# AN-1244 Photo-Diode Current-to-Voltage Converters

**ABSTRACT**

Converting the small output current of a photo-diode transducer to a fast responding voltage is often challenging. This application report provides some ways to use high-speed current feedback and voltage feedback op amps to do the job.

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## 1 Current Feedback Amplifier Solution

Current feedback amplifiers (CFA) are especially suited to implement this function, as shown in Figure 1. With an effective internal buffer on the inverting node of the op amp, the output impedance $R_O$ (internal to U1, not shown) and the photo-diode's output capacitance $C_{IN}$ (typically 10-200pF) introduce a zero in the noise gain at approximately 1/2π × ($R_O$ × $C_{IN}$). In comparison, the zero produced by a voltage feedback op amp in a similar configuration [1/2π × ($R_{IN}||R_F||R_{BIAS}$) × $C_{IN}$] tends to be much lower in frequency and more troublesome. This being the case, $C_{IN}$ has less of an effect on reduction of the converter bandwidth, and achieving stability is easier when using a CFA.

If $C_{IN}$ is sufficiently large, the closed loop phase shift will approach -180° at the cross-over frequency (where open loop transimpedance gain crosses the noise gain function). As with voltage feedback amplifiers, the closed loop amplifier can be compensated by adding a small capacitor ($C_F$) across $R_F$. In the case of Figure 1, using the CLC450 CFA, $C_F$ was experimentally determined to be around 2 pF for about 10% overshoot in the step response. $C_F$ improves stability by counteracting the effect of the zero discussed in the paragraph above by introducing a low frequency pole (1/2π × $R_F$ × $C_F$) and an inconsequential zero (1/2π × $R_O$ × $C_F$).

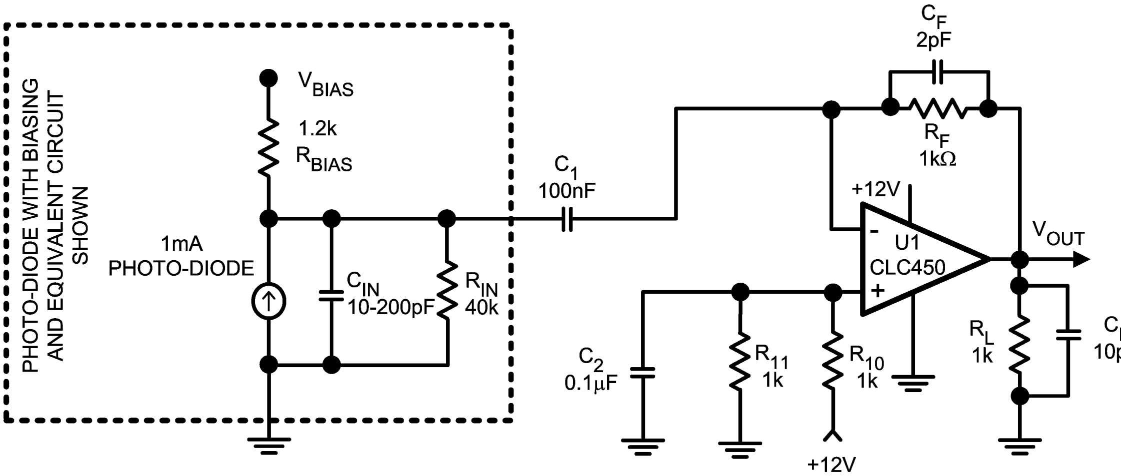


**Figure 1. Single-Supply Photo-Diode Amplifier Using CLC450 Current-Feedback Amplifier**

It is possible to change the required 2 pF compensation capacitor to a more practical value, by adding $R_A$ and $R_B$ in a voltage divider, as shown in Figure 2. The new value of $C'_f$ is (1+$R_B$/$R_A$) × $C_F$. This relationship holds true as long as $R_B$<< $R_F$.

For this example, select $R_A$ = 50 Ω, and $R_B$ = 500 Ω. Therefore, $C'_f$ = (1+500/50) ×2 pF = ~22 pF, which is a much more practical component value. This value needs to be "fine tuned" in the real application for proper step response.

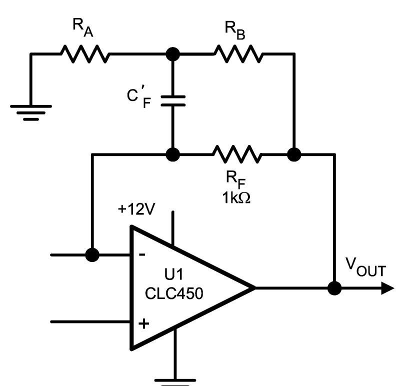


**Figure 2. $R_A$ -$R_B$ Resistor Divider Allows Use of Practical Value for $C'_f$**

## 2 Voltage Feedback Amplifier Solution

It's more difficult to design a good current-to-voltage converter using a voltage feedback amplifier (VFA). As discussed in Section 1, phase shift caused by photo-diode capacitance is often a source of instability. Furthermore, wide bandwidth usually comes at the expense of supply currents and higher supply voltage. However, the new LMH6642 high-speed low-voltage VFA op amp has excellent performance in a transimpedance gain block, as shown inFigure 3. This device can operate down to 2.7 V single supply and its −3dB BW ($A_V$ = +1) is more than 100 MHz (with a supply current of only 2.7 mA). Because of the "Dielectric Isolation" process this device is based on, the traditional supply voltage versus speed trade-off has been alleviated to a great extent allowing low power consumption and operation at lower supply voltages. In addition, the device has rail-to-rail output swing capability to maximize the output swing, and is capable of driving ±50 mA into the load.

With 5 V single supply, the device common mode voltage is shifted to near half-supply using $R_{10}$-$R_{11}$ as a voltage divider from $V_{CC}$. The common-base transistor stage (Q1) isolates the photo-diode's capacitance from the inverting terminal, allowing wider bandwidth and easing the compensation required. Note that the collector of Q1 does not have any voltage swing, so the Miller effect is minimized. The diode on the base of Q1 is for temperature compensation of its bias point. Q1 bias current was set to be large enough to handle the peak-to-peak photo-diode excitation, yet not too large as to shift the U1 output too far from mid-supply. The overall circuit draws about 4.5 mA from the +5 V power supply and achieves about 35 MHz of closed loop bandwidth @1 $V_{PP}$. Figure 4 shows the output large signal step response. $C_F$ can be increased to reduce the overshoot, at the expense of bandwidth.

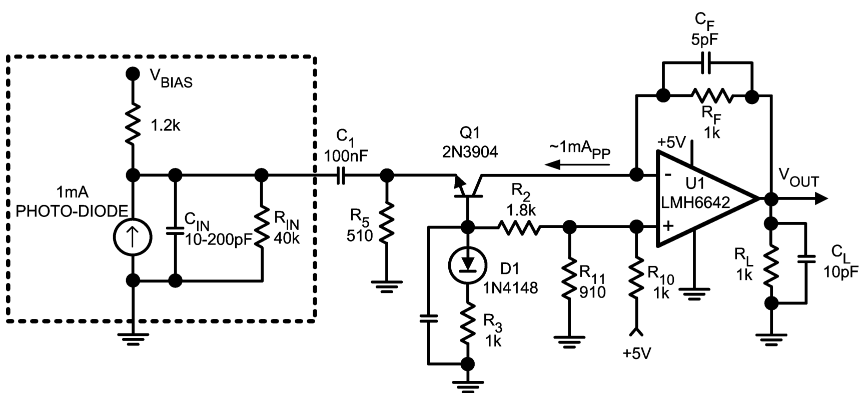


**Figure 3. Single-Supply Photo-Diode Amplifier Using LMH6642 Voltage-Feedback Op Amp**

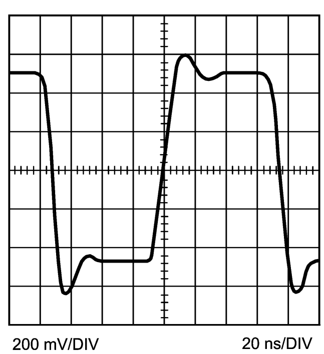


**Figure 4. Output Step Response 20 ns/div, 0.2 V/div**

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