designed by such applications, there are important details that need to be remembered when you choose the resistor divider.

First, in order to efficiently use the available linear input range of AMC1204, the voltage across R2 must be within ±250 mV, because the linear input range of AMC1204 is ±250 mV.

The first inclination to carry out the voltage sensing is to implement the circuit shown in Figure 2.

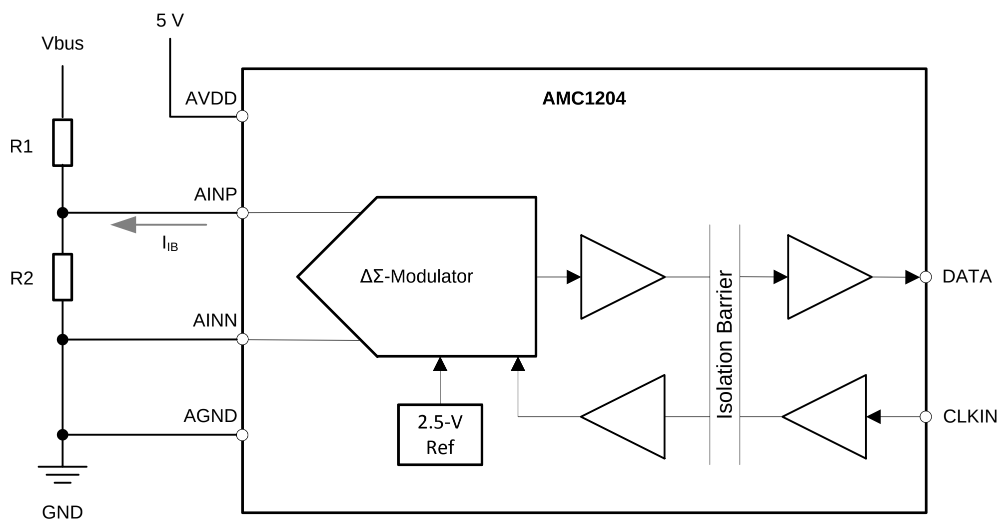

Figure 2. First Rough Solution to Perform Isolated Voltage Monitoring

The resistor divider formed by R1 and R2 in Figure 2 can be governed with Equation 1:

$$V_{R2} = Vbus \frac{R2}{R1 + R2} \tag{1}$$

Where V_{R2} = 0.25 V for AMC1204.

For instance, if the system supply is 30 V and the shunt resistor is 1 kΩ, then R1 can be calculated as 119 kΩ for AMC1204.

Second, as mentioned before, the larger shunt resistor is used, the larger gain error will be obtained. Equation 2 can help you estimate gain error easily.

$$E_G(\%) = \frac{\frac{Vbus}{R1 + (R2//R_{IN})} \times (R2//R_{IN}) - V_{IN}}{V_{IN}} \quad (2)$$

Where V_{IN} = 0.25 V for AMC1204.

Actual influence of offset error and gain error of different shunt resistors for AMC1204 is shown in Figure 3, Figure 4, and Table 1, respectively. When the shunt resistor increases, the offset will not be influenced too much, but gain error will grow linearly. For example, if the shunt resistor is equal to 1.004 Ω, the offset error and gain error is 0.32 mV and –0.97%. But when the shunt resistor rises to 2.4924 kΩ, the offset error is still almost the same, 0.40 mV, however gain error will increase to –17.4%. That is because input bias current of the AMC1204 is small enough, but input impedance is not big enough, so it causes load effect that degrades gain error.

Besides, in the calculation, the load effect is considered, while Delta-sigma modulator error is not. Thus, the result of calculation will be slightly different from that of measurement.

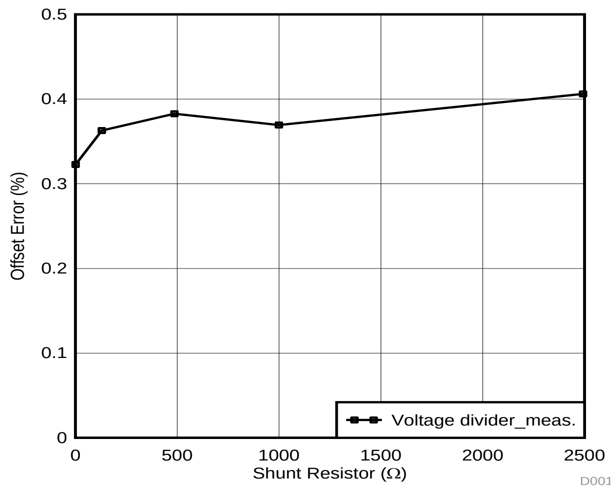

Figure 3. Offset Error vs Different Shunt Resistor (AMC1204)

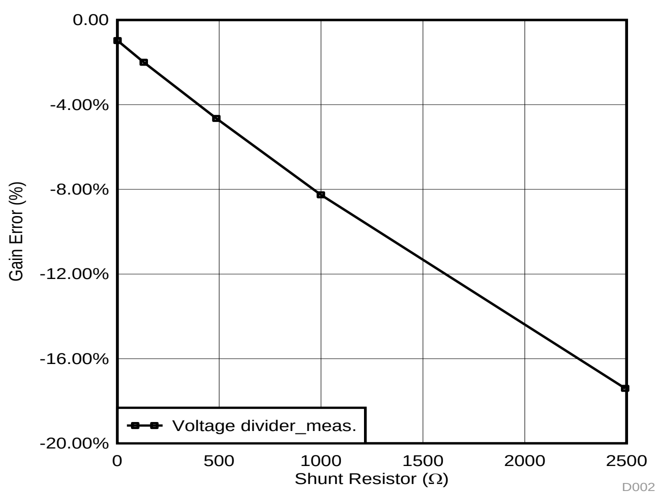

Figure 4. Gain Error vs Different Shunt Resistor (AMC1204)

Table 1. Gain Error vs Different Shunt Resistor (AMC1204)

Gain Error-Shunt Resistor (Ω)	Voltage divider_cal. (%)	Voltage divider_meas. (%)
1.004	–0.008%	–0.97%
129.57	–1.02%	–2.00%
486.1	–3.71%	–4.65%
999	–7.34%	–8.26%
2492.4	–16.51%	–17.40%

The INL will not be influenced by different shunt resistors. No matter how large shunt resisters will be, INL will always be within specification (max: ±8 LSB). The measurement result for AMC1204 is shown in Figure 5.

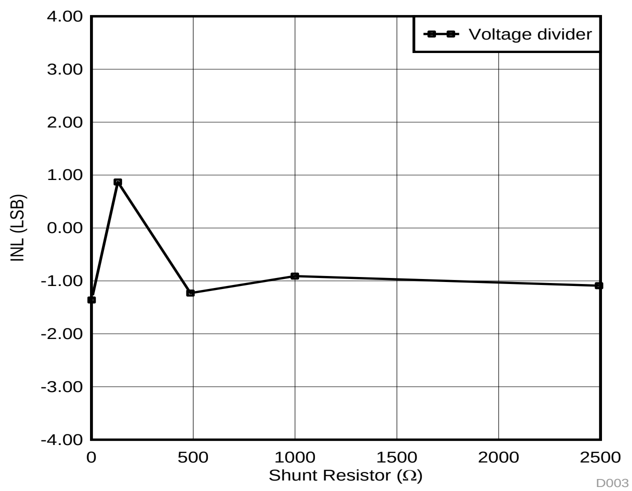

Figure 5. INL vs Different Shunt Resistor (AMC1305M25)

If voltage sensing system is not allowed to add additional compensated circuits, but AMC1204's performance is desired such as offset, gain error within datasheet specification, then shunt resistor, R2, must be lower than 1 Ω.

2 Optimize the Performance of AMC1204 with Large Shunt Resistor

In order to ignore errors which come from the op amp, you need to consider some specifications. First of all, the offset error of the op amp must be much lower than ±1 mV. Secondly, bandwidth of the op amp must be higher than 1 MHz. Third, the input bias current must be smaller to avoid offset error. Last, closed-loop output impedance must be smaller than 1 Ω. Some op amp datasheets just provide open-loop output impedance, you could use Equation 3 to translate or use TI-TINA to simulate.

$$Rout = \frac{R_O}{1 + Aol\beta} \tag{3}$$

Based on this criterion, OPA376 is used.

Vos(max): 25 µV, Vos(typ.): 5 µV

GBW: 5.5 MHz

I_{ib}(max): 10 pA

Rout at DC: 163.5 µΩ

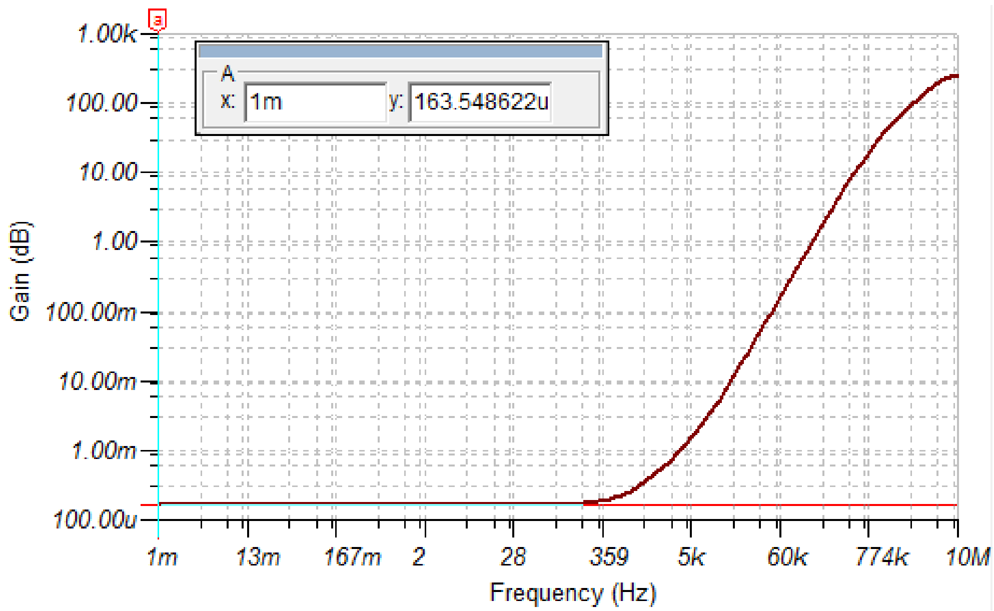

Figure 6. Rout Simulation of OPA376

Simulation and measurement results are shown in Figure 7 and Figure 8. The offset error is almost the same when the shunt resistor is equal to 486.1 / 2.492 kΩ, but the gain error will be reduced from –4.65 / –17.4% to –0.93 / –0.90%, respectively.

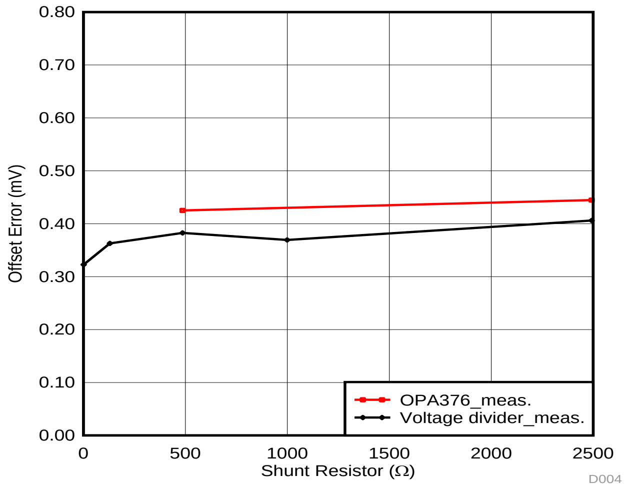

Figure 7. Offset Error vs Different Shunt Resistor With OPA376 (AMC1204)

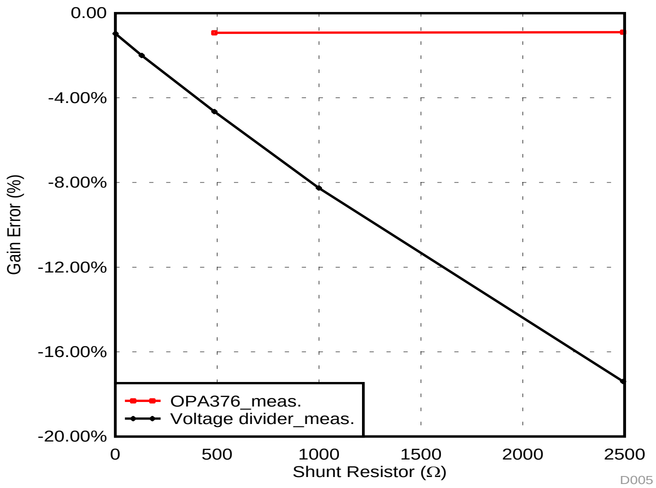

Figure 8. Gain Error vs Different Shunt Resistor With OPA376 (AMC1204)

The designer must be aware that if their system does not have suitable power for the op amp, you might need to design other power paths. Therefore, this is a trade-off between performance and cost.

3 Conclusion

The application report provides straightforward equations to evaluate initial performance when you add large shunt resistor in voltage sensing, and also presents a method to optimize performance of the AMC1204. Hence, as long as you add suitable compensated circuit in these modulators, it can achieve good performance although TI's isolated delta-sigma modulator is optimized by current sensing.

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