Technical Article

Power Performance Trade-Offs in Operational Amplifiers

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High performance with low power consumption: this requirement is coming to bear in more and more applications, especially when it comes to mobile, battery-operated devices. Particularly in the times of IoT, Industry 4.0, and digitalization, these handhelds make many aspects of daily life easier. This is true in applications ranging from mobile vital sign monitoring to the monitoring of machines and systems in an industrial setting. Demands for higher performance and maximum battery life are also seen in end user products, such as smartphones and wearables.

The limited battery energy available for supplying power necessitates efficient components with minimal current in active mode to maximize device runtime. Alternatively, lower power consumption allows one to achieve the same battery life with a lower capacity battery, reducing size, weight, and cost. Temperature management also should not be neglected. Here, too, more efficient components play a positive role. Cooling management, which takes up space, can be reduced because of the lower amount of generated heat. There is an extensive range of low power and even ultralow power (ULP) components available. This article focuses specifically on low power op amps.

Trade-Offs Between Power Consumption and Performance

There are often trade-offs related with the power consumption of an operational amplifier that need to be considered in the selection of a suitable amplifier.

Lower power often also means lower bandwidth. However, this also depends on the given amplifier architecture and stability requirements. The higher the parasitic capacitances and inductances, usually the lower the bandwidth. Thus, for example, transimpedance amplifiers (current feedback amplifiers) offer a relatively high bandwidth, but with lower precision. With a few tricks, the bandwidth-to-power ratio can be improved.

For example, the gain bandwidth (GBW) is typically as follows:

$$GBW = \frac{G_m}{C} \tag{1}$$

G_m is the transconductance, or the ratio between the output current and the input voltage (I_{OUT}/V_{IN}), and C is the internal compensation capacitance.

The classic way to increase bandwidth is to increase bias currents, which will increase G_m at the expense of more power consumption. But we don't want to do that for lower power.

Usually, the compensation capacitance should set the dominant pole, so ideally the load capacitance wouldn't affect the bandwidth at all.

A lower capacitance yields typically to a higher bandwidth, which is then limited by the physical characteristics of the amplifier, but it will also hurt the stability, whereas it usually results in improved stability at a low noise gain. Nevertheless, in reality we can't drive as large of a purely capacitive load at lower noise gains.

Another trade-off in the use of low power op amps is the often higher voltage noise. However, input referred voltage noise will typically be the amp's dominant contributor to the total output broadband noise, but it could be dominated by resistor noise. The total noise is typically dominated by the noise sources in the input stage (for example, collectors have shot noise and drains have thermal noise). The 1/f noise (flicker noise) varies depending on the architecture and is caused by special defects in the component materials, among other things. Thus, it is typically dominated by the component size. In contrast, the current noise is usually lower at lower power levels. However, especially in bipolar amplifiers, it should also not be neglected. In the 1/f region, 1/f current noise can be the dominant contributor to total 1/f noise at the amplifier output. Other trade-offs lie in the distortion performance and the drift values. Low power op amps usually exhibit a higher total harmonic distortion (THD), but like current noise, the input bias and offset currents in bipolar amplifiers decrease with decreasing supply currents. Another important characteristic of operational amplifiers is the offset voltage. It is typically influenced through adaptation of the input-side components and therefore does not cause any significant loss of performance at low power, so VOS and VOS drift are constant over power. The external circuitry and the feedback resistors (R_F) also affect the performance of an operational amplifier. Higher resistance values reduce the dynamic power and the harmonic distortion, but they increase the output noise and the effects associated with the bias current.

To reduce the power consumption even further, many devices often have a standby or sleep function. This enables key device features to be deactivated when not in use and only reactivated when they are needed. The wake-up time is usually longer for low power amplifiers. The trade-offs previously described are summarized in Table 1.

Table 1. Trade-Offs in Low Power Op Amps

	Power Consumption ↓	Feedback Resistance (R_F) ↑
Positive Effect	Current noise ↓ Bias current drift ↓ Offset current drift ↓	Dynamic power ↓ Distortion (THD) @ HF ↓
Negative Effect	Bandwidth ↓ Voltage noise ↑ Distortion (THD) @ HF↑ Wake-up time ↑ Driver power ↓	Output noise ↑ Effects on bias current ↑
Neutral Effect	Offset voltage drift	

A good compromise between these characteristics is offered by the ADA4945-1 bipolar differential amplifier. Due its low DC offset, DC offset drift, and outstanding dynamic performance, it is well suited for numerous high resolution, powerful data acquisition and signal processing applications in which a driver is needed for an ADC, as shown in Figure 1 with the ADA4945-1, driving the AD4022 ADC. Including multiple power modes, you can optimize the performance vs. power trade-offs for the specific converter. For example, its full power mode should pair well with the AD4020, and then you can switch down to low power mode for the lower sample rate of AD4021 or AD4022.

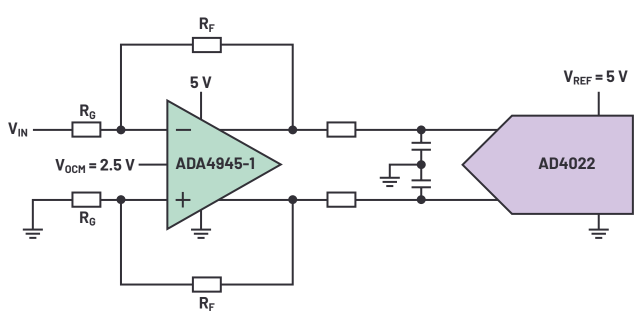

Figure 1. An example of a simplified signal chain for a high resolution data acquisition system.

About the Author

Thomas Brand began his career at Analog Devices in Munich in 2015 as part of his master's thesis. After graduating, he was part of a trainee program at Analog Devices. In 2017, he became a field applications engineer. Thomas supports large industrial customers in Central Europe and also specializes in the field of Industrial Ethernet. He studied electrical engineering at the University of Cooperative Education in Mosbach before completing his postgraduate studies in international sales with a master's degree at the University of Applied Sciences in Constance. He can be reached at thomas.brand@analog.com.