Enabling Smarter Industrial 3D Sensing with Hyperlux™ ID

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The Third Dimension: Depth Perception on the Factory Floor

Every automated assembly and handling component on the modern factory floor utilizes some sort of sensor — usually a laser-based depth finder or an image sensor, often some combination, more often in multiplicity — to ascertain where it is and what it's doing. It perceives the world around it, and it requires some sense of depth.

It's astonishing how accurately our own eyes perceive the world around us. Even so, utilizing all the information that can be extrapolated from what we see, our brains can only make reasonable estimates with regards to depth. We rely on being able to judge relatively which objects are in front of others, or what shape an object may take in three dimensions, using a scale set for us by the scene we're looking into at the time.

By comparison, regardless of their light sensitivity or resolution, electronic image sensors are believed to lack the perceptive capabilities of even the least capable pairs of eyes in the natural world. Nevertheless, it's necessary for a robotic assembly device or an autonomous mobile robot (AMR) to utilize data from image sensors in directing its own movements, sometimes to within 10 microns of positioning accuracy.

For a robotic device, depth perception has more to do with what its devices can infer, typically mathematically, from the limited information available to it. It needs to sense enough data from the objects in its vicinity to be able to calculate depth to at least within 15 cm for far-away objects, and within 5 mm for near objects.

Principal Methods of Depth Sensing

When you make full use of the information embedded in an image processed by an **onsemi image sensor**, it effectively becomes a depth sensor. For technological purposes, there are only a handful of methodologies commonly used to infer depth information from sensed data using a camera, or a light-sensing device such as an interferometer:

Stereoscopic Vision
The human brain utilizes stereopsis to infer relative distance information from two simultaneous images. In a similar way, passive stereoscopic vision is a technology that uses a pair of RGB cameras in conjunction with an imaging processor. Depth is determined first by measuring the distance between the two cameras, and using that as a benchmark in ascertaining the parallax — the perceptible shift in the position of an object being captured by both cameras.

Structured Light
An image sensor — typically high-resolution, mounted on an articulated device capable of capturing images of an object from multiple angles — can record enough data about how projected light patterns are reflected from it, to ascertain its precise shape. This method is helpful when accuracy is more important than speed, as is the case when generating a reference image of an artist's plaster bust, for use in producing replicas.

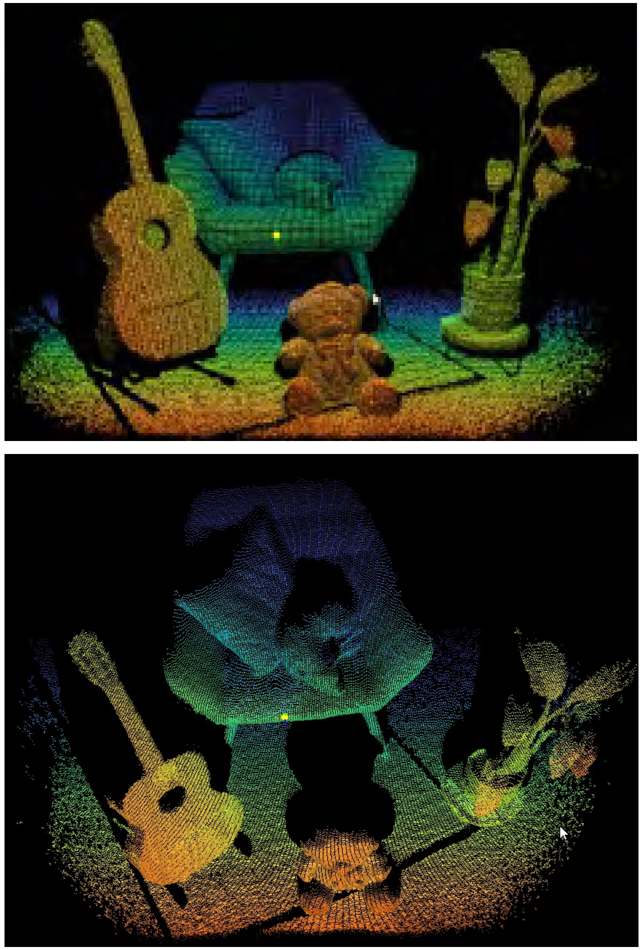
Principal Methods of Depth Sensing

Time-of-Flight Methods

The two depth sensing methods that are of value today for autonomous and robotic devices both involve a calculation using time as the key factor — specifically, the time it takes for photons to be reflected from an object.

Direct Time-of-Flight (dToF) precisely measures the intensity of light reflected from an object by counting the photons received during each discrete interval of time ("time bin"). dToF is the principal scanning technique used by Light Detection and Ranging (LiDAR) devices. Because it's an inherently one-dimensional method utilizing a single laser, inferring anything more from an object other than its distance — for instance, its shape — requires either moving the laser or moving the object, and scanning again.

Indirect Time-of-Flight (iToF) infers distance from the light reflected by an object, usually from an image sensor, utilizing data extrapolated from the phase shifts in the light's modulated frequencies to obtain accurate depth. With phased light, iToF infers distance from phase shifts. Because iToF makes use of entire, two-dimensional images — sometimes more than one at a time — it can calculate accurate, pixel-level distance from entire images all at once. This makes both real-time distance measurement and high-resolution imaging feasible simultaneously from the same devices. However, because the image sensors upon which iToF relies are susceptible to ambient light interference and other distortion phenomena, the method is usually limited to shorter ranges.



A point cloud [top] uses a heat map to represent the proximity of objects reflecting light. Rotating this map in memory reveals the extent to which other objects may be obscured.

Comparing Sensor Modalities

CMOS-based image sensors have a limited unambiguous range of depth perception. Under normal conditions, this range would have a hard stop at one cycle of light modulation. The location of that hard stop **D_{max}** is calculated using this formula:

$$D_{max} = \frac{c}{2f_m}$$

where the constant **c** represents the speed of light, and **f_m** represents the modulated light frequency. For example, a sensor modulating at a single frequency of 60 MHz would have an unambiguous range maximum limit of only 2.5 meters.

The effective range of any image sensor equipped with depth perception is limited by its resolution – a limitation a laser beam doesn't have. It's this distinction that defines the realms of practicality for image sensors, as well as laser-driven instruments such as LiDAR, in industrial applications.

The best and most effective image sensing for navigation in motion comes from a fusion of several modalities, including data from ultrasonic sensors capable of detecting obstacles at short range, and whose depth data is reliable in adverse weather and low light conditions. Time-of-flight sensors are incapable of utilizing color, since both dToF and iToF utilizes 940 nm bandpass filters to block certain light wavelengths that contribute to noise. Radar is very reliable over longer ranges, providing robust signal in fog, rain, or darkness, although its angular and spectral resolutions are relatively coarse.

Sensor modalities	CMOS imaging	Radar	dToF	iToF	Ultra-sonic
Angular resolution	🟢	🟡	🟢	🟢	🔴
Depth resolution	🟡	🟢	🟢	🟢	🟢
Velocity	🔴	🟢	🟡	🟡	🔴
Depth range	🟡	🟢	🟢	🟡	🟡
Traffic signs	🟢	🔴	🟡	🟡	🔴
Object edge precision	🟢	🔴	🟢	🟢	🟡
Lane detection	🟢	🔴	🟡	🟡	🔴
Color recognition	🟢	🔴	🔴	🔴	🔴
Adverse weather	🟡	🟢	🟡	🟡	🟢
Low-light performance	🟡	🟢	🟢	🟢	🟢
Cost	🟢	🟢	🟡	🟢	🟢

Direct Time-of-Flight

The basic components of a dToF ranging system are:

- **The illumination source,** usually a pulsed laser with collimation optics
- **The detector mechanism** or photosensor array
- **The beam steering mechanism** for both source and detector
- **An opto-mechanical subsystem** to provide optics and focus
- **A readout processor** to analyze the signal
- **A power management system** for stable and reliable current

onsemi's contribution to this system are the detector mechanism and the power management system.

Depth sensing using dToF involves a periodic laser pulse, with an eye-safe optical wavelength usually between 905 nm and 940 nm. This pulse is directed toward a target, which diffuses and reflects some of the laser light back toward a sensor. This sensor then converts the reflected photons into electrical signals. The timing functions take account of the reception points for these signals, calculating the differences between them to arrive at a value for time-of-flight **Δt**.

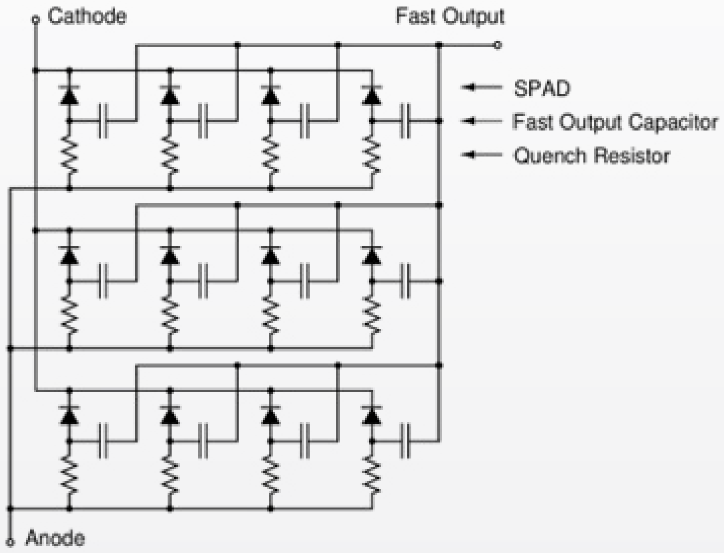
Using **Δt**, it's an academic matter to calculate the distance **D** from the target to the sensor, using this formula:

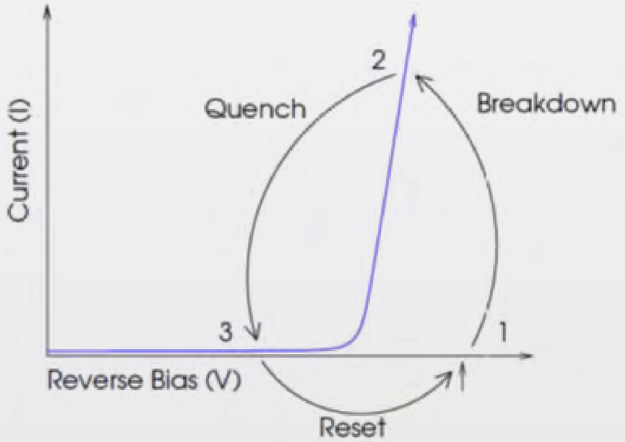
$$D = \frac{c\Delta t}{2}$$

where **c** represents the constant speed of light, and the constant **2** takes into account that **Δt** takes account of photon travel distance in both directions (there and back), when we only need one direction.

It's up to the LiDAR's sensor to discriminate noise photons, or ambient light, from the reflected laser light. When only one **Δt** is calculated using a single measurement of **D** taken with a single laser pulse (a "single-shot"), there's a high probability that noise will reduce the likelihood of an accurate calculation. To more reliably eliminate noise values, a LiDAR often takes several "shots," since noise measurement values are very rarely repeated. One of many measurement techniques may then be employed to extract reliable timing information from the reflected light data, one of which involves utilizing the timing function to repeat the pulse like a practicing musician's metronome, although very quickly.

The Mechanism Behind dToF





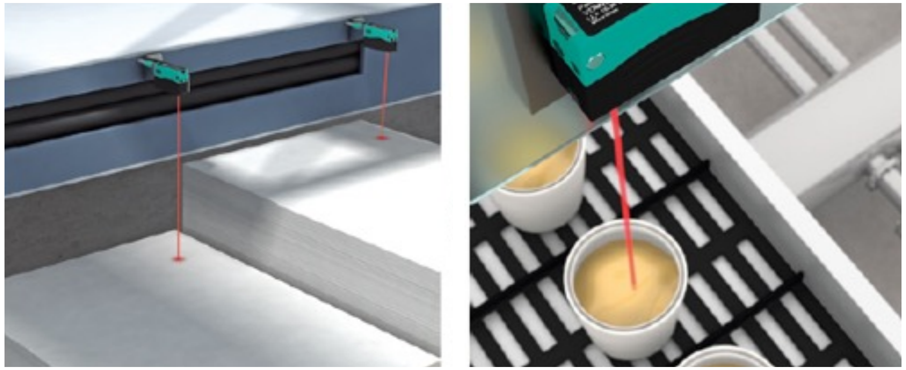
onsemi recommends solid-state silicon photomultipliers (SiPM) for use with LiDAR and dToF. Among the many options available, SiPM uses the least power, while retaining a very high resistance to electromagnetic and optical noise. The basic building blocks of a LiDAR system's SiPM detecting mechanism (effectively its pixels) are single photon avalanche diodes (SPAD) arranged as independent microcells. For onsemi SiPMs, microcell size may be either 20 µm or 35 µm depending upon the size of the sensor unit. Larger cell size provides a bigger target for photon collection, thus increasing photon detection efficiency (PDE), while smaller cell size allows for more microcells in a given area, leading to greater dynamic range. There may be as many as 1,590 SPADs within the active sensory area of the SiPM.

When a SPAD absorbs a photon, one of these microcells "fires." This firing triggers a phenomenon called a Geiger avalanche, which is a condition that occurs specifically because the SPAD is biased above slightly above its own breakdown voltage. This biasing makes the electric field across the SPAD's junction overly intense, or meta-stable. In this state, where current does not flow, a photon striking the SPAD triggers an avalanche, like firing a flare gun atop a mountain peak about to overflow with snow.

The Geiger avalanche triggers a photocurrent to flow through the microcell, which is a kind of amplification — like the force of an avalanche. That's what sends the signal that a photon has been captured. However, as an incidental result, there's also a voltage drop across the SiPM's quenching resistor, which is the SPAD's partner in the SiPM's microcell. This resistor nullifies what would otherwise be a self-sustaining discharge, in turn resetting the SPAD for detecting the next photon to come along. The diagram at right depicts the active lifecycle of a Geiger avalanche, as a function of reverse bias V versus current I.

Single-point Depth Perception

Direct time-of-flight is best suited for single-point, short- and long-range, 2D scanning LiDAR applications. These include tasks where the single dimension of a LiDAR scan is extended to a 2D plane, but also tasks where only one dimension is necessary: For example, when a dispenser needs to know the fill level of a cup or a vat, a dToF LiDAR registering the reflectivity from a single laser beam, is all that's necessary. LiDAR is accurate enough to detect the number of pages in a stack, as assembled by a printing machine or photocopier. 2D dToF may be used for height detection and monitoring, object proximity detection, and as illustrated below, traffic flow monitoring. A simple, single-point scan is enough to estimate the length of moving vehicles, and from that information infer whether the vehicle is a passenger car, public bus, or load-carrying truck — as well as deduce the vehicle's speed.



Single-point depth perception capability is practical and efficient when the application at hand is to infer from light waves whether or not there's something in the distance in the direction of the laser beam. A meteorologist or a geologist might be interested in the spectrographic analysis capabilities made feasible by the returning LiDAR wave. But when the focus of the application is a binary state — the presence or absence of something directly ahead — an SiPM provides greater simplicity and ease of use.

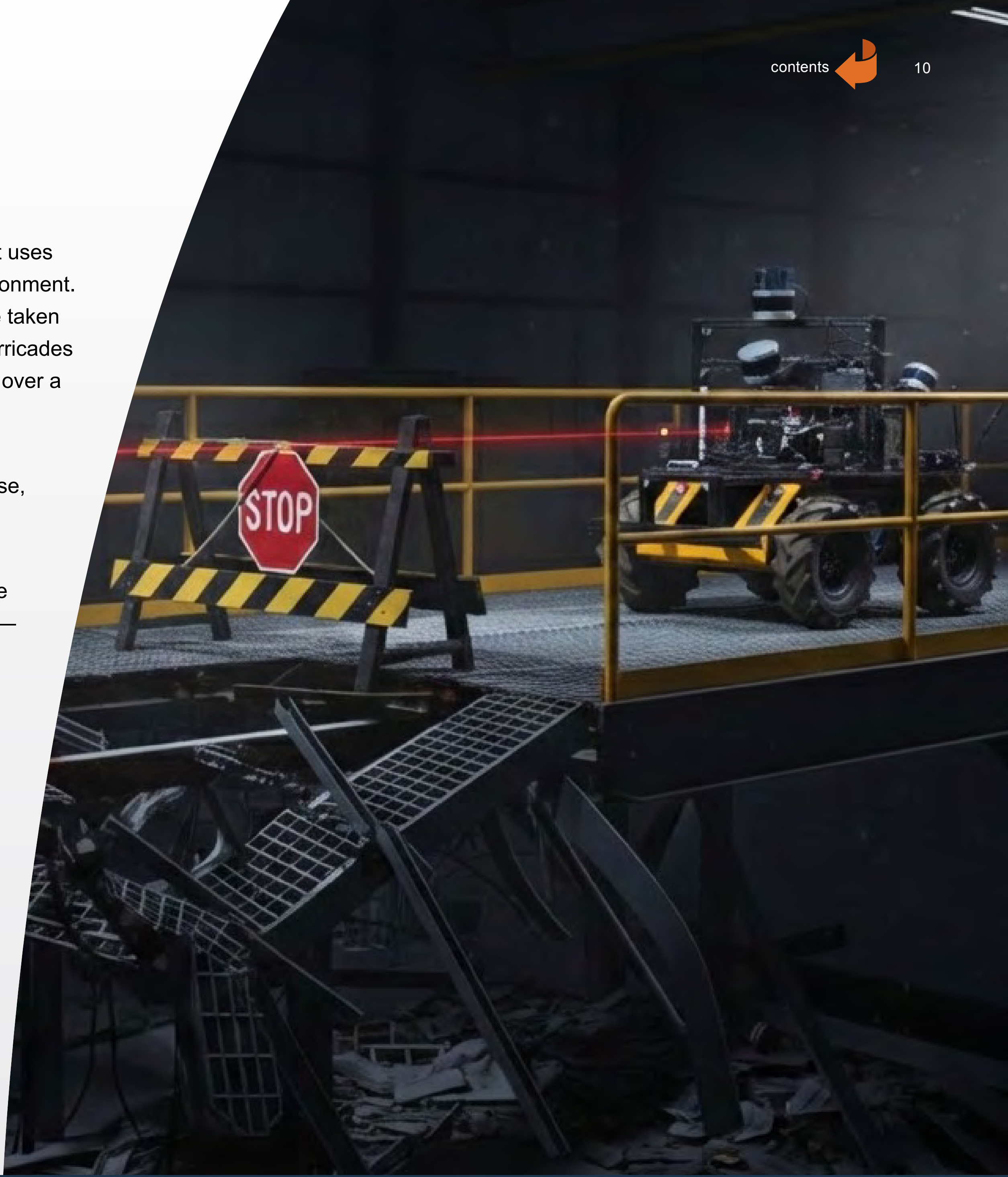
The Limitations of Time-of-Flight Measurement

The more points in space a time-of-flight system can measure, whether it uses iToF or dToF, the more information the system may collect about its environment. Whenever LiDAR plays a role, there's a significant limitation that must be taken into consideration: Negative objects such as staircases, ramps, traffic barricades and traffic ropes tend to avoid being detected when LiDAR is set to scan over a single plane at a height just above them.

One could choose to overcome this obstacle for an autonomous robot or vehicle by adding more LiDAR devices to its sensor mechanism. Of course, this increases cost and complexity, while leaving open the possibility that additional lasers will continue to miss these negative objects.

The best solution is a 3D LiDAR system, which collects a complete image of the scene ahead of it using higher resolution and denser point clouds — heat maps that record the relative proximities of objects ahead. Such a system compiles multiple planes of LiDAR scanning into a 2D array, and may be less expensive to deploy than multiple 2D LiDAR without adding complexity.

3D LiDAR is an effective choice for autonomous vehicle navigation, using simultaneous location and mapping (SLAM). With such a system, a mobile robot may be programmed for obstacle avoidance — including negative objects — safe working zones, object classification and "people counting" for smart city applications.

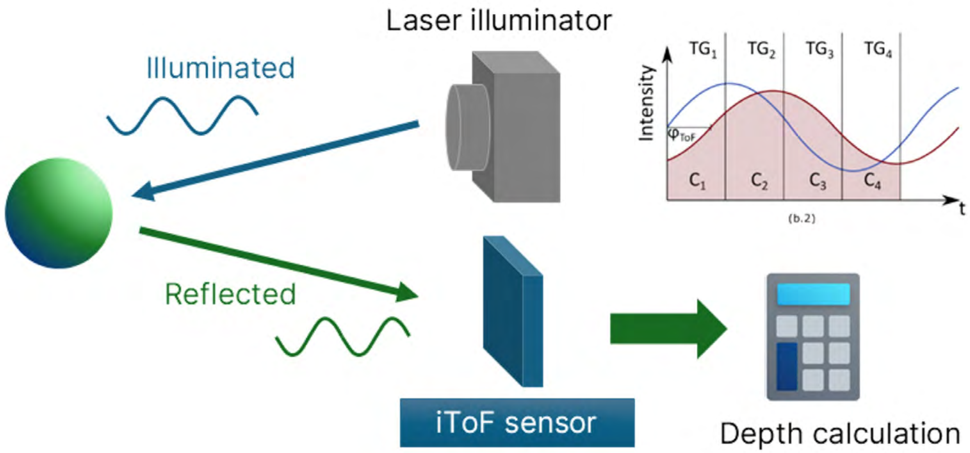


Indirect Time-of-Flight (iToF)

In environments where the object being scanned is nearby, and measurements about its distance and shape must be precise, it's easier and more practical to measure depth using *indirect time-of-flight* (iToF). Like dToF, iToF does compare reflected light to emitted light, though by way of inferred information. The laser illuminator has continuous, sinusoidal wave output at a constant frequency. When the reflected light from the target is captured, depth may be calculated as a function of the differences between the illuminated signal and the received signal.

Using a 940 nm infrared laser diode as an illuminator, an iToF sensor such as onsemi **Hyperlux ID** captures all the received light, all at once, through its global shutter. By comparison, a rolling shutter exposes the sensor to light top-to-bottom, like an old mechanical barrel shutter. This may be satisfactory for consumer-grade digital cameras, although even iToF methods would not fully compensate for a rolling shutter's deficiencies.

The global shutter in onsemi's **AF0130** and **AF0131** enables them to capture eight simultaneous exposures (four phases at two frequencies each), and then store the data from those exposures together as a single captured frame. This reduces motion-induced phase errors to the point of near-elimination.

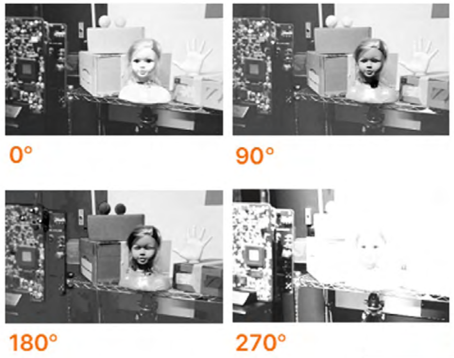


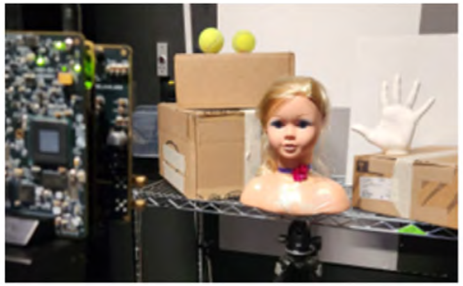
onsemi iToF

How CMOS Sensors Sense Depth

onsemi **Hyperlux ID** model **AF0130** contains an embedded depth-processing ASIC that handles all its depth perception arithmetic on-board. For instance, when light from a constant modulating source such as a laser is reflected by an object, the echoed light will be slightly out of phase. Simple trigonometry gives the ASIC an easy way to infer a single distance value (the "indirect" part of "iToF") from the phase shifts for all four pairs of exposures.

AF0130's real-time processing enables depth data to be put to use immediately for functions such as robot positioning and maneuvering, collision avoidance, physical security alerts, and human gesture detection. For Smart iToF to calculate depth more accurately, it estimates the reflected signal received by each pixel in four separately captured frames — one for each 90-degree phase of the waveform. Utilizing this reflectivity data, **AF0130** produces a *depth map*, combining the data from all four frames into a single frame.





Original

$$S_1 = A\sin(\Delta\varphi) + C \qquad \{\phi = 0^{o}\}$$
$$S_2 = A\cos(\Delta\varphi) + C \qquad \{\phi = 90^{o}\}$$
$$S_3 = -A\sin(\Delta\varphi) + C \qquad \{\phi = 180^{o}\}$$
$$S_4 = -A\cos(\Delta\varphi) + C \qquad \{\phi = 270^{o}\}$$

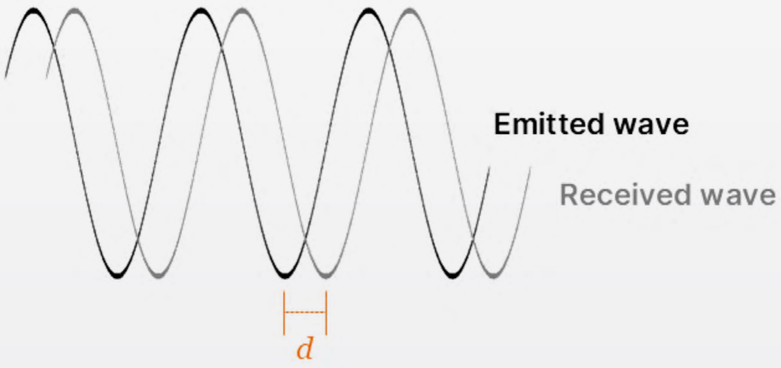
$$\Delta\varphi = \operatorname{atan}\left(\frac{S_1 - S_3}{S_2 - S_4}\right)$$

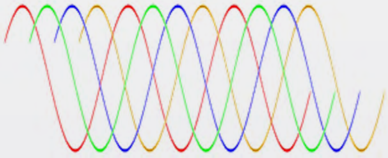
Depth map

onsemi iToF

Calculating Depth from Phase Shifts

When light from a constant modulating source such as a laser is reflected by an object, the echoed light will be slightly out of phase. The degree to which it's out of phase informs the sensor as to distance, although it takes some math to deduce what that distance is. The phase shift between the received light wave and the modulated wave is calculated by assessing the wave amplitude at the edges of the four quadrants: 0°, 90°, 180°, and 270°.





$$
\begin{aligned}
S_0 &= A\sin(-\Delta\varphi) + C \\
S_{90} &= A\,sin(-\Delta\varphi + 90) + C \\
S_{180} &= A\,sin(-\Delta\varphi + 180) + C \\
S_{270} &= A\,sin(-\Delta\varphi + 270) + C
\end{aligned}
$$

The signal value for each phase a is determined by:

$$S_a = A\sin(-\Delta\Phi + a) + C$$

where **A** represents amplitude, and **C** represents the offset of the wave, which takes into account the received signal's base intensity plus ambient light (noise). Next, the phase difference **ΔΦ** for all four angles **S** is calculated using the two-argument arctangent formula:

$$\Delta\Phi = atan2(S_{90} - S_{270}, S_0 - S_{180})$$

With the phase difference **ΔΦ**, the modulation of the laser frequency $\mathbf{f_m}$, and the speed of light **c** all known values, solving for distance **d** at each point becomes academic:

$$d = \frac{c\Delta\Phi}{4\pi f_m}$$

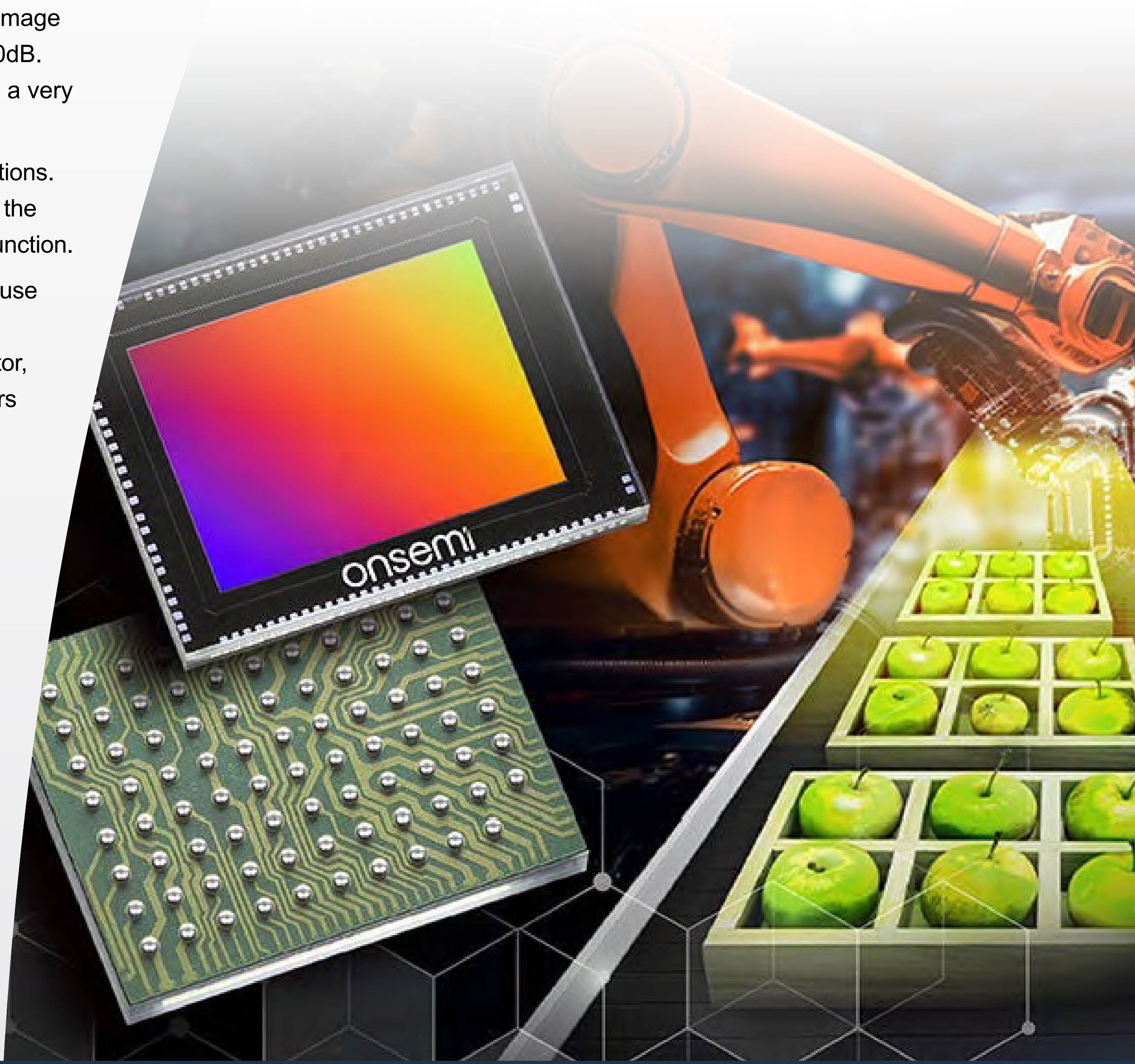
This is how indirect time-of-flight infers depth from image data that represents phase shifts.

onsemi Hyperlux ID CMOS iToF Sensor

Hyperlux technology from onsemi is based around the key tenets of safety and security in industrial and automotive image sensing. onsemi's **Hyperlux** image sensors are capable of delivering competitive dynamic range of up to 150dB. They are designed to maintain stable performance characteristics across a very broad range of extreme temperatures, while utilizing minimum power.

Hyperlux ID AF0130 and **AF0131** are designed specifically for iToF operations. **AF0130** is equipped with on-board image processing, while **AF0131** omits the depth processor for designs where another processor already fulfills that function.

Indirect time-of-flight lends itself well to depth perception applications because the phase data is effectively captured in parallel through the global shutter, rather than serially through a moving laser. However, with a single modulator, iToF is only effective at very short ranges. **onsemi** Hyperlux ID iToF sensors are designed to operate at ranges up to 30 meters — some 20 meters further than competitors' iToF sensors being marketed today.

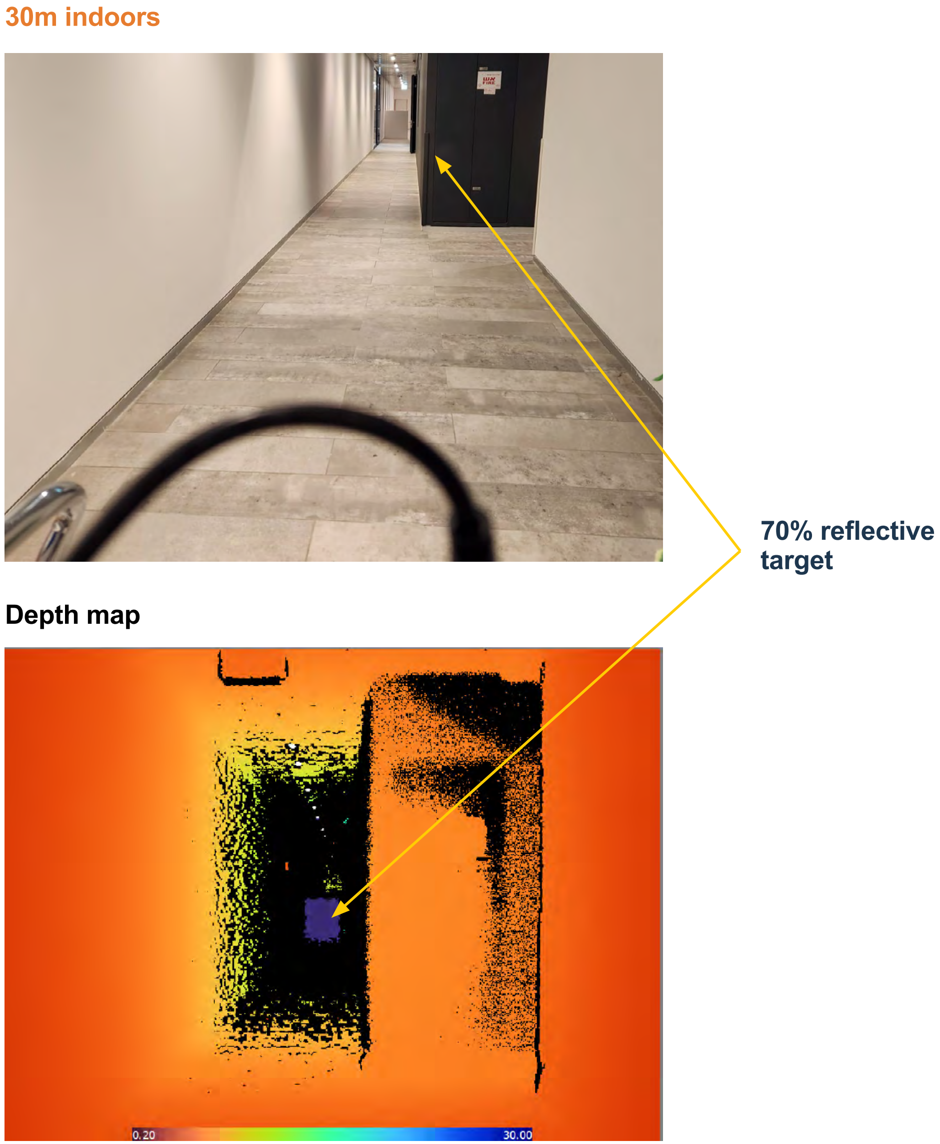


Dual Frequency Measurement for Long-range Detection

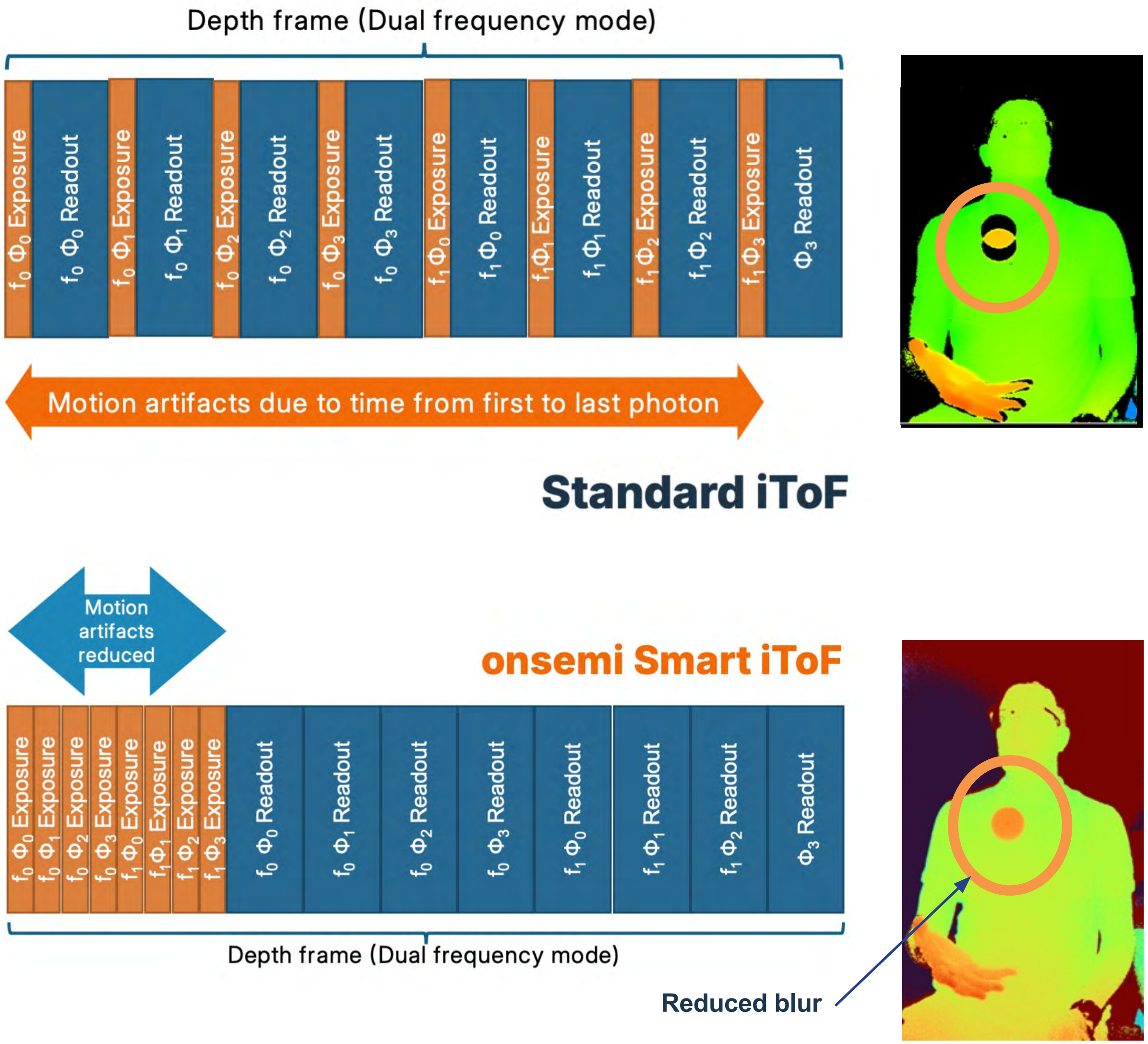
The long-range detection capability of **Hyperlux ID AF013x** is enhanced by way of dual-frequency measurement. As you've seen, a single **AF013x** frame captures eight exposures: four phases at two frequencies each.

Typically, the limiting factor for any iToF sensor is its modulation frequency. With two modulators working cooperatively, the sensor's maximum unambiguous range $\mathbf{D}_{\max}$ is extended using a lower denominator: specifically, the greatest common devisor **GCD** of the two frequencies:

$$D_{max} = \frac{c}{2 \cdot GCD(f_1, f_2)}$$



Minimizing Artifacts by Optimizing Readout Phase Timing



Adjusting Readout Phase Timing

Motion artifacts are the surreal or unrealistic elements of an image attempting to capture objects in motion. With an ordinary CCD-based digital camera, an object in motion at speed shows up in an image with motion artifacts and some distortion. Since a similar-looking blur would show up in a film camera image, it can be overlooked as a fact of photography or even an artistic embellishment.

The problem with capturing fast motion with standard iToF is that, due to the frame capture timing which is often staggered, the motion of an object may either be captured as a large smear or, if motion is going the other way, a complete miss.

onsemi iToF avoids this problem by adjusting its frame capture timing so that the complete frame is exposed up front before the readout phase (transfer to memory) begins. Hyperlux ID does not stagger its frame exposure timing. The result is a full depth of output within a single frame. For applications capturing fast-moving objects — for example, belt conveyors, articulated assembly arms, surveillance cameras, and gesture recognition systems — AF013x almost completely eliminates motion blur on account of slow readout processes.

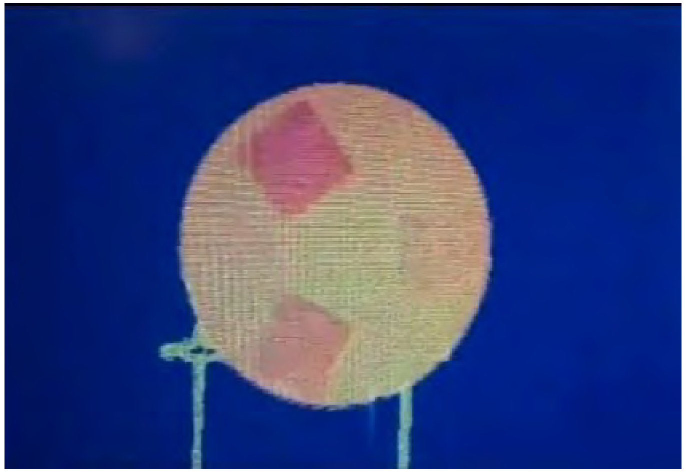
Accounting for Artifacts

The Dreaded Spinning Depth Map

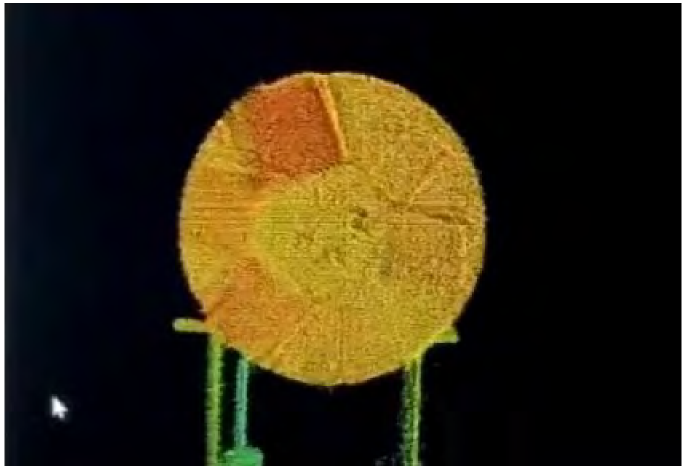
For a high-speed photodetector, what might normally show up as a blur — for example, spinning propeller blades, or a robotic armature in fast motion on the opposite side of the conveyor belt — may appear instead as a strange, disembodied thing hanging in space. It's not a thing, so it's up to the image processing element not to treat it as a thing.

To test the efficacy of **Hyperlux ID**'s all-at-once exposure strategy, onsemi conducted a test using a simple spinning wheel with three blocks of wood attached, each with a different thickness (darker blocks are thicker). The competitor's sensor consistently recorded frames where the wheel appeared to have six blocks attached — an optical illusion caused by the way its sensor interacted with light, including ambient light. By comparison, the video captured with **AF0130** recorded a different optical illusion, where each frame contained only three blocks, but their positions would appear to shift only slightly and then trade places with each other for a blinking effect. Each frame captured by **AF0130** was more true to reality, and the depth map generated using collections of these frames is far more accurate.

Hyperlux ID AF0130



Competitor



There are only three blocks affixed to the spinning wheel. How many do you see in the bottom image?

Calculating Depth More Perceptively

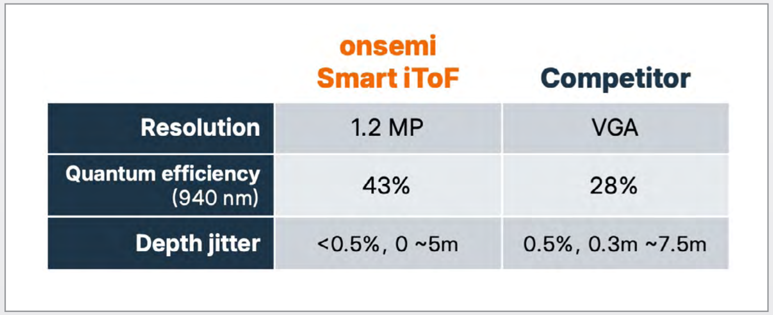
For each given point in a depth map produced by **AF013x**, *pixel response* is a function of the reflectivity of the subject at each given point, calculated as **R_{pix}** using this formula:

$$R_{pix} = f(\rho D + A)$$

where **ρ** represents the reflectivity of a pixel, **D** the distance between the image sensor and that pixel, and **A** the level of ambient light impacting that point. The reflectivity of an object is another way of expressing the strength of the light signal produced by that object.

For the depth map, **onsemi's** DevWareX software makes visible encoded depth chromatically — nearer objects in the redder portion of the spectrum, further objects on the opposite end toward blue-violet.

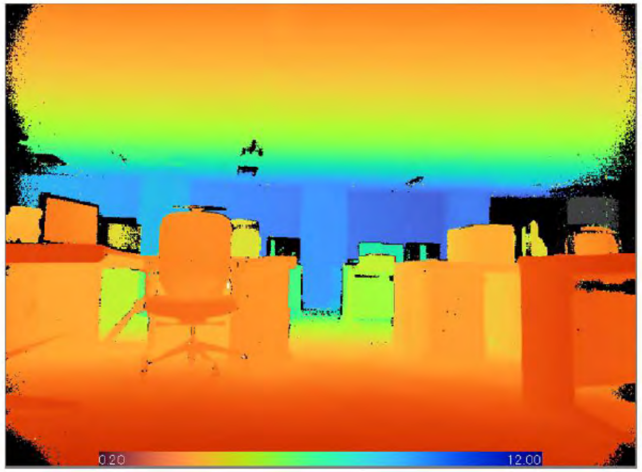
Quantum efficiency (QE) is the measure of a sensor's effectiveness in converting reflected light into an electrical signal. **onsemi** iToF sensors have industry leading **43% quantum efficiency** at 940 nm — nearly twice the efficiency of competitors. This enables much longer range, better reflection of low-reflectivity objects, better imaging capability, and a clearer mono image — all for the same laser power.



	onsemi Smart iToF	Competitor
Resolution	1.2 MP	VGA
Quantum efficiency (940 nm)	43%	28%
Depth jitter	<0.5%, 0 ~5m	0.5%, 0.3m ~7.5m

Single-frame mono test image

Depth map between 0.2 → 12.0 meters



Compiled from four separate images each successive oneout-of-phase with the previous one by 90 degrees

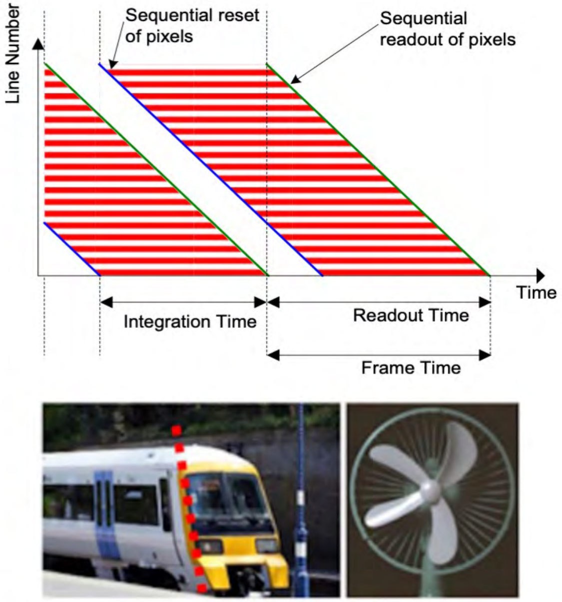
Optimizing Global Shutter Timing

In a consumer-grade DSLR digital camera or a fixed-in-place security camera, a rolling shutter enables light to be exposed to the image sensor a portion at a time. The exposure sweeps from one side of the sensor to the other, with pixels on the already exposed portions being processed concurrently while other portions further down are just being exposed. It's a way for a camera to coordinate its imaging operations, especially at very high resolutions, to avoid buffering too much of an image in memory prior to processing even beginning.

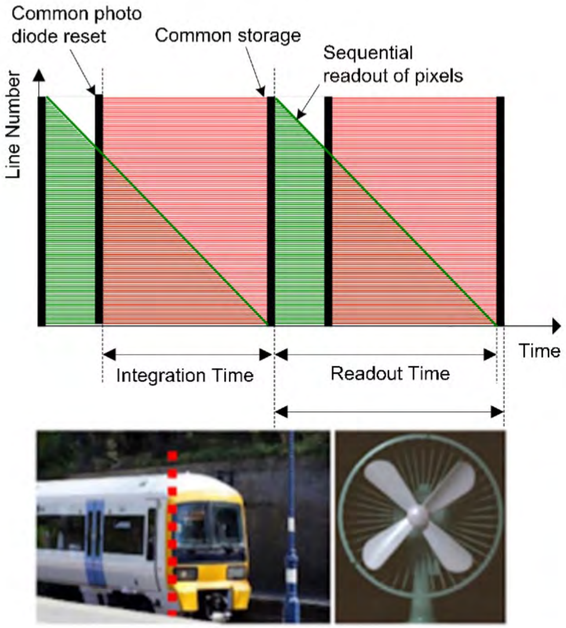
It's a clever technique for a consumer-grade camera, even if it ends up producing images whose realism ends up being slightly distorted, especially when capturing objects in fast motion. That's unacceptable for a depth sensing device that may need to ascertain the shape of what it perceives, and can't get a true picture of reality if the shape it's seeing is warped by time.

Hyperlux ID AF013x's global shutter eliminates the illusion of moving objects appearing to have distorted shapes. All regions of an image are captured at once by the entire photodiode, before the pixel values are stored in memory.

Rolling shutter



Global shutter



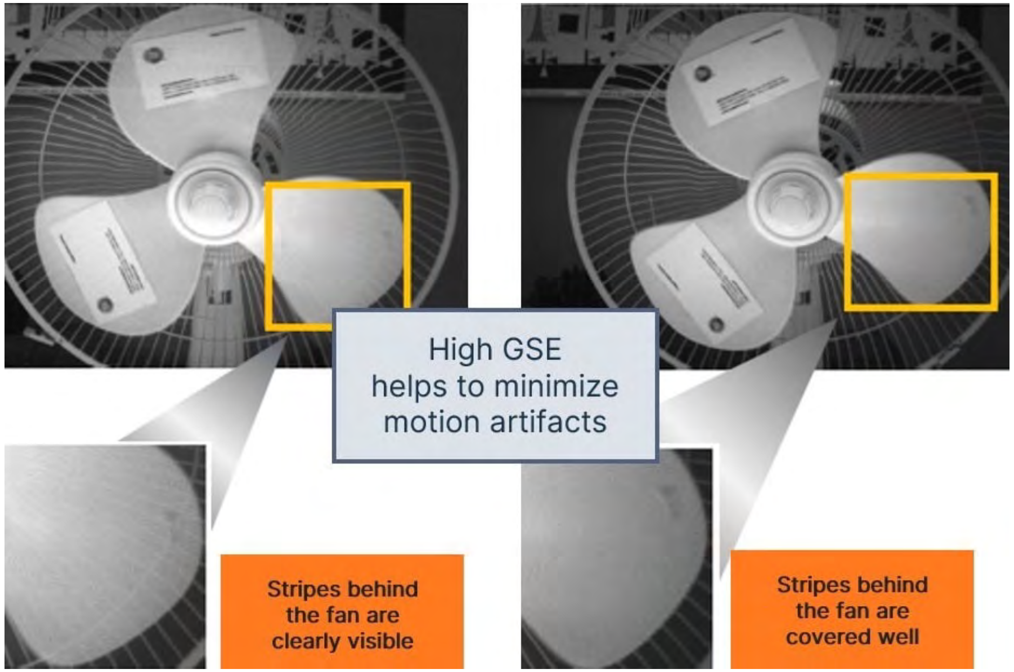
Maximizing Global Shutter Efficiency (GSE)

Here's the math for a typical **AF0130** exposure scenario: Standard image recording speed for a 1.2 MP sensor is about 29.97 frames per second. With a throughput rate for the MIPI storage bus of 1.2 Gbps per MIPI lane, an optimum exposure time (the *first-to-last photon* speed) would be 300 µs. Each pixel in a stored frame is 12 bits, so with two MIPI lines active simultaneously, throughput speed should be about 200 megapixels per second (MP/s).

A 1.2 MP image contains 1280 x 960 pixels, so the readout phase for that image would consume 6.1 ms. **Hyperlux AF0130** can store all the exposure information in the sensor prior to the first readout phase beginning. By comparison, a competitor's sensor would interleave three readout phases between the first four frames. That means its first-to-last photon speed would be 0.3 ms x 4 + 6.1 ms x 3 = **19.2 ms**.

Compare this figure against **AF0130**, whose first-to-last photon speed would be 0.3 ms x 4 + 0.25 ms x 3 = **2 ms**. This simple process gives **AF0130 9.6x** better motion performance at **29.97 fps**.

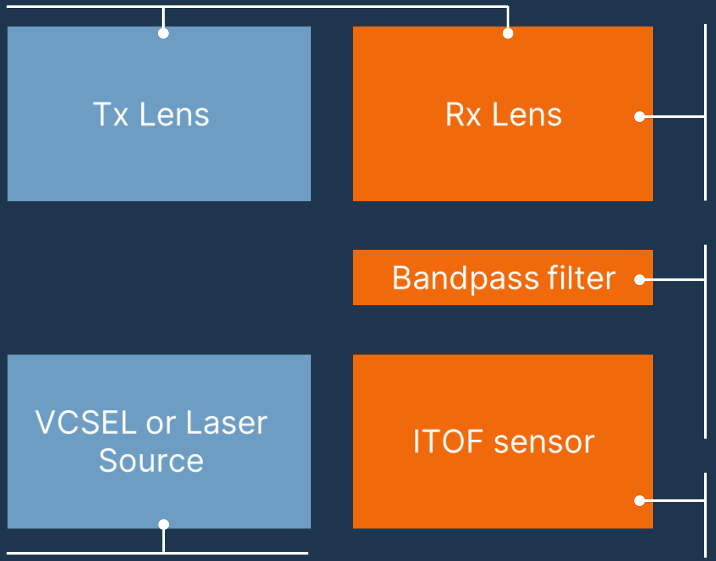
In another scenario, suppose the frame rate is stepped up to about 60 fps. Each MIPI lane would require 2 Gbps for proper throughput to enable depth processing, but let's assume that's feasible. At that throughput rate, which is effectively 333 million pixels per second, the readout rate for one frame would be 3.7 ms. **AF0130**'s first-to-last photon speed would be 0.1 ms x 4 + 0.25 ms x 3 = **1.15 ms**. Compare that to a competitor with 0.1 ms x 4 + 3.7 ms x 3 = **11.5 ms**. This gives onsemi's **Hyperlux ID**-class sensor even faster motion performance: **10x** the competitor at **60 fps**.



Sensing Depth More Accurately in High Ambient Light

An abundance of ambient light can oversaturate the depth signal received from any pixel to the point of obliteration, making it the enemy of iToF depth sensing. Whenever the scene in front of the sensor is flooded with light (think of an industrial assembly shop floor) it becomes more difficult for any image sensor, but especially a CMOS-based sensor using iToF, to determine depth and distance.

For operation in high ambient light, such as bright sunlight of up to 100 klux, onsemi recommends using a tight bandpass filter centered on the iToF emitter wavelength. A majority of onsemi customers are working with applications in the 905 – 940 nm band, which is also where customers will find the most cost-effective LiDAR components. Such filters used in conjunction with the receiving lens allow only narrow spectra around these wavelengths, to pass through to the image sensor. When combined with high illumination power operated within eye safety limits, plus an optical path design incorporating coated optics to reduce lens flaring, ***onsemi*** CMOS-based iToF depth sensors are remarkably efficient in the brightest of outdoor settings.



Reducing field-of-view for the transmit lens Tx and the receiver lens Rx will help provide more laser power per pixel, while improving distance measurement in high ambient light conditions.

Provide a good optical path design to minimize reflections.

Use anti-reflective coatings to reduce glare and blooming effects.

Use a very narrow optical band-pass filter in front of the sensor, centered in order to pass the VCSEL's emission wavelength as it shifts with temperature.

Reduce integration time to include less ambient light.

Increase power to the VCSEL or other laser source (within applicable eye safety limits) to raise the returned signal level relative to the ambient background.

Enabling Adaptability and Fine-Tuning with Contexts

Calibrating **Hyperlux ID**’s global shutter enables the image sensor to be fine-tuned for specific applications. For example, for a situation where the sensor is tuned to a conveyor just two meters away, AF013x can be calibrated to concentrate on reflected light from less than four meters. Specifications that fine-tune the operating characteristics of a sensor can be stored in the sensor itself, as contexts. This way, contexts may be swapped out for one another as the application at hand changes.

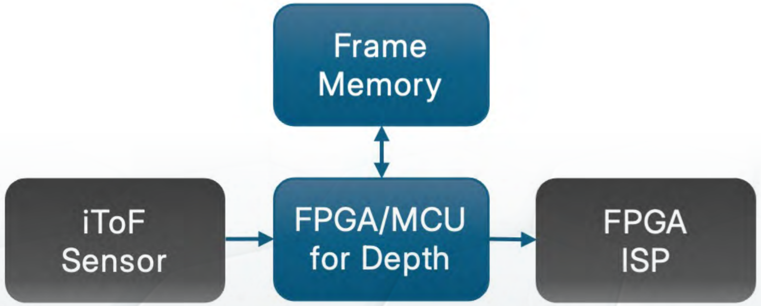
Hyperlux ID products offer up to 64 user-configurable contexts, each of which contains settings enabling on-the-spot adjustment of modulation frequencies, frame integration times, and designation of *regions of interest* (ROI). Enabling a sensor to focus on a designated region of the frame can increase frame rate, as areas outside the ROI may be allowed to be omitted. A user may rapidly switch between contexts as conditions warrant, by way of a single register write.

Reducing Size and Cost by Integrating Depth Calculation

onsemi **Hyperlux ID AF0130** simplifies the engineering of depth sensing devices by integrating its depth calculation functionality on-board. When these functions are managed by a separate signal processor such as an FPGA, the compactness of the device is compromised — not just by the second processor, but also with the addition of power management and delivery systems for both devices, which will inevitably be separate and require unique power delivery strategies. Eliminating all those extra components opens up new design options.

The same amount of data that would comprise as many as eight frames for a standard image sensor, only consumes one with onsemi's Smart iToF technology. Performing calculations on this amalgamated frame reduces the data rate and bandwidth required for the image sensor to interface and communicate with other components.

Competitor iToF solution



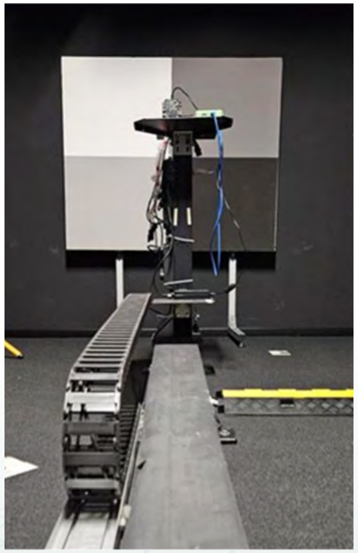
onsemi Smart iToF

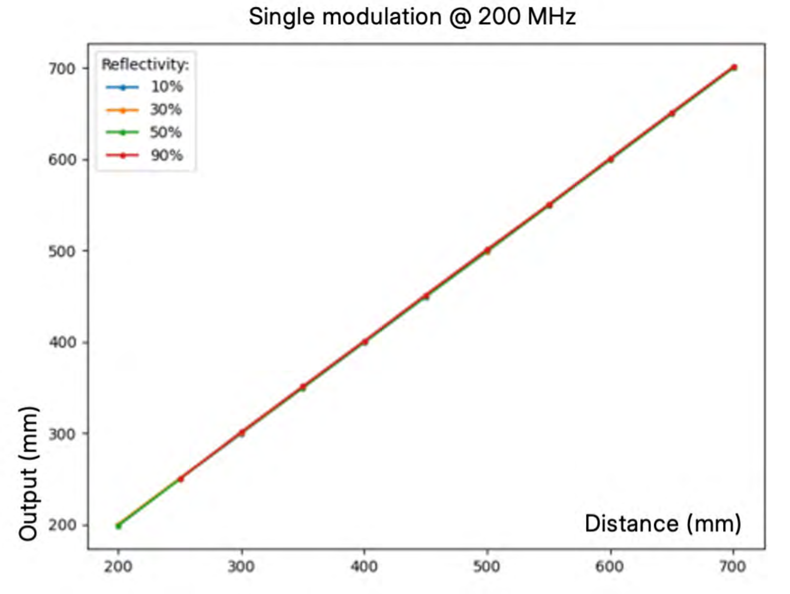
AF0130 Test Results

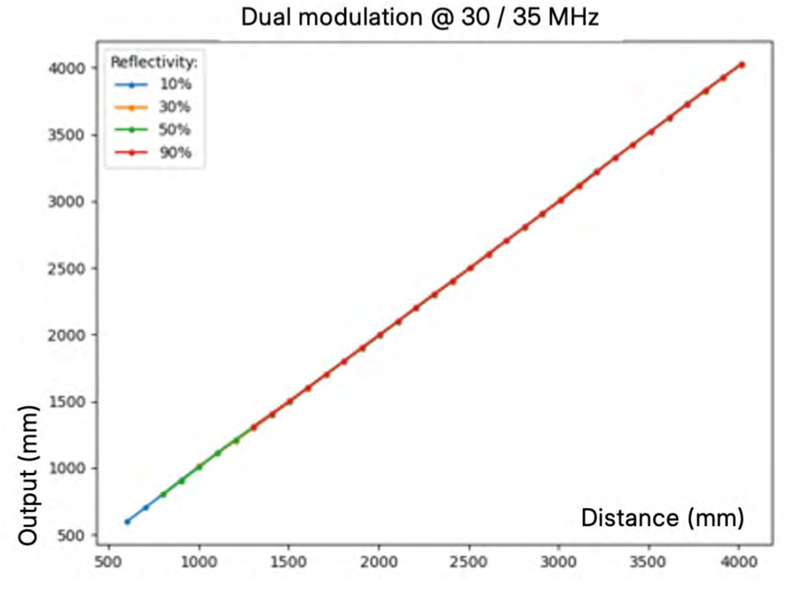
Rail System Test

To test the efficacy of **Hyperlux ID AF0130** in practice, onsemi engineers created a four-meter mechanical rail system on which to mount an **AF0130** evaluation kit. With this, engineers can accurately, electronically measure distance to target, using any target. For this test, engineers employed a test card divided into four quadrants, using materials with 10%, 30%, 50% and 90% reflectivity.

Seven operation modes were tested, incorporating all options for single- and dual-frequency, at multiple ranges, different settings for frames-per-second, and different peak and average power settings. The test was geared to measure the relationship between the output of the sensor for a range of sensed distances, applied against the electronically measured distances of the rail system. Good correlation between the actual distance and measured distance was observed for all settings and target reflectances.



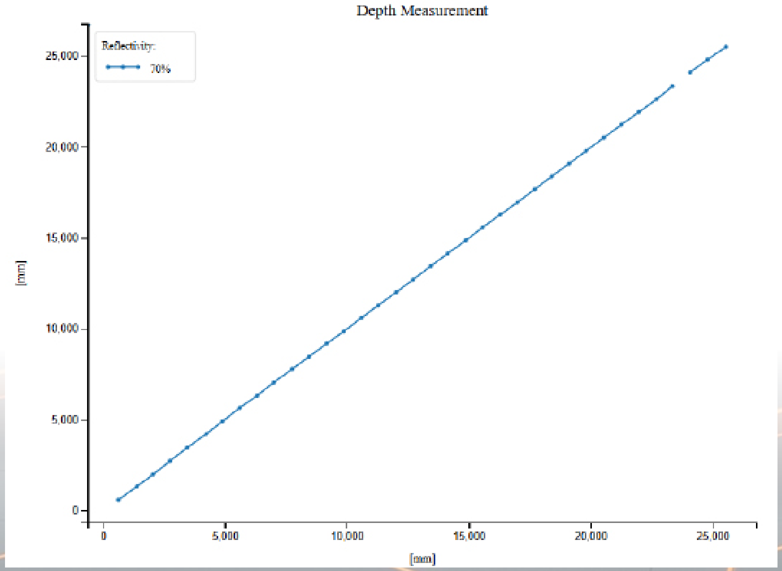


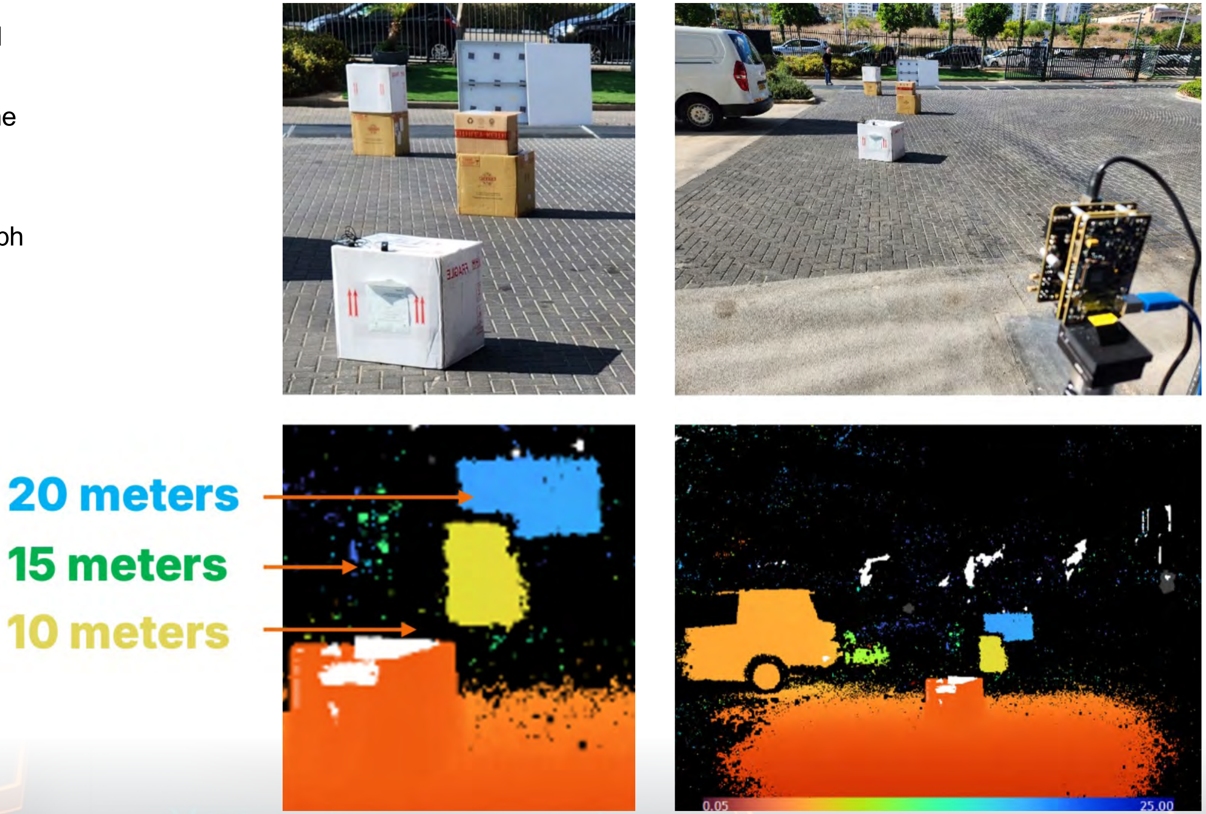


AF0130 Test Results

Long Range Measurement Test

In onsemi's evaluations, **Hyperlux ID AF0130** was able to clearly record a roughly three-foot square, 70% reflective target at 30 meters under fluorescent light in a light, neutral-colored hallway, and at 20 meters in the shade on a hazy day under 20,000 lux of illumination. In the false-color depth map shown at lower right, the recorded color corresponds to the approximate distance of the reflecting object. Again, the relationship graph is extraordinarily correlative.

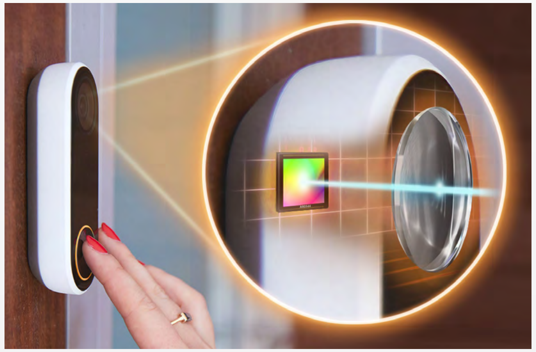




Long-range detection test, outdoors in 70 KLux light
Depth map on bottom from sensor in continuous wave mode

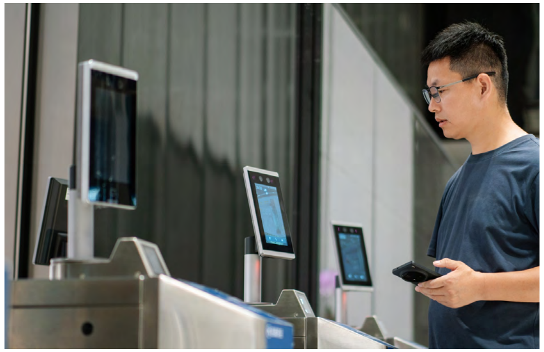
Applications for onsemi iToF

Depth sensing and object recognition applications have become so numerous, it has become easy to lose track of their development.



A smart door lock with facial authentication may need up to 1.2 MP resolution. Operation takes place outdoors at a very close range of less than 1 meter. For this application, Hyperlux ID offers high depth resolution and accuracy and high ambient light rejection.

Manufacturing robotics and logistics systems require sensing ability up to 10 meters distant. For shorter ranges, 1.2 MP resolution remains suitable, especially for automated guided vehicles, autonomous mobile robots, and picking-and-palettizing mechanisms.



Access control systems such as facial recognition for transportation access, usually operate at distances up to 3 meters. Devices will need to be prepared for indoor or outdoor operation.

Applications for onsemi iToF

Gesture recognition systems with 3D detection need to operate at distances up to 6 meters. However, since shape and detail may not be as relevant, such systems can get by with VGA resolution (640h x 480v). High depth resolution and accuracy remain critical here, along with low motion artifacts and high ambient light rejection.

Augmented reality / virtual reality / wearable devices often track motion, so they need sophisticated spatial and object recognition capabilities. Operating distances may be as great as 10 meters indoors or outdoors.

Consumer-grade robots and drones are now requiring depth perception up to 30 meters distant. Minimal motion artifacts are critical to guiding these systems and avoiding damage or injury to others.

Hyperlux ID AF0130 and AF0131 Specifications

	AF0130	**AF0131**
Package	Case 570AZ	Case 570AZ
Active pixels	1280 h x 960 v	1280 h x 960 v
Pixel size	3.5 x 3.5 µm BSI	3.5 x 3.5 µm BSI
Shutter type	Global	Global
One-time programmable memory	1024 x 24 bits x 3	1024 x 24 bits x 3
MIPI interface	2 lanes @ 2 Gbps/lane	2 lanes @ 2 Gbps/lane
Frame rate	60 fps @ 1.2 MP 110 fps @ VGA (Mode 2.2) 54 fps @ VGA (Mode 3.2)	60 fps @ 1.2 MP 110 fps @ VGA (Mode 2.2) 54 fps @ VGA (Mode 3.2)
Supply voltage I/O digital analog	1.2 V, 1.8 V, 2.8 V	1.2 V, 1.8 V, 2.8 V
Operating temperature	-30 °C < TJ < +85 °C	-30 °C < TJ < +85 °C
Optimal performance temperature	0 °C < TJ < +60 °C	0 °C < TJ < +60 °C
Thermal resistance $R_{\theta JA}$	32.0 °C/W	32.0 °C/W
On-board image processing	✓	✗

Making Depth Sensing Feasible for Any Industrial Application

onsemi **Hyperlux ID AF0130** and **AF0131** iToF depth sensors open up new opportunities for both hardware and applications engineering, making feasible new functions and functionality that were not achievable before. These qualities are what make Hyperlux ID exceptional:

- **True-to-life representation of its environment**, maximizing the capabilities of its global shutter through sophisticated readout timing strategies to minimize, if not completely eliminate, distortions caused by motion artifacts
- **High depth resolution and pinpoint accuracy** by means of onsemi's high-performance 1.2 MP BSI pixel array
- **Low system cost, plus compact size and weight**, all of which are reduced by eliminating redundant parts through on-chip integration of frame memory and processing algorithms
- **Maximum ambient light and noise rejection** enabled by Hyperlux ID's unique implementation of Smart iToF, extending depth finding range by as much as 20 meters
- **Developer-ready resources** including onsemi's industry standard Devware development environment, for fast data interfacing with depth maps and point clouds

Learn more at onsemi.com/hyperlux

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for more information and
additional resources.