Low-cost optical sensor overcomes ambient light

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A low-cost solid-state optical system can be useful for measurements of light transmission or reflection in medical applications, in the manufacture of paper, textiles, and paint, and in smoke detection. This optical measurement system, which uses the conventional light-chopping technique to overcome ambient light and electrical noise, can be built for about $13.

The system (Fig. 1) consists of a light-emitting-diode source, a photodiode sensor, operational amplifier A_1, driven by the sensor, integrator operational amplifier A_2, which is connected to the output from A_1 only when the LED is off, and op amp A_3, which is connected to the output from A_1 when the LED is on. A clock drives transistor Q to turn the LED on and off, and also drives field-effect-transistor switches S_1 and S_2 to connect either A_2 or A_3 to the A_1 output.

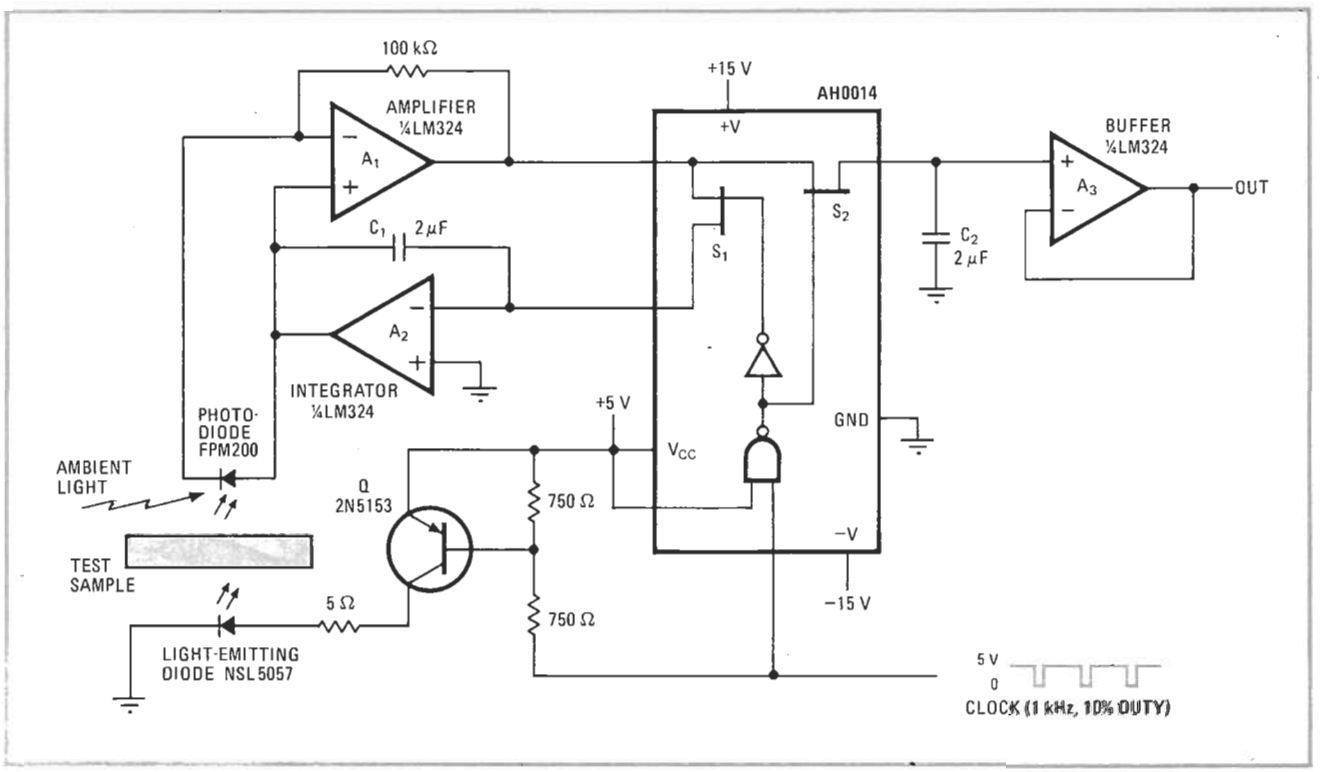
The waveforms in Fig. 2 illustrate the operation of the system. When the LED is on, the material being tested transmits some light to the sensor. The transmitted light, plus ambient light, produces a photosensor current that is converted and amplified in A_1. Electrical noise also contributes to the output from A_1.

To make the system insensitive to the ambient light and electrical pickup, the output from A_1 when the LED is off is fed to the integrator, consisting of A_2 and C_1. The integrator output is applied to the non-inverting terminal of A_1 as an offset voltage to cancel the unwanted output, reducing the voltage from A_1 to zero when the LED is off.

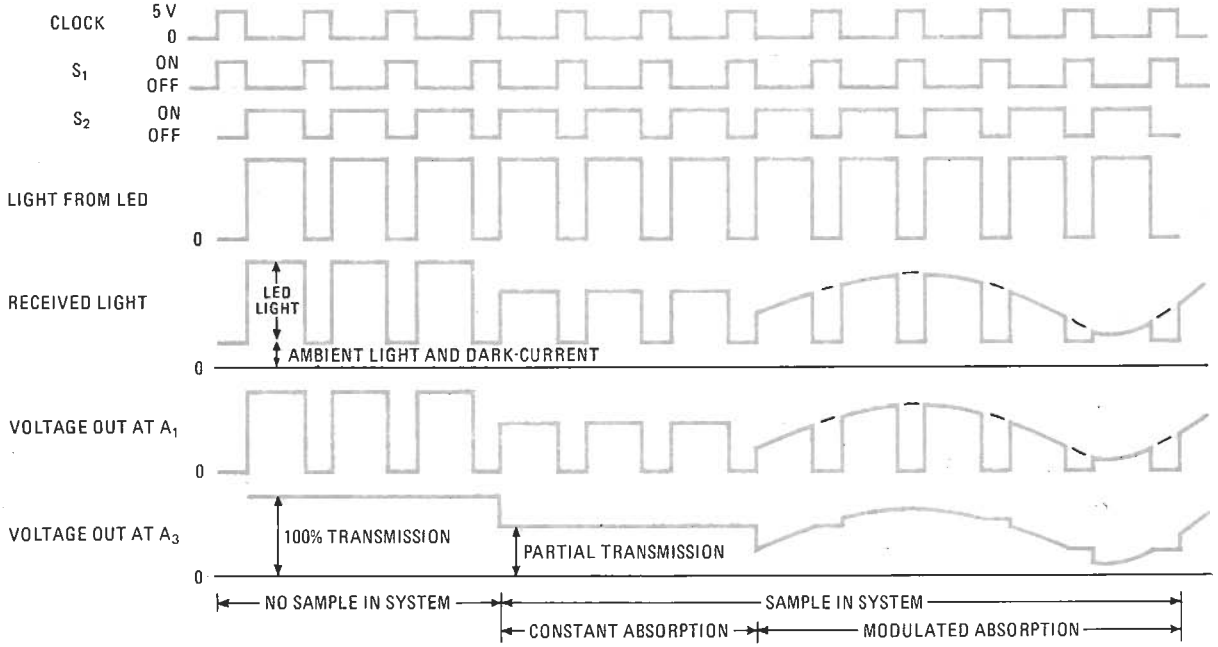
When the clock turns the LED on again, it also opens S_1 to disconnect the integrator from the A_1 output. However, capacitor C_1 holds the offset voltage on the noninverting terminal, so that the net voltage from A_1 results only from the LED light.

The effect of the integrator is to measure the magnitude of the ambient light and noise while the LED is off, remember this magnitude, and subtract it from the incoming signal when the LED is on. The output from A_2 is a measure of the ambient light and noise.

While the LED is on, FET switch S_2 is closed, so the output from A_1 is applied to capacitor C_2. The capacitor holds this voltage during the off period, while S_2 is open. Thus S_2 and C_2 constitute a sample-and-hold circuit. Amplifier A_3 serves as a simple output buffer, delivering the over-all output signal to whatever indicating meter or control circuit is to be driven by the optoelectronic measurement system. □



1. Keeping it light. Despite presence of ambient light, optoelectronic measurement system accurately indicates optical absorption or reflection by test sample. (For reflection measurement, geometry is changed so that LED light bounces from sample to sensor, instead of passing through sample.) Effects of stray light and electrical noise generate offset voltage that is subtracted from total voltage when LED is on.



2. Chopping it right. Timing diagrams and waveforms illustrate operation of optoelectronic sensing and measurement system. Amplifier output is connected to integrator while LED is off, and integrator generates offset voltage to cancel outputs caused by ambient light and spurious voltages. When LED is on, amplifier output is connected to sample-and-hold and buffer, but offset still cancels background signals. (Proportions of timing diagrams are distorted for clarity. To avoid excessive dissipation, actual duty cycle of LED is 0.1.)