Application Brief
Photo-Diode Current-To-Voltage Converters

Hooman Hashemi

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 $\frac{1}{2\pi}(R_o C_{IN})$.

In comparison, the zero produced by a voltage feedback op amp in a similar configuration $\left[\frac{1}{2\pi} \left(\frac{R_{IN}}{R_f} C_{IN}\right)\right]$ 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 ($\frac{1}{2\pi R_f C_f}$) and an inconsequential zero ($\frac{1}{2\pi R_f C_f}$).

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 $(1+R_B/R_A) \times C_f$.

For this example, select $R_A=50\,\Omega$ and $R_B=500\,\Omega$. Therefore, $C_f=(1+500/50) \times 2\,\text{pF}=22\,\text{pF}$, 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

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

National Semiconductor
The Sight & Sound of Information

Advertisement
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 +5V power supply and achieves about 35 MHz of closed loop bandwidth @1 VPP.

Figure 4 shows the output large signal step response. Cf can be increased to reduce the overshoot, at the expense of bandwidth.

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 has -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.

With 5V single supply, the device common mode voltage is shifted to near half-supply using R10-R11 as a voltage divider from VCC. 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.

Visit The National Edge, our online technical journal for an archive of Application Briefs and other interesting information.

edge.national.com

Data Sheet Download

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and/or other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information furnished by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or “enhanced plastic.” Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer’s risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td>Communications and Telecom</td>
</tr>
<tr>
<td>Amplifiers</td>
<td>Computers and Peripherals</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Consumer Electronics</td>
</tr>
<tr>
<td>DLP® Products</td>
<td>Energy and Lighting</td>
</tr>
<tr>
<td>DSP</td>
<td>Industrial</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td>Medical</td>
</tr>
<tr>
<td>Interface</td>
<td>Security</td>
</tr>
<tr>
<td>Logic</td>
<td>Space, Avionics and Defense</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Transportation and Automotive</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Video and Imaging</td>
</tr>
<tr>
<td>RFID</td>
<td></td>
</tr>
<tr>
<td>OMAP Mobile Processors</td>
<td></td>
</tr>
<tr>
<td>Wireless Connectivity</td>
<td></td>
</tr>
</tbody>
</table>

For more information, please visit TI E2E Community Home Page at e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated