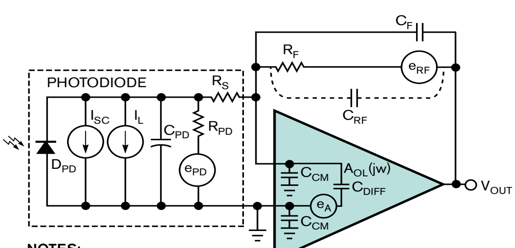
BY BONNIE BAKER

The eyes of the electronic world are watching

Silicon photo sensors have been in electronic circuits since the inception of the era of silicon electronics. More than likely, scientists quickly discovered the photo-sensing characteristics of silicon in the lab, as they worked from the daylight hours into the evening. To this day, IC designers regularly cover their wafers under test to shield out extraneous light. Although the light sensitivity of silicon is an undesirable by-product of the silicon, system designers have exploited this transfer of light into electrical energy in various systems. Consequently, a wide variety of applications use silicon to sense the intensity and characteristics of light.

In these systems, a silicon sensor converts light into charge or an electrical current. These silicon sensors are the "eyes" in the electronics world that users can employ to analyze blood, search noninvasively for tumors, detect smoke, position equipment, or perform chromatography, to name a few applications. Basically, system designers understand how to convert light into a current, but the real challenge is determining how to convert the low-level currents from the photo sensor into a useful electrical representation. To further exacerbate the difficulty of the design, the required accuracy in these applications continues to increase.

The traditional design topology of the transimpedance amplifier captures this low-level signal in a hybrid approach that starts with an amplifier and a high-value resistor in the feedback loop. The circuit design uses resistance to provide a real-time, linear representation of the light source. This circuit places the photodiode across the amplifier's inverting input and ground of the operational amplifier. A resistor with a value of 100 kΩ to 10 MΩ connects the inverting input of the amplifier to the output. You then connect the noninverting input to ground (**Figure 1**). Light excitement on the photo sensor generates charge. The only path of escape for this charge is through the high-value resistor in the amplifier's feedback loop.



NOTES:
D_{PD}=IDEAL PHOTODIODE.
I_{SC}=CURRENT GENERATED BY LIGHT.
I_L=LEAKAGE CURRENT.
C_{PD}=DEVICE CAPACITANCE.
e_{PD}=DEVICE-VOLTAGE NOISE.
R_{PD}=DEVICE PARALLEL RESISTANCE.
R_S=DEVICE LEAD RESISTANCE.
C_F=FEEDBACK CAPACITOR.
R_F=FEEDBACK RESISTOR.
C_{RF}=FEEDBACK-RESISTOR PARASITIC CAPACITANCE.
e_{RF}, e_A=RESISTOR- AND AMPLIFIER-VOLTAGE NOISE.
C_{CM}=COMMON-MODE-AMPLIFIER CAPACITANCE.
C_{DIFF}=DIFFERENTIAL-AMPLIFIER CAPACITANCE.
$A_{OL}(jw)$=AMPLIFIER OPEN-LOOP GAIN.

Figure 1 A transimpedance photo-sensing circuit is not without its design challenges.

The simplistic approach in **Figure 1** is not without its design challenges. The operational amplifier must have relatively low-picoampere input-bias currents and low input capacitance. An appropriate amplifier for this circuit would have a FET- or a CMOS-input stage with low-voltage noise and microvolt-offset specifications. In the end, the designer optimizes the stability, bandwidth, low-noise performance, and layout of this transimpedance-amplifier circuit.

The final design method is not always intuitively obvious. The photo sensor, operational amplifier, amplifier-feedback element, and these parts' parasitics combine to create quite a rat's nest of formulas for consideration. The signal after the transimpedance amplifier requires a multipole analog filter. In this manner, combining the input and filtering stages separates the signal of interest from the noise floor. A sampling ADC digitizes the signal after the analog filter.

Photo-sensing circuits have changed over the years. The first approach was purely analog, using the transimpedance amplifier and following it with a lowpass filter. From the classic transimpedance amplifier, the switched integrator has gained favor. The switched integrator was the first step toward bringing the digital portion of the circuit closer to the signal source. The migration of the photo-sensing-application product has moved on to totally integrated systems, such as the charged digitizing ADC. **EDN**

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