DESIGN NOTES

325MHz Low Noise Rail-to-Rail SOT-23 Op Amp Saves Board Space – Design Note 254

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The new tiny LT®1806 combines 325MHz gain bandwidth, 3.5nV/√Hz voltage noise, 100μV input offset voltage and rail-to-rail inputs and outputs in a SOT-23 package. The device is fully specified on 3V, 5V and ±5V supplies with a guaranteed maximum input offset voltage of 850μV at either rail over temperature. It is available in commercial and industrial temperature grades.

1MΩ Transimpedance Amplifier Achieves Near Theoretical Noise Performance with Large-Area Photodiodes

The circuit of Figure 1 shows the LT1806 in an ultralow noise transimpedance amplifier applied to a large-area high capacitance photodiode. The LT1806 is used for its high gain bandwidth and low noise. The IFN147 ultralow noise JFET[1] operates at its I_{DSS} (V_{GS} = 0V) with a typical transconductance of 40mS. With its source grounded, the JFET and its drain resistor, R5[2], set a voltage gain of about 8. The combination of the ultralow noise JFET gain stage and the LT1806 low noise amplifier achieves the ultralow input noise performance. The circuit's input voltage noise was measured at 0.95nV/√Hz. Figure 2 compares the noise performance of the circuit with that of a competitor's monolithic 6nV/√Hz JFET op amp, both with a 680pF capacitive source.

Why is it necessary to have both low voltage noise and low current noise to achieve low total noise in a large-area photodiode transimpedance amplifier? Because the transimpedance circuit's noise gain, which applies to voltage noise but not to current noise or resistor noise, rises drastically with frequency (noise gain = 1 + Z_F/X_C). As a sample calculation, a 500pF photodiode has an impedance of 3.2kΩ at 100kHz, giving a 1MΩ transimpedance circuit a noise gain of 314 at that frequency. The theoretical noise floor of the 1M resistor is 130nV/√Hz (at room temperature), so any input voltage noise above 0.41nV/Hz (130nV/√Hz/314) will overtake the resistor noise at 100kHz. Discrete JFETs are available with ultralow voltage noise, but they have high input capacitance (75pF max for the IFN147). Serendipitously, the input capacitance of the JFET is relatively insignificant compared to the 500pF of the example large-area photodiode. Although the capacitance of the JFET does increase the overall noise gain slightly, its much lower input voltage noise is well worth the slight increase in

[1]Equivalent to Japanese 2SK147.

[2]For devices with I_{DSS} higher than about 12mA, R5 should be reduced to 100Ω to avoid saturating the JFET.

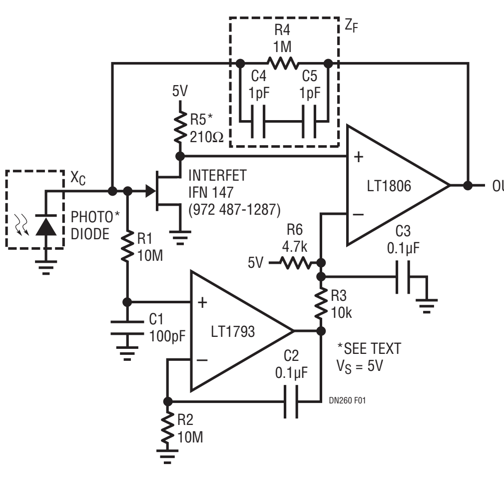

Figure 1. Ultralow Noise, 2.4GHz Gain Bandwidth Large-Area Photodiode Amplifier

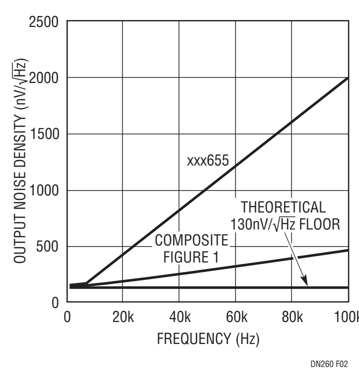

Figure 2. Composite Amplifier vs Competitor Op Amp xxx655

total capacitance and noise gain. Table 1 and Figure 3 show the bandwidth and noise performance achieved with several large-area photodiodes (and a small-area SFH213 for comparison). Note that large-area detectors also place extra demands on the gain bandwidth of an amplifier. The final case in Table 1 shows a 1MΩ transimpedance amplifier with 650kHz bandwidth from a 660pF photodiode. Although this may not seem like much bandwidth, it necessitates a gain bandwidth product of at least 1.8GHz in the amplifier.

The task of the LT1793 is to keep the JFET biased at its I_{DSS} current (V_{GS} = 0V); it was selected for its low 100pA maximum input offset current over temperature. The LT1793 senses the input voltage at the JFET gate through R1 and nulls this voltage through the LT1806 inverting pin and back around through R4. The time constants formed by R1C1 and R3C3 ensure that the LT1793 noise characteristics do not add to the total noise. C1 shunts the already low LT1793 current noise to ground and R3C3 keeps the LT1793 and resistor thermal noise away from the LT1806 low noise op amp input. Note that with the JFET gate at 0V, there is no reverse bias across the photodiode, eliminating dark current issues.

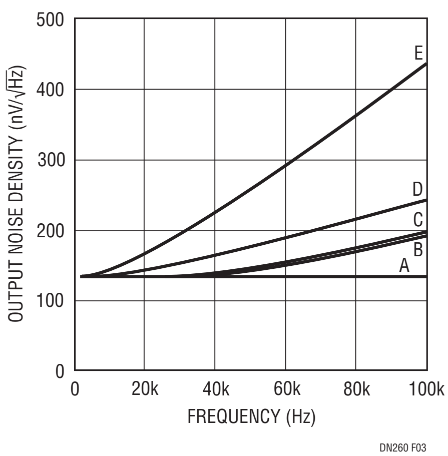

Figure 3. Output Noise Spectra for Various Photodiodes

At first glance, the circuit does not appear stable, since the JFET circuit puts additional gain into the op amp loop and this is usually a recipe for disaster. The reason the circuit is stable (and with quite a bit of margin) is that the gain is greater than unity at frequencies above a few hundred Hz. Because of the relatively high value of the feedback impedances (1MΩ and 0.5pF) and the 75pF minimum input capacitance of the JFET, the gain of the circuit is 150 minimum above 300kHz. The LT1806 is a 325MHz gain bandwidth, unity-gain-stable op amp, so it is quite comfortable maintaining stability above 300kHz in what it sees as about a gain of 19 (150/8). Note that because the JFET circuit has a gain of 8, the gain bandwidth of the composite amplifier is about 2.4GHz. Also of interest are the open-loop gains of 2.4 million (8 • 300,000) in the fast loop and 350 billion (3.5 million • 300,000/3) in the slow loop. These numbers, along with the gain bandwidth and the 1M feedback resistor, determine the impedance that the photodiode sees looking into the amplifier input.

Conclusion

The LT1806 offers exceptional bandwidth and low noise in a SOT-23 package. The rail-to-rail inputs and outputs make the op amp easy to apply and maximize the available dynamic range. The tiny package makes the op amp a compelling choice where PCB real estate is at a premium. The composite photodiode amplifier shown above is just one example where the LT1806 meets a difficult set of requirements. Let's talk about YOUR difficult set of requirements today.

Table 1. Performance of the Composite Amplifier with Various Photodiodes

	Vendor	Part Number	Optical Character	Typical V = 0 Capacitance	Approximate Bandwidth
A	Siemens/Infineon 408-456-4071	SFH213	Fast IR PIN	11pF	250kHz
B	Siemens/Infineon 408-456-4071	BPW34B	Enhanced Blue PIN	72pF	390kHz
C	Opto-Diode 805-499-0335	ODD45W	Narrow IR GaAlAs	170pF	380kHz
D	Fermionics 805-582-0155	FD1500W	Extended IR InGaAs	300pF	500kHz
E	Siemens/Infineon 408-456-4071	BPW21	Visible Spectrum	660pF	650kHz

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