Technical Article

What Are the Advantages of Using JFET-input Amplifiers in High-speed Applications?

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As an introduction to this post, let me provide some background. Voltage-feedback amplifiers are sometimes categorized based on the type of transistors in the device: either bipolar, complementary metal-oxide semiconductor (CMOS) or junction field-effect transistor (JFET). A few amplifiers may even use a combination of these transistors to extract their benefits in various amplifier stages. For example, JFET-input amplifiers include an input differential pair using JFETs which enable a very large amplifier input impedance, which is followed by gain and output stages using bipolar transistors.

JFET-input amplifiers are used as test and measurement analog front ends, current sense amplifiers, analog-to-digital converter (ADC) drivers, photodiode transimpedance amplifiers, or as a multichannel sensor interface through multiplexers. In this post, I'll discuss the advantages of using JFET-input amplifiers in these applications using the OPA2810 as an example. The OPA2810 is a 110MHz, 27V, wide-input differential voltage ($V_{IN,Diff}$) tolerant rail-to-rail input/output FET input amplifier.

Data Acquisition and Current Sensing

Test and measurement equipment measures a voltage signal using an amplifier as a unity-gain buffer or in a noninverting gain configuration. The equipment must measure the voltage signal without disturbing the measured quantity, which is possible with the high-Z inputs and low bias currents in a JFET-input amplifier. In power analyzers and oscilloscopes, the presence of a large impedance attenuator at the front end makes it even more necessary to use a high-Z input amplifier.

The JFET-input and CMOS amplifiers' inputs are connected with the gates of the input differential pair transistors, which causes very small bias currents in the range of few picoamperes. The OPA2810's very high input impedance, with bias current of ~2pA varying minimally across its input common-mode voltage range, is made possible through the use of a main JFET input stage along with a CMOS auxiliary stage operating within 2.5V of the positive supply. Current-sensing applications measure the voltage drop caused by current flowing through a shunt resistor. The relatively small variations in bias current with change in input common-mode voltage (linear operating region away from the supplies), as shown in Figure 1 for the OPA2810 operating off a ±12V supply, help minimize variation in offset voltage with input signal swing, to give a high accuracy current-sensing circuit.

Test and measurement equipment must also recreate input signals on the amplifier output accurately, which is enabled with the exceptional distortion performance of the OPA2810 due to its large 75mA linear output drive capability. Since the equipment usually is line-powered, the amplifier must operate off supply voltages greater than 24V.

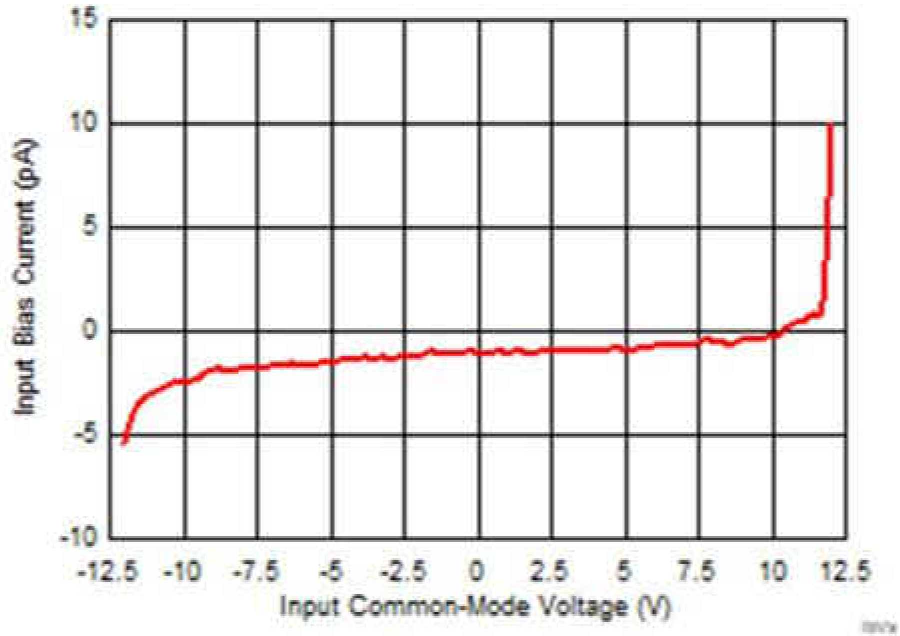


Figure 1. Bias Current Variation with Input Common-mode Voltage for the OPA2810

Wideband Photodiode Transimpedance Applications

In wideband photodiode transimpedance applications, the photodiode current is converted into a voltage using an amplifier configured as shown in Figure 2. Although a high-speed amplifier's gain-bandwidth product is useful for achieving a large closed-loop gain, the low input current noise and bias currents in a JFET-input amplifier help improve output noise performance in circuits using high to very high transimpedance gains while reducing output voltage offsets due to bias currents. You must use a feedback capacitor, C_F, to make this circuit stable. Calculating the values of the components in Figure 2, using equations in this blog post, "What you need to know about transimpedance amplifiers, part 1," results in the gain magnitude and phase plots shown in Figure 3.

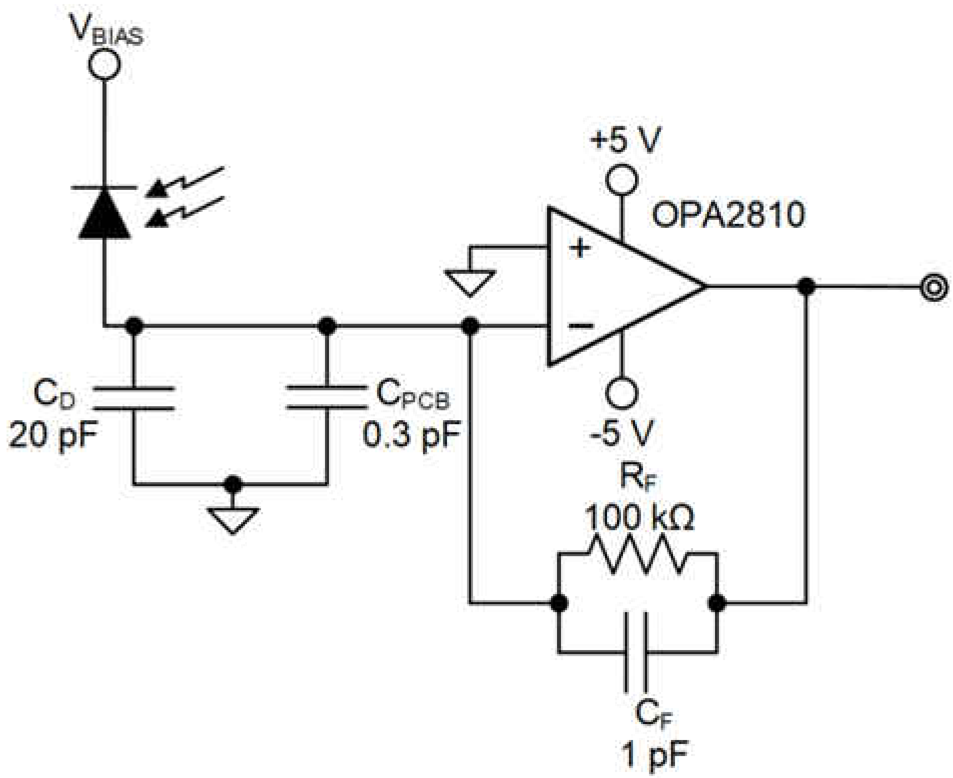


Figure 2. Photodiode Transimpedance Amplifier Circuit with Feedback Compensation Capacitance

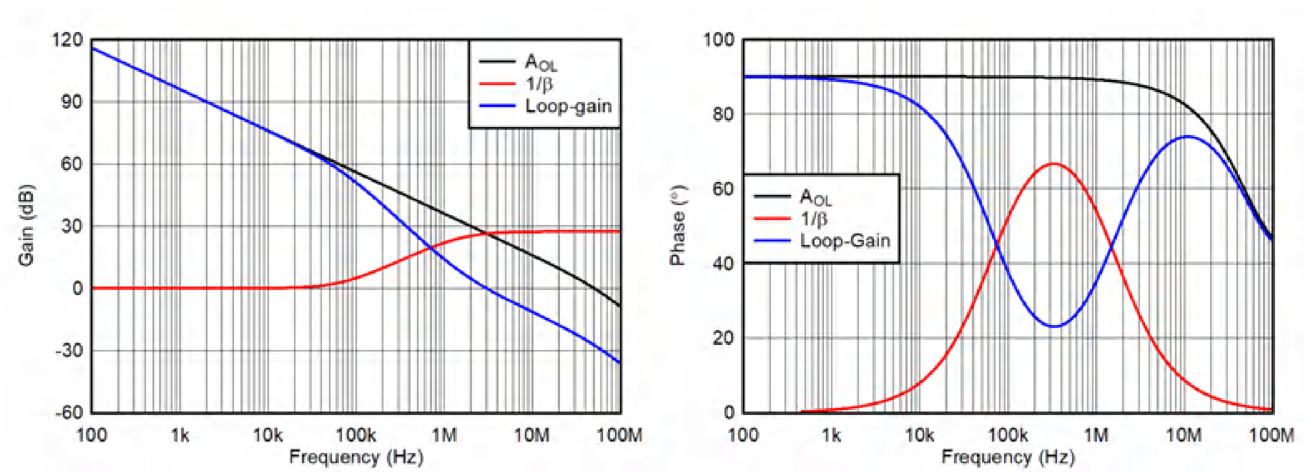
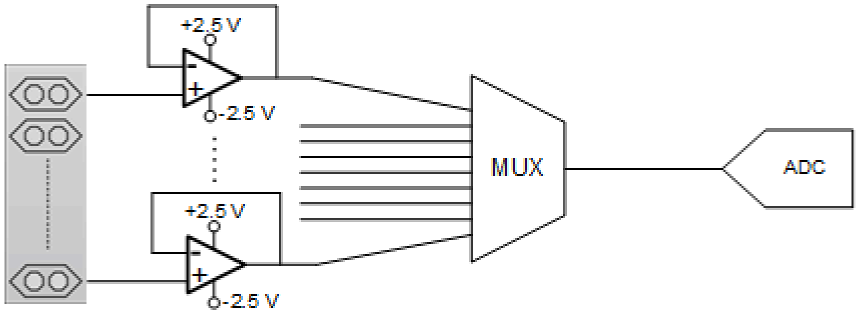


Figure 3. Gain Magnitude and Phase Bode Plots for the Transimpedance Amplifier in Figure 2

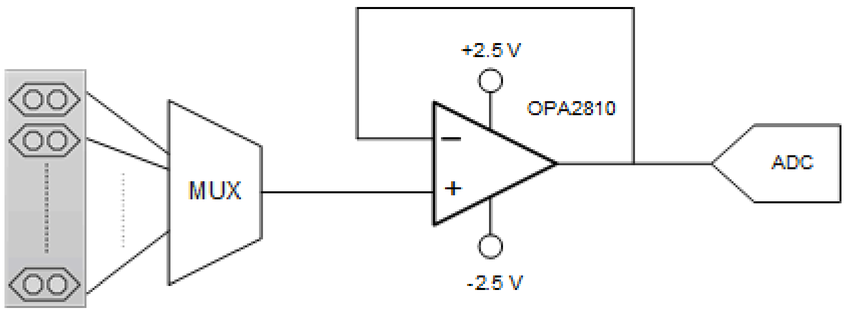
Multichannel-input Data-acquisition Systems

High-Z input amplifiers are particularly useful when interfaced with sensors that have relatively high output impedance. Such multichannel systems usually interface these sensors with the signal chain through multiplexers. You can use the circuit shown in Figure 4a with an amplifier to interface with each sensor and connect to the inputs of a multiplexer. An alternate circuit, shown in Figure 4b, uses a single fast-settling amplifier at the output of a multiplexer that is directly connected to the sensors. This gives rise to large signal transients when switching between channels, where the amplifier's settling performance and maximum allowed input differential voltage begin to matter.

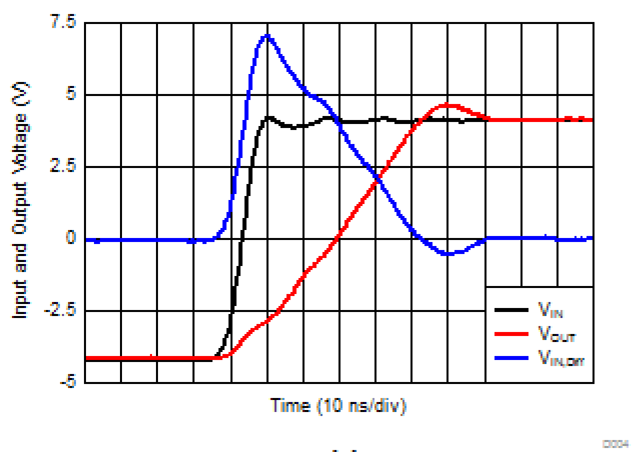
Figure 4c shows the output voltage and input differential voltage when applying an 8V step at the noninverting input of the OPA2810 configured as a unity-gain buffer in Figure 4b.



(a)



(b)



(c)

Figure 4. A Multichannel Sensor Front End with Multiple Slow-settling Amplifiers (a); Using a Single OPA2810 with Fast Settling (b); Large-signal Transient Response Using the OPA2810 (c)

Because of the fast input transient, the amplifier is slew-limited and the inputs cease to track each other (a maximum $V_{IN,Diff}$ of 7V is seen Figure 4c) until the output reaches its final value and the negative feedback loop is closed. For standard amplifiers with a 0.7-1.5V $V_{IN,Diff}$ rating, you must use current-limiting resistors in series with the input pins to protect from irreversible damage, which also limits the device frequency response. The OPA2810 has in-built input clamps that allow the application of as much as 7V of $V_{IN,Diff}$, with no need for external resistors and no damage to the device or a shift in performance specifications. Such an input-stage architecture coupled, with its fast settling performance, makes the OPA2810 a good fit for multichannel sensor multiplexed systems.

ADC Drivers

In a majority of these applications, high-speed amplifiers may be driving successive approximation register (SAR) or pipeline ADCs. Because the ADCs have input capacitors switching in and out during the sampling intervals, you must use an amplifier to prevent from input loading when driving these converters. For fast sampling rates, the ADC input needs to settle fast to within 0.5 LSB, before the digitization starts, which is made possible with the use of high-speed amplifiers due to their larger gain-bandwidth product, resulting loop gain and improved settling performance. The OPA2810 settles to within 0.001% of the final value within around 130ns with a 10V input step and unity gain on a 24V supply, as shown in Figure 5. Because of its large slew rate and fast settling performance, you could use the OPA2810 amplifier to digitize multiple lower-frequency signals at its input. Using a high-voltage JFET-input amplifier at a supply voltage greater than the ADC helps achieve an improved signal-to-noise and distortion ratio (SINAD) through the use of the ADC's full input dynamic range.

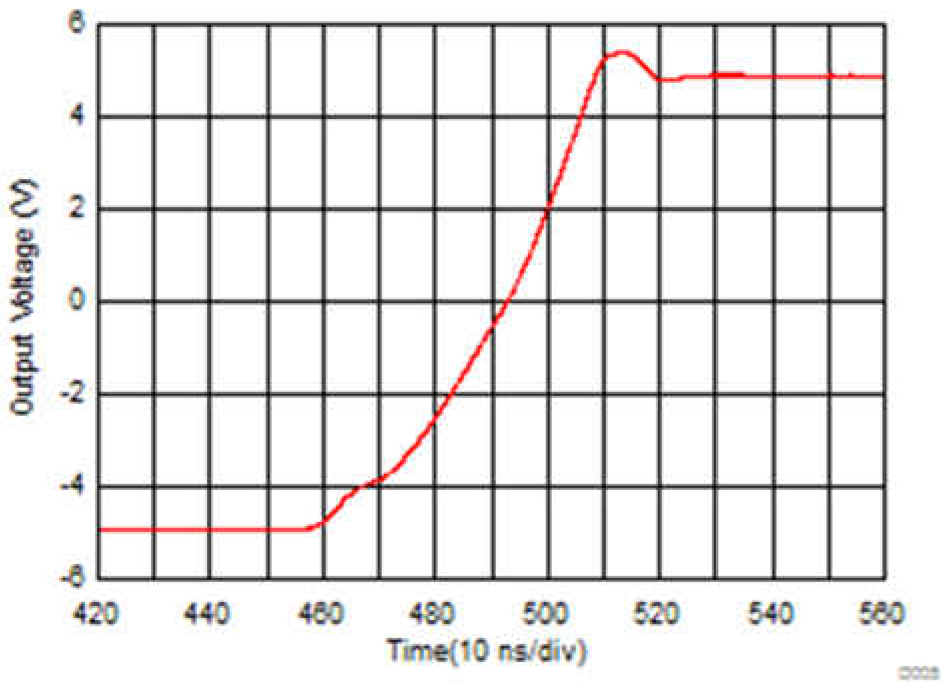


Figure 5. Large Signal Transient and Settling Response

Hence, JFET-input amplifiers, like the OPA2810, offer a variety of benefits in different high-speed applications discussed above due to their high-Z inputs, superior distortion performance, fast settling and wide-supply range. Make sure to look at the family of high-Z input high-speed amplifiers from TI to select the one that best suits your application requirements.

Additional Resources

- Download the Analog Design Journal article, "Source resistance and noise considerations in amplifiers" for more information on various amplifier topologies.
- Read the blog post, "What you need to know about transimpedance amplifiers – part 1."
- Browse more than 40 training videos on operational amplifier (op amp) topics like noise, bandwidth and stability.
- Search TI high-speed op amps and find technical resources.