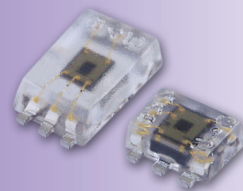




*Innovations Embedded*

## Ambient Light Sensor (ALS) Applications in Portable Electronics

*Longer battery life drives the need for ALS*



# Ambient Light Sensor (ALS) Applications in Portable Electronics

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## Introduction

In portable electronic products, reducing the power consumption to provide the user with increased battery life is one of today's critical design considerations. The liquid crystal display (LCD) and its associated back-lighting are among the more (and frequently the most) power hungry loads in portable products. As a result, the use of an ambient light sensor (ALS) to optimize the operation of the backlight LEDs under a variety of environmental lighting situations is increasing while, at the same time, the preferred technology choices available to designers for sensing have shifted towards more integrated solutions.

## How are Ambient Light Sensors Used?

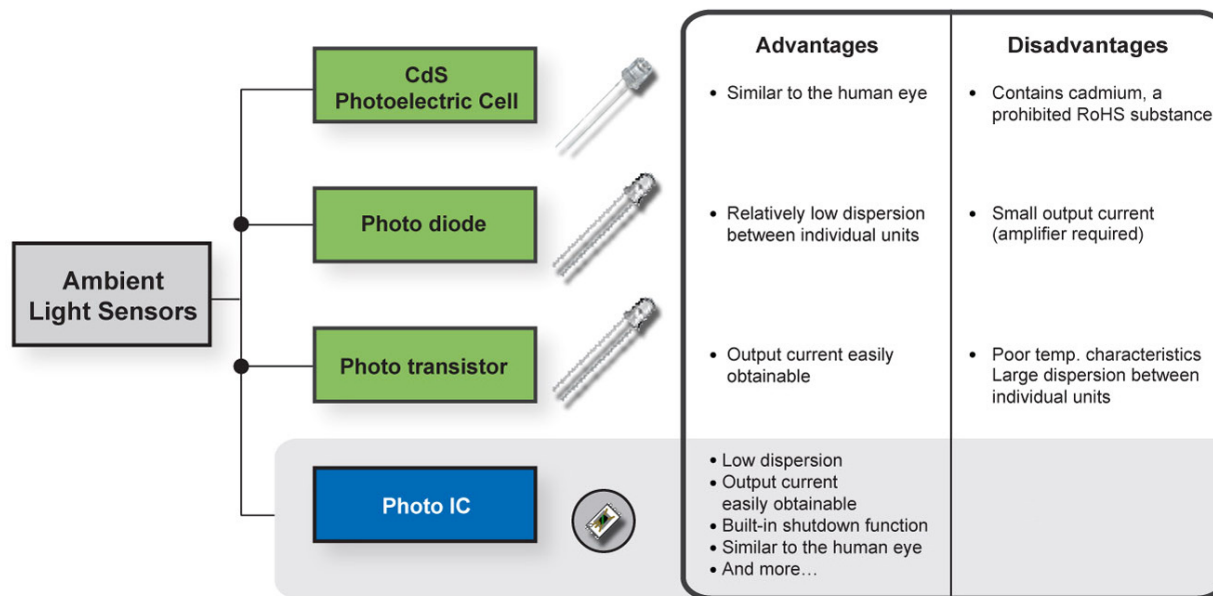
Ambient light sensors are also called illuminance or illumination sensors, optical sensors, brightness sensors or simply light sensors. One very important application for ALS technology is cell phones. In a cell phone, the ALS enables automatic control of display backlight brightness over a wide range of illumination conditions from a dark environment to direct sunlight. With the ALS input, a microcontroller (MCU) or baseband processor increases or decreases the display brightness depending on the environment. This control dramatically improves visibility and reduces power consumption since LCD backlighting can draw as much as 51% of the power in the input standby mode. In addition, the ALS signal can be used to instruct the keypad LED driver to minimize keypad backlighting reducing up to 30% of the power in the input standby power mode. In a bright environment, the LED keypad brightness is reduced for minimal power consumption.

In addition to cell phones, ambient light sensors can be used in a variety of LCD-equipped portable products including PDAs, notebook PCs, digital cameras, video players, GPS-based navigation systems, and more. Any portable product with an LCD is a candidate for ALS technology to reduce power consumption. This includes automobiles where the use of LCDs is increasing for navigation, entertainment and comfort systems as well as control monitoring and dimming mirrors. Any product with an LCD that requires supplemental light for proper viewing can benefit from using an ALS to reduce the power consumption and improve visibility under varying lighting conditions. This includes televisions and home appliances, especially those with increased electronic control and user-driven menus requiring larger LCD panels.

The market research firm Databeans, Inc. estimates the current total available market (TAM) for ALS to be 7% of LED revenue, or roughly \$327 million worldwide. According to Susie Inouye, Research Director and Principal Analyst at Databeans, "Due to the large number of feature-rich phone products that will drive demand, we expect this revenue to grow at a compound annual growth rate of 21% each year over the next five years to reach close to \$860 million by 2014."

## Types of ALS Technologies

Today, designers have more technology choices for ambient light sensors including photoelectric cells, photodiodes, phototransistors, and photo ICs. Each technology has advantages and disadvantages. One of the key criteria for selecting an ALS is its ability to detect wavelengths visible to the human eye in the 380 to 780 nm range. Figure 1 shows a summary of the advantages



**Figure 1. Photo IC ALS technology addresses limitations of discrete photo cell, photodiode and phototransistor products.**

and disadvantages of available technologies.

While cadmium sulfide (CdS) photoelectric cells have advantages of response similar to the human eye, they contain cadmium, a prohibited RoHS (Restriction of Hazardous Substances) material which makes them unusable in the consumer market. As of July 2006, any product containing RoHS-restricted materials cannot be sold into certain markets in order to reduce the environmental impact of electronic equipment waste.

Photo diodes have a relatively low dispersion between individual units but a low output that requires an external amplification circuit.

Photo transistors have easily obtainable output current but poor temperature characteristics and a large dispersion between individual units requiring additional calibration steps in end products.

Photo ICs, also referred to ALS ICs, are the newest technology, developed to address the shortcomings of other ALS approaches. In addition to increased functions possible with integration including amplification, logic control, and shutdown capability, the photodiode sensing has a relatively low dispersion. Both analog and

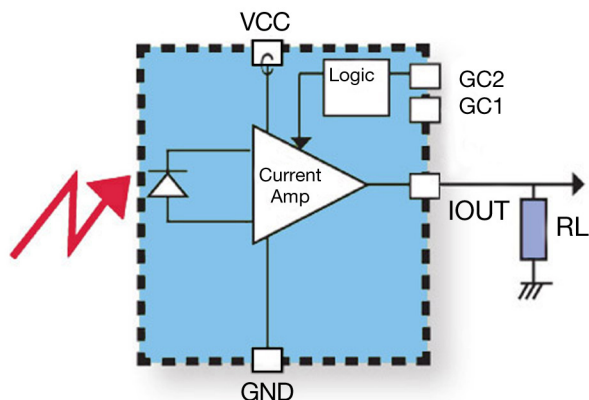
digital photo ICs are available, each having advantages depending on the application. The photo IC has integrated functionality which eliminates the need for additional circuitry that takes up more board space and adds cost. As a result, many designers are making the transition to photo ICs from discrete devices.

## Topology of ALS ICs

Both analog and digital ALS devices are silicon monolithic circuits with an integrated light-sensitive semiconductor photodiode—a PN junction which converts light into an electrical signal. Both technologies are available in small surface mount technology packages. Understanding the difference between analog and digital photo ICs is essential to selecting the proper ALS solution.

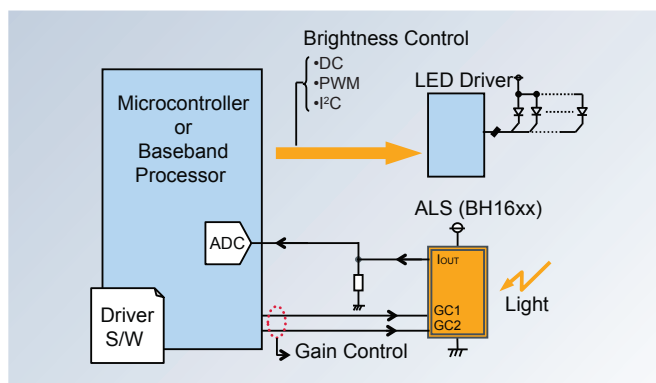
## Analog ALS ICs

The analog ambient light sensor IC has an analog current output proportional to the incident light level. As shown in Figure 2, the IC combines the photodiode, signal amplification and control logic. The current source



**Figure 2.** The typical analog ALS IC combines a photodiode with a current amplifier and control circuitry.

output is typically converted to a voltage by means of a simple load resistor. This voltage output is typically applied to either the input of an analog-to-digital converter (ADC) interface on an MCU (Figure 3) or directly as an input to an LED driver IC equipped with auto-luminous control (Figure 4).

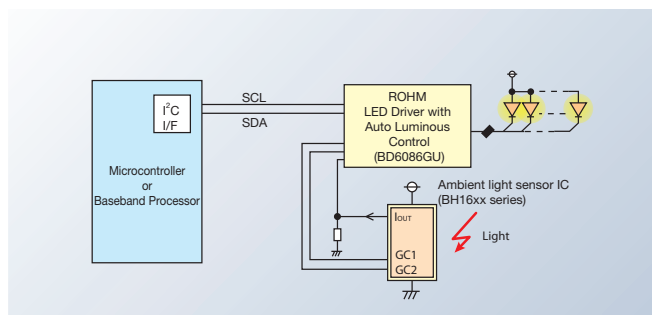


**Figure 3.** The output of the analog ALS provides the control input to the system MCU. The processor, in turn, controls the LED brightness based on the lighting environment (The ROHM analog ALS, illustrated here, has two gain control inputs allowing selection of shutdown mode or high, medium or low gain.)

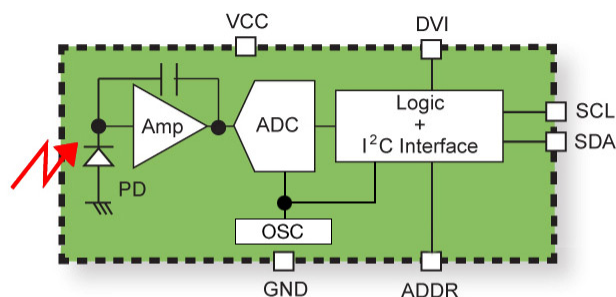
Fundamental design advantages for the analog ALS include an output current that is proportional to the brightness of the environment and spectrum sensitivity similar to the human eye.

## Digital ALS ICs

The typical digital output ambient light sensor (Figure 5) has a 16-bit digital I²C output. In addition to amplification for the photodiode, the IC's integrated ADC converts the



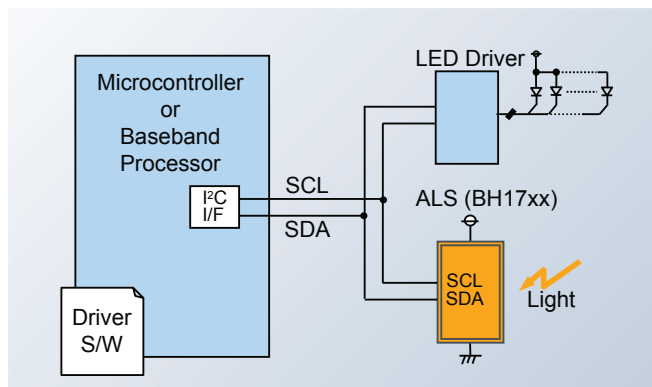
**Figure 4.** When used in combination with an LED driver with auto luminous control, the analog ALS output provides direct light level control.



**Figure 5.** A digital ALS integrates photodiode, amplification circuitry, an ADC and the interface logic.

photosensor's output to an I²C signal for direct connection to the I²C communication bus of an MCU or baseband processor. Figure 6 shows how the I²C interface simplifies the circuitry in an application by removing the need for an external ADC.

The digital ALS includes more integration than an analog ALS and can result in an overall cost savings as well as space savings on the printed circuit board (PCB).



**Figure 6.** In a digital ALS application, the controller communicates directly with both the ALS and LED driver using an I²C interface.

## Selecting the Right Topology for the Application

Deciding whether an analog or digital type ALS is the most appropriate solution requires answering a few simple questions about the application.

1. What communications bus/interface options are available? (Example: I<sup>2</sup>C or GPIO?)
2. Is an A/D converter input available?
3. What degree of lighting control is required?
4. What environmental considerations are important?
  - a. Operating temperature range?
  - b. Variable light level / light sources?
5. How important is power consumption?

In terms of power consumption, a digital ALS will likely draw more power in both the active mode (for example 190  $\mu$ A for the ROHM Semiconductor BH1750FVI) and power down mode (1.0  $\mu$ A for the same digital ALS) due to the integration of the ADC when compared just to an analog ALS (97  $\mu$ A and 0.4  $\mu$ A, respectively for the ROHM Semiconductor BH1620FVC). However, the total power consumption may be comparable when a separate ADC + MCU or broadband controller is taken into account. In either case these values are quite low when compared to the power savings achieved by their ability to control the LED power consumption.

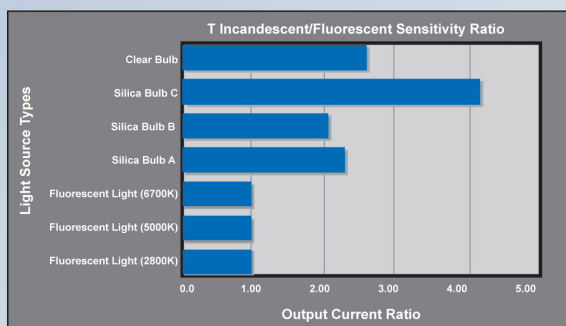
## ROHM Semiconductor Solutions

ROHM offers both analog and digital ambient light sensor ICs that have spectral sensitivity similar to the human eye. Both are offered in compact, surface-mount packages - the WSOF5 package (1.6 x 1.6 x 0.55 mm) as well as the WSOF6 package (3.0 x 1.6 x 0.7 mm).

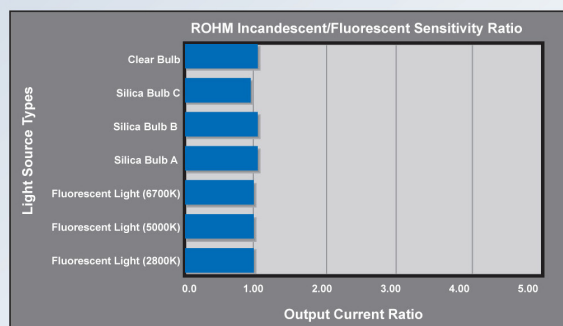
ROHM ambient light sensors all operate over a temperature range of -40 to 85°C to ensure stable operation under extreme conditions. Figure 7 (b) shows that ROHM's photodiode output is very stable regardless of light source providing both reduced power consumption and an improved user experience.

## Analog ALS Solutions

ROHM Semiconductor ALS ICs have an output current proportional to light (current sourcing) with a measurement range of 0 to 100,000+ lux (lx). These ICs feature light sensing accuracy of  $\pm 15\%$  based on ROHM's unique laser trimming technology that also ensures high output sensitivity. Each of these devices features an input voltage supply range from 2.4 to ~5.5V. A resistor connected to the output current ( $I_{out}$ ) pin converts the current output to a linear voltage from 0V up to the supply voltage level for highly efficient component operation.

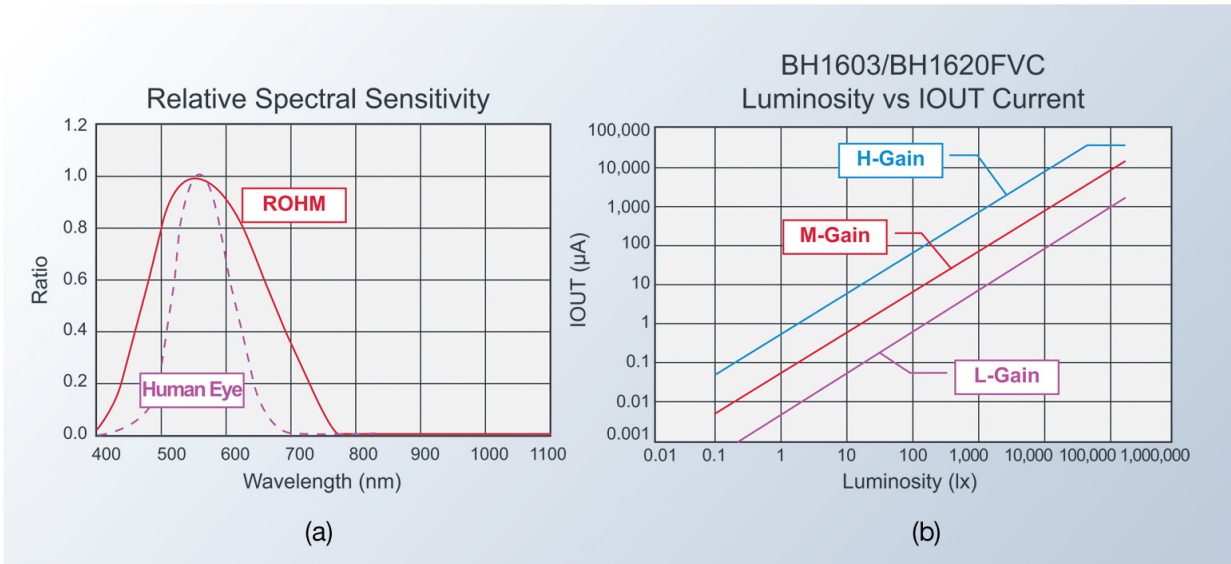


(a)



(b)

**Figure 7. A competitor's sensor output (a) produces different values depending on the light source but ROHM ALS ICs (b) deliver stable output regardless of the light source.**



**Figure 8. Spectral sensitivity (a) and luminosity vs. IOUT (b) for the BH1603FVC demonstrate performance advantages that design engineers should consider when selecting an ALS.**

Figure 8 shows the relative spectral response of the ROHM Semiconductor analog ALS and luminosity versus output current. Multiple photodiodes with different junction depths provide a stable output with little variation between various light sources. Since wavelengths outside of the range of human vision, such as ultraviolet and infrared, may cause inaccurate light sensor readings, it is important to choose a light sensor that has spectral sensitivity similar to the human eye. While the data in Figure 8 (a) is specifically for an analog ALS, this same performance is inherent in the digital designs as well. In addition to an  $I_{out}$  proportional to the luminosity in lux, ROHM's analog ALS products have selectable high-gain, medium-gain and low-gain modes, a proprietary function. These gain control modes allow for direct

control of the internal amplifier gain via the GC1 and GC2 input pins. As shown in Figure 9, these three gain modes provide designers even greater design options for trading off performance versus power consumption.

## Digital ALS Solutions

ROHM was among the first companies to offer a digital light sensor, further demonstrating its leadership in ambient light sensor technology. Digital ALS ICs measure brightness and output a 16-bit digital signal over an I<sup>2</sup>C bus interface, supporting FAST mode (400 KHz) and 1.8V logic interface. The digital ALS ICs can detect a wide range of intensities (0 to ~65,535 lx). A unique internal shutdown function enables low current consumption.

A number of other features distinguish these digital phototensor ICs and are described below.

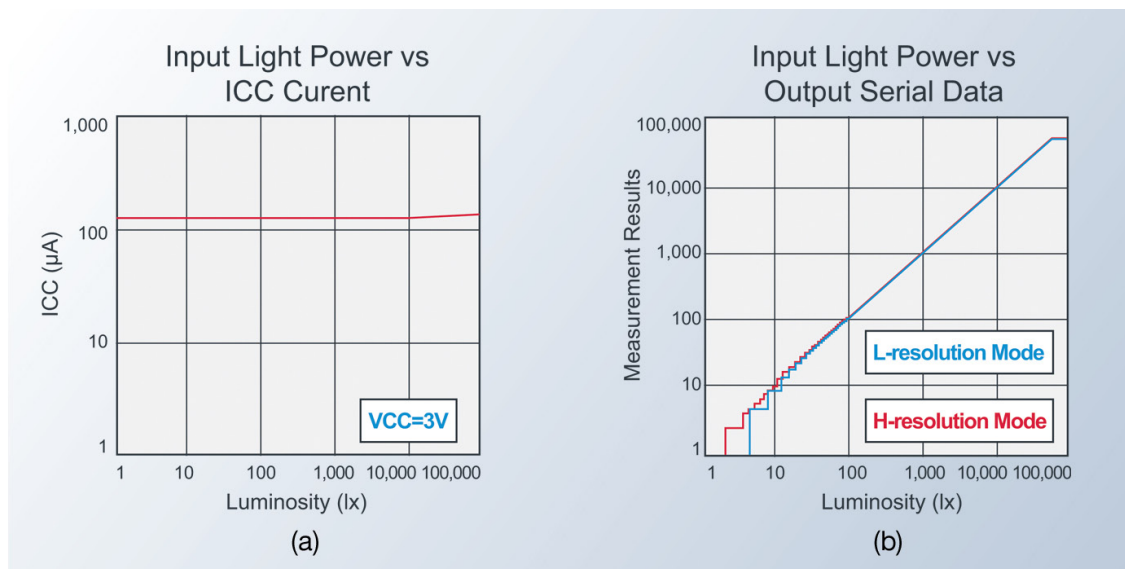
In the operating environment, it is important for a light sensor to generate a consistent output regardless of the light source. As shown in Figure 7 (a), a competing solution outputs different values depending on the light source, which could cause the system to turn on the backlighting when it is not needed. This reduces the battery life and potentially interferes with the end user's experience.

GC2	GC1	Mode	Function
0	0	Shutdown	IOUT OUTPUT Disabled
0	1	H-Gain Mode	60μA @ 100 lx
1	0	M-Gain Mode	10μA @ 100 lx
1	1	L-Gain Mode	1μA @ 100 lx

1: Connect to VCC 0: Connect to GND

**Figure 9. Mode settings for ROHM Analog ALS ICs provide for Shutdown and three levels of output current, offering improved design flexibility in performance vs. power consumption.**





**Figure 10. ICC current is independent of luminosity (a) for ROHM Semiconductor's digital ALS solutions as demonstrated by the performance of the BH1715FVC. At the same time, these units are compatible with a wide range of intensities (0 to ~65,535 lux) (b).**

Excellent spectral response is another key characteristic of ROHM's digital ALS products. Figure 10 shows two electrical response graphs for the BH1715FVC. Figure 10 (a) demonstrates that luminosity has a minimal impact on the digital light sensor's supply current ( $I_{CC}$ ) which improves power consumption. Figure 10 (b) indicates luminosity versus output serial data measurement results for high and low resolution modes.

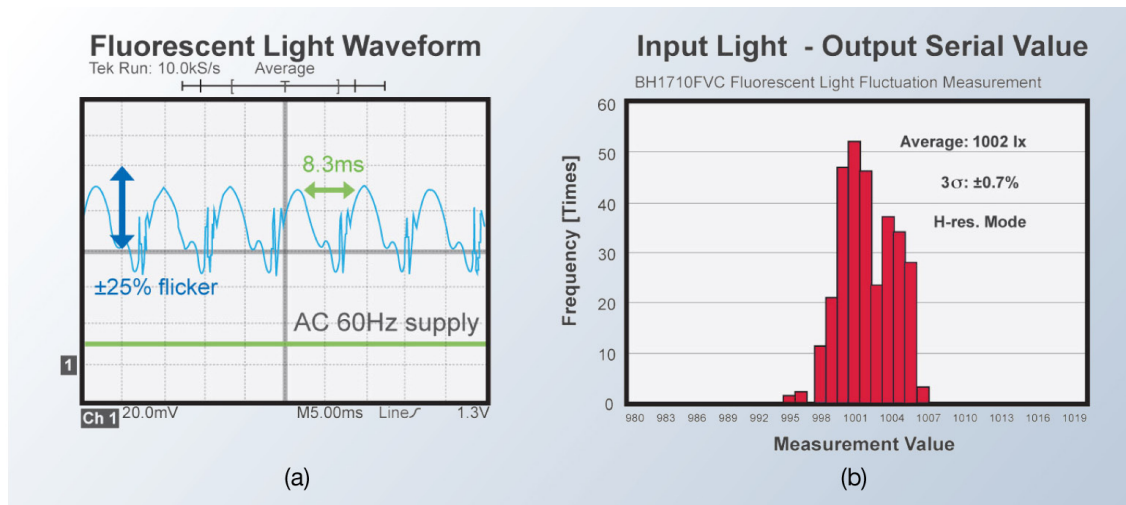
A comparison of the two resolution modes for improved lighting control is shown in Figure 11. The H-resolution mode has the highest resolution (1 lux increments) and is suitable for measuring very low lux levels, but it takes the longest time to measure a light sample. The advantage of operation in this mode is a higher accuracy light

sample and superior optical noise rejection since this capability improves with increased measurement time. Operation in H-Resolution mode eliminates optical noise at 50Hz/60Hz. An example of optical noise reduction with a fluctuating fluorescent light source output, demonstrating values stable within  $\pm 1\%$ , is shown in Figure 12.

The L-resolution mode samples in 4 lux increments and takes the shortest time to measure a light sample. Note that in contrast to the analog ALS, different operating modes do not impact the power consumption in digital units.

Mode	Measuring Time Typ. [ms]	Minimum Resolution [lx]	Feature
H – Resolution	120	1	<ul style="list-style-type: none"> <li>• High resolution</li> <li>• Superior optical noise rejection characteristics (50/60Hz)</li> </ul>
L – Resolution	16	4	<ul style="list-style-type: none"> <li>• Measuring time and the resolution are well-balanced</li> </ul>

**Figure 11. ROHM Semiconductor's digital light sensors have High- and Low-Resolution modes.**



**Figure 12.** Fluorescent light output fluctuates  $\pm 25\%$ , synchronized with the AC supply (a). By detecting fluctuating light synchronized with the AC supply (50/60Hz), the BH1715FVC digital ALS outputs values stable within  $\pm 1\%$  (b).

## Conclusions

Ambient Light Sensors are an important tool for enhancing performance in LED-backlight LCD displays. ROHM has demonstrated leadership in this technology by offering both analog and digital units. In addition, ROHM offers design assistance in the form of ALS IC Evaluation Kits and optical simulation design support for all its ALS technologies.

When an ambient light sensor is required for portable and many other applications, ROHM Semiconductor has the right solution.

Complete information about the ROHM ALS IC product line is available at:

[www.rohmsemiconductor.com/als.html](http://www.rohmsemiconductor.com/als.html)

## References:

1. ROHM Semiconductor [High-Performance Ambient Light Sensor IC Series Selection Catalog](#).
2. Data sheets for ROHM Semiconductor [BH1603FVC](#), [BH1620FVC](#), [BH1715FVC](#), [BH1721FVC](#) and [BH1750FVC](#) Ambient Light Sensors.





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