Application Brief

Photo-Diode Current-To-Voltage Converters

Application Brief 104

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

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 10-200 pF) introduce a zero in the noise gain at approximately $1/2\pi(R_O C_{IN})$. In comparison, the zero produced by a voltage feedback op amp in a similar configuration $[1/2\pi(R_{IN}||R_f||R_{BIAS})C_{IN}]$ 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 ($1/2\pi R_f C_f$) and an inconsequential zero ($1/2\pi R_O C_f$).

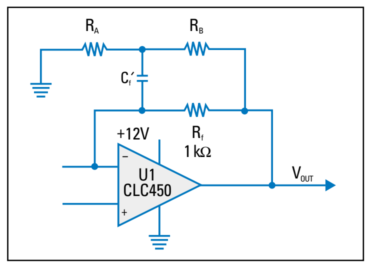

Figure 2. R_A-R_B Resistor Divider Allows Use Of Practical Value for C_f

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 $(1+R_B/R_A) \times C_f$. This relationship holds true as long as $R_B << R_f$.

For this example, select $R_A=50\Omega$, and $R_B=500\Omega$. Therefore, $C_f=(1+500/50) \times 2$ 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.

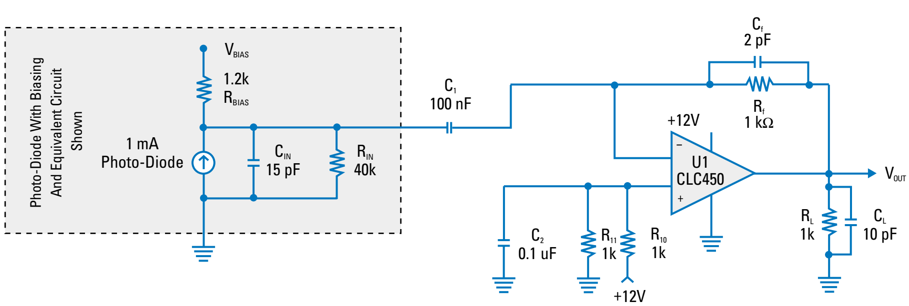

Figure 1. Single-Supply Photo-Diode Amplifier Using CLC450 Current-Feedback Amplifier

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Voltage Feedback Amplifier Solution

It's more difficult to design a good current-to-voltage converter using a voltage feedback amplifier (VFA). As discussed above, phase shift caused by photo-diode capacitance is often a source of instability. Furthermore, wide bandwidth usually comes at the expense of supply current and higher supply voltage. However, the new LMH6642 high-speed low-voltage VFA has excellent performance in a transimpedance gain block, as shown in *Figure 3*. This device can operate down to 2.7V single supply and its -3 dB 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 vs. 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.

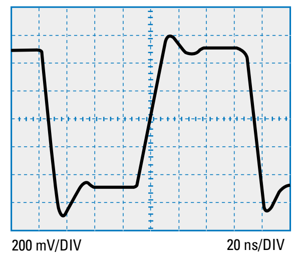

Figure 4. Output Step Response 20 ns/DIV, 0.2V/DIV.

The diode on the base of Q_1 is for temperature compensation of its bias point. Q_1 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 U_1 output too far from mid-supply. The overall circuit draws about 4.5 mA from the +5V 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.

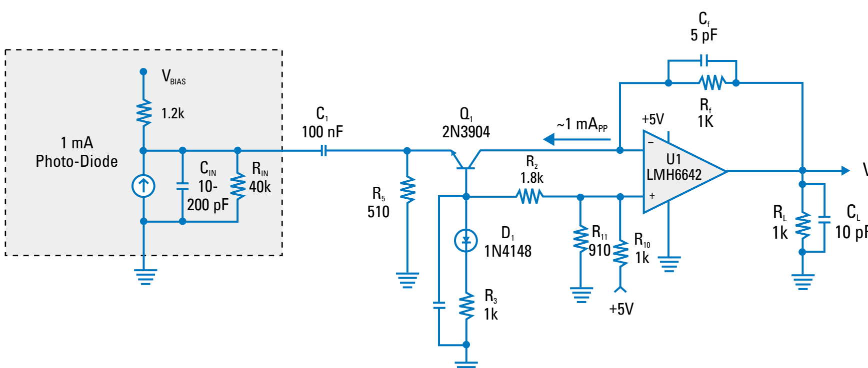

Figure 3. 5V Single-Supply Photo-Diode Amplifier Using LMH6642 Voltage-Feedback Op Amp

With 5V 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 (Q_1) isolates the photo-diode's capacitance from the inverting terminal, allowing wider bandwidth and easing the compensation required. Note that the collector of Q_1 does not have any voltage swing, so the Miller effect is minimized.

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