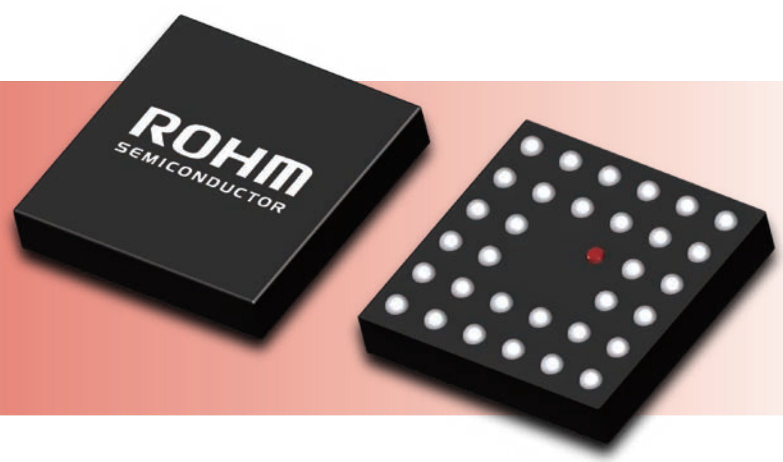
ROHM
SEMICONDUCTOR

Innovations Embedded

Optical Image Stabilization (OIS)



White Paper

Introduction

Whether capturing still images or recording moving video, image stabilization will always be a major factor in reproducing a near perfect digital replica. A lack thereof will result in image distortion through pixel blurring and the creation of unwanted artifacts. While media capturing devices such as digital cameras, digital camcorders, mobile phones, and tablets have decreased in physical size, their requirements for pixel count density and resolution quality have increased drastically over the last decade and will continue to rise. The market shift to compact mobile devices with high megapixel capturing ability has created a demand for advanced stabilization techniques. Two methods, electronic image stabilization (EIS) and optical image stabilization (OIS), are the most common implementations.

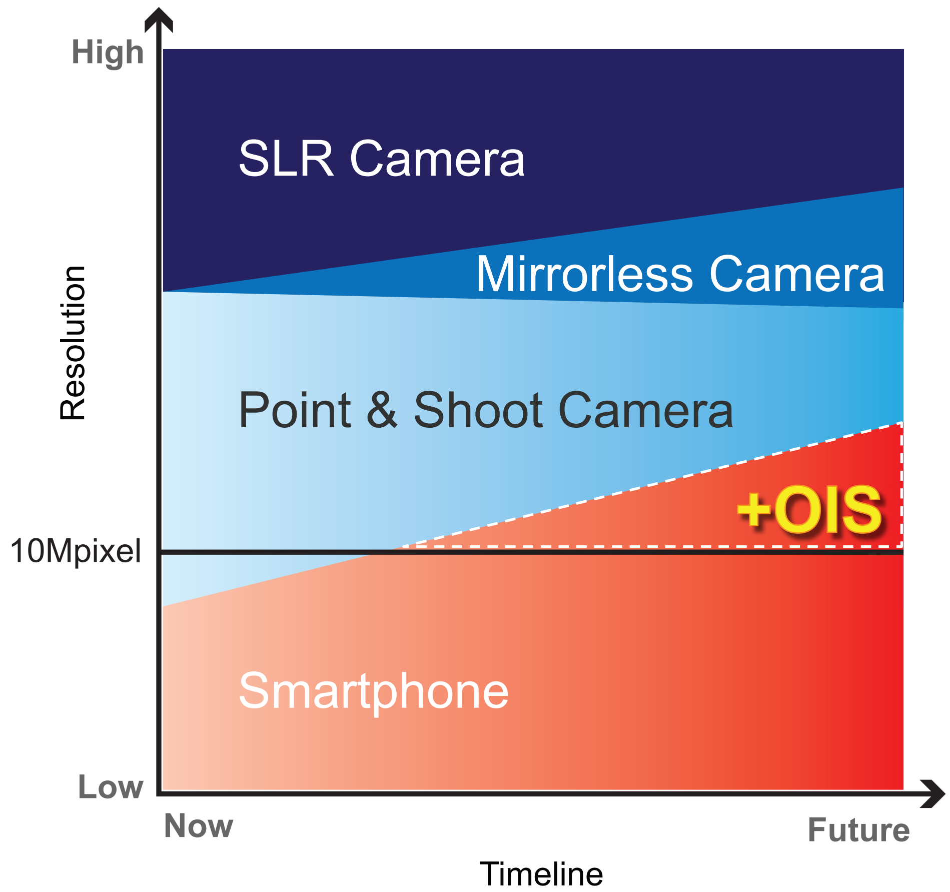


Figure 1. Optical Image Stabilization Target Market

Image Stabilization Principles

Image stabilization is used to reduce blurring associated with motion and/or shaking of the camera during the time the image sensor is exposed to the capturing environment. However, it does not prevent motion blur caused by movement of the target subject or extreme movements of the camera itself, only the relatively small shaking of the camera lens by the user – within a few optical degrees. This camera-user movement can be characterized by its pan and tilt components, where the angular movements are known as yaw and pitch, respectively. Camera roll cannot be compensated since 'rolling' the lens doesn't actually change/compensate for the roll motion, and therefore does not have any effect on the image itself, relative to the image sensor.

EIS is a digital image compensation technique which uses complex algorithms to compare frame contrast and pixel location for each changing frame. Pixels on the image border provide the buffer needed for motion compensation. An EIS algorithm calculates the subtle differences between each frame and then the results are used to interpolate new frames to reduce the sense of motion. Though the advantage with this method is the ability to create inexpensive and compact solutions, the resulting image quality will always be reduced due to image scaling and image signal post-processing artifacts, and more power will be required for taking additional image captures and for the resulting image processing. EIS systems also suffer when at full electronic zoom (long field-of-view) and under low-light conditions.

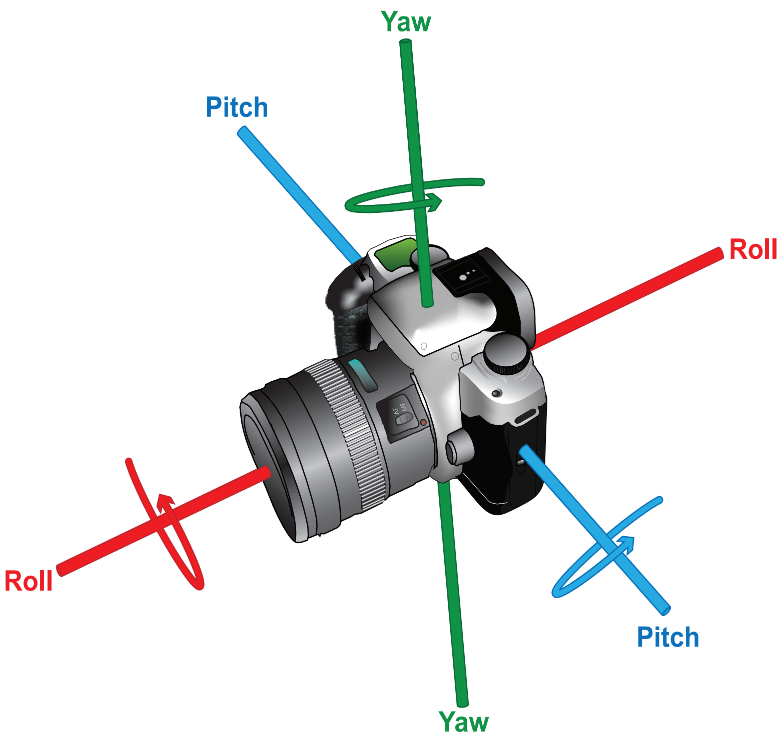


Figure 2. Axes of Motion

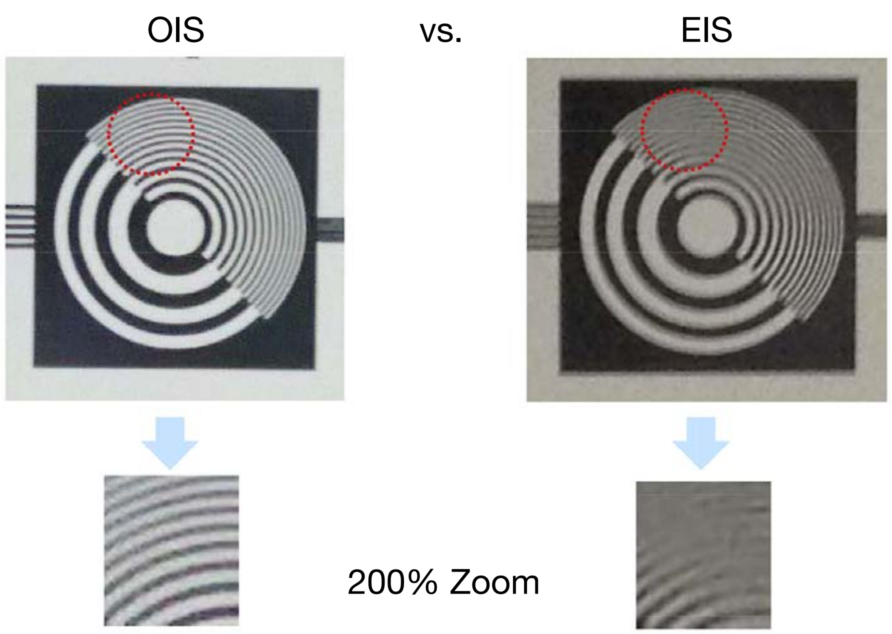


Figure 3. OIS and EIS Image Quality Comparison

OIS Behavior

OIS is a mechanical technique used in imaging devices to stabilize the recording image by controlling the optical path to the image sensor. The two main methods of OIS in compact camera modules are implemented by either moving the position of the lens (lens shift) or the module itself (module tilt).

Camera movements by the user can cause misalignment of the optical path between the focusing lens and center of the image sensor. In an OIS system using the lens shift method, only the lens within the camera module is controlled and used to realign the optical path to the center of the image sensor. In contrast, the module tilt method controls the movement of the entire module, including the fixed lens and image sensor. Module tilt allows for a greater range of movement compensation by the OIS system, with the largest tradeoff being increased module height. Minimal image distortion is also achieved with module tilt due to the fixed focal length between the lens and image sensor. Overall, in comparison to EIS, OIS systems reduce image blurring without significantly sacrificing image quality, especially for low-light and long-range image capture. However, due to the addition of actuators and the need for power driving sources compared to no additional hardware with EIS, OIS modules tend to be larger and as a result are more expensive to implement.

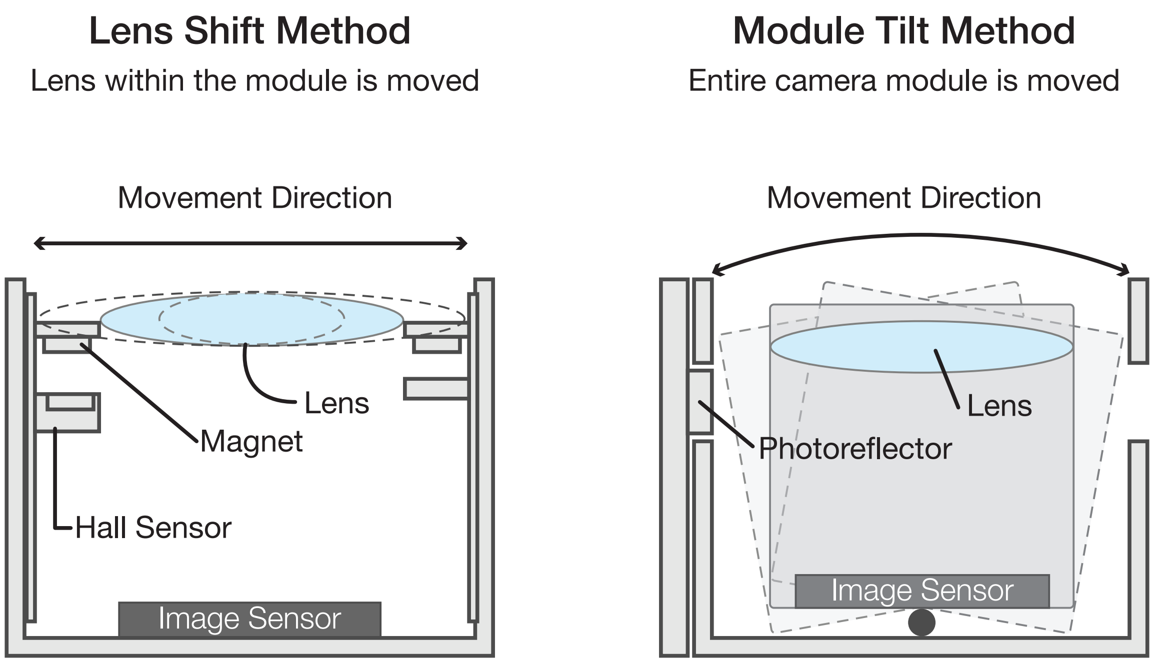


Figure 4. Main Methods of OIS Compensation

OIS Module Components

An OIS system relies on a complete module of sensing, compensation, and control components to accurately correct for unwanted camera movement. This movement or vibration is characterized in the X/Y-plane, with yaw/pan and pitch/tilt movements detected by different types of isolated sensors. The lens shift method uses Hall sensors for lens movement detection while the module tilt method uses photoreflectors to detect module movement. Both methods require a gyroscope in order to detect human movement. ROHM's OIS controllers use gyroscope data within a lens target positioning circuit to predict where the lens needs to return in order to compensate for the user's natural movement. With lens shift, Hall sensors are used to detect real-time X/Y locations of the lens after taking into consideration actuator mechanical variances and the influence of gravity. The controller uses a separate internal servo system that combines the lens positioning data of the Hall sensors with the target lens position calculation from the gyroscope to calculate the exact driving power needed for the actuator to reposition the lens. With module tilt, the process is similar but the module's location is measured and repositioned instead of just the lens. With both methods, the new lens position realigns the optical path to the center of the image sensor.

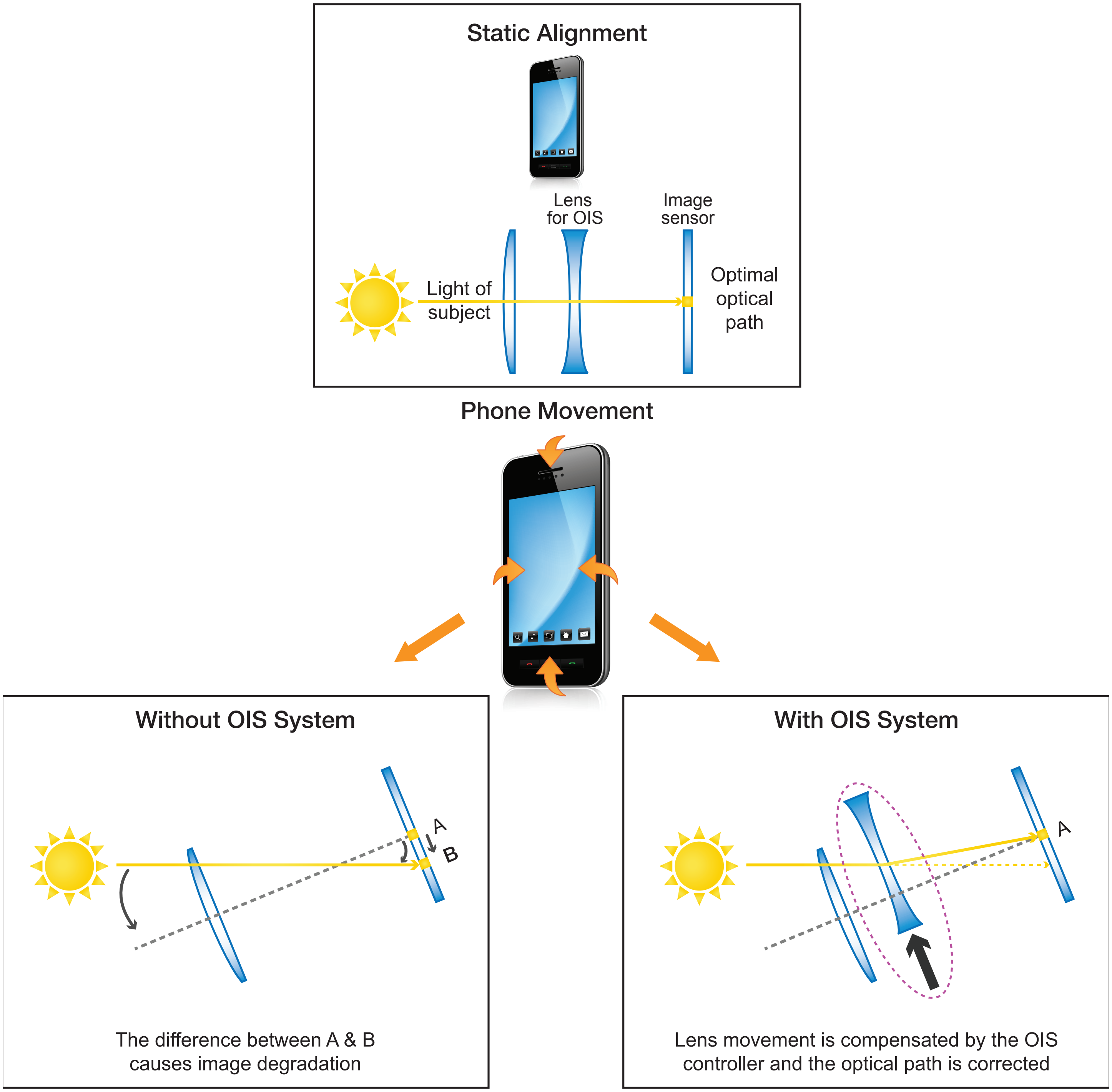


Figure 5. Lens Shift OIS Principle

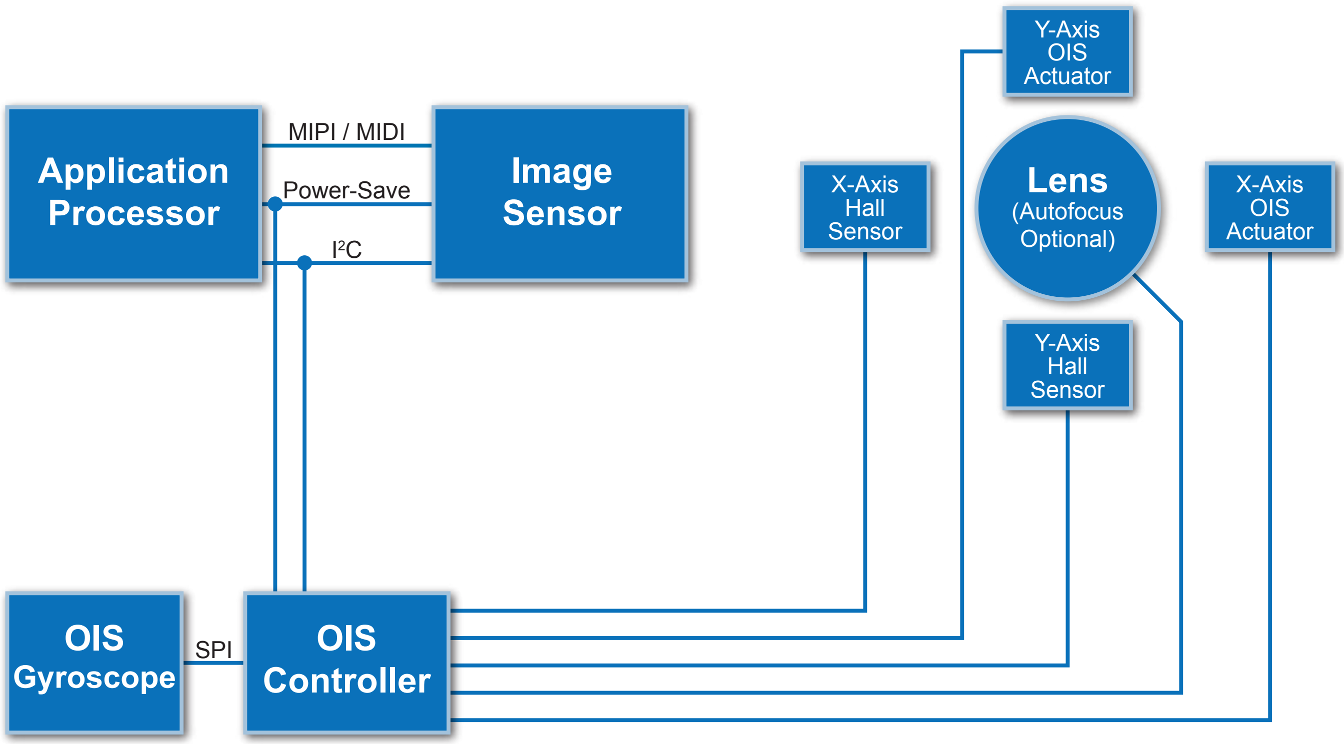


Figure 6. General OIS Block Diagram

OIS System Control

OIS control is designed to be very simple from the customer's standpoint, consisting of simply ON/OFF and enable/power-save modes. The only other commands are either optional manual control of the lens in the X/Y plane or changing the OIS performance based on ambient conditions such as day, night, sports, picture, video, or viewfinder. This allows for minimal I^2C traffic from the host application processor to the OIS controller and simplifies software driver development for the end customer. All of the actual OIS control algorithms are performed autonomously on the controller itself, using the internal processor and RAM for the calculations.

ROHM's OIS Architecture

ROHM offers two OIS controller architectures, including a fully programmable ARM Cortex-M0 processor with custom programmable digital signal processing for 'gyroscope signal processing' and 'servo control', as well as ROHM's custom, fully programmable RMCU processor with integrated programmable 'gyroscope signal processing' and 'servo control'. All of the OIS work memory and control calculations are performed on the OIS controller

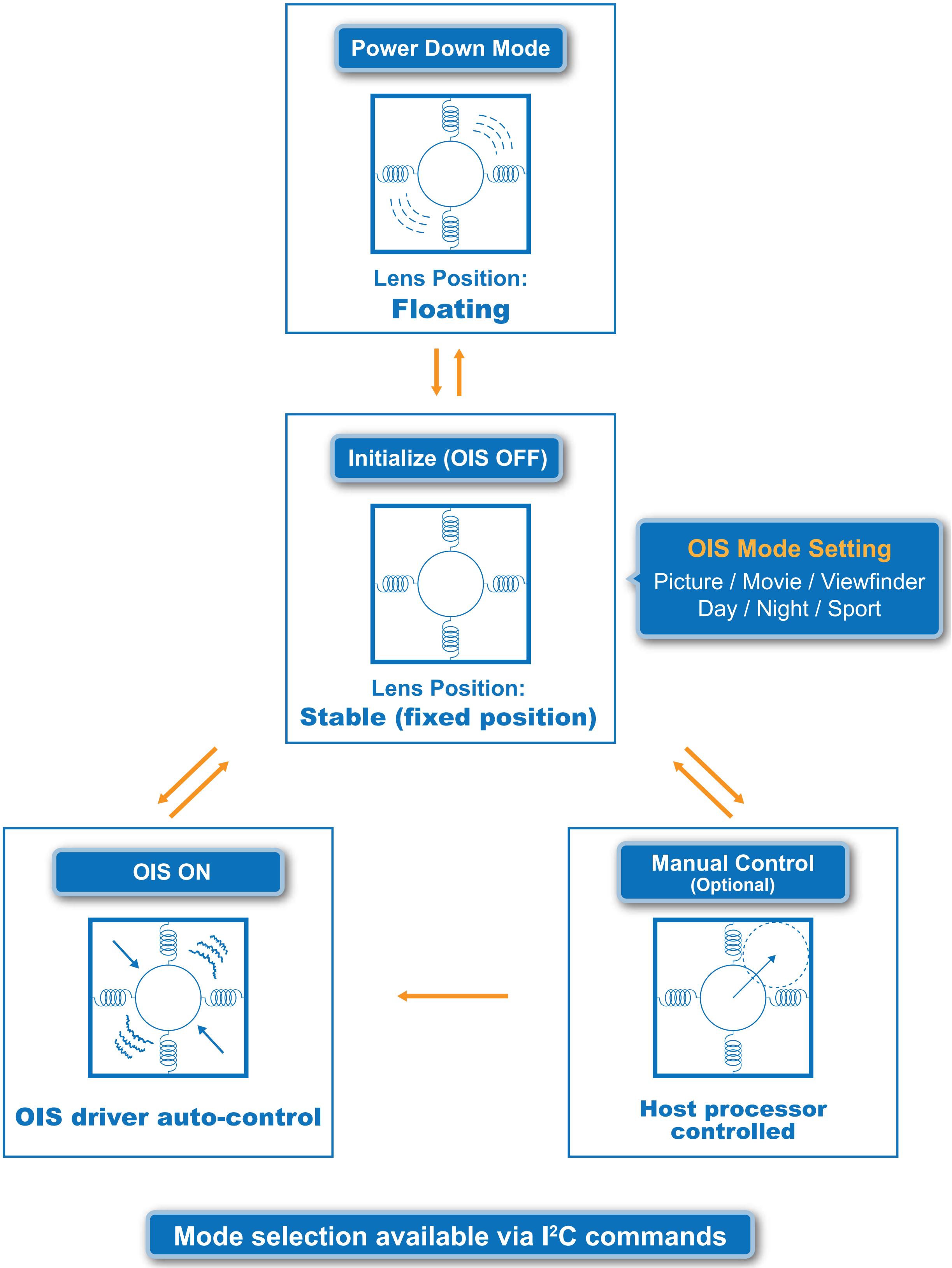


Figure 7. Standard OIS Operation Modes

itself without the need for the external host processor's computational power or external memory for storing calculation variables. Both offerings achieve the smallest chip size, lowest external component count, and smallest overall mounting area on the market.

With industry-leading experience in OIS architecture, ROHM's lineup of OIS controllers offer full control of the X- and Y-axis voice coil motor (VCM) drivers, Hall amplifier and current drivers, photoreflector drivers, I^2C interface, PLL oscillators, 12-bit ADC, SPI master interface for digital gyroscope (along with support for analog gyroscopes), and many other features. The lineup also includes options that support integrated drivers for autofocus, neutral density filter, or shutter functions. Selectable PWM/BTL linear operation is supported for choosing either improved VCM-driving power efficiency or improved image quality. In addition, ROHM's controllers feature class-leading power consumption due to wafer processing and optimized chip architecture. Both of ROHM's proprietary 'servo control' and 'gyroscope signal processing' circuits use a unique digital filter design that dynamically compensates for gyroscope and actuator temperature drift while at the same time not removing intentional pan and tilt movement by the camera user. The controllers can be implemented into either lens shift, module tilt, or other less commonly used control systems such as lens tilt. Customizable OIS control software is also included for automatic lens control, automatic pan-tilt detection, and access to different programmable capturing modes and calibration settings.

Image Stabilization Performance

Image stabilization is measured by suppression ratio (SR) and is utilized to gauge OIS performance. The SR is calculated using a spatial test chart with a target pattern. Images of the target pattern are captured with OIS ON/OFF and with/without vibration. The images are then used to compute a ratio comparing the amount of blur measured in the images, which determines the final SR. The test is typically used to provide a final guarantee that all of the components in the OIS system are functioning properly.

The pictures in Figure 8 are representations of motion blur of the target pattern. The D_{STATIC} image represents the ideal image where there

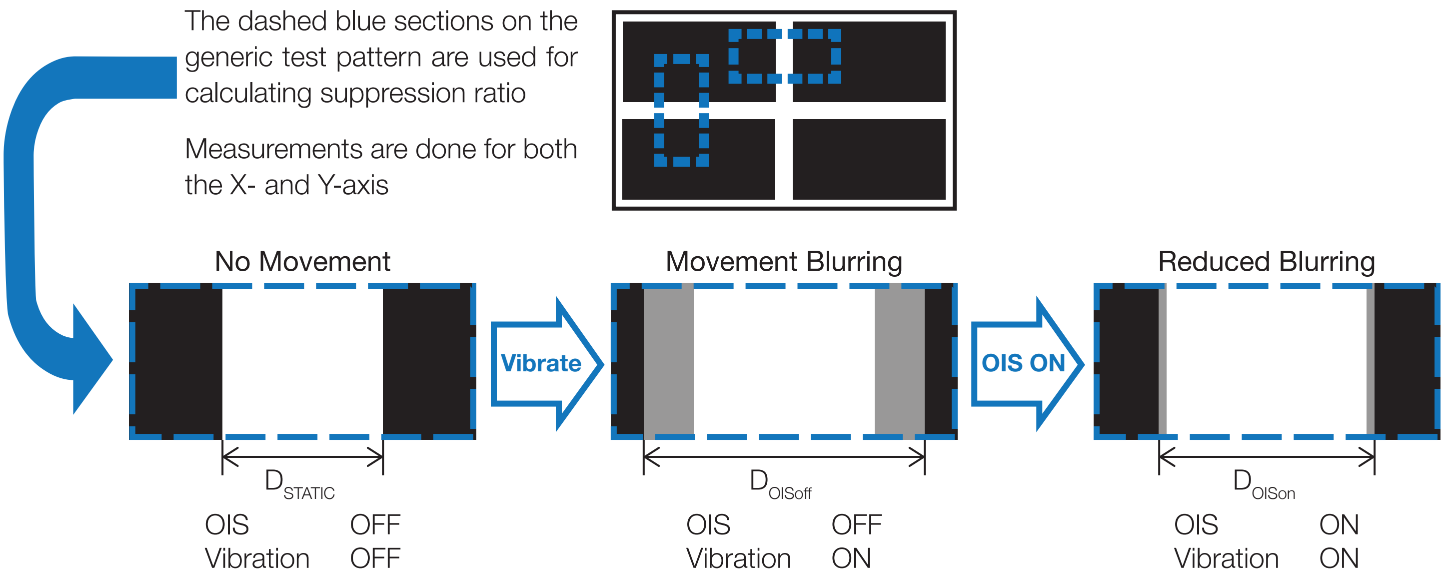


Figure 8. Generic Spatial Test Chart Reference Image

$$\text{Suppression Ratio [dB]} = 20\log\left[\frac{D_{OISoff} - D_{STATIC}}{D_{OISon} - D_{STATIC}}\right]$$

Equation 1. Suppression Ratio Calculation

is no vibration/motion of the image. An ideal OIS system attempts to match the quality of a still image with no motion blur, and the D_{STATIC} image is the benchmark when calculating the SR/performance of the OIS system. In this example, the D_{STATIC} image has the shortest zoomed white area distance due to no movement/blurring of the captured image. The D_{OISoff} image represents the appearance of the image when the image is vibrating/moving, with no image stabilization being used. As a result, the D_{OISoff} image exhibits much more blurring compared to the other images, which increases the zoomed white distance due to the blurring effect from the image sensor when an image is captured. The observed amount of blur is what needs to be corrected, or suppressed, in order to have the D_{OISoff} image match the D_{STATIC} image as closely as possible. The D_{OISon} image represents the actual benefit of the OIS system being tested. In this example, the D_{OISon} image is vibrating/moving while the image stabilization system is enabled. The image's blurring is suppressed due to the stabilization and the distance of the zoomed white area is less when compared to the D_{OISoff} image. After all three images have been captured, the blurring effect of each image is measured as a function of pixel count by counting the amount of pixels within the width of the zoomed white area and then using Equation 1 to calculate the final SR. This process is repeated for each of the desired image shaking frequency performance targets and for each axis.

Simulating the OIS System

Proper OIS operation requires simulating the performance of the entire system, taking into account the interaction of all of the OIS system components. ROHM is able to offer market-leading OIS control algorithms due to extremely accurate simulation tools. Most OIS controller suppliers are able to sufficiently simulate the ideal performance of golden OIS components such as the actuator, however ROHM has developed specialized simulation tools that allow for not only proper simulation of OIS components, but real-world OIS component simulations as well. The actuator, being a mechanical system, has the most variance due to the manufacturing process as well as external stimuli. As such the actuator is a very complex component to realistically simulate, making it very difficult to accurately simulate the entire system's SR. ROHM's simulation tools have been market proven to provide accurate,

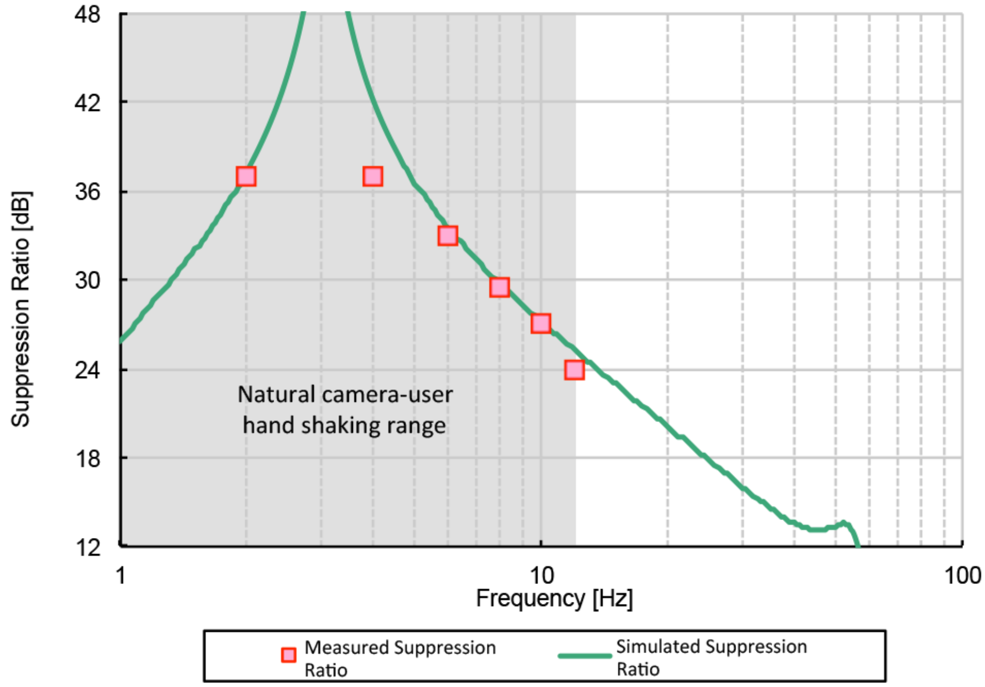


Figure 9. Real-World OIS Performance vs. ROHM's Simulated OIS Performance

real-world results, allowing for fast lead-time turnaround in implementing custom firmware features required by customers.

Manufacturing Supply Chain

The typical OIS camera supply chain consists of an actuator vendor, a gyroscope vendor, a Hall sensor or photoreflector vendor, a module integrator, and ROHM's OIS controller. In addition to the controller, ROHM manufacturers Hall sensors and photoreflectors, allowing ROHM to have the most comprehensive system knowledge for providing the best OIS results.

Assembly Calibration Process

OIS systems require a calibration process for proper operation. All of the components within the OIS system posses individual manufacturing variances and exert influences on each other after the assembly process, in addition to mechanical misalignment variances created by the assembly process itself. A properly functioning system requires the OIS controller to know the subtle sensitivity variances of the actuator, gyroscope, Hall sensors, and controller, as well as the mounting variances introduced by the assembly process. Once the calibration process has been performed, the calibrated data is used by the OIS controller to intelligently modify the control of the OIS system and its components. ROHM's calibration procedure is defined and market-tested, and ROHM provides all of the necessary calibration software and support so that the customer doesn't need to develop any custom factory calibration procedures.

Summary

ROHM offers a control and calibration software package that minimizes the amount of resources required by the customer for implementing OIS within their product and ensures market-leading performance with the fastest product time-to-market. Additionally, ROHM has formed partnerships and established a working history with all of the required sensor/actuator manufacturers and module integrators, making it possible to provide a complete, fully integrated OIS support package that enables customers to meet their OIS performance and production schedule requirements for launching their OIS-embedded camera products on the market. Contact a ROHM representative today to help start your OIS design.

ROHM Semiconductor
6815 Flanders Drive, Suite 150
San Diego, CA 92121

www.rohm.com | 1.888.775.ROHM

NOTE: For the most current product information, contact a ROHM sales representative in your area.

ROHM assumes no responsibility for the use of any circuits described herein, conveys no license under any patent or other right, and makes no representations that the circuits are free from patent infringement. Specifications subject to change without notice for the purpose of improvement.

The products listed in this catalog are designed to be used with ordinary electronic equipment or devices (such as audio visual equipment, office-automation equipment, communications devices, electrical appliances and electronic toys). Should you intend to use these products with equipment or devices which require an extremely high level of reliability and the malfunction of which would directly endanger human life (such as medical instruments, transportation equipment, aerospace machinery, nuclear-reactor controllers, fuel controllers and other safety devices), please be sure to consult with our sales representative in advance.