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Embedded Unveiled

by Richard Wotiz (USA)

Camera Image Stabilization

Image stabilization (IS) helps reduce blurriness that results from slight camera movements when shooting without a tripod. This article details several IS techniques as well as some cameras featuring different types of IS systems.

Digital cameras are all around us, from the first-generation models that have been around since the mid-1990s to the cameras built into modern smartphones. I like to photograph nature scenes, sometimes in the forest under a heavy tree canopy that can be quite dark even on a bright sunny day. When shooting at the slow shutter speeds required by a dimly lit scene, image stabilization (IS) helps to reduce blurriness that comes from slight camera movements when shooting without a tripod. IS has been around since the mid-1990s in high-end lenses for film cameras. It first appeared in compact point-and-shoot digital cameras around 2003, and is now available in many recent models.[1]

This month I'll take you through a tour of various IS techniques, then we'll peek inside a couple of cameras that include different types of IS systems.

A common rule of thumb is that a 35-mm film camera that's held by hand can, on average, take a blur-free image at a shutter speed no slower than 1/FL, where FL is the focal length of the lens. In a digital camera with a smaller image sensor, the focal length is first scaled up to its equivalent 35-mm value. A camera's specification sheet will often list its 35-mm equivalent FL. The ones I'll be looking at have charge-coupled device (CCD) sensors that are approximately one sixth the size of a 35-mm film frame. This means the FL multiplier, or crop factor, would be six. So, a zoom lens that's currently set to a 20-mm FL would need to be scaled up to 120 mm, giving a minimum safe exposure time of 1/120 s. You can typically gain two to four extra exposure steps with IS. That would enable you to shoot as slow as 1/30 s, or possibly even 1/8 s, and still have a reasonably blur-free image.

STEADYING THE IMAGE

The methods used for steadying the image from a handheld camera fall into two broad categories. First, you can steady the entire camera. There are mounting systems that do this with purely mechanical means. Some operate on a similar principle to the circus tightrope performer who holds a long pole for balance. The camera and its battery pack are placed on opposite ends of a pole. This increases the moment of inertia, making the camera more stable. A complex arrangement of pulleys and springs isolates the pole from the photographer's movements. The whole system basically acts like a mechanical low-pass filter. It typically requires careful setup and specialized training, and is frequently used for action shots on movie sets. There are also gyro-based mounting systems. They aren't as difficult to set up or use, though they require a source of power and can be quite heavy.

The other IS method works inside the camera by making small mechanical adjustments to the optical path. It uses an accelerometer or gyro sensor to detect slight vibrations and drives an actuator to compensate for the movement. When taking pictures of a distant subject, even the slightest rotation of the camera is greatly amplified, which a gyro sensor can detect. For close-ups and

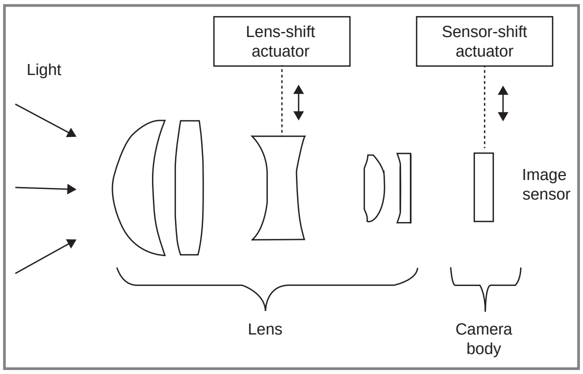


Figure 1—The basics of an image-stabilized camera. Only one of the two actuators shown will be present, depending on the mechanism type. The actuator moves either the sensor or part of the lens in both the horizontal and vertical direction, perpendicular to the direction of the incoming light.

macro photography, linear camera movement becomes more significant, so an accelerometer would be best. Most compact cameras available today use only a gyro sensor, though a few higher-end models have both sensor types. The mechanism can either be located inside the camera body or it can be part of the lens. Figure 1 shows both of these internal IS systems, which I'll be taking a closer look at. (See the Resources section at the end of this article for more information on various types of IS.)

In addition to these methods, some cameras use various software techniques to reduce blur. This can be as simple as increasing the sensor's sensitivity, which also increases the image's background noise, or it could be a more sophisticated image-processing algorithm. These are not true IS, though they are often referred to as "digital image stabilization," or some related term that is unfortunately often designed to confuse rather than inform.

When I first came up with the idea for this article, the only digital camera I had ever owned was one I bought about 10 years ago. It weighs in at just under 1 lb, including the modified camcorder battery pack I mounted to the outside so I could get a reasonable number of shots on a recharge. Now seemed like a good time to find something more recent. I picked up a pair of inexpensive used cameras with IS, knowing they might be sacrificed for a good cause. I had never taken a camera apart before, so I first armed myself with a new jeweler's screwdriver set and a large magnifying glass, just in case.

INSIDE THE LENS

The first camera I opened up uses lens-based IS, often referred to as optical IS. It uses a pair of tiny electromagnetic positioners to shift one of the lens elements in either direction perpendicular to the optical axis. Photo 1a shows the mechanism in one compact package. The entire assembly fits inside the center portion of the lens, with the flex cables enabling it to move as the lens zooms or retracts. The round metal objects near the bottom are the shutter and aperture actuators. This camera model doesn't have a true variable aperture. Instead, it has a neutral-density filter that can swing in front of the shutter to provide a second aperture setting. The underside of the IS mechanism is hidden behind the orange flex circuit layers. You can see it disassembled in Photo 1b. The two magnets attached to the floating-lens carrier (bottom of photo) get sandwiched between the drive coils and the plastic support frame. The camera's microcontroller supplies a pulse-width modulation (PWM) signal to the coils to shift the lens in a horizontal plane to stabilize the image. Hall-effect sensors under each magnet provide position feedback. At the top of the photo are two of the smallest ball bearings I have ever seen. When they fell out of the lens carrier (along with some equally tiny springs), I realized there was little chance that I would ever reassemble these pieces into a working camera. I think that was the mechanical equivalent of letting out the magic smoke!

The camera was packed so tightly that I couldn't get to any of the IS wiring without disassembling the lens, but I still wanted to see the mechanism in action. I found that the drive coils needed about 50 mA to reach their limit of travel. I tried feeding one of them with a sine wave, and I could get reliable end-to-end movement up to 65 Hz. Most people's hands will shake with small vibrations in the range of 10 Hz to 30 Hz, which this mechanism can easily accommodate.

SENSOR SHIFT

The second camera I looked at has a sensor-shift mechanism, which is sometimes called mechanical IS. Since this is located entirely outside of the lens, I found it much easier to examine. Photo 2 shows the camera with its

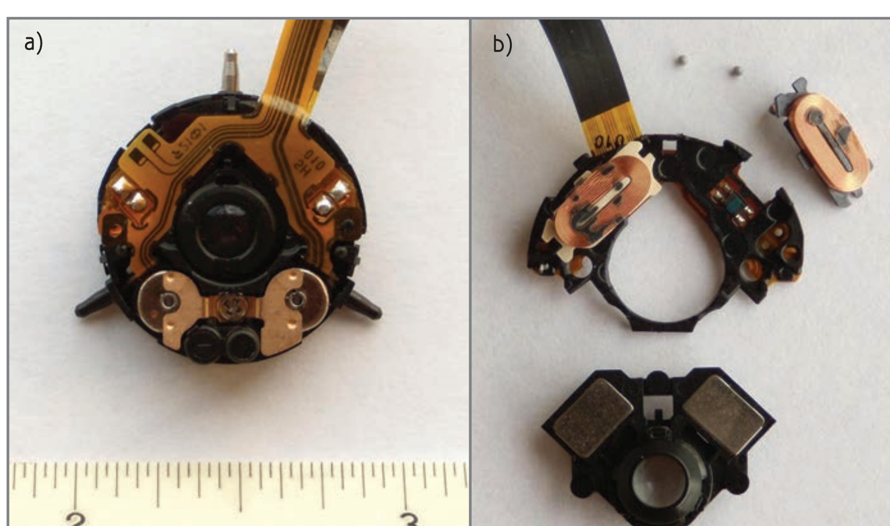


Photo 1a—A lens-based IS mechanism that sits inside the lens barrel. This is the back side of the actuator assembly. b—This is a front view of the actuator components. The lens and magnet assembly (bottom) float on ball bearings between the drive coils and the plastic frame. A Hall-effect position sensor is visible below the former location of one of the coils.

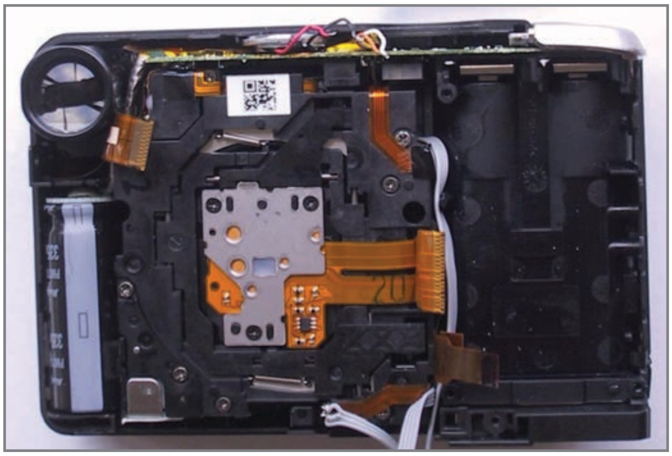


Photo 2—Rear view of the sensor-shift IS mechanism. The image sensor (under the metal plate) slides horizontally and vertically on tiny metal shafts. You can see the gray wires I connected to the IS components to monitor their operation.

Photo 3—Top view of the horizontal sensor-shift actuator. At the top left corner is one of the smallest stepper motors I have ever come across, only 0.3" long. It has an internal leadscrew to move its shaft horizontally, which presses against a carriage to move the image sensor. The larger motor to its right controls zooming and lens retraction.

back, liquid crystal display (LCD), and circuit board removed. The metal plate visible at the center covers the back of the sensor. If you look closely just above the plate, you'll see the two small exposed ends of a shiny horizontal metal shaft. The sensor assembly slides back and forth on this shaft. Vertical movement occurs on a pair of shafts on either side of the sensor, but they're darker colored and harder to see. I removed the lens assembly so I could get a closer look at the actuators and their wiring. Photo 3 is a front view of the horizontal actuator tucked in the corner next to the larger zoom motor. I connected wires to the actuators and the nearby position sensors and ran them down to the bottom of the camera. Then I put everything back together and was pleasantly surprised to find that the camera still worked.

I turned on the camera while looking at the various signals I had just gained access to and discovered that the actuators were actually stepper motors and the sensors were simply limit switches. On power-up, the camera drives each stepper to the end of its travel (until the limit switch trips) then back to center, one at a time (see Photo 4). This process takes about 1 s, and gave me a convenient pattern that I used to sort out the different signals. I found that the steppers are bipolar, with each one driven by a pair of H-bridges. Photo 5 shows the drive signals in more detail. I recognized the waveform as a half-step drive sequence, with a rate of one full step every 2.2 ms. (You can read more about stepper motor waveforms in Miguel Sánchez's article "Three-Axis Stepper Controller," *Circuit Cellar* 234, 2010.)

It's difficult to make much sense of these waveforms as they relate to sensor position. I transferred the raw data to my PC and formatted the two sets of four phase bits at each time interval into a pair of 4-bit numeric values. Then I loaded the numbers into a spreadsheet and converted these phase signals into actual position data. Figure 2a shows this data in a more readable format. You can see the horizontal stepper go to its limit of 180 half-steps then back to center. The vertical stepper follows a slightly different pattern that I found to be dependent on the camera's orientation. Here, it goes up to 204 before settling at 154. It goes back down to 0 when the camera is powered off. You can download the spreadsheet, as well as others showing various position waveforms, from *Circuit Cellar*'s FTP site.

Figure 2b shows a 1-s exposure while I'm holding the camera in front of me. There are slight horizontal and vertical

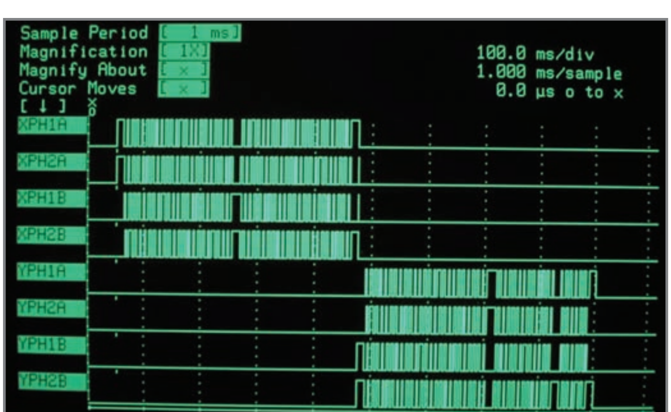


Photo 4—The horizontal (X) and vertical (Y) steppers go through their initialization sequence at power-up. The A and B signal name suffixes are the positive and negative terminals of each phase winding, respectively.

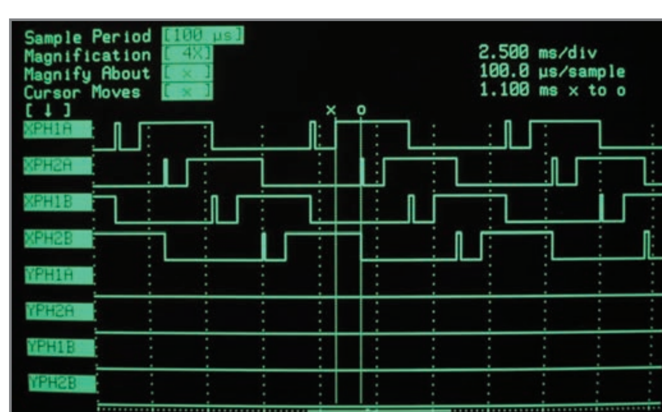
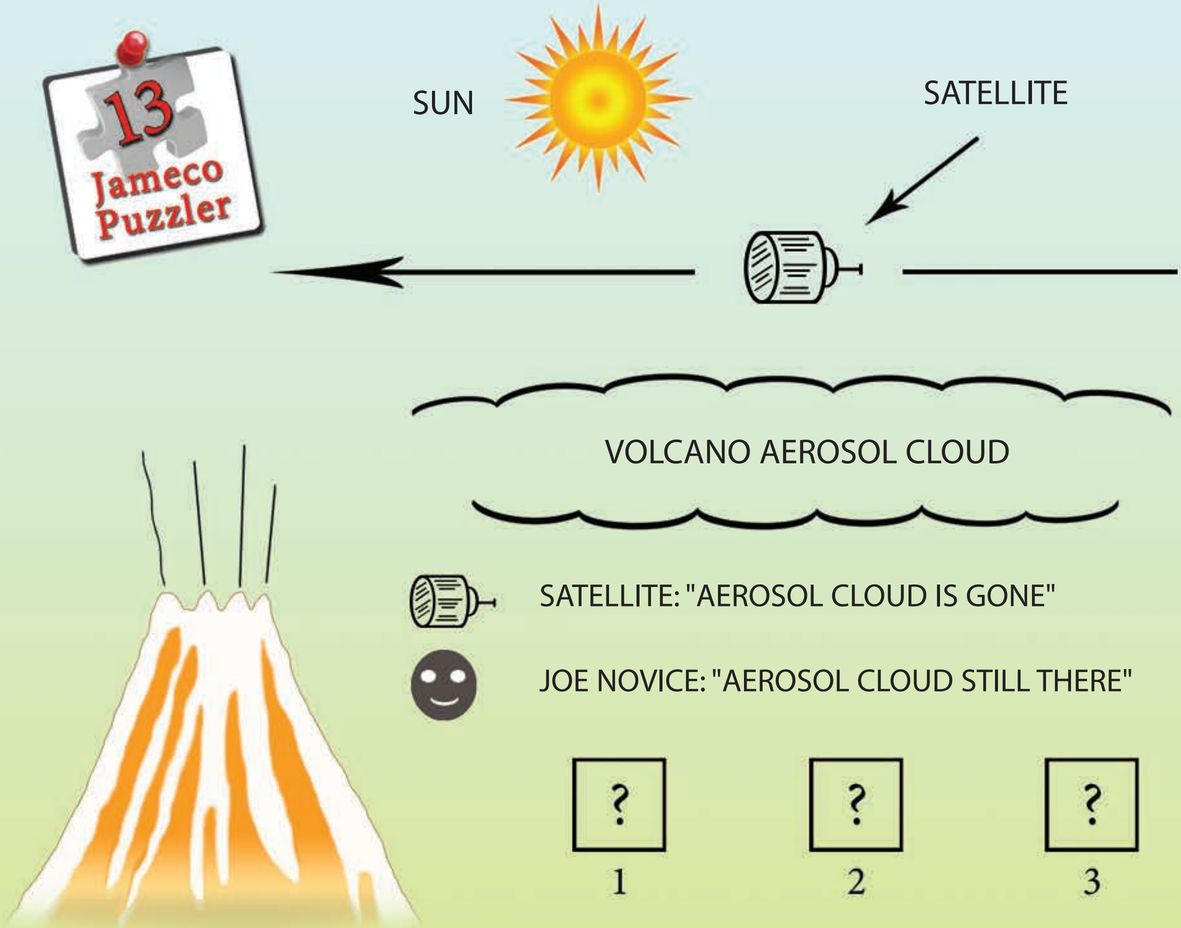


Photo 5—A closer look at the waveform of Photo 4. You can clearly see the half-step pattern. The narrow pulses are noise from the inductive spikes when the opposite ends of each winding are driven low.

Can You Solve This?

Forrest M. Mims III Puzzler



Can you describe any of the three methods
Joe used to detect the aerosol?

Satellites provide global coverage of clouds, water vapor, dust, smoke and the ozone layer. The colorful images provided by the data from these satellites looks very impressive. But satellite instruments don't always stay calibrated and problems can occur when satellite orbits drift. Amateur scientist, Joe Novice learned about this when he heard a satellite scientist say that the global aerosol cloud formed by the eruption of a giant volcano had dissipated much sooner than expected. Joe suspected the satellite was simply wrong, but he was not a satellite scientist. How did he use some everyday items and several electronic components to prove he was right?

What's your solution? See if you are correct at ***www.Jameco.com/teaser13*** where you will find all three of Joe's solutions.

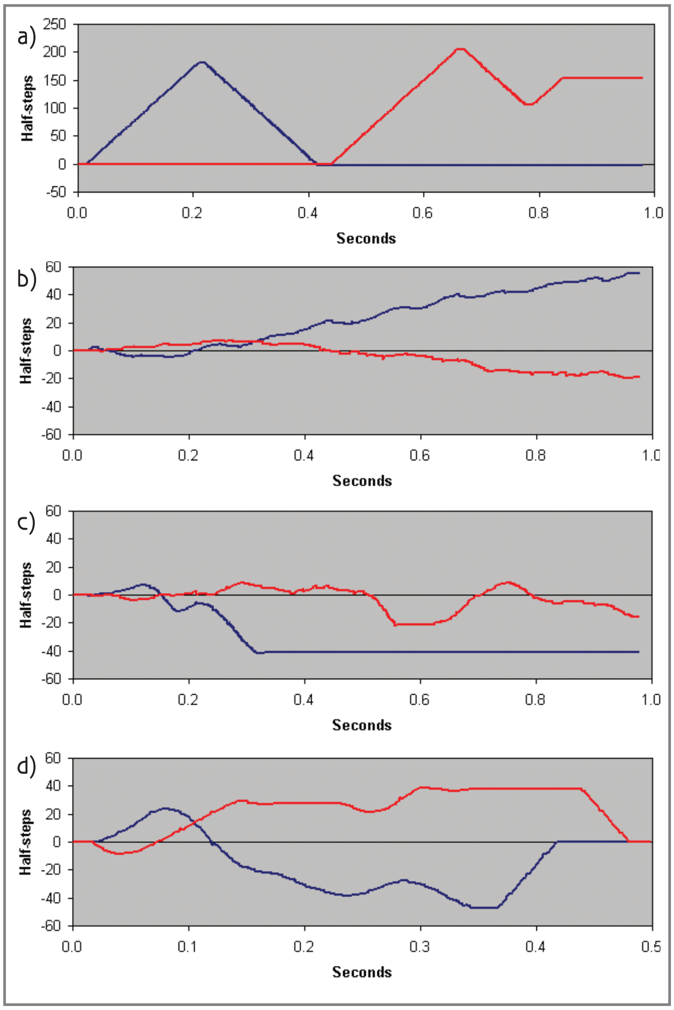


Figure 2—Each of these graphs shows the stepper phase waveform data converted into a set of position values. The horizontal position is shown in blue, and the vertical position in red. a—The initialization sequence from Photo 4. b—A 1-s exposure while I held the camera with one hand. c—Another 1-s exposure, while I was slowly panning horizontally. d—This 1/3-s exposure shows both steppers returning to their standby positions afterward.

oscillations at about 10 Hz, which is typical of the slight movement of muscles in the hand. The slow drift is sometimes steady, as shown here. At other times it appears more random. I had to manually set a long 1-s exposure time because the IS system is only active while the shutter is open. Other cameras enable you to set different modes where IS can be active either continuously or when the shutter button is pressed halfway, but that would have a significant effect on battery life. I measured the current consumption during the exposure at 280 mA without IS, increasing to 550 mA with IS turned on. Idle current was 380 mA with the LCD backlight at full brightness or 340 mA when dimmed. The steppers also make a slightly audible ticking sound while they're running, so I could imagine it might get annoying if they were enabled all the time. I never noticed that with the lens-based actuator in the other camera.

The IS system automatically detects panning when it sees steady movement which causes it to freeze the appropriate stepper at its current position. In Figure 2c, the horizontal stepper stops moving after about 0.1 s of constant travel. This seems like a convenient feature, compared to some other cameras that require you to manually set their IS function to panning mode to disable horizontal shifting. After each shot, the steppers move back to their standby position, which you can see at the end of the 1/3-s exposure in Figure 2d. I found that the IS performance varied with the camera's zoom setting. All of the previous shots were done at maximum zoom. With a wide exposure, the system was much less sensitive to movement, and the maximum step rate slowed down to 2.8 ms per full step. That makes sense, since the farther you're zoomed in, the greater the effect a given amount of camera rotation will have on the image.

SMILE

I learned a great deal about compact cameras while writing this column, and I hope you've learned some while reading it, too. I put aside my 10-year-old camera for a more modern replacement, though for now it still has a few wires sticking out of it. I expect to get more use out of it since it's much smaller and lighter than the old one, and actually fits in a pocket. I'm also used to the larger LCD. Going back to my old camera's smaller display almost feels like I'm watching an antique TV with its tiny screen in the center of a large console. I think it's finally time to let that image fade into the past. ■

Richard Wotiz has been taking products apart ever since he was old enough to pick up a soldering iron. He's been helping others put them back together since 1991, when he started his design consulting business. Richard specializes in hardware and software for consumer products and children's toys. He can be reached at rw601@spiraltap.com.

PROJECT FILES

To download the code, go to ftp://ftp.circuitcellar.com/pub/Circuit_Cellar/2012/262.

REFERENCE

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RESOURCES

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