Proximity Detection

Solutions for Emerging and Innovative Applications

TAOS, Inc. ▸ August 2010

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Proximity detection technology has been around for decades, but has taken a big leap forward in the last few years to address the need to automatically turn off smart phone touchscreens when held next to the ear. As a result, this leap forward has led to the development of smaller, more cost-effective, lower-power solutions. This paper provides an overview of proximity detection technology, including how IR emitter-based proximity detectors work and how they work in conjunction with Ambient Light Sensors (a related technology). This paper explains several technical details, including ambient IR compensation, for a variety of applications that help reduce power consumption, increase privacy, augment consumer convenience and enhance styling, and concludes with a discussion of current and future applications for leveraging the capabilities of proximity detection.

Anybody who has been through a modern airport or pushed a shopping cart through a supermarket doorway has come in contact (or more precisely, *not* come in contact, but gotten close) with a technology that has been around for decades, though until recently was largely limited to a handful of familiar applications. This technology — Proximity Detection — senses when someone comes close to a door, or puts their hands under a water faucet, or walks away from a toilet, and then electronically triggers an event (such as toilet flush, or door opening). With the recent advent of the iPhone and other smartphones, a need arose for a new form of Proximity Detection that uses far less power and occupies much less space than traditional designs. This has led to the invention of a new generation of Proximity Detection solutions that are just now beginning to find a wider variety of applications beyond smartphones. This paper will explain what these new Proximity Detection solutions are and how they work, and outline a few of the many applications where they can help save power, minimize wear and tear, improve hygiene and provide other tangible user benefits at minimal incremental BoM cost.

History of Proximity Detection

Broadly speaking, Proximity Detection technology is almost a century old, beginning with the “Theremin” vacuum-tube based musical instrument, invented in 1919, that played different sounds as hands moved nearer or further from its capacitance-based sensors. Automatic door sensors were first envisioned in science fiction years before becoming commercially available (see any old “Star Trek” rerun), but by the 1980s radar and IR-based sensors (and occasionally ultrasonic audio) started replacing floor mat switches for supermarket doors. That’s roughly when the toilet and faucet controls became commonplace too. But these sensors, based on discrete analog components were too big and power hungry for battery-powered applications.

In 2007 a new smartphone Proximity Detection application arrived with the iPhone. Millions of smartphone users now experience it on a daily basis, yet many may barely notice, because it happens so smoothly: The Proximity Detection sensor powers down the touch screen when the phone is held next to the ear. Shutting off the touch screen has two important benefits: First, if the screen comes in contact with the user's ear or cheek, the phone will not respond when the touch screen is accidentally pressed. Second, as the display is usually the single biggest power hog, shutting it off helps lengthen battery run time.

The small size and low power required by handsets made traditional approaches to Proximity Detection unworkable. To answer this need, a new generation of low-power Proximity Detection integrated circuits has been introduced. Many design engineers are just now becoming aware that these new Proximity Detection solutions exist, getting a sense of how easy they are to design with, and learning what they can do.

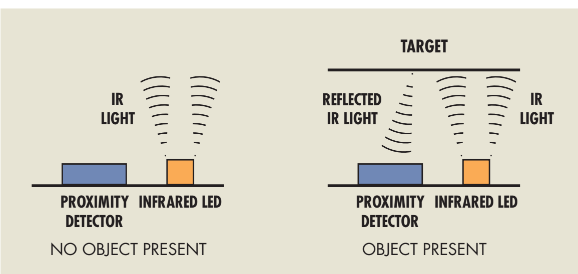


Figure 1: IR Proximity Detection

How Proximity Detection Works

Today's Proximity Detection technology utilizes reflected radio (microwave), IR energy, or sound energy (ultrasonic waves), with infrared (IR) energy being the preferred signal type for most electronics applications. IR energy has numerous advantages, including the fact that it's invisible and can be transmitted through darkened glass or translucent materials. (Capacitance-based systems depend on human skin, and won't sense walls or other objects, or work with some gloves.)

With reflected IR technology, an infrared emitting diode emits IR energy towards the target object. If the target object is not present there will be no reflected energy. If the target object is present, the IR energy will reflect off the object and be directed towards the sensor, and if this reflected energy exceeds a predetermined level a "proximity event" is declared (see Figure 1). Note that the IR emitting diode is commonly referred to as an "IR LED" — and we'll use that convention here.

A block diagram of the main components is shown in Figure 2. The LED only emits IR when triggered by the proximity detector, saving power. (The IR wavelength is typically 850, 880 or 940nm.) The proximity detector is a mixed-signal device that detects and gathers the IR energy and converts it into a digital format for processing. Inside the proximity detector an internal IR photodiode creates a current that's proportional to the sensed IR energy. This energy is accumulated and then converted to a digital format by ADCs (analog-to-digital converters). The proximity detector also contains comparators that can be set to specific energy levels to create an interrupt to the MCU/Microprocessor when specific energy levels have been detected (or cease to be detected, such as when someone moves away from a computer).

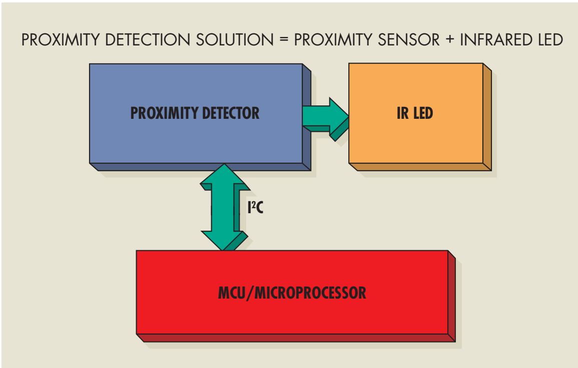


Figure 2: Proximity Detection System Components

The proximity detector system interface is typically an industry standard, such as I^2C, for easy connection to the MCU/microprocessor. The MCU/microprocessor manages the setup and configuration of the proximity sensor and executes a proximity detection algorithm appropriate for the system implementation.

Proximity Detection and ALS: IR Proximity Detection technology is closely related to Ambient Light Sensing (ALS) technology. While Proximity Detection requires a measurement of infrared energy level, ALS determines the level of visible (photopic) light, and is very useful for adjusting screen brightness to save power — making the screen its brightest only when ambient light levels are high.

As space in a handset is extremely tight, TAOS has responded to market needs by developing a new generation of devices that combine a digital ambient light sensor and Proximity Detection. With ALS and Proximity Detection combined into a single monolithic silicon chip, designers have more space and a more power efficient way to control display screens.

There are many applications where both ALS and Proximity Detection are relevant to the same piece of equipment, especially for display and touch screen applications. In a cell phone, ALS adjusts screen brightness to save power in indoor light, while Proximity Detection shuts off the touch screen when the phone is brought up to the ear. In a TV set, ALS can adjust brightness while Proximity Detection turns the set on and off with a wave of the hand, or activates an onscreen menu. Or a TV may dim the screen at night, and also shut it off entirely if no one is nearby. (For more information about ALS technology as it applies to TV design, see "Ambient Light Sensing in Green TVs." [1])

PC and Basic Switch Applications: Detecting when a user is holding a phone to the ear is a very short range application, involving distances of under a few inches. Proximity Detection has many longer range applications, especially for computers. A notebook or desktop computer can detect the absence of a user to automatically shutdown the screen or enter standby mode (see "Display and Touchscreen Applications," below.)

The further the distance is, the more IR energy will be required to reach the target and be reflected sufficiently for sensing. Fortunately, this often correlates with the availability of power. Cell phones, where power is at a premium, are a short range application, while desktop PCs, where power is more abundant, are medium range (and distances over a meter are considered long range).

When considering the use of Proximity Detection technology designers should be aware of an almost revolutionary development: Proximity Detection can now be used to replace practically any switch.

Instead of pressing a pushbutton or touching a sensor, with Proximity Detection the user may simply wave a hand to turn a device on or off, or control its operation. The advantages may include sleek design, increased product durability (no mechanical switches or touch sensitive spots to wear out), safety, and/or improved hygiene (especially important where many people may need to operate the same piece of equipment.)

Proximity Detection Components

The burgeoning smartphone market has rapidly fostered the development of low-cost Proximity Detection integrated circuits based on infrared technology. These proximity detector chips ease an engineer's work and open new possibilities in the design of consumer electronics, industrial, medical and military equipment.

Developed initially for use in handsets, TAOS Proximity Detection products reflect the current state-of-the-art in low-cost, low-power solutions. Occupying as little as $4mm^2$ of board space, TAOS Proximity Detection solutions are small enough for any portable application. Power consumption is minimal, and for many applications there is a net power savings that results from shutting down the screen.

With TAOS Proximity Detection solutions, an LED provides an IR signal source, and an IR sensor detects the reflected light level. Utilizing a microcontroller (or microprocessor) and digital algorithms to control the device, TAOS Proximity Detection technology is unique in several ways, including the integration of ALS and Proximity Detection into a single device occupying minimal space and consuming minimal power. TAOS Proximity Detection is also unique in the way it adjusts for ambient light.

Adjusting for Ambient IR

Ambient IR energy can pose a significant challenge to the Proximity Detection device. While trying to measure the amount of reflected IR energy, it is also affected by ambient IR levels. In outdoor sunlight, for example, there may be so much IR present already that the incremental IR from the Proximity Detector system is very difficult to detect — the victim of a very low signal (reflected IR) to noise (ambient IR) ratio.

TAOS makes the only Proximity Detection solutions available that reliably compensate for ambient IR on every pulse cycle of the IR LED. As explained later in the "Power Consumption" section, pulsing the IR LED drastically reduces its power drain, and the number of pulses can adjust the range of the system. As shown in Figure 3, TAOS Proximity Detection devices utilize the "off" time of each IR LED pulse to measure the ambient IR level. When the IR LED turns on, a measurement is taken representing the combined reflected IR and ambient IR. The background IR reading is subtracted from the total to calculate the true measurement of reflected IR energy. The readings from multiple pulses are integrated together (from 1 up to 255 pulses). Performing this calculation on each cycle of the pulsed IR LED ensures that the ambient IR level can never saturate the integrated signal — a distinct problem with less sophisticated systems.

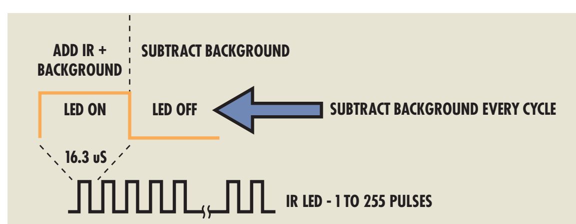


Figure 3: TAOS Proximity Detection systems compensate for ambient IR by subtracting the background IR level on every cycle of the IR LED, preventing saturation.

Applications

As the availability of low-cost, low-power off-the-shelf Proximity Detection solutions is still relatively recent, new applications are appearing constantly, and many have yet to be dreamed of. Broadly speaking, we can divide them into two categories — those involving displays or touchscreens, and non-display applications.

Display and Touchscreen Applications: Touchscreens are a booming business, with sales expected to grow from $3.6 billion in 2008 to $9 billion by 2015, and penetration in cell phones growing from 16% (representing 220-million units) to 40% over that same time.[2] Practically every one of these can benefit from Proximity Detection. In addition to shutting off the touchscreen when the phone is brought to the head, the phone can also go into speakerphone mode automatically when a hand is removed.

For PC display screens and TVs, Proximity Detection can be used to activate onscreen menus without touching the display, or turn a display or TV on and off, or go into standby mode when no one is watching. In a digital camera, detecting the user's eye approaching the camera can dim or power-off the display, and disable the touchscreen.

For laptops and netbooks, Proximity Detection offers more efficient power management than the traditional timers that wait for the user to stop activity before powering down. As soon as the user moves away from the computer, it goes into a power saving mode. For desktop PC display screens, Proximity Detection offers the "green" advantage of power savings plus the added benefit of privacy. In office environments where sensitive documents are being worked with, the possibility of these documents being seen by unauthorized eyes is reduced if the screens turn off or the PCs enter standby mode whenever a worker gets up and walks away from their desk.

For eBooks, portable game consoles, media players, portable DVD players, navigation systems and other portable devices Proximity Detection systems can extend battery life by automatically powering down or shutting off the display when not in use.

Non-Display Applications: If you think of Proximity Detection as a replacement for switch technology, you get a sense of the expansive array of potential applications. As touch-sensitive switches have gradually been replacing mechanical switches for many applications, Proximity Detection based switches have similar potential as a general-purpose replacement. Since the range of sensitivity is easily adjustable by the design engineer, a setting of a few millimeters would appear to users to be like a touch switch that you don't need to touch, and that works fine even when gloves are worn.

Proximity Detection based switches can add to consumer convenience to power on or off televisions, computers, air conditioners, and a myriad of other devices. For medical equipment applications, Proximity Detection based switches can eliminate or minimize the need to touch controls, thereby reducing the spread of germs.

For power tools, user presence detection can improve product safety by automatically shutting off if the tool is dropped. Alarm clocks can be made with touch-less snooze switches. The built-in water and ice dispensers in refrigerators can detect the presence of a glass. Robotic vacuums can detect walls and furniture without the need for mechanical bumper switches. Printers can detect whether paper is present without mechanical switches. Bathroom scales can turn on automatically as feet approach.

New Applications: Future applications may go even further by combining multiple proximity sensors to recognize hand movements and gestures for advanced controls such as display scrolling, page selection and menu navigation. With several sensors mounted along the right side of a computer display, for example, the timing of the sensors can be compared to determine whether a user is waving their hand up or down, thus determining whether the displayed page should scroll up or down.

With proper calibration, Proximity Detection can also be used to measure not just whether or not someone is present, but how close he or she is. Some 3D displays — especially those that do not require wearing special glasses — can benefit from knowing the distance to a viewer in order to present the best possible experience. Display systems may be optimized for a viewer's focal point. We are genuinely at the dawn of an exciting new era with these many possibilities!

Sensor Placement

When incorporating Proximity Detection into a new application attention must be paid to the mounting and placement to optimize sensitivity and performance. The sensor must be mounted so that it can face out to "see" the reflected IR signal, and not be covered up in normal use.

Careful attention must also be paid to the spacing between the IR LED and the sensor (typically about 6mm), and to ensuring that internal leakage of IR to the sensor (within the case) is kept to an absolute minimum.

Most LEDs emit IR from their sides as well as from their front, so designers must incorporate a baffle to block this leakage. When concealed behind dark glass or plastic, reflections off this surface may also create IR leakage, sometimes requiring a notch in the surface to minimize reflections. In some circumstances, short light pipes (typically a few millimeters long) may be needed to direct light to the sensor.

When utilizing a single device for Proximity Detection and Ambient Light Sensing (ALS), the sensor must be placed in a location where it can "see" what the current ambient photopic (visible) light level is. One unique advantage of TAOS combination ALS and Proximity Detection solutions is TAOS' patented Dual Diode technology, which allows for more flexible aesthetic design by concealing the combination sensor behind dark plastic or glass. With TAOS' Dual-Diode technology, one photodiode is responsive to both visible light and IR energy, while the other is primarily responsive only to IR energy. As a result of taking these two readings, it becomes much easier to subtract out the unwanted signal, and determine true ambient photopic light levels.

Placing the sensor behind dark glass or plastic allows product designers to create a sleek, smooth and continuous look with no holes needed to let light through. By spacing apart sensors behind a dark plastic bevel, for example, a TV manufacturer can provide ALS-based screen dimming, plus all of the standard controls for power, volume, channel change, and input select without any visible buttons. This also makes it easier to create environmentally sealed enclosures.

Power Consumption and Size: The TAOS single-chip ALS and proximity solution is available in a small 2 mm by 2 mm package (see Figure 4). This single-chip approach simplifies system design, reduces part count, increases system reliability, and lowers assembly costs.

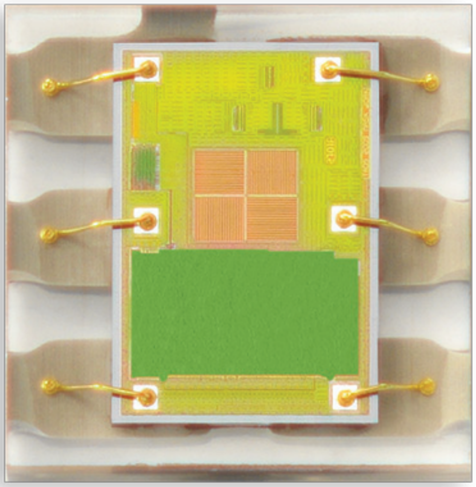
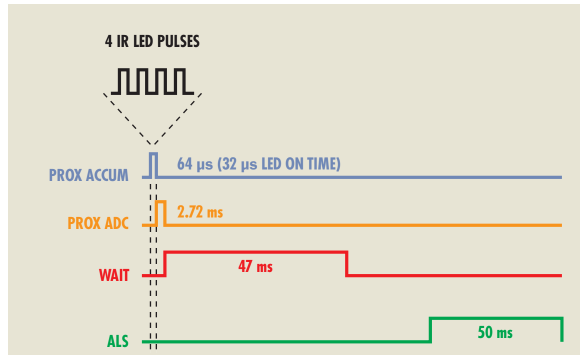


Figure 4: TAOS single-chip package that includes an ALS device and a proximity detector.

Power consumption for a complete Proximity Detection solution can vary depending on the range needed, but overall is extremely low, typically just a fraction of a milliamp. There are two parts to the overall power consumption — the IR LED and the sensor.

Power Management with Wait State Timing Cycle: While at first glance the LED might appear to be an unacceptable power hog, requiring as much as 100mA or more, this is *not* a continuous drain. Rather, the advanced timing of the Proximity Detection system pulses the LED for just a fraction of each second, typically in 8-microsecond bursts, thus reducing average power consumption drastically. In the timing example shown in Figure 5, an IR LED requiring 100-mA of driver current consumes a mere 32-µA on average, because it is actually on for a period of just 64-µs within each 100-ms cycle. Since the LED is pulsed (with a 50% duty cycle), this amounts to just 32-µs of actual "on time" per timing cycle. The timing cycle shown takes one tenth of a second (100-ms), so it's repeated ten times per second. The LED is therefore on for a total of just 320-µs per second — or roughly 1/3000th of the time.



Example: 100 ms CYCLE TIME

STATE	DURATION (ms)	CURRENT (mA)
PROX ACCUM (LED ON)	0.064 (0.032)	100.0
PROX ADC	2.7	0.175
WAIT	47	0.065
ALS	50	0.175

AVG = ((0.032 x 100) + (2.72 x 0.175) + (47 x 0.065) + (50 x 0.175)) / 100 = 155 µA

Figure 5: Power consumption for a typical combination Proximity Detection and ALS application, using a 100-mA LED for Proximity Detection, amounts to an overall average of 155-µA. First the system emits 4 IR pulses, then the ADC converts the received IR level to a digital signal (if it exceeds a threshold, a proximity event has occurred), then it goes into Wait State, and then it measures ambient photopic light (ALS).[3]

The timing example shown in Figure 5 takes advantage of Wait State for half of each cycle to further reduce power consumption. With the TAOS TSL2771 combination ALS and proximity sensing device, Wait State power drain is just 65-µA. The total average power consumption — including the IR LED — is a mere 155-µA. Utilizing a 3-volt power source, that's less than half of one milliwatt.

Range and IR Power: The range of the Proximity Detection system depends on the current driving the IR emitter and the number of IR pulses per timing cycle. With TAOS devices the external IR LED may be driven with between 12mA and 100mA, programmed through the integrated constant current source driver. An external transistor may be used for higher current. The chart below (Figure 6) shows the correlation between the number of pulses, driving current, and range of the device (relative distance to the target):

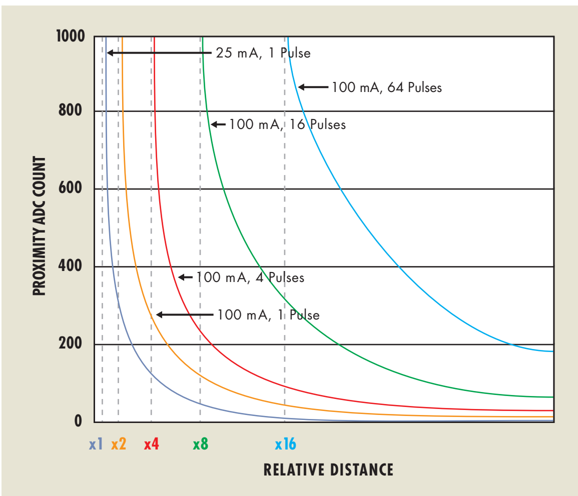


Figure 6: Proximity Detection range (shown as relative distance) depends on the current driving the IR emitter, and the number of pulses of IR energy emitted. The ADC Count represents the detected IR signal level that determines if a proximity event has occurred.[3]

Conclusion

Proximity Detection technology has been around for many years but was previously cumbersome to design into most applications, especially portable devices. Now, a new generation of low-power, low-cost Proximity Detection solutions are opening new creative opportunities for product designers and engineers. These include screen applications that can save power and improve privacy, and non-display applications where increased convenience and better hygiene are major benefits. In choosing a Proximity Detection solution, TAOS Inc.'s experience as a pioneer in the smartphone market, and cutting-edge patented technology such as integrated Proximity Detection-Ambient Light Sensor solutions incorporating Dual-Diode technology make TAOS Proximity Detection superior for most applications. To learn more about adding a Proximity Detection solution to your next product design, visit the TAOS, Inc. web site at www.taosinc.com.

Footnotes

1. "Ambient Light Sensing in Green TVs" TAOS Inc. White Paper (http://www.taosinc com/ConsumerWhitePaper/WhitePaper.aspx)

2. DisplaySearch 2009 Touch Panel Market Analysis Report (http://www.displaysearch.com/cps/rde/xchg/displaysearch/hs.xsl/090520_touch_screen_module_revenues_forecast_to_reach_9b_by_2015.asp)

3. TAOS TSL2771 Data Sheet (http://www.taosinc.com/getfile aspx?type=press&file=TSL2771-E41.pdf)

About TAOS, Inc. (Texas Advanced Optoelectronic Solutions)

With more than a decade of analog mixed-signal technology innovation and market leadership, Texas Advanced Optoelectronic Solutions (TAOS), Inc. designs and manufacturers digital and analog light-sensing solutions that deliver increased system integration, design flexibility and functionality to a wide range of products in the consumer, computer, industrial, medical and automotive markets. Integrated ambient light sensing and proximity detection solutions enable “Green” displays by reducing system power consumption. An expanding portfolio of programmable analog and digital RGB color sensors provides accurate color discrimination, determination and measurement.

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