BURR - BROWN® BB APPLICATION BULLETIN
Mailing Address: PO Box 11400 • Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd. • Tucson, AZ 85706
Tel: (520) 746-1111 • Twx: 910-952-111 • Telex: 066-6491 • FAX (520) 889-1510 • Immediate Product Info: (800) 548-6132

TAME PHOTODIODES WITH OP AMP BOOTSTRAP

by Jerald Graeme, (602) 746-7412

Applying a basic op amp current amplifier to photodiodes presents three severe problems: high nonlinearity, oscillations, and a latch condition. All three result from the presence of load-signal voltage feedback to the photodiode. A simple bootstrapping arrangement can remove them all.

In the basic circuit, Figure 1, two resistors, R_1 and R_2, control the positive and negative feedback, respectively. Consequently, they also control the current amplifier's gain. All the signal current, i_P, from the photodiode flows through R_1 (negligible current flows into the op amp's input), thereby defining the input-to-output voltage drop of the op amp. Because of the op amp's very high open-loop gain and the feedback arrangement, the circuit replicates that voltage across R_2 to keep the differential voltage between the op amp inputs close to zero. As a result, feedback current i_O flows into the load Z_L through R_2. Thus, the current gain i_O/i_P, or A_i, equals R_1/R_2.

Because the photodiode's responsivity changes as its voltage changes with light input, voltage variation across Z_L, which is also across the photodiode, causes nonlinearity. Even worse, the photodiode's capacitance, C_D, rolls off the negative feedback from R_1 at high frequencies. Consequently, the positive feedback from R_2 can dominate, and oscillations, can result. In fact, C_D inadvertently converts the circuit to a conventional op amp square-wave generator. If large enough to stop oscillations, a dominant roll-off bypass capacitor C_B added across the load would devastate the circuit's bandwidth.

Moreover, under the condition of input overloads, which can occur during turn-on, a high impedance load could create a latch state in conjunction with the diode. If the load impedance supports a great enough voltage, positive feedback takes continuous control at the amplifier's noninverting input. At the inverting input, the photodiode clamps the voltage and prevents negative feedback recovery.

Bootstrapping, though, removes each of the problems caused by load voltage on the photodiode (see Figure 2). In the new circuit, the load voltage drives the end of the photodiode that's grounded in the basic circuit. Also, a feedback-tee circuit option becomes possible. With only the very small op amp differential input error signal across the photodiode, its response is essentially linear. Moreover, the canceled-out positive feedback signal on C_D avoids the square-wave generator action.

Through its effect on feedback, bootstrapping preserves bandwidth in two ways. The negative-feedback network riding on top of the positive-feedback signal always ensures a net negative feedback. The circuit requires little, if any, load bypassing. As a result, this arrangement reduces the bandwidth-limiting bypassing effect of the load and its capacitance comparable to that of traditional current-to-voltage conversion circuits. Also, because positive feedback can no longer dominate, the circuit eliminates input clamping by the photodiode and the latch state.

The bootstrapping circuit also benefits from the use of a feedback-tee network. In the bootstrapping circuit, the tee, like the photodiode, also rides atop the load to similarly avoid the positive-feedback effects. Tee networks offer a degree of frequency-response control. In the tee, capacitor C_1 blocks the low-frequency shunting effects of R_3 to produce a high-pass response without an amplified offset voltage. (Request PDS-653.)

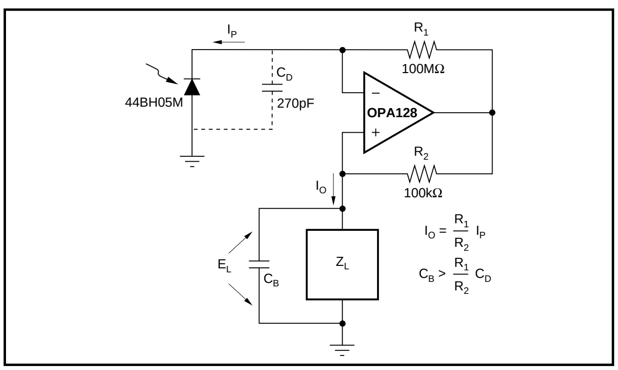

FIGURE 1. Basic Photodiode Circuit.

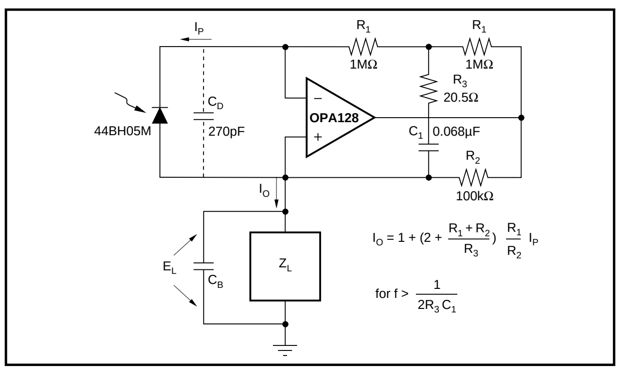

FIGURE 2. Bootstrapped Photodiode Circuit.

Printed in U.S.A. May, 1995

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

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

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.