BIGSHOT USER GUIDE

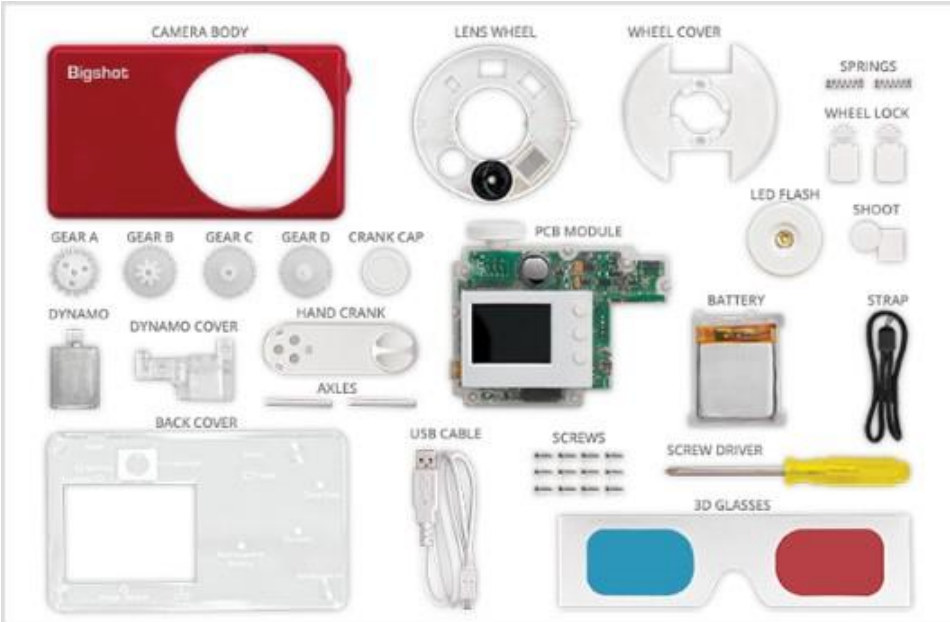
[ENGLISH]

www.bigshotcamera.com

Contents

BUILD

A. Getting Started



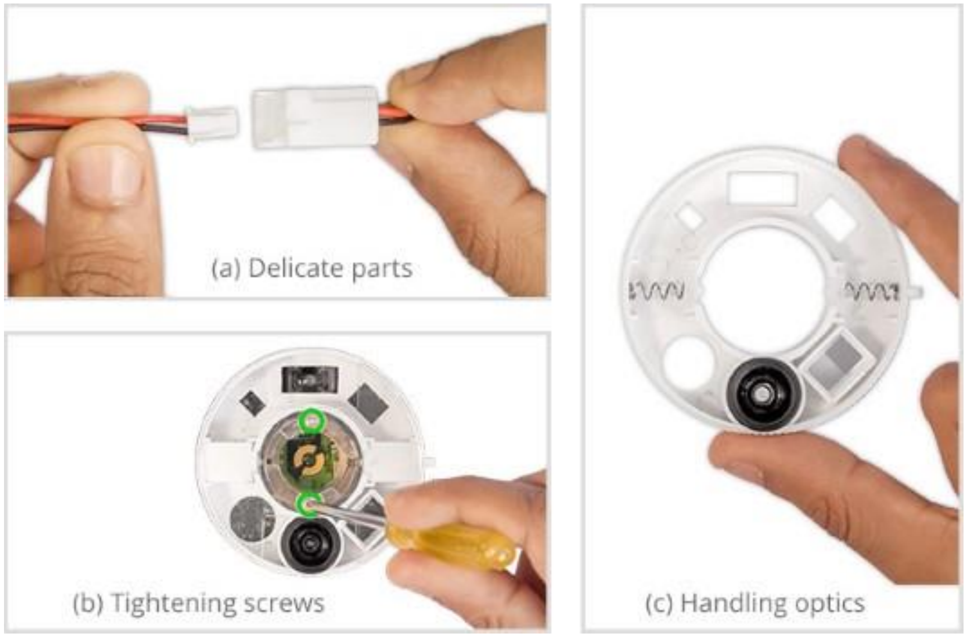
A1. Bigshot can only be assembled in one specific sequence. Make sure you follow the sections and the steps of each section in order. Note: Two extra springs and several extra screws have been provided.

(a) PCB Module

(b) Rechargeable Battery

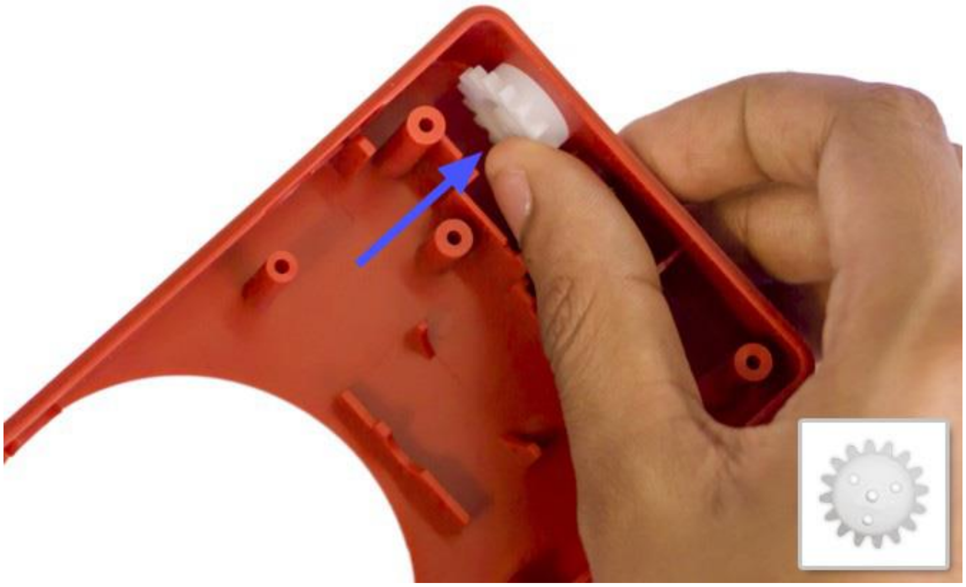
(c) LED Flash

A2. Bigshot can only be assembled in one specific sequence. Make sure you follow the sections and the steps of each section in order.

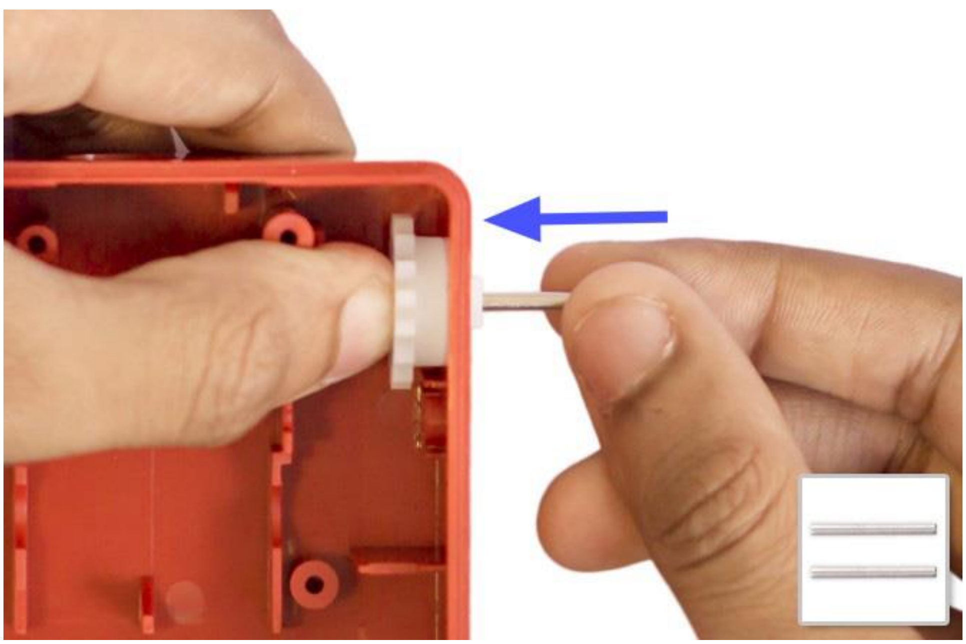


A3. Safety Warning: Do not open the plastic casing of the (a) printed circuit board, (b) rechargeable battery, or (c) LED flash as it could make the camera malfunction or cause injury to you.

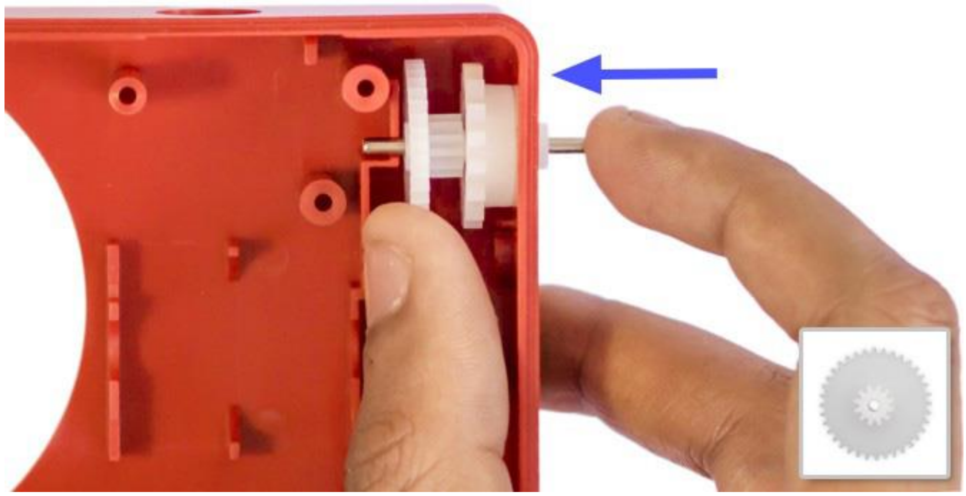
B. Power Generator



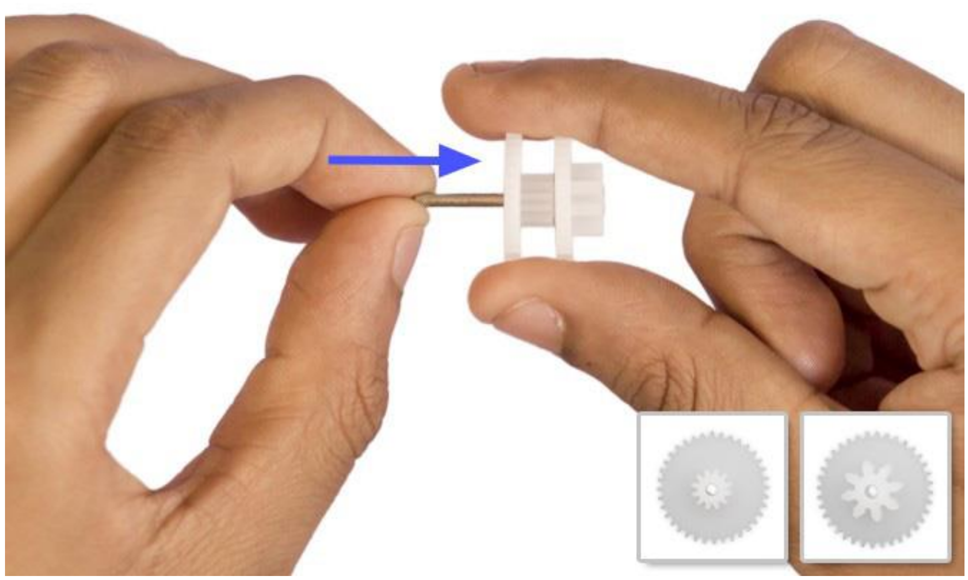
B1. Slide gear A into the hole on the side of the camera body. The blue arrow tells you the direction in which to slide the gear.



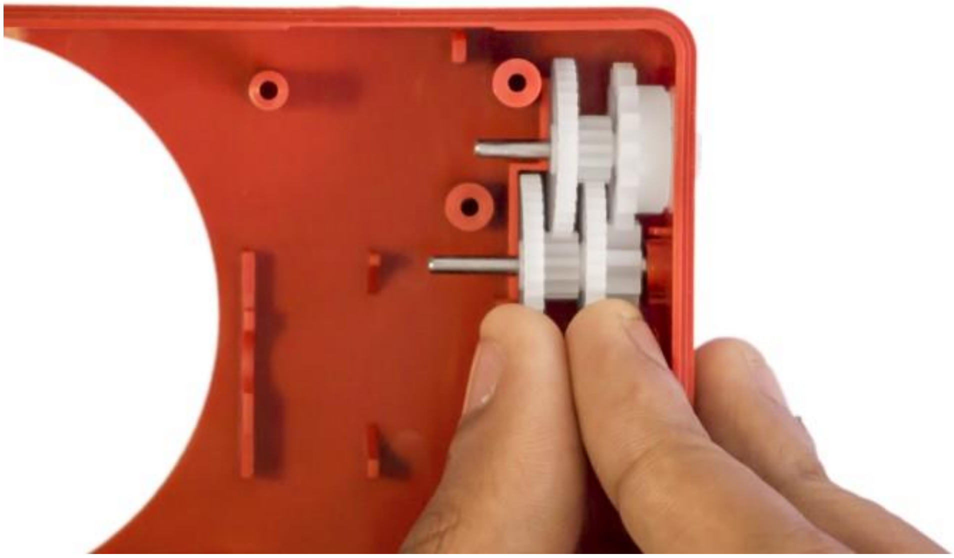
B2. While holding the gear in place with one finger, insert one of the axle rods into the middle hole of the gear. Push the rod in until it touches the finger holding the gear.



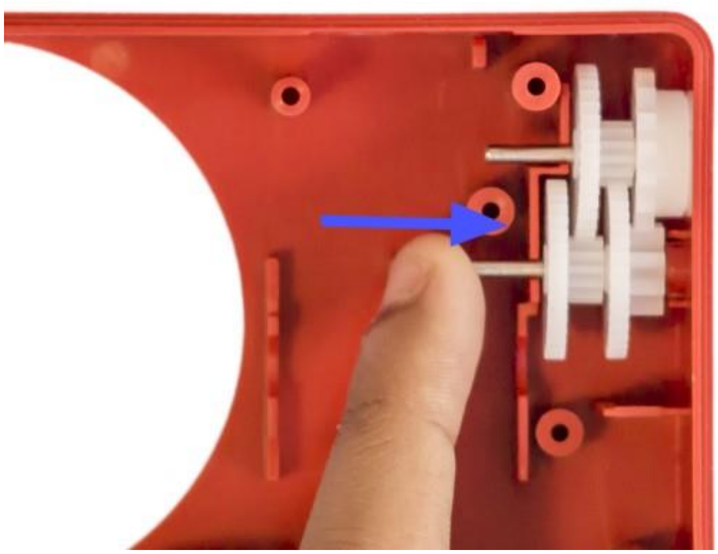
B3. Place gear C next to the first gear as shown, and push the rod through both the gears until it is all the way in. The left end of the axle should now sit in the notch on the camera body and the two gears should be free to spin.



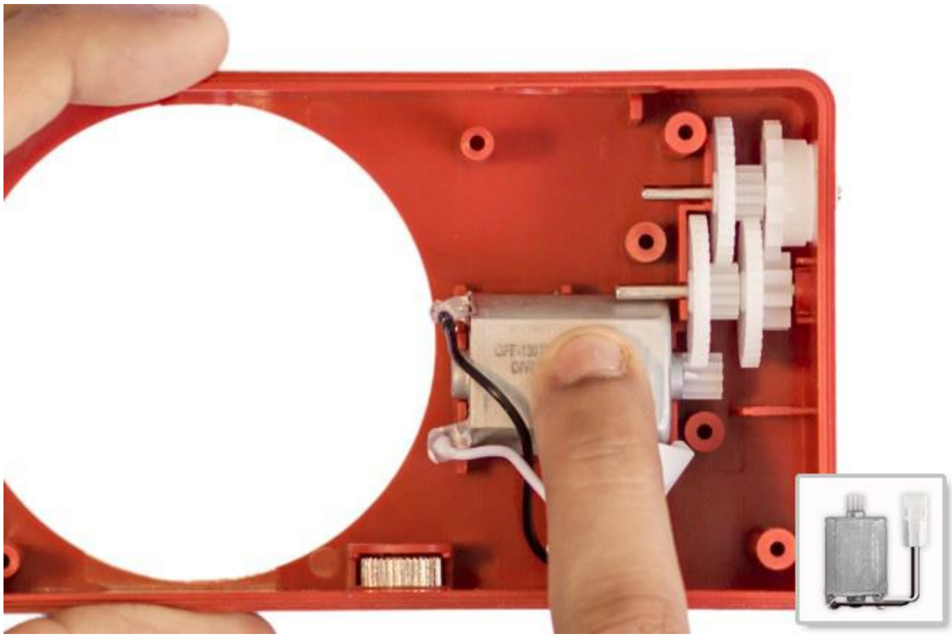
B4. Take gear B and gear D and hold them together as shown. Now push the second axle rod through both gears such that it pops out just a bit at the other end.



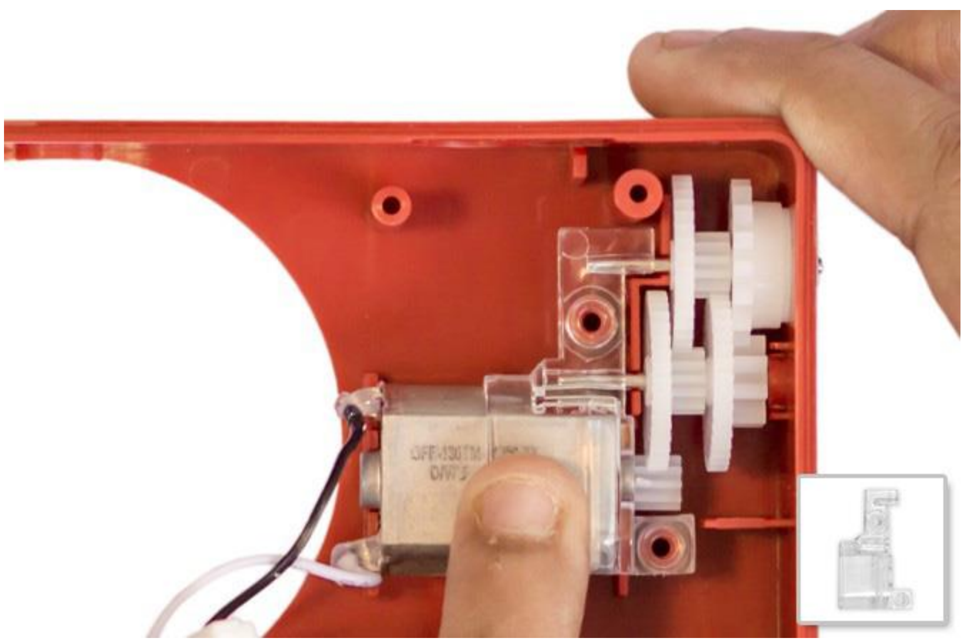
B5. Take the gear assembly you just made and place it below the first set of gears, as shown. Make sure the left end of the rod rests in the notch in the camera body.



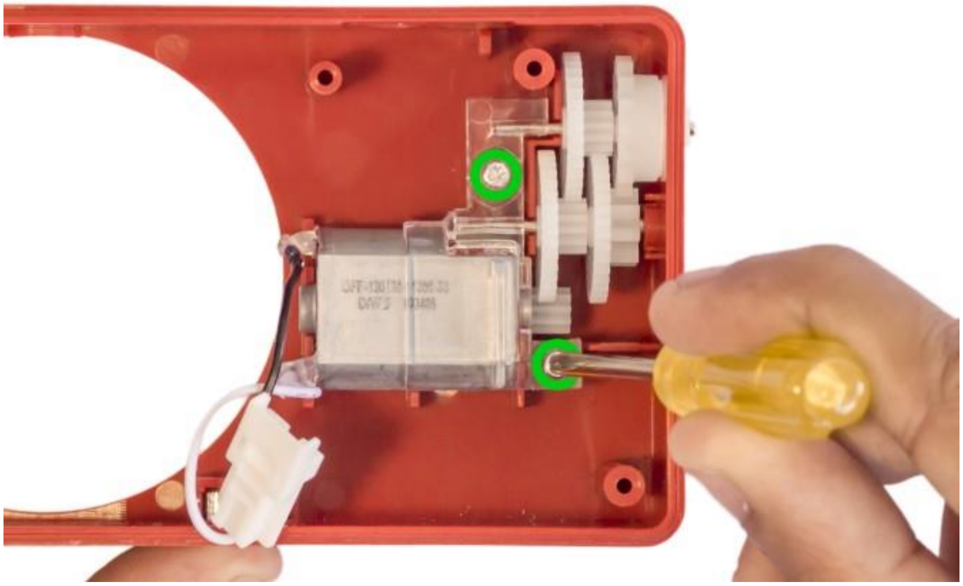
B6. Take the gear assembly you just made and place it below the first set of gears, as shown. Make sure the left end of the rod rests in the notch in the camera body.



B7. Place the dynamo into the camera body. Make sure the dynamo gear meshes correctly with gear B. Don't try to rotate any of the gears as it may cause the axle rods to pop out of their positions.



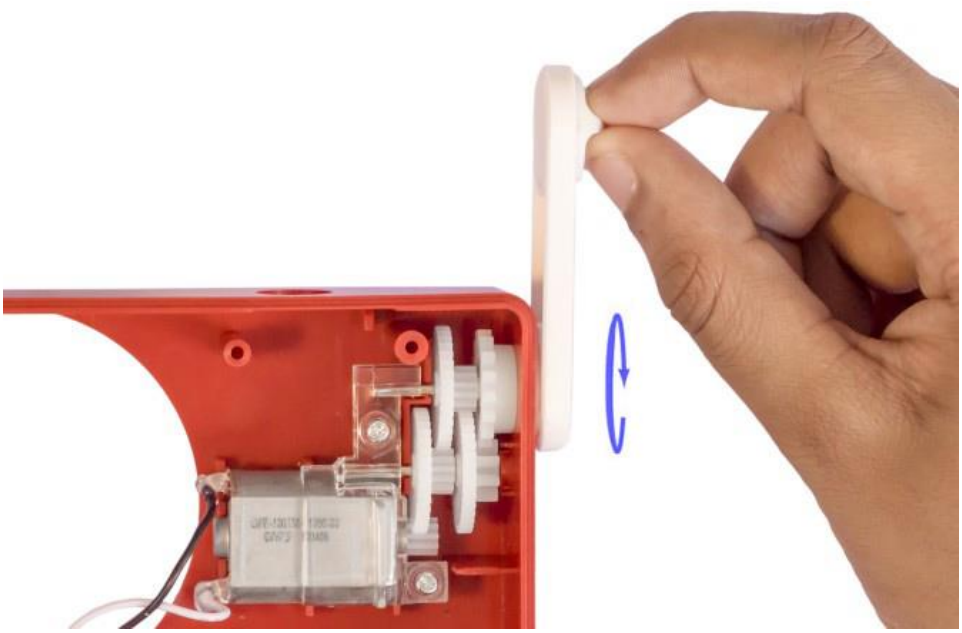
B8. Use the dynamo cover to secure the dynamo and the two axle rods in place.



B9. Fasten the dynamo cover with two screws, as shown above.

B10. Take the hand crank and push-fit its triangular notch onto the triangular head of gear A of the gearbox.

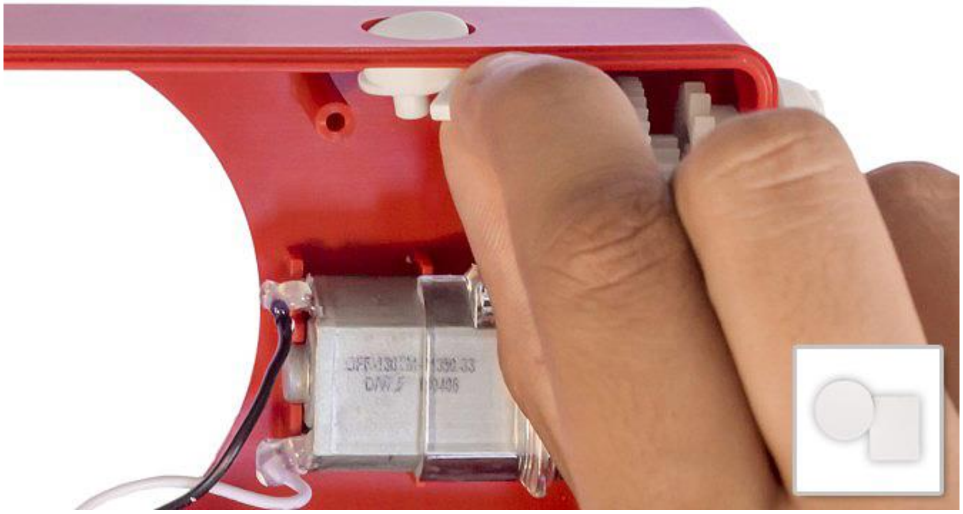
B11. Fasten the hand crank onto gear A using three screws, as shown.



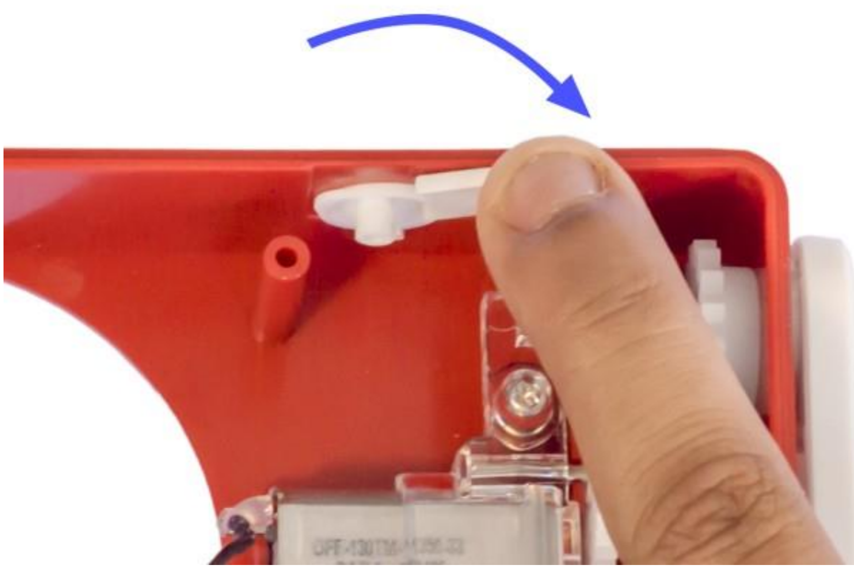
B12. Rotate the hand crank clockwise. If it does not rotate smoothly, one of the parts of the gearbox may be misaligned. Carefully undo the previous steps and reassemble the gearbox.

B13. Clip the white crank cap onto the hand crank so that it covers the three screws. Before snapping the cover in place, make sure you have lined up the three tabs on the cover with the slots on the hand crank.

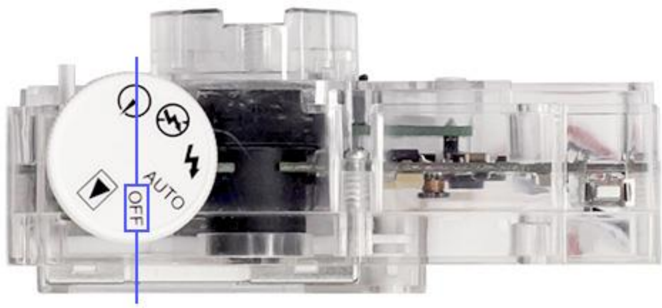
C. Electronics



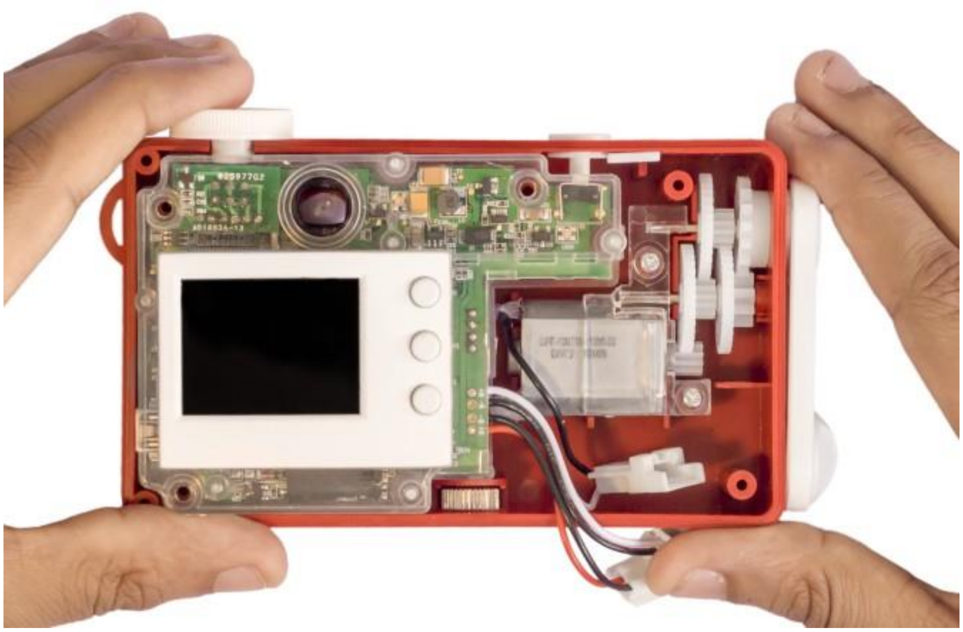
C1. Place the shoot button into the hole on the top face of the camera body. You will have to insert it at an angle, as shown.



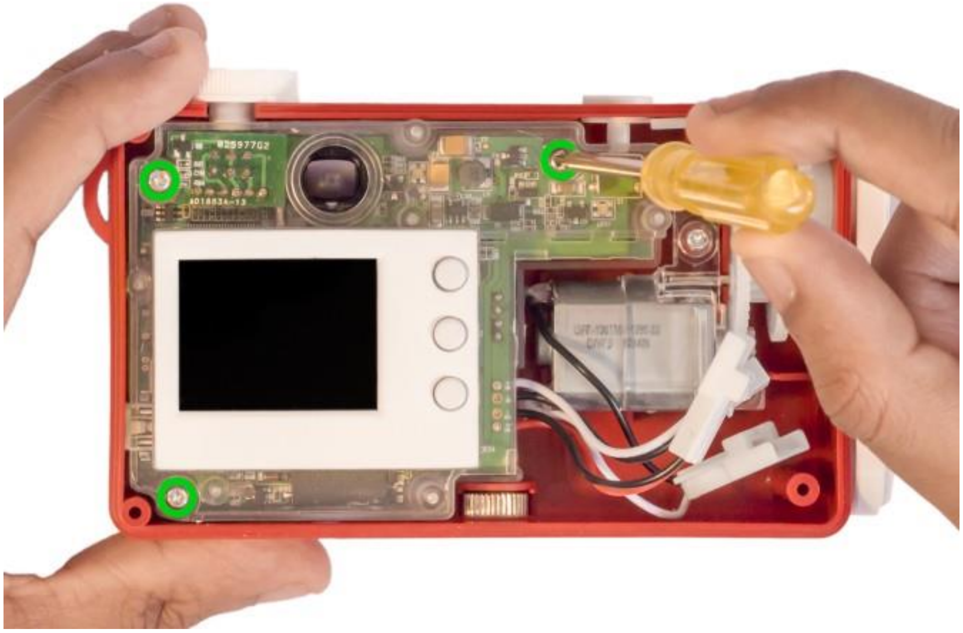
C2. While the shoot button is in the hole, rotate its arm clockwise until the arm slides into the notch on the camera body.



C3. Pick up the PCB module and turn the mode knob to the position shown above.

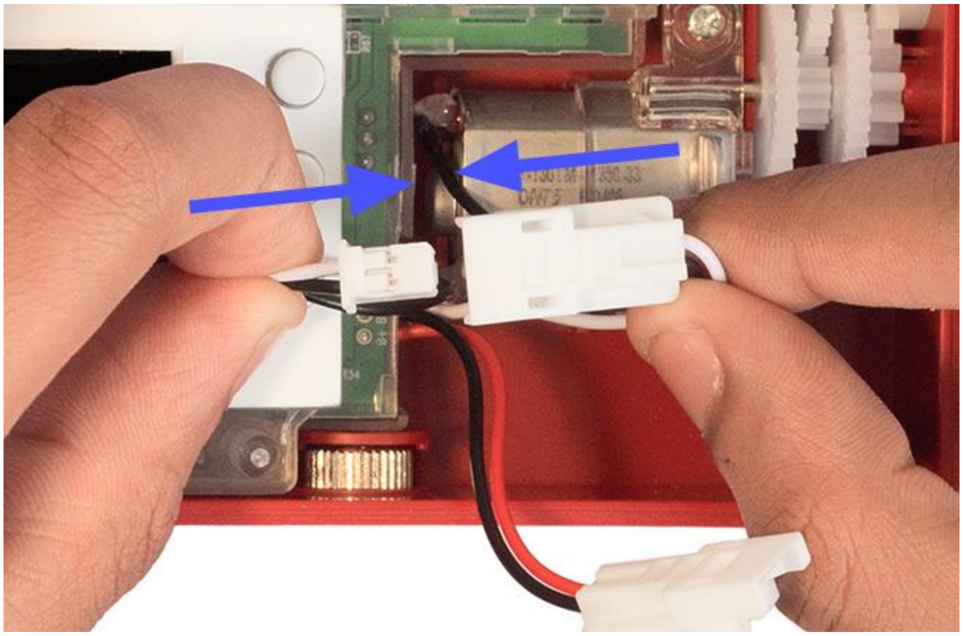


C4. Insert the PCB module into the camera body. Make sure the pillars in the camera body go through the holes in the PCB module.

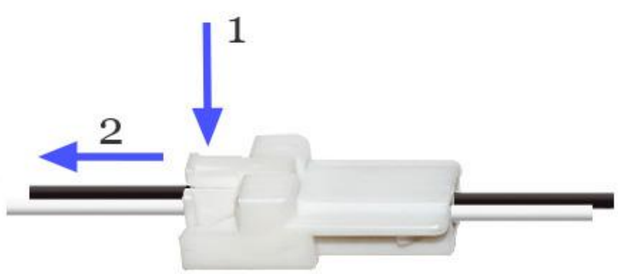


C5. Fasten the PCB module onto the camera body using three screws.

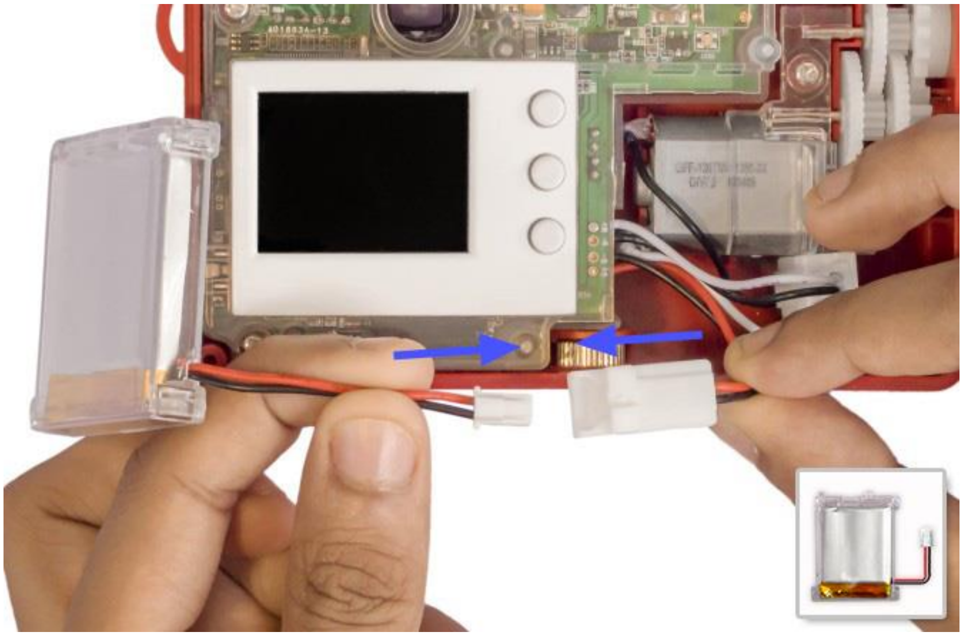
C6. Now set the mode knob to the OFF position. It must remain in the OFF position during the remaining assembly process.



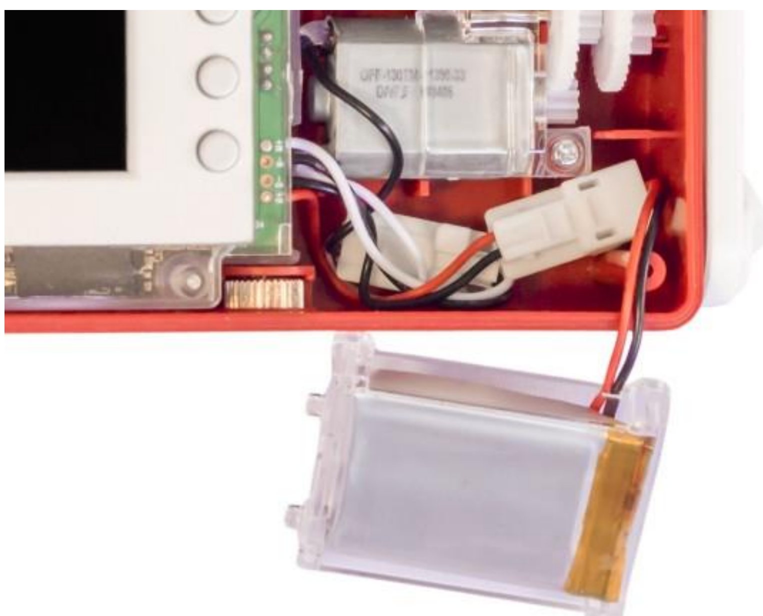
C7. Find the connector attached to the pair of wires from the PCB that have the same color combination as the wires from the dynamo. Hold the two connectors in each hand and gently join them until they click.



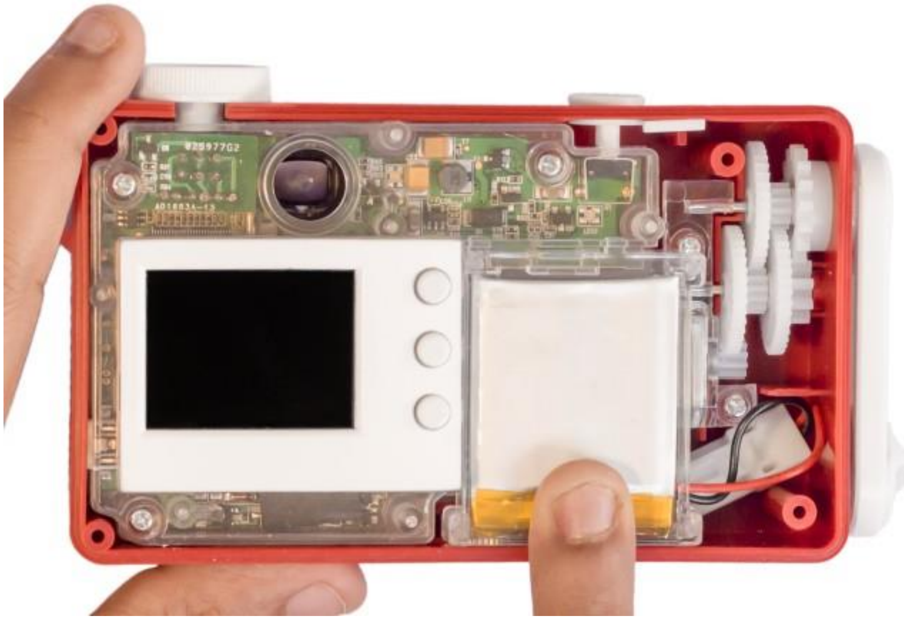
C8. If you want to disconnect the wires, first press down on the smaller connector and then pull it out as shown above.



C9. Take the remaining connector from the PCB module and the connector from the battery. Gently connect the connectors so that they click.



C10. Place the connectors from the dynamo and the battery into the space at the bottom of the camera body. Make sure that the wires do not touch the gears.

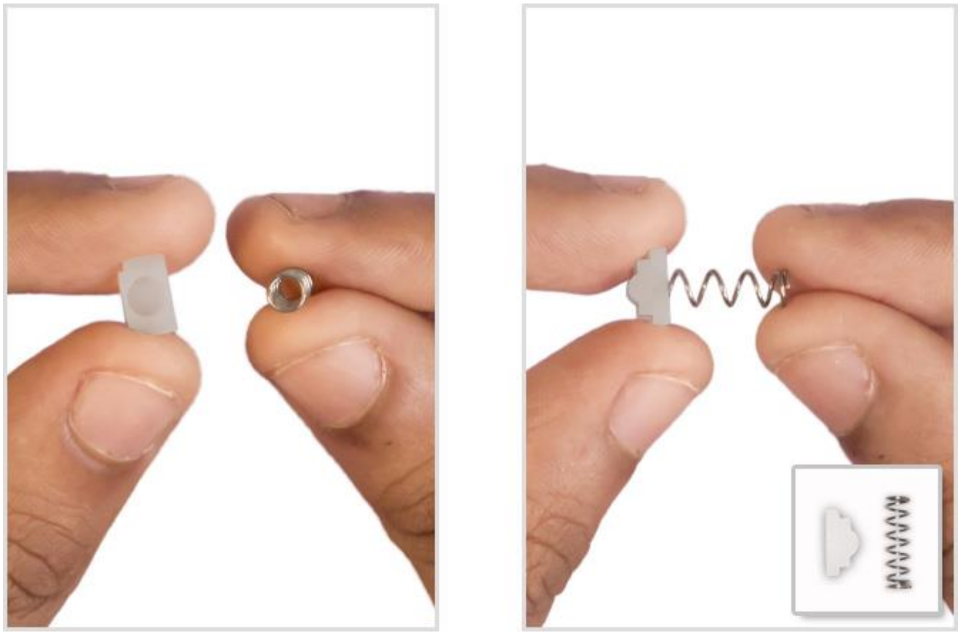


C11. Now set the battery into the camera body as shown.

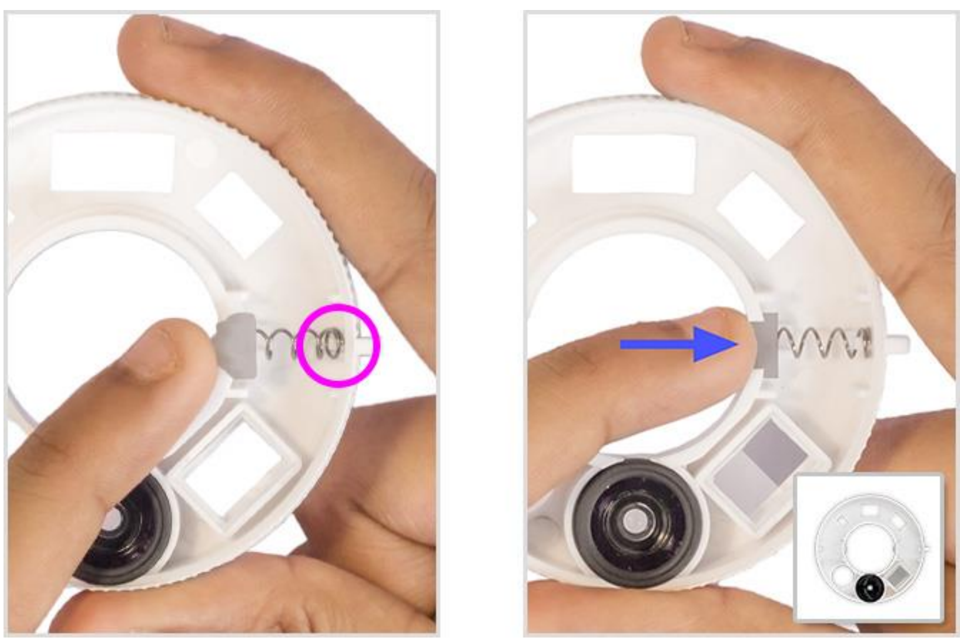
C12. Place the clear back cover on top of the camera body. Make sure the screw holes on the cover align with the screw inserts on the camera body.

C13. Fasten the back cover with four screws.

D. Lens Wheel



D1. Take one of the four springs (two of which are extra) and one of the two locks and insert the spring into the circular pit in the lock.



D2. Insert the free end of the spring into the small bump (purple circle) on the lens wheel, as shown on the left. Now slowly push the lock to compress the spring, as shown on the right. The lock will slide into the lens wheel and should snap into its notch on the wheel.

D3. Use the same method to attach the second lock to the opposite side of the wheel.

D4. Place the spring cover on top of one of the springs and push it in. The cover should snap into the lens wheel so that it does not stick out of the wheel.

D5. Now cover the other spring with the remaining spring cover.

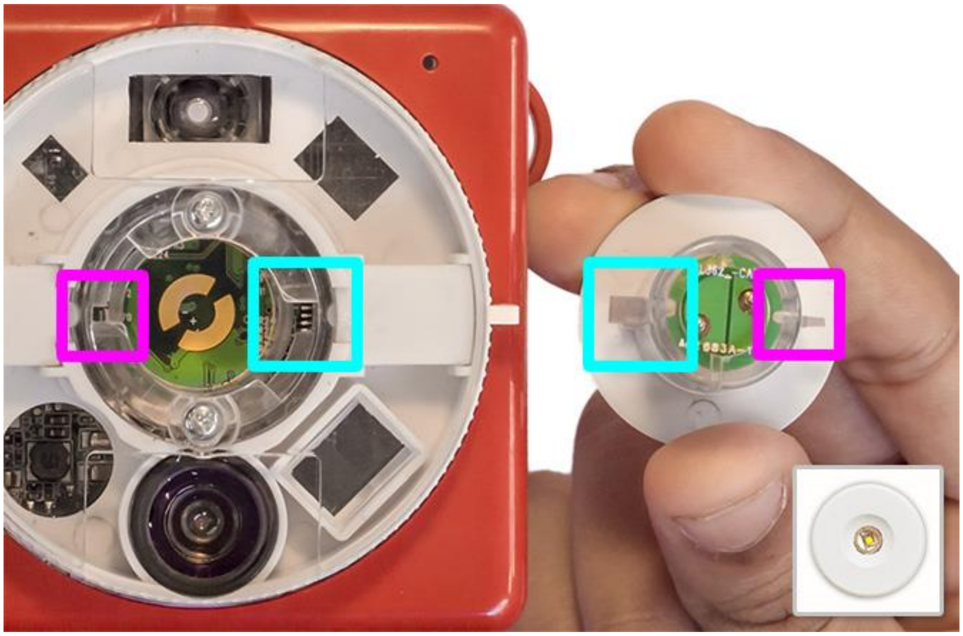
D6. Push-fit the lens wheel into the casing of the PCB module. Make sure the two locks on the lens wheel align correctly with the two notches on the PCB module, as illustrated by the blue and purple boxes.

D7. After you have attached the lens wheel, try gently rotating it in each direction. It should snap into each of the three lens settings.

D8. Place the lens cover on top of the lens wheel so that the two screw holes on the cover and the wheel are aligned.   Make sure the tiny dot on the cover, shown in blue, is to the right.

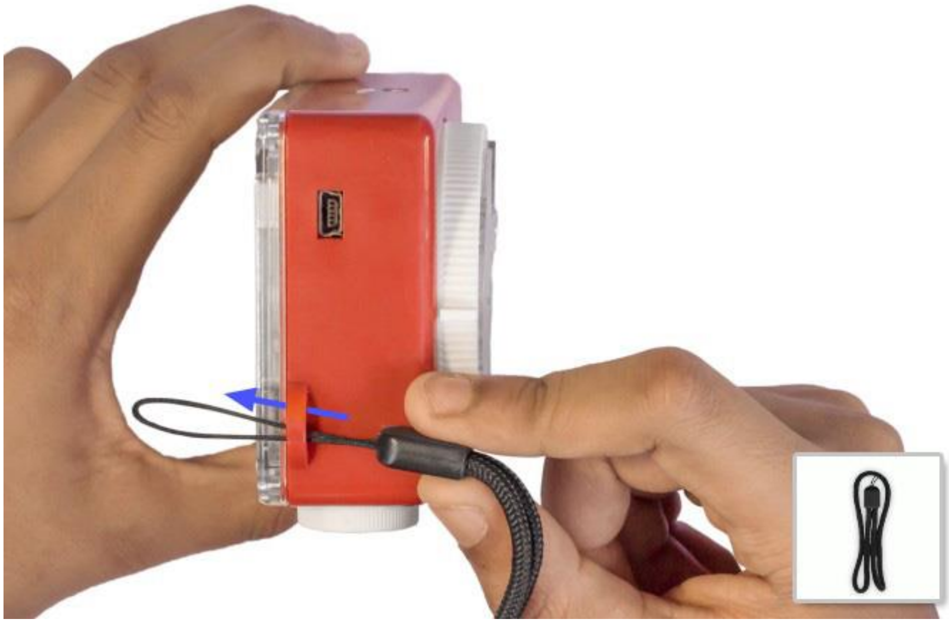
D9. Then, fasten the lens cover with two screws.

E. LED Flash



E1. The flash module can be inserted into the PCB module in only one orientation. The blue and purple boxes above can be used to match the tabs on the flash module with the notches on the PCB module. Push the LED flash module into the PCB module.

E2. Turn the LED flash module clockwise by about 30 degrees to lock it into the PCB module. Even if the LED flash module feels loose, you can be sure it is connected to the PCB module.



E3. The wrist strap has a tiny loop and a large loop. Squeeze the tiny loop together and slide it through the eyelet on the side of the camera body.

E4. Pass the big loop through the little loop as shown on the left.

E5. Then, pull on the big loop to tighten the strap.

E6. You're done! Now, head over to the Use section to learn about how to use your new Bigshot!

LEARN

The Science of Bigshot

This section is an interactive book that describes a wide range of science and engineering concepts that make Bigshot work. Each concept is described using simple explanations, clear illustrations and interactive demos. When you are done learning about Bigshot, play the Quiz to see how much you know!

Power Generator

Introduction

Batteries power all digital cameras in the market today, and Bigshot is no different. However, unlike any other camera, Bigshot also comes with a manual power generator that lets you take photos even when the battery runs out of charge.

Figure 1 shows the components of Bigshot's power generator. The dynamo, seen at the center, is an electric generator similar to those that power our homes. When a user turns the hand crank, the dynamo converts the mechanical energy of that rotation into electrical energy. For the dynamo to generate enough power for Bigshot to take a photo, the crank must be spun at thousands of rotations per minute. Turning the crank at such speeds with your hand is impossible. Therefore, instead of directly connecting the crank to the dynamo, the camera uses a gearbox in between. The gearbox spins the dynamo at very high speeds, even when the user rotates the crank slowly.

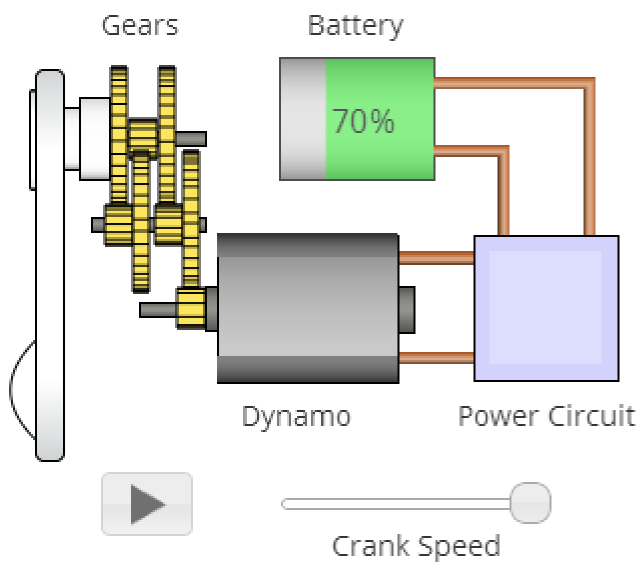


Figure 1: Bigshot power generation (Online demo)

The electrical energy produced by the dynamo is stored in a rechargeable battery. Each time a photo is taken, the camera draws energy directly from the battery. Once all the energy is used up, the battery can be recharged by cranking the dynamo again.

Click on the play button in Figure 1 to see how the rotating hand crank drives the power generator. Use the slider to control the rotation speed.

Gears

Gears are used in almost every machine with spinning parts – in wristwatches, bicycles, cars and even trains. A gear is generally cylindrical in shape with grooves – called teeth or cogs – cut along its boundary. Two gears with identical teeth can mesh together perfectly. Figure 2 shows two intermeshed gears. One gear's teeth lock between the other's so that turning the first gear causes the second one to turn as well (click on the play button).

Any two gears working together this way provide “mechanical advantages” that have made them useful in all kinds of machines. Depending on their relative sizes, one gear can either increase or decrease the speed of rotation of the other. In addition, they can be used to reverse the direction of rotation. Observe that in Figure 2 the two gears A and B rotate in opposite directions. Moreover, gear B spins faster than gear A. The ratio of their speeds is called the gear ratio.

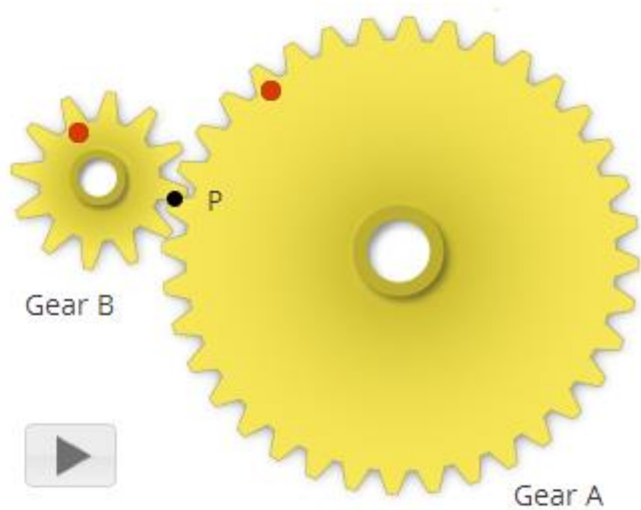


Figure 2: Two intermeshed gears (Online demo)

How fast does B spin compared to A? Since the teeth on both gears must be of the same size for the gears to intermesh, the smaller gear has fewer teeth than the larger one. Notice that by the time the smaller gear B makes a complete rotation (all of its teeth have passed by the point P), the larger gear A would not have completed a full rotation (not all of its teeth will have passed by P). In other words, the smaller gear spins faster than the bigger one. It can be shown [1] that the speeds of the two gears, A and B, are related by the following equation:

$$Speed\ of\ A\ \times\ Number\ of\ teeth\ on\ A\ =\ Speed\ of\ B\ \times\ Number\ of\ teeth\ on\ B.$$

The number of teeth on a gear depends on its outer boundary, or circumference. The gear's circumference, in turn, is proportional to its diameter. Therefore, we can write the above equation as:

$$Speed\ of\ A\ \times\ Diameter\ of\ A\ =\ Speed\ of\ B\ \times\ Diameter\ of\ B.$$

For example, in Figure 2, the diameter of gear A is 3 times that of gear B, which means that gear B rotates 3 times faster.

Gearbox

To generate enough power in a few seconds to take a photo, Bigshot's dynamo must be spun at thousands of rotations per minute. However, it is humanly impossible to rotate the crank at such a speed.

One solution is to interconnect the crank and dynamo using two gears. However, in order to boost the rotation speed by a factor of say 100, the first gear has to be 100 times as big as the second one. That would make the camera huge!

This problem can be solved by using multiple gears. A series of intermeshed gears of different sizes is called a gearbox. Bigshot's gearbox, shown in Figure 3, uses eight gears that work together to convert the slow rotation of the hand crank to a very fast rotation of the dynamo shaft, without requiring the camera to be unreasonably large. The inset at the top-right corner of Figure 3 shows a compound gear B. It consists of two separate gears (B1 and B2) that are not meshed but rather fixed together. Rotating either one of the gears rotates the other at the same speed. Gears C and D are also compound gears, and are composed of gears C1 and C2, and D1 and D2, respectively. Gear A is two times larger than gear B1. The remaining larger gears (B2, C2 and D2) are three times as large as the smaller gears (C1, D1 and E).

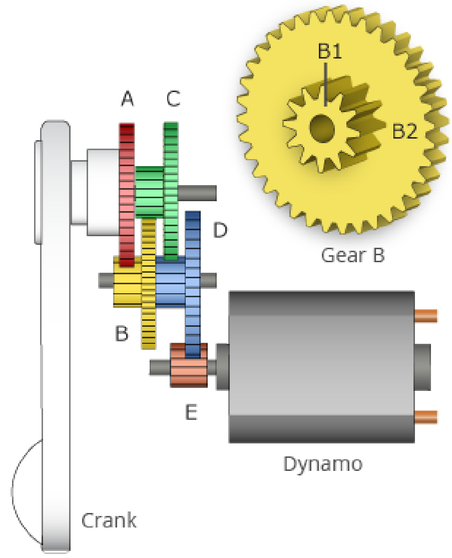


Figure 3: Bigshot's gearbox

Gear A is directly attached to the crank and hence rotates at the same speed as the crank. It is meshed with B1, which rotates twice as fast as A. Since B2 is fixed to B1, it also rotates at this speed. The speed further increases three times when B2 drives C1. Now we can see that each time the rotation transfers from one compound gear to the next, the speed increases by a factor of three. This means that by the time the rotation of the crank transfers through the four gears to reach the dynamo shaft, the speed would have increased by a factor of 2×3×3×3=54 times. That is, a single rotation of the crank makes the dynamo spin 54 times!

For example, if we rotate the crank at 30 rotations per minute, the dynamo spins at 30×54 = 1620 rotations per minute, which is a high enough speed to generate the power needed for Bigshot to take a photo.

Electromagnetic Induction

In the early 1800s, physicists discovered an important link between electricity and magnetism. They found that when a conducting wire is placed inside a magnetic field that is changing, an electric voltage is induced (generated) in the wire.

This phenomenon, known as electromagnetic induction, is demonstrated in Figure 4. A long wire is wrapped around a cardboard cylinder to form a coil. A voltmeter is connected to the two ends of the coil. When the magnet is moved into and out of the coil (click on the play button), the magnetic field around the coil is changed. The voltmeter's needle fluctuates in response, indicating that a voltage is induced within the coil. The faster the magnet moves, the greater the induced voltage. When the magnet stops moving, the voltmeter's needle instantly returns to zero, showing that a changing magnetic field is required to generate electricity.

Electromagnetic induction is the principle behind the generation of electricity from mechanical energy, be it in small dynamos like the one used by Bigshot or large hydroelectric plants that generate power for our homes.

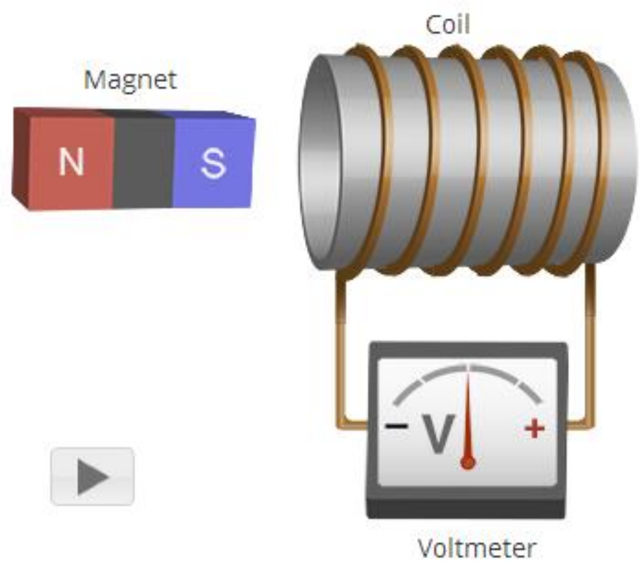


Figure 4: Electromagnetic Induction (Online demo)

Dynamo

A dynamo is a device that converts mechanical energy into electrical energy. Figure 5 shows the structure of a simple dynamo. A coil made of conducting wire is positioned between the North and South poles of two permanent magnets. When the coil is stationary, no voltage is induced. But when the coil is rotated it experiences a changing magnetic field. This induces a voltage within the coil.

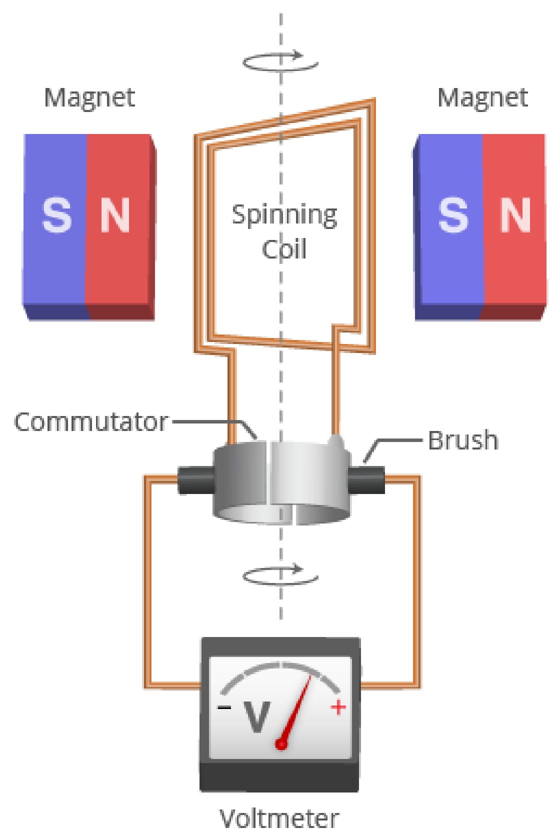


Figure 5: A simple dynamo

For the first half of a rotation the left side of the coil swings by the North Pole of the left magnet and for the second half of the rotation it swings by the South Pole of the right magnet. As a result, for the first half the coil generates a voltage with one polarity (either positive or negative) and for the second half the voltage has the opposite polarity. This type of voltage – one that switches between positive and negative – is called alternating voltage. Figure 6a shows the typical sinusoidal-shaped alternating voltage generated in the dynamo coil. The height of the sinusoidal wave, which represents the strength of the voltage induced in the coil, depends on the strength of the magnetic field, the number of loops in the coil, and the speed at which the coil rotates [2].

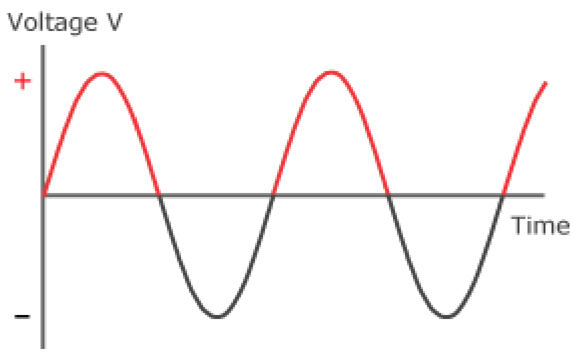


Figure 6a: Induced Voltage

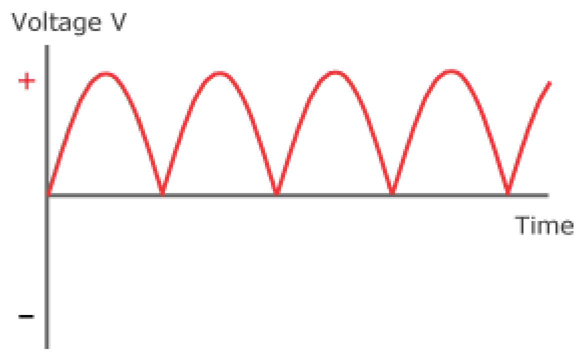


Figure 6b: Rectified Voltage

The spinning coil of the dynamo is connected to the circuit that it powers using a commutator. The commutator consists of two half-cylinders of smooth conducting material that are separated by a small gap. Each half-cylinder is permanently attached to one end of the rotating coil, and the commutator rotates with the coil. Two stationary brushes, usually made of carbon, press against the spinning commutator. The brushes act as the terminals (outputs) of the dynamo.

In addition to acting as the terminals of the electricity-generating coil, the commutator performs another very important function. It keeps the dynamo's generated voltage from alternating between positive and negative. Each brush slides along the two halves of the commutator, switching halves the instant the voltage in the coil reverses polarity. This ensures that the voltage produced by the dynamo is no longer fluctuating between positive and negative, but is instead always positive. This type of voltage is called direct voltage, and is shown by the curve in Figure 6b. This process, where alternating voltage is converted to direct voltage, is called rectification.

Rechargeable Batteries

If you have ever used a gadget that runs on disposable batteries, then you have experienced the frustration of having to replace used batteries with new ones. Over time the cost of replacing batteries in a device can be more than the cost of the device itself! Fortunately, the days of disposable batteries are numbered. All modern digital cameras, including Bigshot, use rechargeable batteries. If they run out of power, you can connect them to a power source to charge them again. In the case of Bigshot, if you happen to be out shooting photos when the battery runs out of charge and you do not have access to a power source, you can simply crank the dynamo to recharge the battery and continue to shoot photos. Let's now take a closer look at how a battery works.

A battery is a device that stores chemical energy in its materials and converts it, on demand, into electrical energy. The two main parts of a battery – the anode and the cathode – are immersed in an electrolyte, which is a liquid or gel with ions (see Figure 7). An ion is an atom or molecule in which the number of electrons is not equal to the number of protons, giving it a net positive or negative electric charge. If the electrolyte is negatively charged, its ions will chemically combine with the material of the anode, producing a residual material and releasing electrons. If the anode is connected to the cathode via an external circuit (the device that the battery powers), the free electrons flow through the circuit to the cathode as electric current. The cathode's material consumes these electrons to produce another residual material. The battery will continue to produce electricity until one of its electrodes or its electrolyte runs out of the material needed for the chemical reaction to take place.

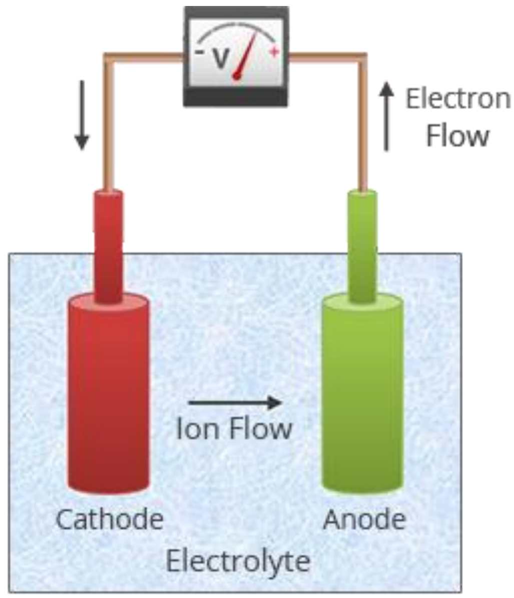


Figure 7: A simple battery

A rechargeable battery produces electricity exactly the same way as a non-rechargeable one. However, rechargeable batteries use special materials for their anode, cathode and electrolyte that allow the chemical reactions described above to be reversed. To recharge the battery, you can connect it to an external electrical power source, such as a dynamo, such that current flows in the reverse direction. The residual materials formed on the anode and cathode as well as in the spent electrolyte will react with the electrons to reproduce the original materials of the anode, cathode and electrolyte. The battery is now recharged and as good as a brand new one!

Power Circuit

Figure 8 shows a simplified diagram of the power generator circuit used by Bigshot. Besides the components described in the previous sections, the power circuit has a special semiconductor chip, called a diode which is placed between the dynamo and the rechargeable battery. It acts as a one-way switch allowing charges to flow from the dynamo to the battery but not the other way. Without the diode, there would be no way to stop the charges in the battery from heading back into the dynamo. If that happened, the dynamo would act as a motor and will automatically spin the hand crank!

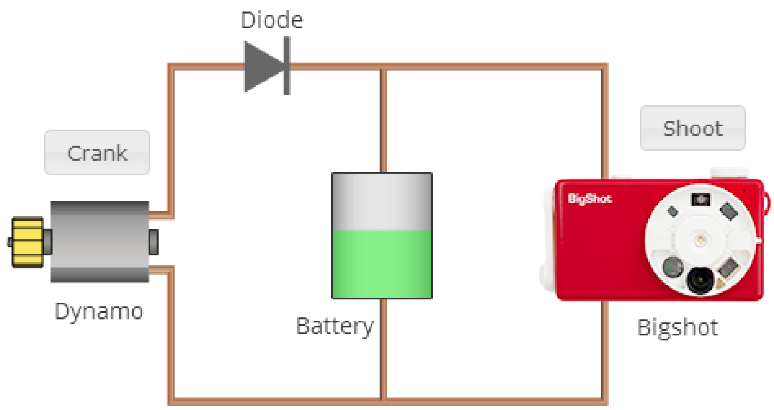


Figure 8: Simplified version of Bigshot's power circuit (Online demo)

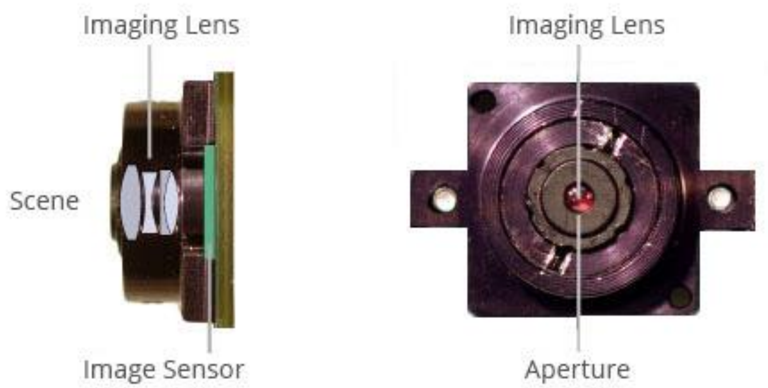
Click the two buttons in Figure 8 to see how cranking the dynamo causes electric power to be stored in the rechargeable battery, while pressing the shoot button causes the battery's power to get used.

Imaging Lens

Introduction

The centerpiece of any camera is its lens. Usually made from glass or clear plastic, the lens receives light from a scene and focuses it to form an image. As seen in Figure 9(a), Bigshot's lens is actually a series of glass and plastic pieces that are encased in a holder. Figure 9(b) shows the lens from the front.

Although every modern camera uses a lens, did you know that it is possible to capture an image without one? In fact, the very first camera, the pinhole camera, was invented well before the lens!



(a) Side view (b) Front view

Figure 9: Bigshot's Lens

Pinhole Camera

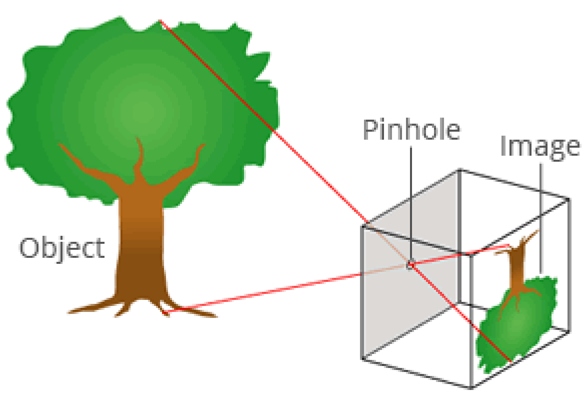


Figure 10: Pinhole Camera

(Image Credit: Wikipedia)

Figure 11: Perspective distortion

(Image Credit: Flickr/DeiselDemon)

A pinhole camera, or *camera obscura* (meaning "dark room" in Latin), is the most basic type of camera. It is simply a closed box or room with a tiny hole on one side (see Figure 10). Pinhole cameras are fun to build, and we show you how to build one here.

In Figure 10, rays of light from points on the tree pass through the pinhole and strike the opposite side of the box. This forms an image of the tree inside the box. This image looks exactly the way your eye would capture it, only it is upside-down. The size of the tree in the image depends on the tree's distance from the pinhole – the farther the object is, the smaller its image will be. For example, even though the width of the railway track in Figure 11 is the same along its entire length, the track appears to get narrower with distance from the camera. This effect is called *perspective distortion*. We experience this distortion as well. In fact, it is useful as it helps us gauge how far objects are from us.

Pinhole cameras present an interesting dilemma. To form a sharp image, the pinhole must be tiny. However, the smaller the pinhole gets, the less light it passes through and the darker the image gets. Indeed, it is not possible for a pinhole camera to capture an image that is both bright and sharp. The lens, however, is designed to do exactly that.

Refraction

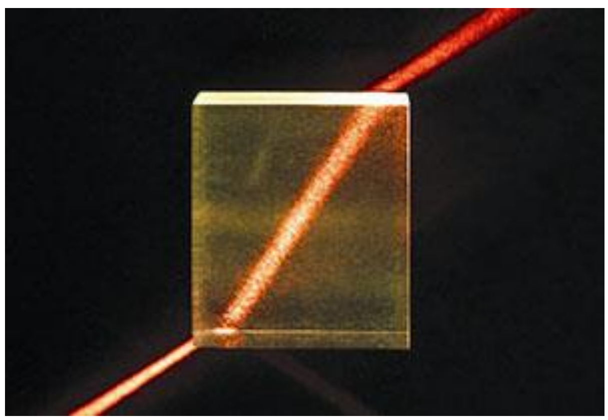


Figure 12: Refraction though a glass slab (Image Credit: Santilli-Foundation)

When a ray of light passes from one clear material to another (say, from air to glass or air to water), it bends at the boundary and follows a different direction. This phenomenon, called refraction, can be seen in Figure 12, where a beam of light traveling through air bends as it enters and exits a glass slab.

Refraction is a common occurrence in nature. Without refraction there would not be beautiful rainbows, shimmering mirages or many other spectacular natural phenomena. Another effect of refraction you may have noticed is that swimming pools appear to be shallower than they actually are and their floors look distorted. Our eyes as well as cameras rely on refraction to capture images. So let’s take a closer look at how refraction works.

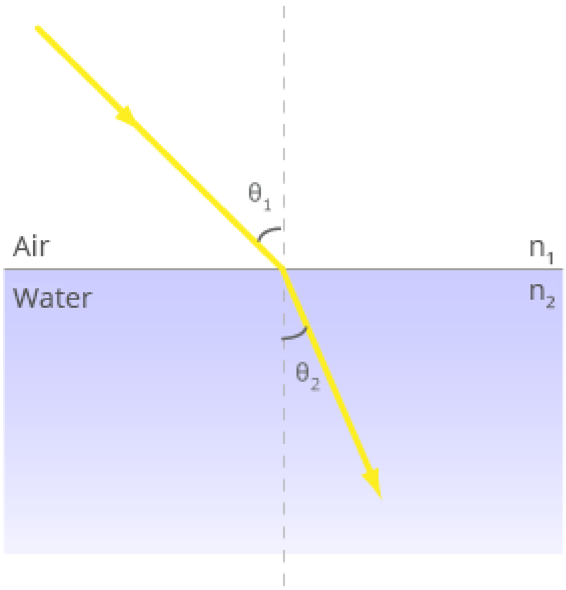


Figure 13: Geometry of refraction

Figure 13 shows a ray of light that is refracted as it passes from air to water. The amount of bending depends on the angle at which the light ray strikes the boundary, as well as the refractive indices of the two materials (in this case, air and water). The refractive index is simply the bending power of a material. Let us say the refractive indices of air and water are n_1 and n_2, respectively. Then, according to Snell's law, a ray coming towards the surface at an angle θ_1 will be refracted at an angle θ_2 such that [3]:

$$n_1 \times sin(\theta_1) = n_2 \times sin(\theta_2).$$

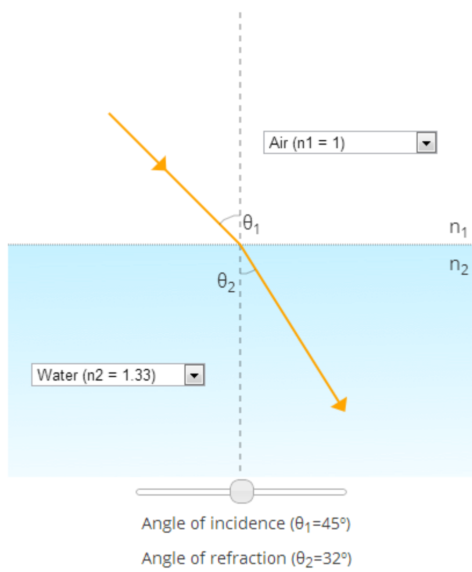


Figure 14: Select a material to see how it bends light (Online demo)

It is remarkable that this simple equation guides the design of virtually all optical devices, from your reading glasses to camera lenses to powerful telescopes and microscopes. Use the demo in Figure 14 to check out the bending powers of several common materials.

How Does a Lens Work?

Lenses are usually made of glass or plastic, and use refraction to either converge (funnel) or diverge (spread) the light that they receive. Depending on the application, lens makers carefully design the shape of the lens to achieve the right amount of convergence or divergence.

Most lenses are spherical – that is, each of their surfaces is a part of a sphere. Lenses that bulge outwards are called *convex* lenses and ones that cave in are called *concave* lenses. As shown in Figure 15 and Figure 16, convex lenses converge light and concave lenses diverge light.

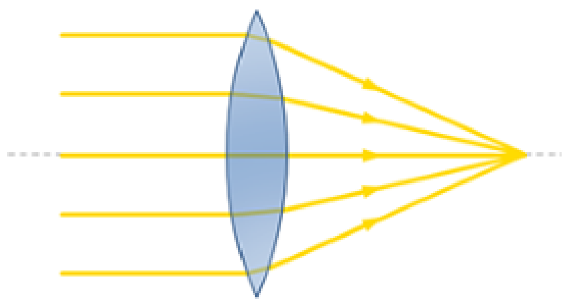


Figure 15: A convex lens converges light

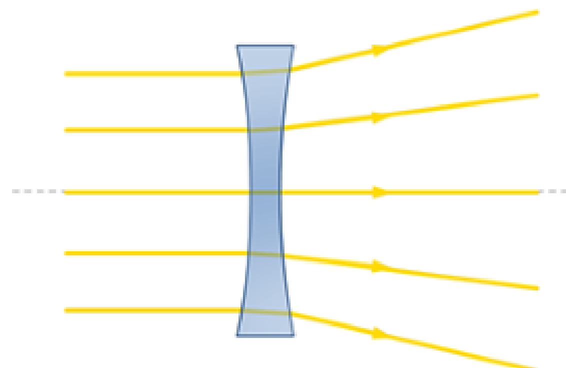


Figure 16: A concave lens diverges light

Sometimes a single lens may not be enough to achieve the kind of bending we need. In such cases, several lenses of different shapes and sizes may be used to form a *compound lens.*

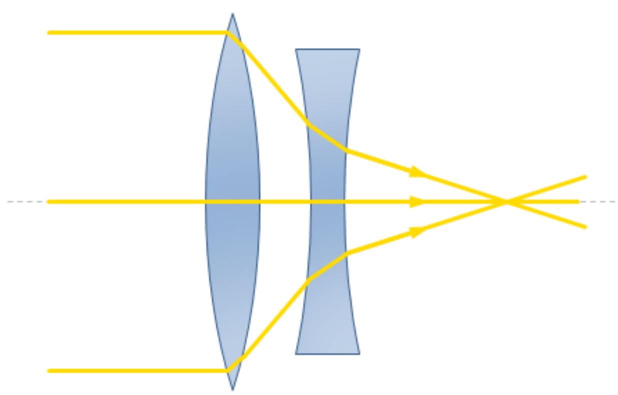


Figure 17: A compound lens comprised of a convex and a concave lens

While modern cameras use compound lenses with several individual lenses with complex shapes to capture high quality images, their working principle can still be described using a single thin convex lens. Let's take a closer look at how a thin lens works.

Thin Lens: A Simple Imaging Lens

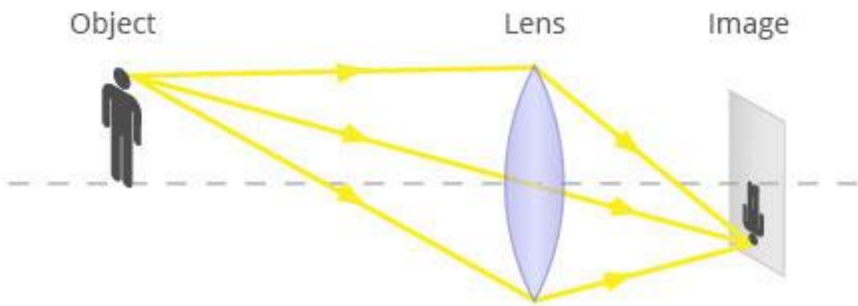


Figure 18: Imaging using a thin convex lens

Say you want to take a picture of your friend. Consider a single point on your friend, such as the top of her head. This point radiates light in various directions. By holding a thin convex lens in front of her, you can collect the light rays from that point and converge them onto a single point, as shown in Figure 18. Since the lens does the same thing to all the points on your friend, a complete image of her is formed behind the lens. If we place a flat board (plane) right where the light rays are being focused, we can see the image that is formed. Better yet, we can record the image by placing an image sensor or a strip of film there instead of the board. Together, the lens and the image sensor form a camera.

In order to figure out where exactly we need to place the image sensor, and how sharp and how bright the captured images will be, we need to understand some basic properties of the lens.

Properties of a Lens

Figure 19: Changing aperture of a lens using an iris (Online demo)

Aperture: The total light-receiving area of the lens is called its aperture. The larger the aperture, the greater the amount of light received by the lens from each point in the scene, and hence the brighter the image. The size of the aperture (opening) can be controlled using a manually adjustable diaphragm, or *iris*, which is placed right next to the lens. This enables us to increase the aperture size when photographing dark objects, and make the aperture smaller when photographing very bright objects. The iris of a camera lens therefore serves the same purpose as the iris of the human eye. Use the buttons in Figure 19 to see how the iris of a lens works.

Focal Length: Figure 20 shows a simple convex lens. Each of the lens's two surfaces is part of a sphere of radius R. The dotted line that connects the centers of these spheres is called the *optical axis*. The lens converges incoming light rays that are parallel to the optical axis toward a single point on the optical axis called the *focal point*. The distance between the focal point and the center of the lens is called the focal length (f) of the lens. It is a measure of the focusing power of the lens and is related to the radius of curvature (R) and refractive index (n) of the lens as follows [3]:

$$f = \frac{R}{2(n-1)}$$

Thicker lenses with a shorter radius of curvature R have a shorter focal length, while thinner lenses with a longer radius of curvature R have a longer focal length. The focal length is the most important property of a lens and it determines where exactly the image is formed.

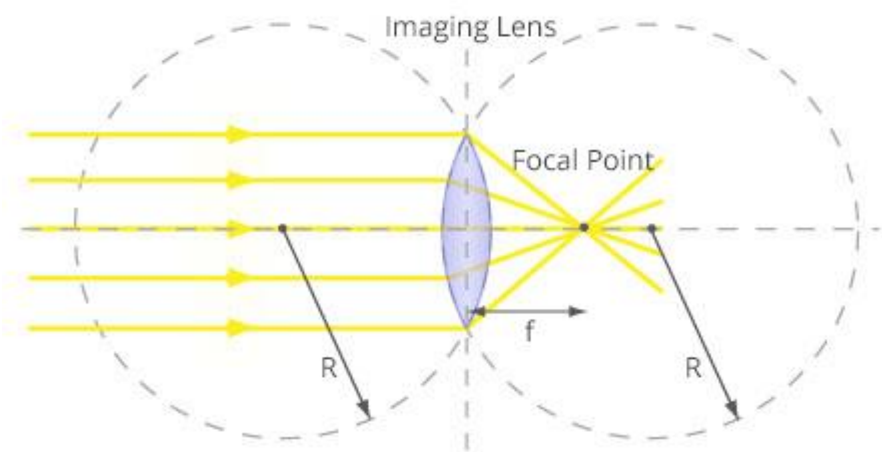


Figure 20: Focal point of a convex lens

Focusing

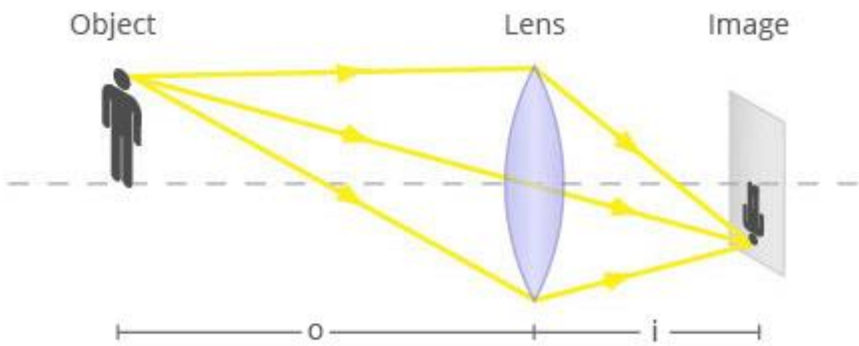


Figure 21: Imaging with a thin lens

Let us revisit the example of you taking a picture of your friend with a thin convex lens. If your friend (object) is standing at a distance o from the lens, and the focal length of the lens is f, then the distance i at which her image is formed can be found using the *thin lens law* [3]:

$$\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$$

The above equation tells us that, for an object at distance o, there can be only one distance i at which the image is focused. If the image sensor is not located at this distance i, your friend will appear blurred in the image. For this reason, most cameras allow you to adjust the distance between the sensor and the lens so that your object of interest can be brought into focus. This process is called *focusing*.

Image Appearance

The interplay between the scene, the lens and the image sensor is demonstrated in Figure 22. The sliders at the bottom allow you to control the positions of the object (car), the image sensor, and the aperture size. By moving the image sensor back and forth, you can see the car and the building go in and out of focus in the captured image. For any chosen position of the image sensor, the vertical dotted line shows where an object must be for it to be in focus. Moving the car towards the dotted line will bring it into focus. Hence, you can get a sharp image of an object by either moving the image sensor, or the object, or both.

Use the third slider to control the size of the aperture. As expected, a larger aperture makes the image brighter. However, a larger aperture also makes the non-focused parts of the image more blurry, while

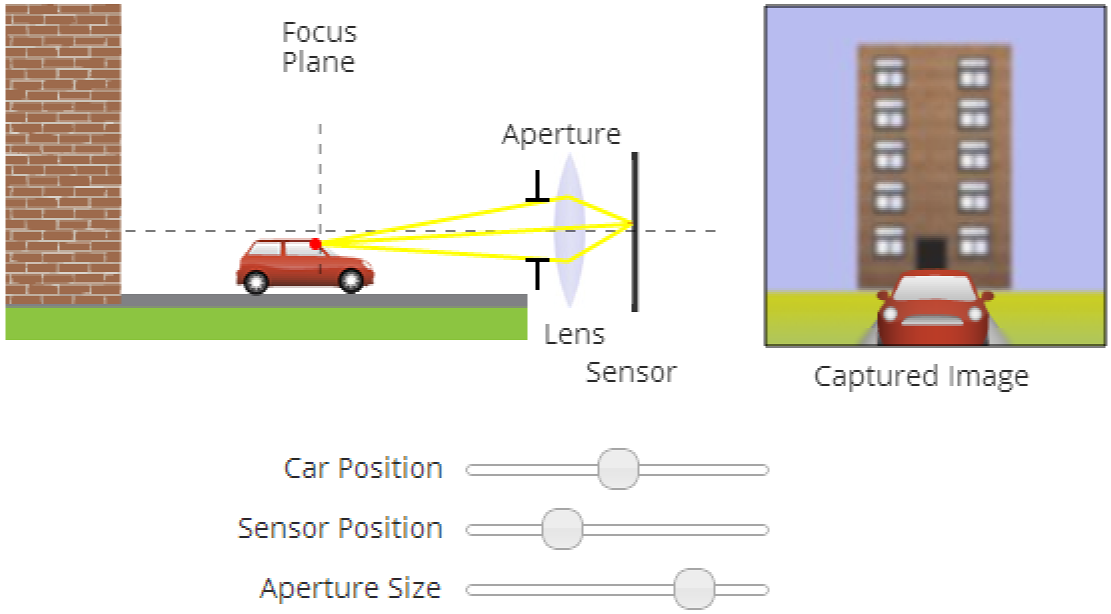


Figure 22: Image formation (Online demo)

a smaller aperture increases the overall sharpness of the image. Reducing the aperture to a tiny hole will turn the lens into a pinhole. As we know, a pinhole camera produces an image without any blur, but it is an extremely dim image.

Let's summarize the process of taking a photo. The lens captures the light from the scene and forms an image on the image sensor. You adjust the relative distance between the lens and the sensor until the object you are interested in is in focus. You then increase or reduce the aperture size to adjust the brightness of the image. With these choices made, you are ready to "shoot" your photo.

Image Sensor

Introduction

In a digital camera, the lens forms an image of the scene on a small electronic chip called the image sensor. The sensor measures this light and converts it to a digital image. Figure 23 shows an image sensor like the one used in Bigshot.

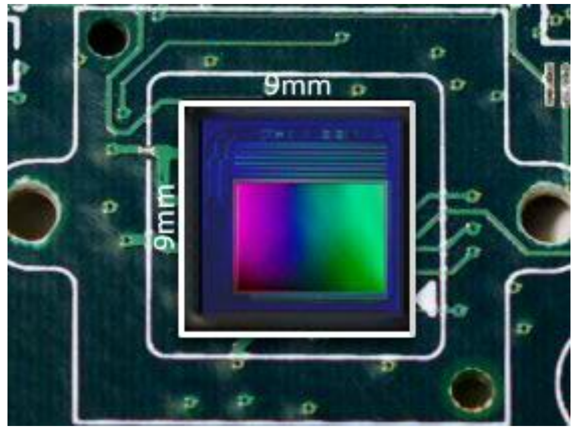


Figure 23: Image sensor (Online demo)

The sensor works much like the retina inside the human eye. On the retina, a dense grid of light-sensitive cells converts incoming light to electric signals. These signals are carried to the brain, where they are interpreted as images. Similarly, Bigshot's image sensor has a grid of detectors called picture elements, or pixels for short. Place the mouse over Figure 23 to see how an image sensor's pixels look under a microscope. When exposed to light, each pixel generates an electric charge that is proportional to the brightness of the light it receives. The charge is converted to a number and stored in memory. The numbers collected from all the pixels form a complete digital image.

Let's take a closer look at how an image sensor works.

Pixel: The Picture Element

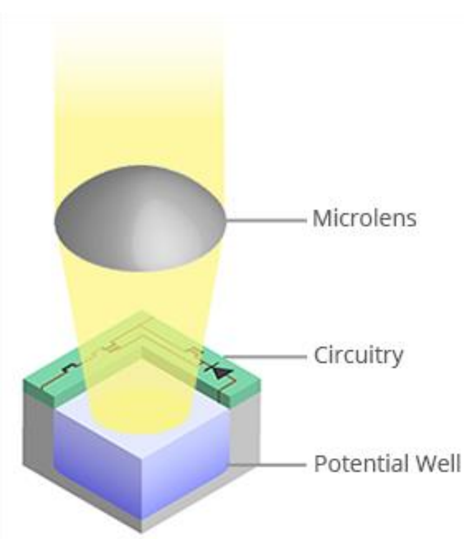


Figure 24: Structure of a pixel

A digital image sensor is a grid of small light-sensing elements called picture elements, or pixels. Each pixel is typically a few microns wide. A micron is a millionth of a meter.

Figure 24 shows the structure of a single pixel. The pixel's detector (shown in blue) is generally made of silicon and is "sensitive" to light. When light strikes the pixel, some of its energy is transferred to the electrons inside the silicon atoms. If the energy is high enough, the electrons dislodge from their parent atoms. This is called the *photoelectric effect* [4].

The freed electrons are collected in a bucket-like region known as the *potential well*. The number of freed electrons – the amount of charge that builds up in the potential well – directly depends on how much light falls on the pixel. The stronger the light, the more electrons are freed. Therefore, the voltage in the potential well is a measure of the image brightness at that pixel.

Bigshot uses a type of image sensor called Complementary Metal Oxide Semiconductor (CMOS, pronounced "see-moss"). In CMOS sensors, each pixel has its own circuitry for measuring the voltage of its potential well [5]. As seen in Figure 24, the circuit takes up precious real estate on each pixel which could otherwise be used by the light sensitive detector. To address this problem, each pixel is equipped with a microlens (a tiny lens) that focuses the incoming light away from the circuitry and onto the detector. Thus, each pixel is able to capture all the light focused by the imaging lens onto it.

Image Sensor: A Grid of Pixels

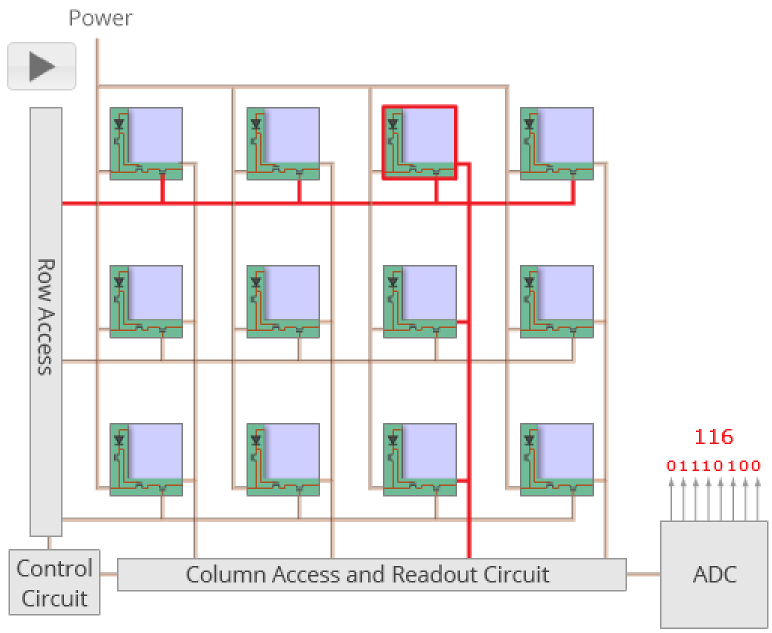


Figure 25: Image readout circuit (Online demo)

An image sensor is usually a two-dimensional grid of pixels. The number of pixels on the grid is called the *resolution* of the image sensor. Bigshot has a 3 megapixel sensor, which means it has about 3 million pixels (arranged in a grid of 1536 rows and 2048 columns).

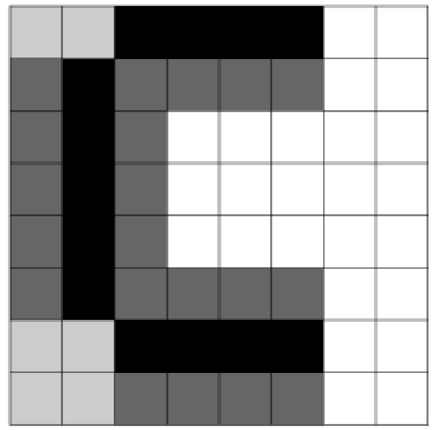
Figure 25 shows a small (3×4) grid of pixels – each with its own microlens and circuitry – connected to an external *read-out circuit*. Each pixel generates a voltage (measured in *volts*) that is proportional to the light energy falling on the pixel. The voltages of the entire grid of pixels are read out one pixel at a time and converted to numbers by the analog-to-digital converter (ADC). Press the play button at the top-left to see the read-out process in action.

The end result of the read-out process is a two-dimensional array of numbers that is called a *digital image*. Each number represents the light energy falling at the corresponding pixel. In an 8-bit sensor, black is 0, white is 255, and all the numbers in between are shades of gray. In Figure 26, a digital image is shown as an array of numbers on the left and brightness levels on the right.

The pixels we have described above can only measure the brightness of the light falling on them – they are color blind. Now, let's take a look at how pixels can measure color.

100	100	0	0	0	0	255	255
50	0	50	50	50	50	255	255
50	0	50	255	255	255	255	255
50	0	50	255	255	255	255	255
50	0	50	255	255	255	255	255
50	0	50	50	50	50	255	255
100	100	0	0	0	0	255	255
100	100	50	50	50	50	255	255

(a)



(b)

Figure 26: Digital and visual representations of an image

Understanding Color

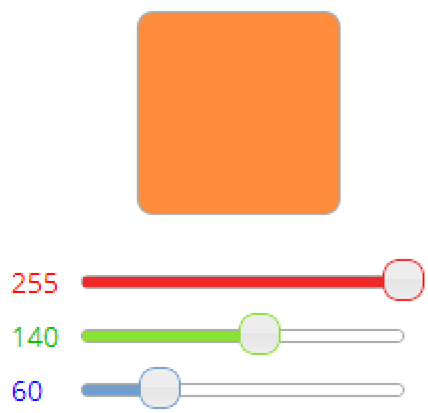


Figure 27: Color mixer (Online demo)

Our eyes can perceive a few million colors. Remarkably, most of these colors can be produced by mixing just the three primary colors of light – red, green and blue – in varying proportions [6]. The demo in Figure 27 shows this phenomenon. Use the sliders to control the amount of each primary color. Think of a color. Can you guess how much of red, green and blue would be needed to make that color?

This demonstration gives us a hint of how we might use our (color blind) image sensor to measure color. If we place a red filter (red-tinted clear plastic) in front of the image sensor, we would get an image where each pixel measures the amount of red light falling on it. If we now take two more images using a green and a blue filter, each pixel would have measured the amounts of red, green and blue light falling on it. These three images together represent a *color image* of the scene. But, is there a way to capture the same information by taking just one image instead of three?

Sensing Color Using Filter Mosaics

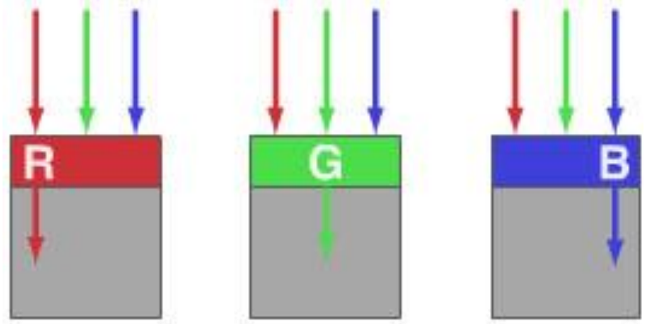


Figure 28: Pixels with color filters

Unfortunately, there is no simple way to have a single pixel simultaneously measure the red, green and blue light falling on it. A red filter placed above a pixel allows just the red portion of the incoming light to pass through and blocks the green and blue portions (see Figure 28). Similarly, green and blue filters allow pixels to measure only the green and blue components of the light, respectively.

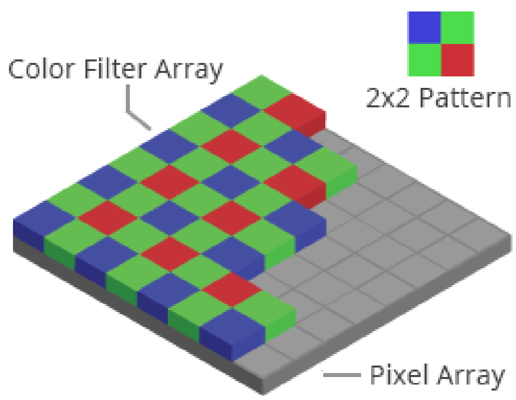


Figure 29: Bayer color filter array

Bigshot's image sensor, like most image sensors, employs a mosaic of tiny red, green and blue color filters, each filter positioned just beneath the microlens of a pixel. A popular design for the mosaic is the Bayer pattern [7] shown in Figure 29. Now the question is, how do we estimate the red, blue and green light falling on any given pixel, if it is able to receive only one of the three colors – red, blue or green?

Figure 30a shows a 3×3 grid of pixels in the Bayer pattern. Let us assume the number at each pixel to be the amount of red, green, or blue light it detects. For example, the red component of the center pixel is 246, but its green and blue components are unknown. The two missing colors are estimated using the green and blue measurements made by neighboring pixels. This process is called *interpolation*.

The simplest way to interpolate the missing values is to average the values of neighboring pixels of the same color (see Figure 30b). So, the interpolated value of the green component at the center pixel is (163+165+161+155)/4=161. The interpolated value of the blue component is (192+190+186+188)/4=189. The detected red value along with the interpolated green and blue values together make up the final color (246, 161, 189) of the pixel shown in Figure 30b.

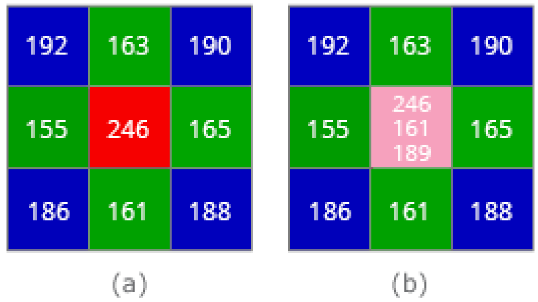


Figure 30: Color interpolation

This way, each pixel will have three values – the actual value of the color it measures through its filter, as well as two interpolated values for the two missing colors. The interpolation is applied to each and every pixel to obtain a full color image. The color interpolation process is known as *demosaicing*. Click on the play button in Figure 31 to see demosaicing in action.

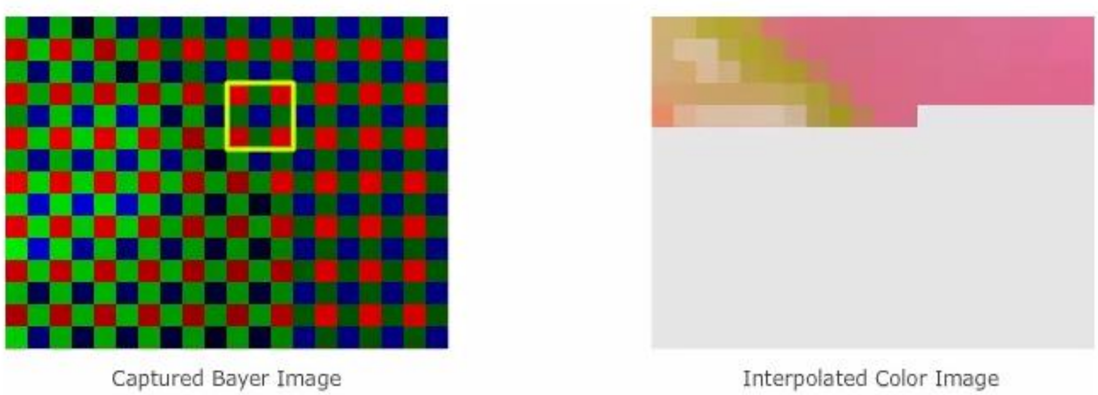


Figure 31: Demosaicing (Online demo)

Polyoptic Wheel

Introduction

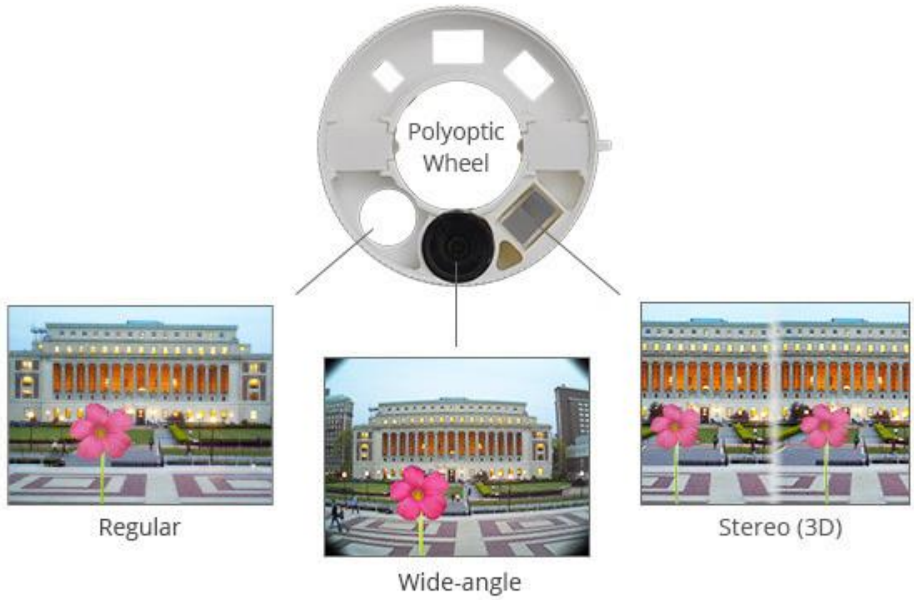


Figure 32: Bigshot's polyoptic wheel and the types of images it captures

You may have seen a Swiss Army® Knife, which is a compact, foldable gadget that includes a variety of tools such as knives, screwdrivers and scissors. Likewise, Bigshot's polyoptic wheel includes several optical modules that allow you to explore different creative dimensions as a photographer. The optical modules on the wheel work with the primary lens on Bigshot's printed circuit board (PCB) to capture three types of photos – regular, wide-angle (panoramic) and stereo (3D). As seen in Figure 32, the wide-angle photo appears distorted and the stereo photo has two views within the same image. These photos are automatically processed after they are downloaded from the camera to generate the final panoramic and 3D photos. In this section, we take a closer look at how the lens wheel works.

Afocal Optics

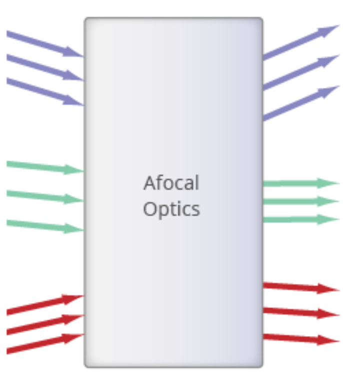


Figure 33: Afocal optics

Since the focus of the primary lens (which sits outside the lens wheel on the camera's PCB) is fixed once and for all, the modules on the wheel should not introduce any additional focusing, else the final captured image will be blurred. That is, they should not converge or diverge incoming light beams – they can only change the direction and thickness of an incoming beam of parallel light rays, as shown in Figure 33. Such an optical module is called afocal [8] and can be designed to increase or decrease the field of view of the primary lens while keeping the image sharp (focused) [9].

Regular Lens

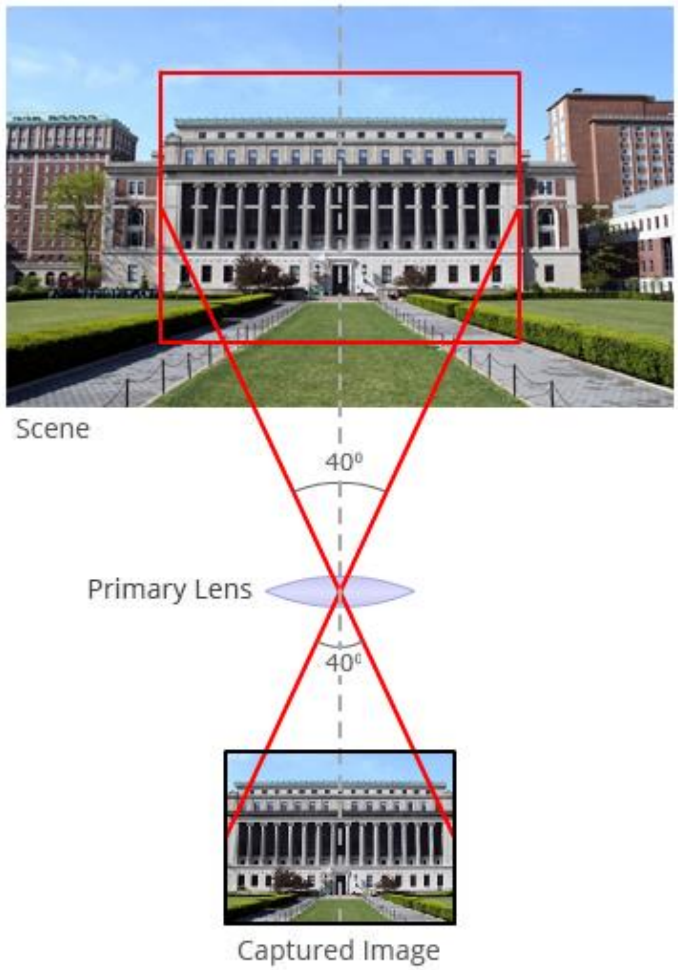


Figure 34: Image formation with the primary lens

The polyoptic wheel's first setting allows the user to take regular perspective photos, of the type taken by any other camera. For this setting, the wheel does not use an optical module, just a hole through which light from the scene passes to the primary lens on the printed circuit board. Figure 34 shows a simplified (single lens) version of Bigshot's primary lens, which has a field of view of 40° in the horizontal direction. The lens projects this field of view (shown using the red rectangle) onto the image sensor. For more details of how lenses work, visit Imaging Lens section.

Wide Angle Lens

The polyoptic wheel's second setting allows you to take wide-angle images with a horizontal field of view (FOV) of 80°. In this setting, a wide angle lens on the wheel works with the primary lens on the PCB. The captured image is bulgy-looking and is said to have "barrel" distortion. When it is downloaded from the camera, the image is converted by Bigshot's software into a distortion-free *panoramic* photo.

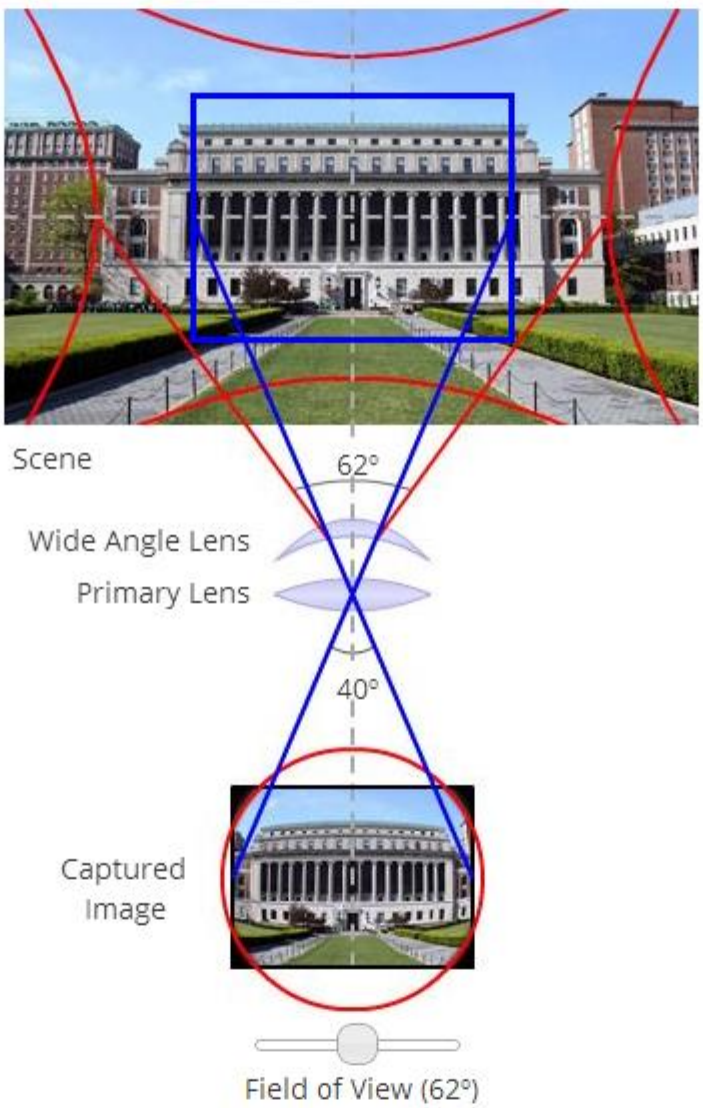


Figure 35: Image formation with a wide-angle lens (Online demo)

Figure 35 compares the FOV captured by the wide-angle lens together with the primary lens (shown in red), to that captured by the primary lens alone (shown in blue). Although the wide-angle lens has a fixed shape, you can use the slider to see how a designer might alter the shape of the lens to vary the field of view.

Stereo Prism

In 1838, Charles Wheatstone, a British scientist, discovered that the horizontal separation between our two eyes is what allows us to perceive depth (how far objects are from us) [10]. One eye sees what the other eye does, but from a slightly different viewpoint. In these two images, an object will appear in different locations, and the relative shift between these locations depends on how far the object is. The closer the object is, the greater the shift. The brain uses the two images to estimate the depths of objects in the scene. Therefore, if the two eyes are presented two different views (called a stereo pair) of the same scene, the brain is able to perceive depth. This technique is known as *stereoscopy*.

An *anaglyph* image is a special kind of stereo pair where the red color from the first image is combined

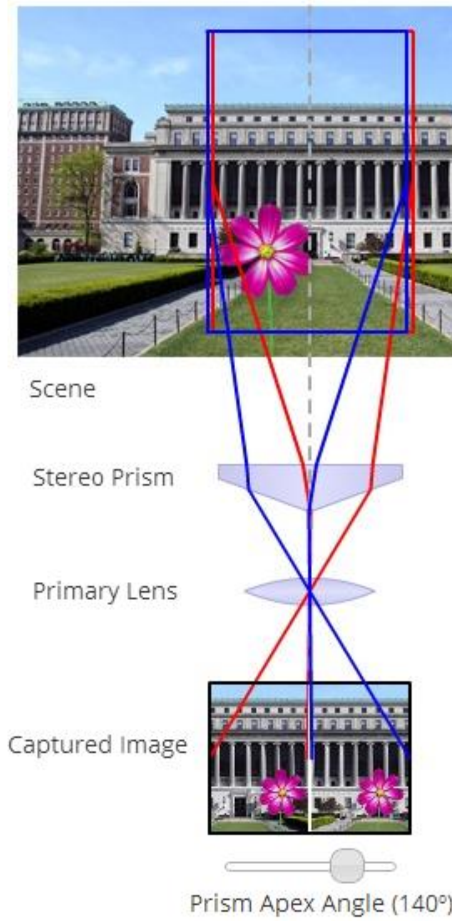


Figure 36: Stereo (3D) image formation with a biprism (Online demo)

with the blue and green colors of the second image. Since objects are shifted in the two images, an anaglyph image looks blurry when viewed normally. To experience 3D perception, one must view the anaglyph using red-cyan tinted glasses – with the red-tinted glass on one eye and the cyan-tinted on the other. The red-tinted eye sees only the red component of the first image and the cyan-tinted eye sees only the blue-green component of the second image in the anaglyph. Our brain then combines these two views to perceive depth.

Traditionally, stereo pairs are captured using two cameras placed side-by-side. However, Bigshot captures the stereo pair with a simple *biprism* [11] [12]. The demo in Figure 36 shows how a biprism captures the two perspectives. If the prism were absent (move the slider to the left to make the prism a flat sheet), then the captured image is exactly the one produced by just the imaging lens. On introducing the biprism (move the slider to the middle), the FOV of the primary lens is split into two halves, shown by the red and blue rectangles. The two views are effectively two side-by-side perspectives of the scene, but are captured on the same image sensor. When this stereo pair is downloaded from the camera, Bigshot's software processes it to produce an anaglyph. When you view the anaglyph through red-cyan tinted glasses, you will be able to experience your photo in 3D.

Wheel Position Sensor

The captured wide-angle or stereo photos must be processed using computer software to get the desired panoramas or 3D anaglyphs, respectively. However, before it can process an image, the software must know whether it is a wide-angle or a stereo image, since the type of processing depends on the type of image. For this, Bigshot uses a wheel position sensor that identifies the lens setting being used and embeds this information in each captured photo.

Figure 37: Microswitches

The wheel position sensor is simply a pair of tiny mechanical, push-button switches (see Figure 37) located behind the lens wheel. The switches are very sensitive and can be turned on by applying a small force.

On the back of the lens wheel, there are grooves and bumps that are precisely located to turn on a different combination of the switches for each of the three wheel positions. As shown in Figure 38, when the wheel is in the regular setting, switch S1 is turned off, but switch S2 is turned on. When the wheel set to panoramic, both switches are turned off. Finally, when the wheel is in stereo setting, S1 is on and S2 is off. The camera reads the on and off states of the two switches as 1's and 0's, respectively, and embeds this information within the captured photo. The sequence of 0's and 1's representing each setting is called a *binary sequence*.

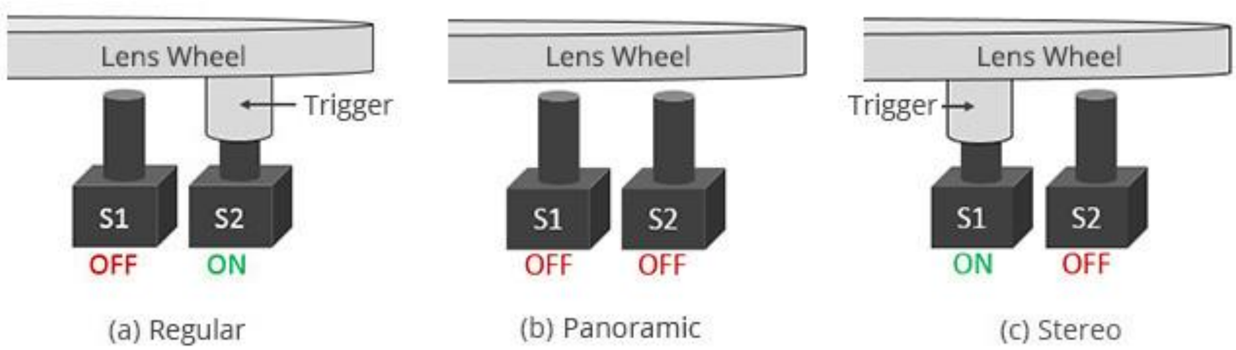


Figure 38: Two microswitches used to detect three settings of the lens wheel

Binary Counting: We just saw that the three positions of the wheel could be uniquely identified by binary sequences of length two: 01, 00, and 10, respectively. Now consider a wheel with many more (say, M) optical modules. How many switches would we need to uniquely identify each of the M positions?

To answer this, we need to understand the concept of *binary counting*. A binary sequence of length two can have four unique values: 00, 01, 10 and 11. So, two switches are required to detect up to four positions. Now consider a binary sequence of length three. It can have eight unique values: 000, 001, 010, 011, 100, 101, 110 and 111. So, three switches can detect up to eight positions. In general, a wheel position sensor with N switches can identify up to 2^N settings. For example, the wheel in Figure 39 uses just 4 switches to identify 16 wheel positions. Use the two buttons to control the position of the wheel and see the outputs of the switches.

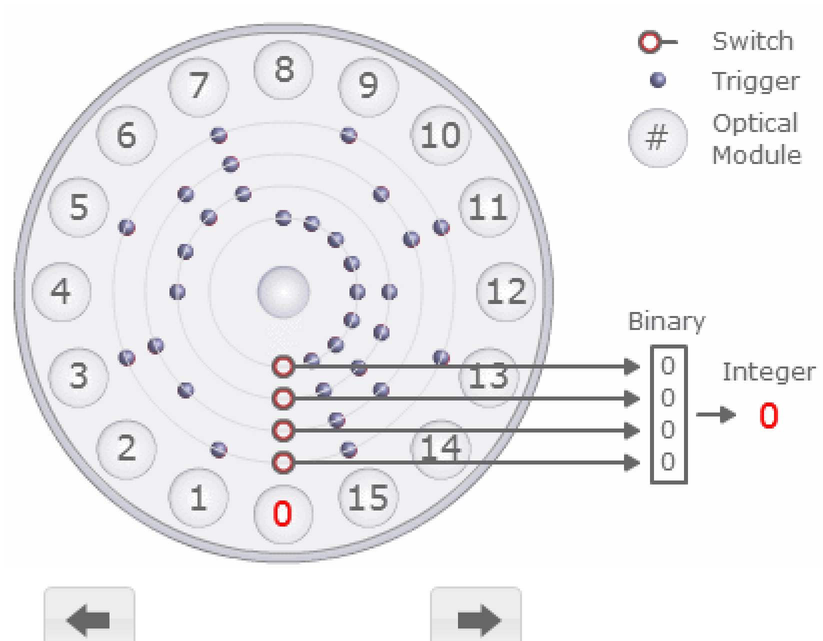


Figure 39: Binary counting enables 4 switches to detect 16 wheel positions
(Online demo)

Viewfinder and Eye

Introduction

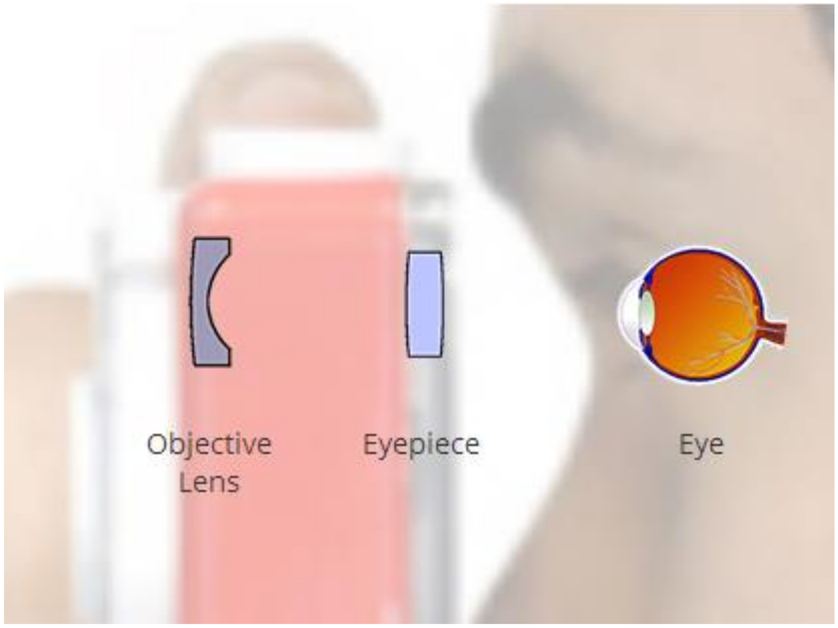


Figure 40: Bigshot's viewfinder (Online demo)

The viewfinder of a camera is a small "window" that the photographer looks through to see the field of view that is captured by the camera's lens. It allows the photographer to frame a scene before taking the photo.

The viewfinder is usually a separate set of lenses that is located above the camera's lens. Unlike the camera's lens, it is not designed to converge light to form an image on its own. Rather, it works together with the lens inside the photographer's eye to form an image on the retina of the eye. Figure 40 shows a photographer looking through Bigshot's viewfinder. Placing the cursor on the figure (or touching it) will reveal the lenses of the viewfinder and the structure of the eye.

Viewfinder Optics

Figure 41 shows the two lenses that make up Bigshot's viewfinder: an eyepiece that is attached to Bigshot's back cover and an objective lens that is mounted on Bigshot's front cover. Together with the lens in an eye, the viewfinder acts as a multi-element (compound) lens that forms a focused image in the eye that has the same field of view as the one formed on the camera's image sensor.

In optics terminology, the viewfinder is *afocal* [13]. That is, it neither converges nor diverges a beam of light it receives (see the rays of light in Figure 41). It only alters the direction and thickness of the beam in order to give the photographer a field of view similar to that of the camera's lens. The task of focusing the incoming light to form an image on the retina of the eye is left to the eye's lens.

Typically, the viewfinder is located above the camera's lens and hence the photographer and the camera view the scene from two slightly different perspectives. As a result, there will be a slight shift – also known as parallax – in what you see through the viewfinder and what the camera captures. The parallax is larger for things that are closer. However, it reduces quickly with distance from the camera and is negligible for distant scenes.

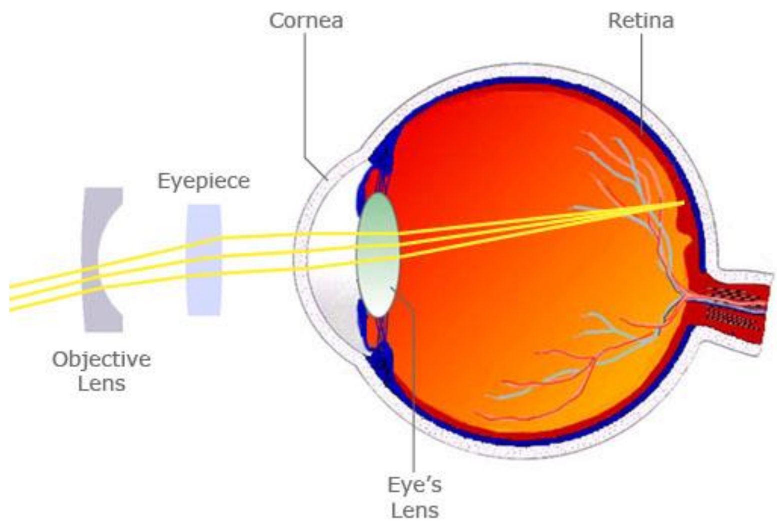


Figure 41: Viewfinder optics

Viewfinder Stencil

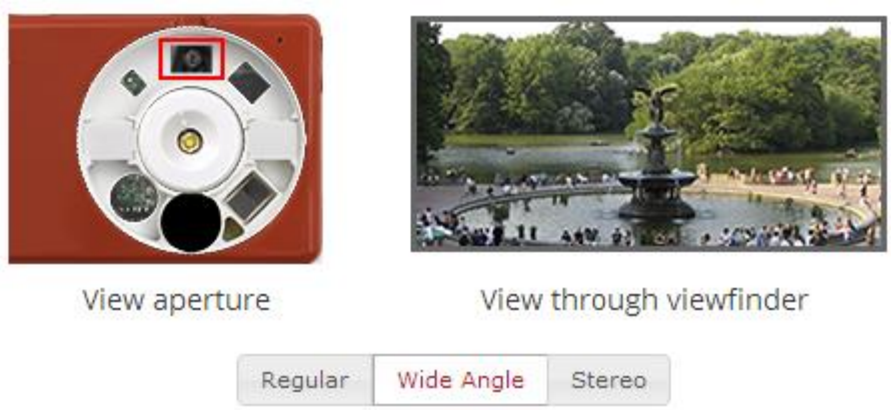


Figure 42: Viewfinder stencils (Online demo)

The viewfinder's goal is to help the photographer frame a photo by providing the same view as that captured by the camera. However, Bigshot's polyoptic wheel has different types of lenses on it, each producing a different horizontal field of view (FOV). The wheel has three settings – regular with a 40° FOV, wide-angle with an 80° FOV, and stereo with a 16° FOV. For each setting, Bigshot's viewfinder needs to convey the appropriate field of view to the photographer.

Bigshot achieves this with a simple trick. The two viewfinder lenses (objective and eyepiece) are designed to produce a field of view that is larger than any of the lens settings. As shown in Figure 42, the top half of the polyoptic wheel has three cutouts, or stencils, that are used to mask the viewfinder's field of view. These stencils are appropriately sized and positioned so that, for each lens setting, the correct field of view is seen by the photographer. Click on the three buttons in Figure 42 so see the viewfinder stencils in action. For each setting, the image on the right shows what the photographer sees.

The Human Eye

The human eye [14] is a remarkable organ. Like a camera, the eye is able to refract light and produce a focused image. This image is recorded, processed and transmitted to the brain. In fact, almost every aspect of the modern camera can be traced back to a feature in the human eye.

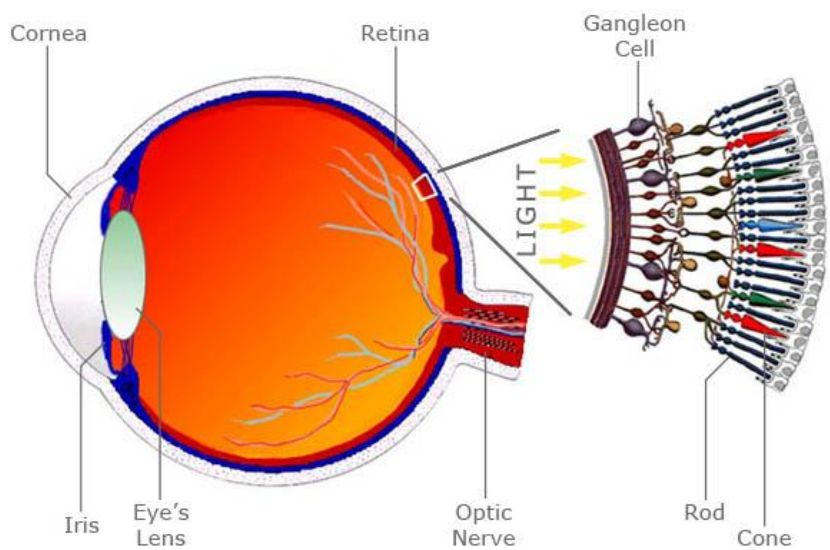


Figure 43: Anatomy of the human eye (Image credit: webvision.umh.es)

The eye is essentially a ball (the eyeball) filled with a water-like fluid. In the front of the ball is a transparent cover known as the *cornea*. The cornea has the dual purpose of protecting the eye and refracting light as it enters the eye. After light passes through the cornea, a portion of it passes through an opening (aperture) known as the *pupil*. A diaphragm, called *iris* (the colored part of the eye), can enlarge the pupil in low-light conditions to let in more light or reduce it in very bright conditions to let in less light.

Light that passes through the pupil enters the eye's imaging lens, which is made of a transparent fibrous material. Unlike most camera lenses, the eye's lens is able to change its shape. This property of the lens is used for focusing. The lens squishes (gets more curved) when we look at very close objects and relaxes (gets flatter) when we look at distant objects.

The inner surface of the eye on which the image is focused is known as the *retina*. The retina contains two types of light sensing cells – *rods* and *cones*. The rods detect the brightness of the image formed on them and the cones sense the color. They send the detected brightness and color information as nerve impulses to the brain via the optic nerve. The brain, upon receiving these impulses, interprets them as images.

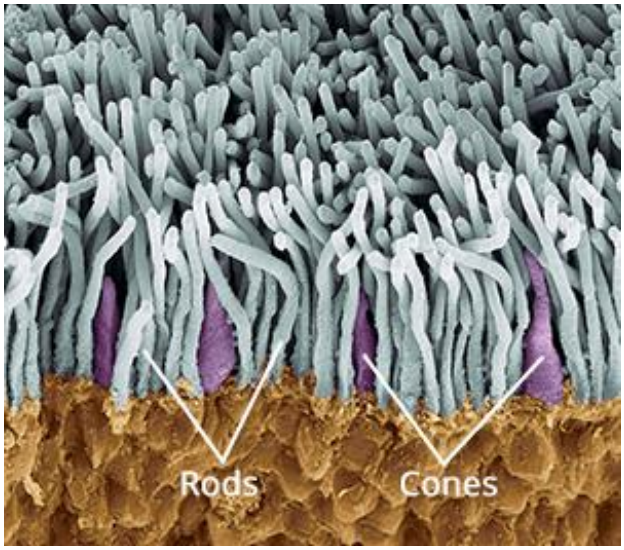


Figure 44: Rods and cones on a retina

As we can see, the similarities between a modern camera and the human eye are striking. The camera is not just inspired by the eye, it actually imitates it closely. The camera's lens is like the eye's lens and cornea, the aperture of a camera lens is akin to the iris, the image sensor plays the role of the retina and the pixels are like rods and cones.

LED Flash

Introduction

Figure 45: A light emitting diode

Photos taken in dim lighting tend to be dark. Thus, cameras are often equipped with a flash. While taking a photo, if the camera senses that the scene is dark, it flashes light on the scene before recording the photo.

While most cameras use a Xenon bulb for a flash, Bigshot uses a Light Emitting Diode (LED). Even though they are not as bright as Xenon bulbs, LEDs are smaller, last longer, require less power and are highly efficient. Almost all of the power that they consume is converted into light and very little is lost in the form of heat.

Due to these advantages, LEDs are now widely used in everyday electronic devices such as TVs, computer monitors, traffic signals and streetlights. Recently, LEDs are even being used for home lighting and in automobile headlamps. Figure 45 shows an LED embedded inside an epoxy bulb. In what follows, we will describe how an LED works.

Semiconductors That Emit Light

Semiconductors are materials that can conduct electricity fairly well – better than insulators but not as well as conductors. This property makes them unique and extremely useful. Common semiconductor materials include silicon, germanium, gallium arsenide and silicon carbide. Semiconductors are the foundation of modern electronics and are widely used in everyday devices like phones and computers.

Semiconductors in their pure (normal) state are often not as useful as in their impure state. A semiconductor can be made impure by adding and/or removing electrons from some of its atoms. As shown in Figure 46, an *n-type semiconductor* has an abundance of additional electrons. In a *p-type semiconductor*, some atoms have one or more electrons removed from them to create "holes". Due to the missing negatively-charged electrons, holes are said to be positively charged. Typically, when electrons and holes are brought together they will recombine. During recombination, the electrons will lose energy in the form of either heat or light, depending on the type of semiconductor used.

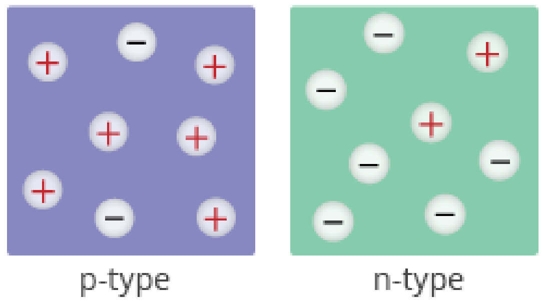


Figure 46: n-type and p-type semiconductors

An LED uses n- and p-type semiconductors and the process of recombining electrons with holes to produce light. Different semiconductor materials produce different colors (wavelengths) of light. For example, aluminium gallium arsenide produces red light, indium gallium nitride produces green light and zinc selenide produces blue light.

Light Emitting Diode

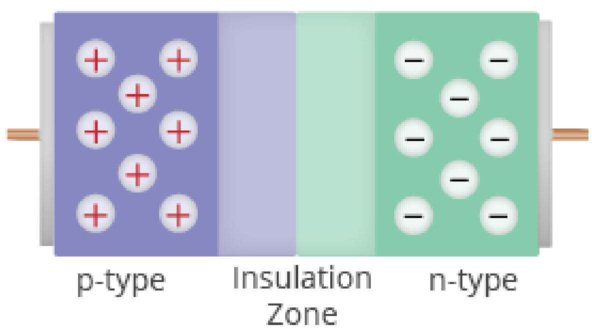


Figure 47: A diode

A *diode* (also called a p-n-junction) is a simple electronic device that is formed by simply attaching an n-type and a p-type semiconductor to each other, as shown in Figure 47. On attaching the two semiconductors, a weak *insulation zone* forms at the edge between them. This zone prevents the negatively charged electrons in the n-type material from combining with the positively charged holes in the p-type material. As seen in Figure 47, the diode has positive and negative charges bunched up on the two sides of the insulation zone. In this state, the diode is said to be turned off.

The weak insulation zone can be overcome by applying a high enough voltage between the two ends of the diode. That is, the diode can be turned on by connecting the p-type and n-type semiconductors to the positive and negative ends, respectively, of a power source such as a battery, as shown in Figure 48. This allows the charges to pass freely through the insulation zone. When pairs of electrons and holes collide and recombine with each other, they release energy as flashes of light. Hence the name light emitting diode. When an LED is turned on, millions of electron-hole pairs recombine simultaneously, making the LED appear as if it is glowing like a bulb. When the power source is

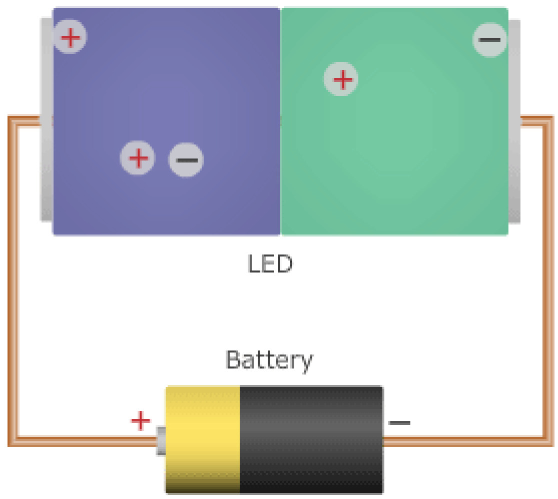


Figure 48: A light emitting diode in action (Online demo)

disconnected, the insulation zone is formed again, the electrons and holes stop recombining, and no light is emitted.

LCD Display

Introduction

Figure 49: Bigshot's liquid crystal display

Liquid crystal displays (LCDs) are flat, thin electronic displays. You can find them in watches, cameras, cell phones, tablets, TVs and many other electric and electronic gadgets. LCDs are lighter and require significantly less power than older display technologies. They are so widely used that there is a good chance you are reading this article on an LCD screen.

The LCD, similar to an image sensor, has a two-dimensional grid of pixels. Instead of measuring light, however, each pixel in the LCD emits light. Since the brightness of each pixel can be controlled independently, the display can be used to show an image.

The working principle of an LCD is based on a fascinating property of light called polarization and a special type of material called liquid crystal that can control the polarization of light. Keep reading to learn about these and how they come together to bring an LCD to life.

Light Polarization

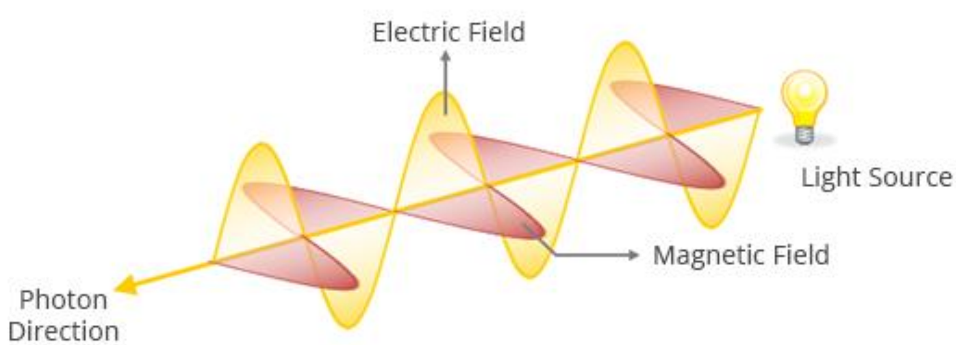


Figure 50: Wave nature of light

It is easy to visualize a light ray as a stream of particles (called *photons*). But, did you know that light can also be described as waves? In fact, a single photon can be considered as two waves of electric and magnetic fields – one perpendicular to the other. Figure 50 shows a light wave with its electric and magnetic components. In Figure 51a, the illustration of a light wave is made simpler by showing just its electric field.

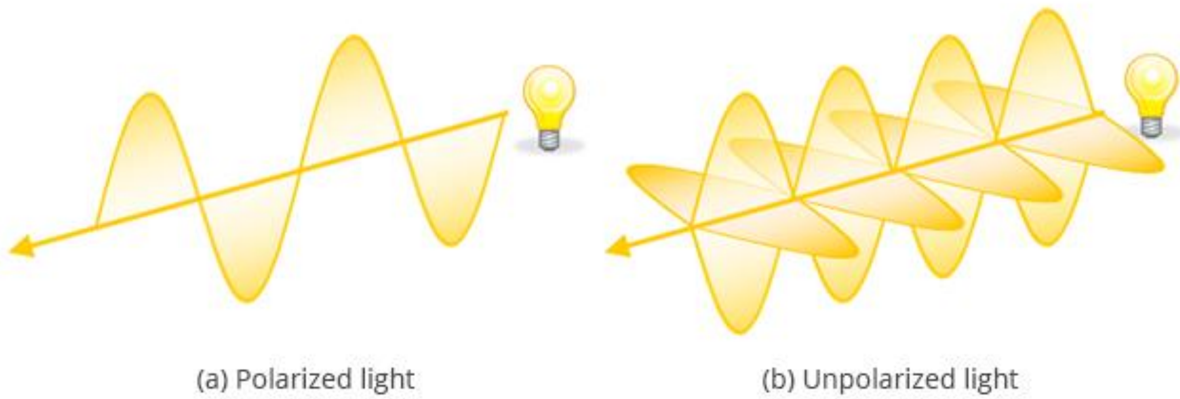


Figure 51: Polarized and unpolarized light

A light source like an electric bulb contains a large number of molecules that emit light. If the orientations of the electric fields produced by these emitters are the same, then we say the light is *polarized*. The single light wave shown in Figure 51a is of course polarized. The direction of polarization (or polarity) is said to be along the plane of the electric field. In most cases, however, the electric fields emitted by the particles are not aligned. That is, the light is composed of many light waves with electric fields in practically every direction. In Figure 51b, the light is composed of two waves with perpendicular electric fields. Such light has no single polarity and is said to be unpolarized.

Polarization Filter

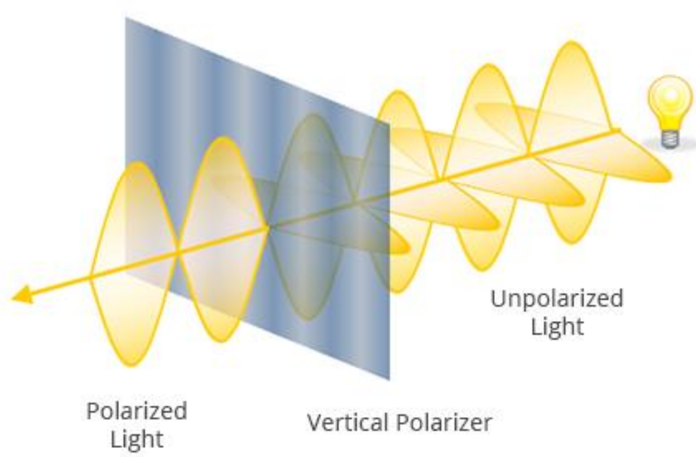


Figure 52: A vertical polarizer only permits vertically polarized light to pass through

A polarizing filter is a material, usually a special type of transparent crystal, which allows light waves of a specific polarization direction to pass through it. Figure 52 shows a vertical polarizer at work. Vertically polarized light waves pass through the filter unaffected, while horizontally polarized waves are completely blocked by it. What happens to a wave that is in between horizontal and vertical polarization? Such a wave can be thought of as being made of a vertical and a horizontal component, and only its vertical component passes through the filter. As a result, its strength is diminished.

In the demo in Figure 53a, we have a polarizer P1 placed in front of a regular white light source. The light emitted by the source is unpolarized (includes waves of all polarizations). The light coming through the filter has been polarized and, in the process, it loses half its brightness. This is true regardless of how P1 is rotated. You can see this by using the slider to rotate P1.

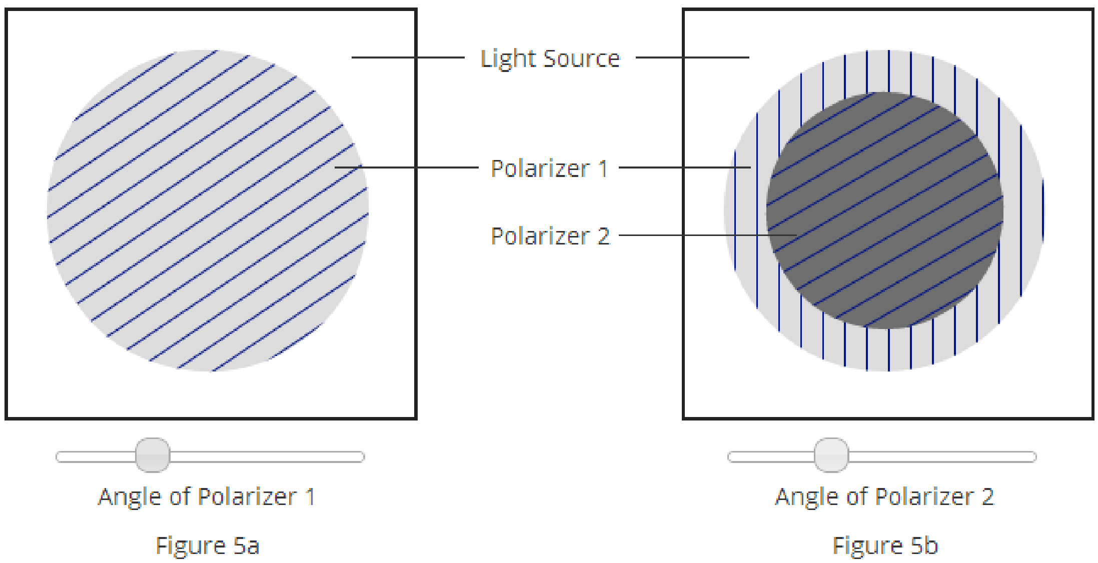


Figure 53: Controlling the brightness of light using polarizers (Online demo)

In Figure 53b, we have a second polarizer P2 placed in front of P1. Move the slider to the extreme left to align the polarization directions of both the filters. You see that P2 passes all the light from P1 through it. Now, if you slowly rotate P2 by moving the slider to the right, the light passing through P2 gets dimmer and dimmer, until it gets completely blocked when the polarity of P2 is perpendicular to that of P1.

The use of two polarizers to control the brightness of light is the core principle behind LCDs. However, in an LCD, the brightness of each pixel needs to be independently controlled. Since a typical display has millions of pixels, it would be impractical to mechanically rotate polarizers within each one of the pixels. In the next section, we learn about a new type of material called a liquid crystal and how it helps overcome this problem.

Liquid Crystals

The name "liquid crystal" sounds like a contradiction, but it is a state of matter that has properties between those of solid crystals and liquids. Like ordinary liquids, its molecules are free to move about.

At the same time, like solid crystals, the orientation of its molecules can be aligned with one another in a regular pattern.

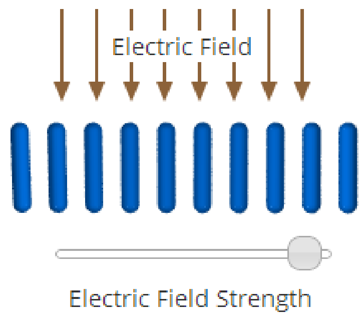


Figure 54: In-plane-switching of liquid crystals (Online demo)

LCDs commonly use what are known as *Twisted Nematic* (TN) crystals. The molecules of a TN liquid crystal are cylindrical and are oriented in a twisted pattern as shown in Figure 54 (move slider to the left). The first molecule is perpendicular to the last molecule, and the in-between molecules automatically align themselves to form a twisted structure.

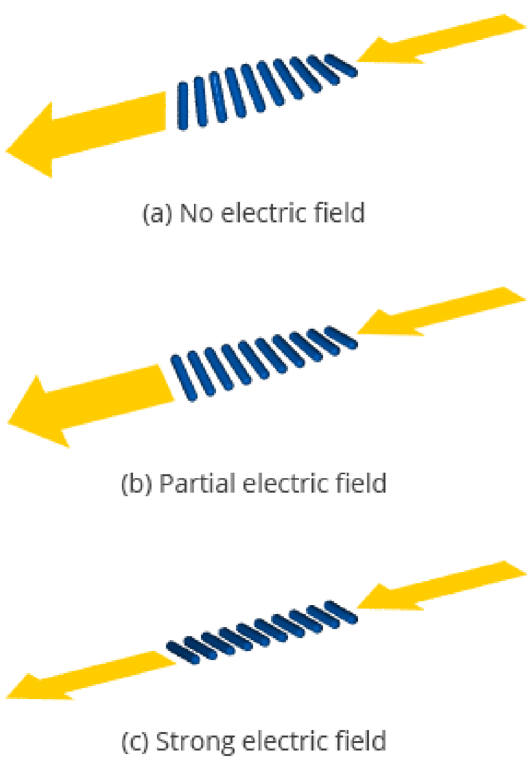


Figure 55: Effect of liquid crystals on light polarization

These liquid crystals have two special properties that play a critical role in LCDs. The first is their ability to orient themselves along an electric field when one is applied. In the demo in Figure 54, when you increase the strength of the applied electric field by moving the slider to the right, the molecules of the liquid crystal get untwisted. For a strong field, the molecules are all aligned with the field. The second property is the ability of liquid crystals to twist the polarization of light passing through them. As shown in Figure 55, when no electric field is applied across the crystal, its molecules rotate the plane of polarization by 90 degrees. That is, horizontally polarized light becomes vertically polarized. When a partial electric field is applied, the polarization plane is partially twisted to be between horizontal and vertical. When a strong electric field is applied, the light passes through with its polarization unchanged.

Now, let us look at how polarizers and liquid crystals can be put together to control the brightness of an LCD pixel.

LCD Pixel

A pixel in a liquid crystal display is a thin multilayered sandwich of many components, as shown in Figure 56. It has two horizontal polarizers, one at the back and the other in front. In between these

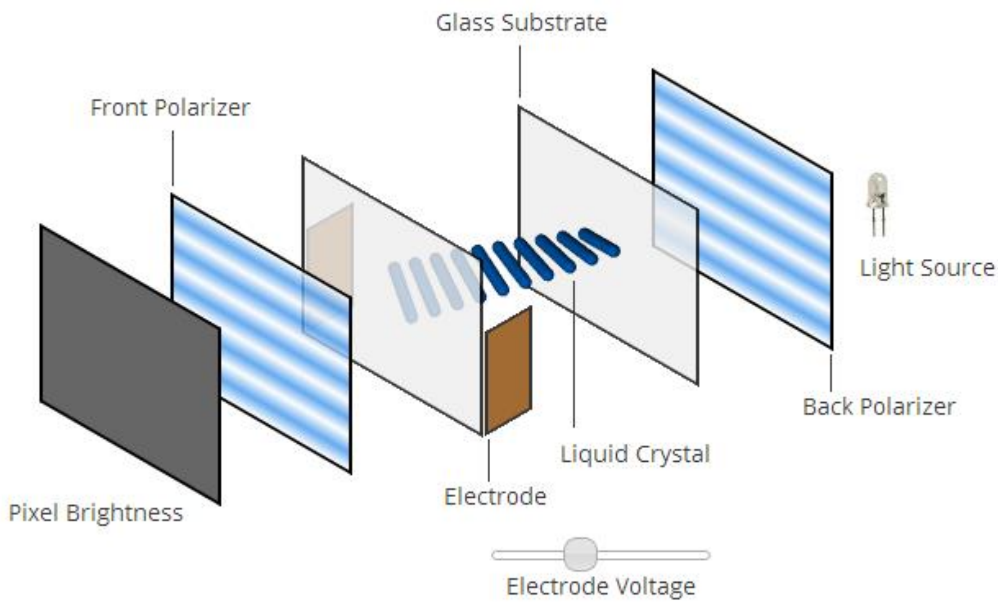


Figure 56: Structure and working of an LCD pixel (Online demo)

two, is a sandwich of electrodes and liquid crystals. All pixels in an LCD are illuminated using an unpolarized light source, such as an LED.

Brightness: The light from the light source passes through the back polarizer and becomes horizontally polarized. When the slider in Figure 56 is at the extreme left, no voltage is applied between the electrodes, and the liquid crystals rotate the polarization of this light by 90 degrees. However, this vertically polarized light is completely blocked by the horizontal polarizer in the front and we see a dark (black) pixel.

Now move the slider to the extreme right to apply the maximum voltage between the electrodes. The resulting electric field is strong and it causes the horizontally polarized light to pass through the liquid crystal unchanged. It then passes through the front polarizer unhindered and we see a bright (white) pixel. To display shades of gray, use the slider to apply a partial voltage between the electrodes. The beauty of this system is that the brightness of each pixel can be chosen by simply controlling the voltage applied to it, without the use of moving parts.

Color: Displaying color in an LCD is simple. Each pixel is physically divided into three smaller sub-pixels, as shown in Figure 57. The three sub-pixels are covered with red, green and blue filters and are used to display the brightnesses of the red, green and blue components of light, respectively. Although the sub-pixels operate as independent pixels, given their tiny size and proximity, our eyes will fail to distinguish them as separate pixels. Instead of seeing three separate pixels, we perceive them as one pixel emanating a combination of red, green and blue light. As we described in Image Sensors, virtually

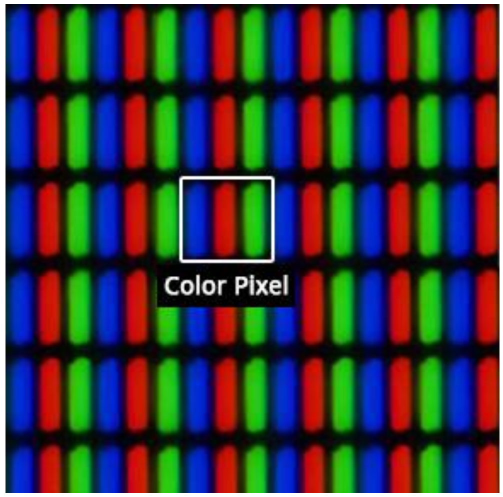


Figure 57: An LCD under a magnifying glass reveals that each pixel is made of red, green and blue sub-pixels

all the colors we sense in the real world can be produced using different combinations of red, green and blue light.

Electronics

Introduction

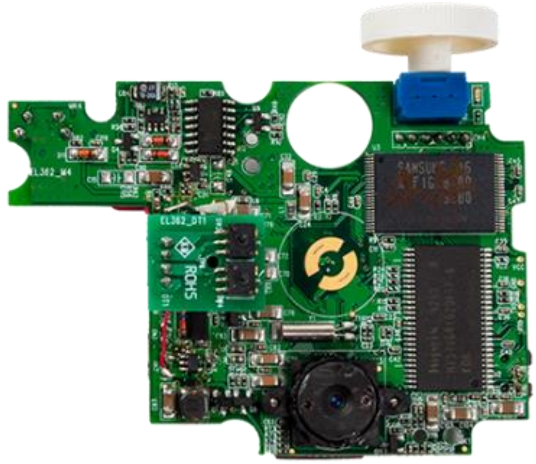


Figure 58: Bigshot's printed circuit board (PCB)

We know from the previous sections that Bigshot uses mechanical components (such as gears) to generate power, optical components (such as lenses) to form an image, and a display (LCD) to show captured photos to the user. However, to measure, compress and store images, as well as provide visual and auditory feedback to the user, Bigshot relies on a set of electronic components. These components are mounted on a green printed circuit board (PCB), as shown in Figure 58. The PCB has built-in wiring that connects the various components and allows them to communicate with each other. Let's take a closer look at some of Bigshot's main electronic parts.

Electronics Components

Bigshot's key electronic components can be divided into three categories: photo capture components, user interface components and the camera controller. The photo capture components include the image sensor, camera flash and memory. They are responsible for capturing and storing photos. The interface components, which include the mode dial, shoot switch, liquid crystal display (LCD), LED indicators, buzzer and the universal serial bus (USB), allow the photographer to interact with Bigshot. For instance, the photographer can control Bigshot using the mode knob and shoot button and get visual feedback via the LCD. The camera controller is the brain of the camera and coordinates the operation of all the electronic components. Figure 59 shows some of the key electronic components in Bigshot. Click on the buttons to find the components and learn what they do.

Camera controller: This is the brain of Bigshot. Similar to the central processing unit (CPU) of a computer, it follows a set of predefined instructions (called firmware) to control and coordinate all other components of the camera. The controller is fast enough to read (fetch), understand (decode) and follow (execute) millions of simple instructions per second.

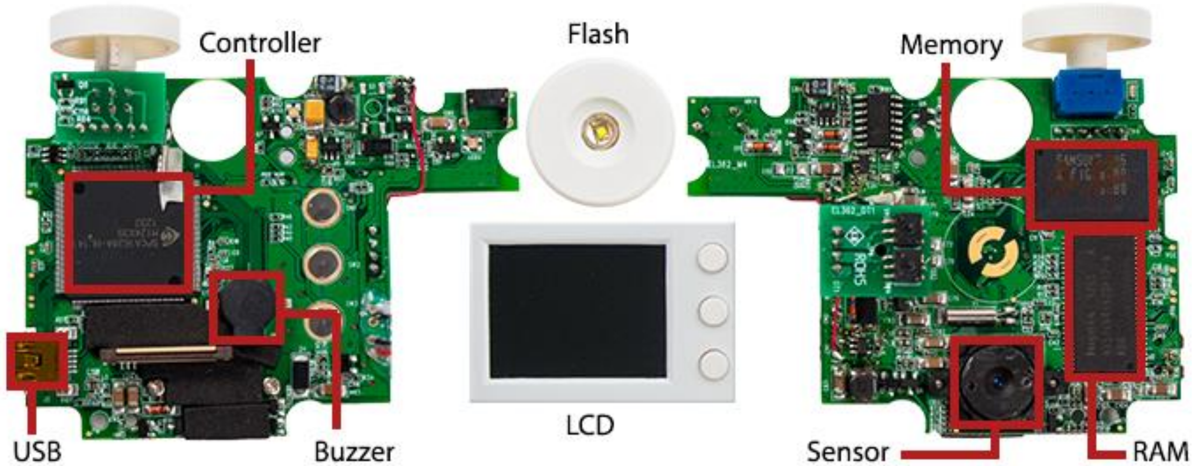


Figure 59 : Bigshot's electronics components (Online demo)

Universal Serial Bus (USB): This is a widely used technology that enables devices to communicate with each other. USB devices use a simple "language" (also called communication protocol) to "talk" to other USB devices. USB is used by virtually all commercial digital cameras, cell phones and music players. Bigshot uses it to enable you to download photos to a computer.

Buzzer: A buzzer is an electro-mechanical device that produces a beeping sound. It is often used in alarm clocks, timers and other devices to provide audible feedback to the user. For instance, the buzzer in Bigshot beeps to let you know when it is done taking a photo.

LED Flash: When a picture is taken of a dim scene, the camera flash lights up the scene so that the photo taken will be brighter. Bigshot uses an LED (Light Emitting Diode) as a flash bulb. LEDs are tiny electric bulbs that are energy efficient.

Image sensor: This is a tiny electronic chip consisting of an array of light-sensitive elements called pixels. Each pixel measures the light focused onto it by the imaging lens. The independent measurements made by all the pixels on the sensor, together, form a digital image. Bigshot's image sensor has 2048x1536 pixels.

LCD: Bigshot uses its LCD (liquid crystal display) to provide an instant preview of captured photos. Although the LCD is just a few millimeters thick, it is composed of multiple layers of glass, electronics, color filter arrays and liquid crystals. Today, thin, light and low-powered LCDs are used in computers, TVs, tablets, cameras, cell phones and other electronic devices.

Random Access Memory (RAM): RAM is a temporary storage device that is designed to provide fast access to the data stored in it. When turned on, Bigshot temporarily stores its firmware as well as the photos that need to be displayed on the LCD in the RAM for quick access. RAM loses the data stored in it when the camera is turned off.

Flash Memory: Flash memory (not to be confused with LED Flash) serves as the storage center for captured photos. It is a special type of electronic chip that can retain its information even when the power is turned off. For this reason, flash memory is widely used in memory cards, USB memory sticks, and solid-state hard drives for general data storage.

Firmware

Although the camera's controller coordinates the overall working of the camera and is often referred to as the camera's brain, it does not have any inherent intelligence – it needs to be told how to control the camera. This is done by loading a set of instructions called *firmware* into the controller. Although the firmware is written by a human, it is not in English or any other human language. Simple electronic chips such as the controller can only understand instructions in terms of 1's and 0's – also called *machine language*. The instructions in the firmware determine what the controller should do for every possible usage scenario of the camera. There is even an instruction that tells the controller when to stop reading instructions!

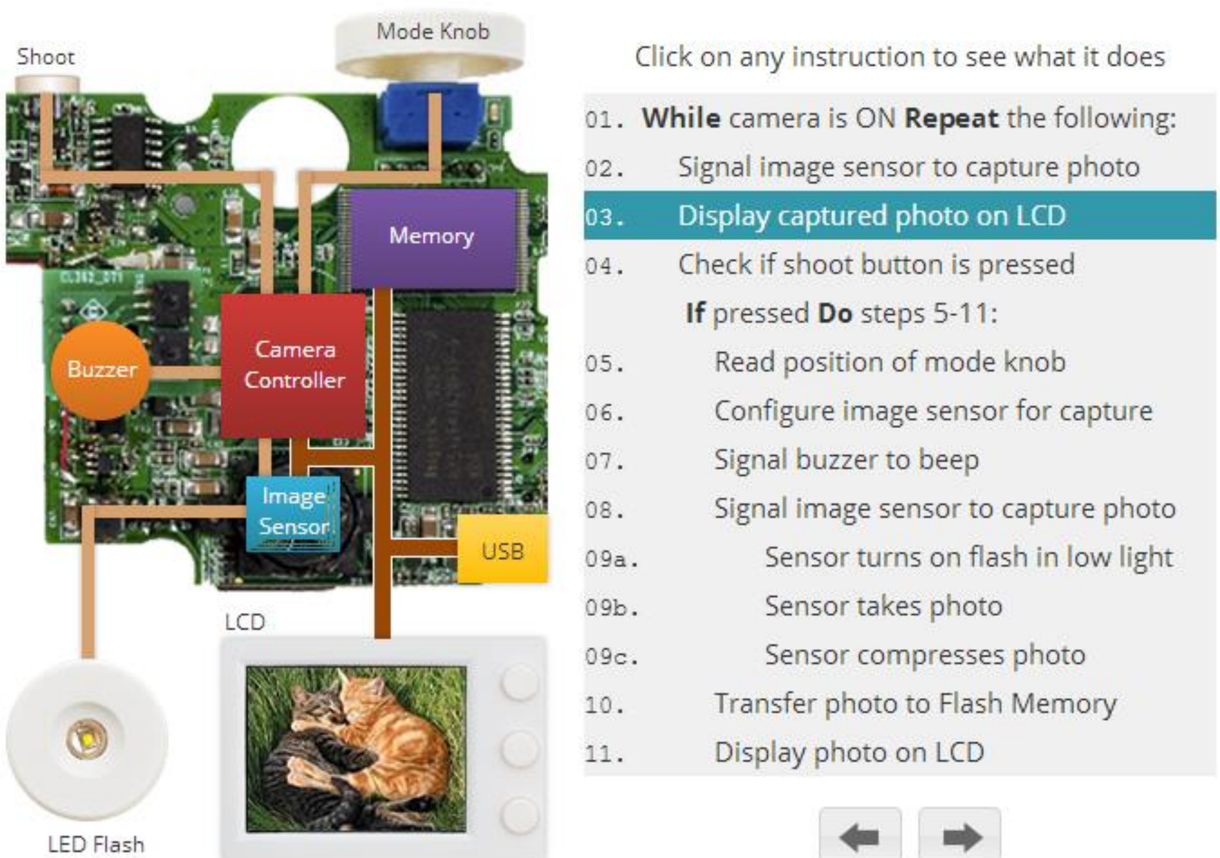


Figure 60: Firmware in action (Online demo)

Firmware in Action

Figure 60 shows Bigshot's firmware in action. While the actual instructions are long and complex strings of 0's and 1's, here they are shown in plain English so we can easily understand the action that results from each instruction. Note that the instructions given in Figure 60 represent a very small piece of the complete firmware. It only describes the sequence of actions taken by the controller in the particular event where the photographer presses the shoot button while the camera is in the Auto Flash mode. Some of the instructions (like Step 8) tell the camera controller to give orders to other components.

Image Processing

Introduction

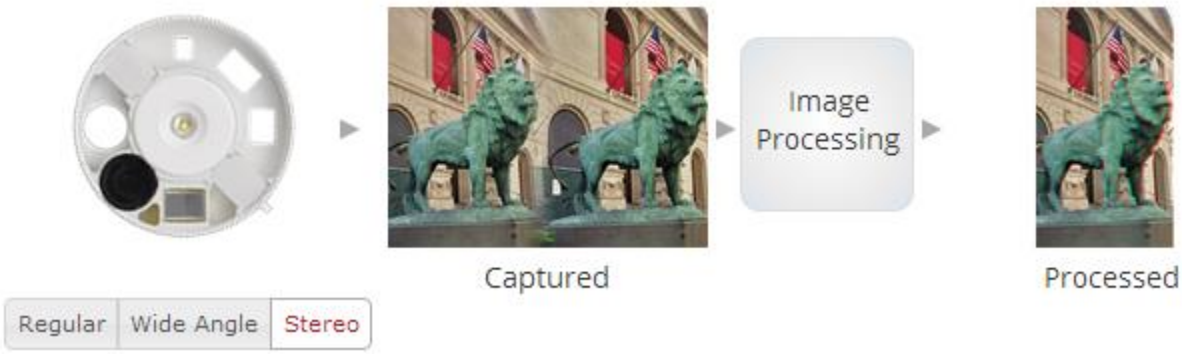


Figure 61: Captured and processed images (Online demo)

Figure 61 shows the three types of images that Bigshot can capture (click on the buttons to control the lens wheel setting). As you can see, the photos taken with the wide-angle lens and the stereo prism are not ready to be viewed by the user – they need to be processed to create panoramic and 3D photos, respectively. Bigshot's computer software applies the appropriate processing to each image after it is downloaded from the camera. The software also enhances the brightness, color and sharpness of the image. If the image is taken under lower light conditions and is noisy (grainy), the software can reduce the noise as well.

In general, the process of editing or modifying images is called image processing. In this section, we look at a few basic image processing operations and how they alter the appearance of a photo.

Image Representation

Figure 62: An image as a set of numbers

Digital photos are represented as a two-dimensional grid of "pixels" (short for picture elements). Associated with each pixel are two pieces of information – its position in the photo and its color. The position of a pixel is its horizontal and vertical distance from the top-left corner of the image. For example, in Figure 62, a pixel with position (56, 60) is the 56th pixel counting from left to right and the 60th pixel counting from top to bottom.

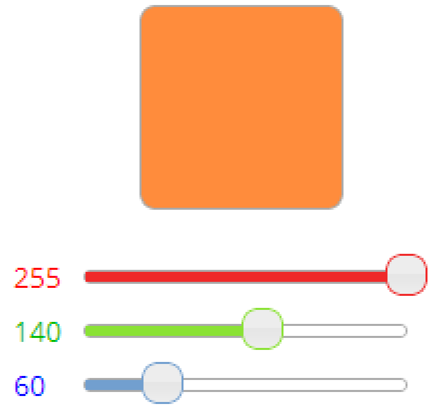


Figure 63: Color mixer (Online demo)

Our eyes can perceive millions of colors. Remarkably, most of these colors can be produced by mixing just three primary colors of light – red, green and blue – in varying proportions [6]. Therefore, the color of a pixel is typically represented using three numbers – the brightnesses of the three primary colors. The interactive demo in Figure 63 shows how red, green and blue can be mixed to generate virtually all the colors we experience. Use the sliders to control the amount of each primary color. You can read more about pixels and color in Image Sensor.

How is an Image Processed?

Figure 64: How an image is processed (Online demo)

Most image processing operations follow a simple procedure. Given an input image, the output image is calculated one pixel at a time. The color at each pixel in the output image is usually some mathematical combination of colors of pixels within a small neighborhood (window) centered on the same pixel in the input image. In some cases, instead of a neighborhood of pixels just the corresponding pixel in the input image is used.

The demo in Figure 64 helps you visualize the above process. The output image is computed one pixel at a time from left to right and top to bottom. In this example, the color of each pixel is calculated using a small window of 3 × 3 pixels centered on the corresponding pixel in the input image. In the following sections, we will describe how three widely used image processing operations work.

Changing Brightness

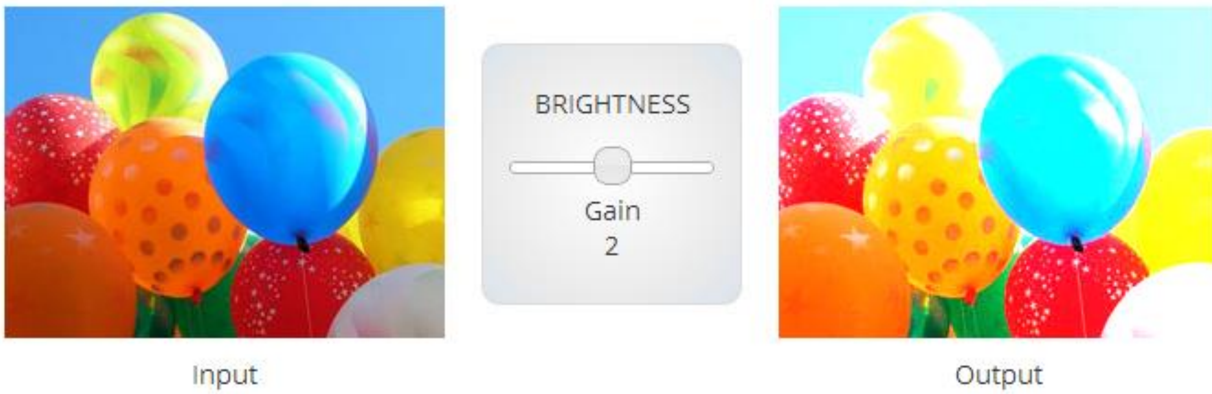


Figure 65: Changing image brightness using gain (Online demo)

The photos we shoot are sometimes too dark or too bright. The brightness levels in these photos need to be adjusted to make them look better. The brightness of an image can be changed by simply multiplying the color values (R, G and B) of each pixel by a single number (α). That is:

$$New\ value = \alpha \times Old\ value.$$

If α is greater than 1, the color values increase, and the image gets brighter. On the other hand, if α is less than 1, the image gets darker. This process is called *gain adjustment*. Drag the slider in the demo in Figure 65 to the right (Gain > 1) to brighten the image or to the left (Gain < 1) to make it dimmer.

You can now imagine applying a variety of simple mathematical operations, like addition, subtraction, multiplication, division, exponentiation, etc., to the color of each pixel to alter the appearance of an image.

Reducing Noise

Figure 66: Comparison of an image with (left) and without (right) noise

Images captured using digital cameras usually have randomly distributed speckles on an otherwise smooth area (see the green background in the left image of Figure 66). These speckles are just random fluctuations in brightness and are referred to as *image noise*. Noise makes images appear grainy and hence is undesirable.

Noise is caused by various factors, including, imperfections in the camera electronics, malfunctioning pixels, and errors in the analog-to-digital converter (see Image Sensor). The only way to reduce noise

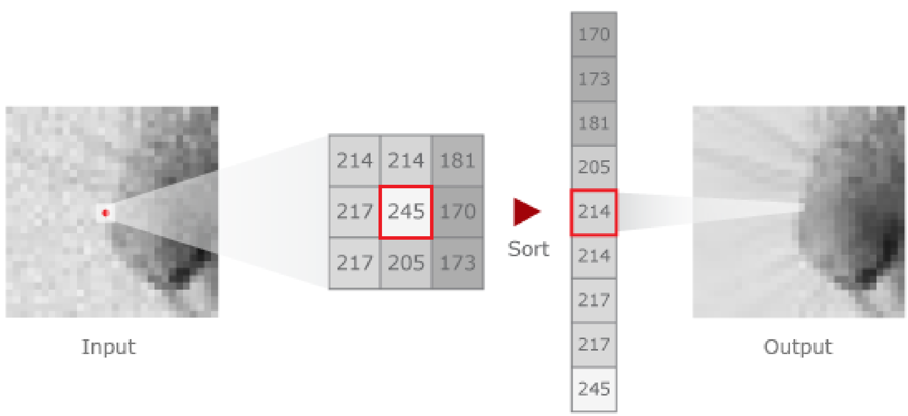


Figure 67: Median Filtering

in a photo after it has been taken is by using image processing. A common way to digitally reduce the noise is to "smooth" the fluctuations out. However, smoothing causes the image to appear less sharp. Luckily, there are noise-reduction techniques that do not lower image sharpness so much. Let us look at a simple method called *median filtering*.

Figure 67 illustrates the idea of median filtering on a black and white image. For each pixel in the output image, we choose a small window around the same pixel in the input image. The pixel values in this window are sorted in increasing order. The output pixel is then assigned the middle value (also known as the median) of the sorted sequence. This process is repeated for each and every pixel to generate a complete output image. For a color image, the same operation is applied to each color (R, G and B) separately.

The amount of noise reduced using median filtering depends on the window size. The larger the window, the greater the reduction in noise. However, as the window size grows, we lose more detail from the input image. For very large windows, the output image begins to appear "washed out." You can vary the window size using the slider in Figure 68 to see how the output image changes.

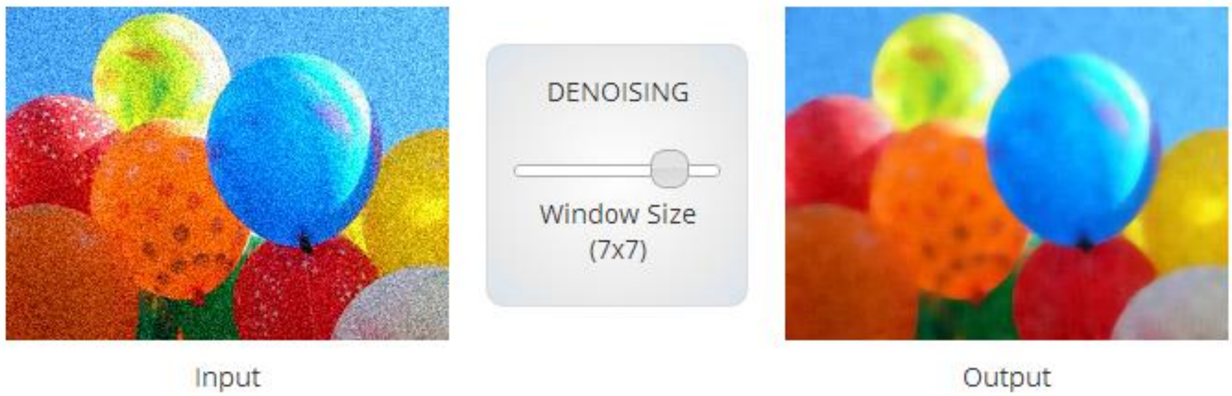


Figure 68: Noise reduction (Online demo)

Geometric Warping

Figure 69: An image (left) and its three warped versions

Warping is any process that changes the shapes portrayed in an image. A warp could be as simple as a stretch or a rotation, or it could be a complex distortion. Nevertheless, the basic idea of warping is to relocate pixels in the input image to different positions in the output image. The pixel relocation, or *re-mapping*, is usually done according to some mathematical equation.

Warping could be applied either optically or digitally. An example of an optical warp is the bulgy-looking image captured by a wide-angle lens (see third image from left in Figure 69). An example of a digital warp is the panoramic image produced from the wide-angle image. Let us now look at how one can digitally undistort a wide-angle image.

Consider a scene photographed using a regular lens, as shown in Figure 70a. The image of scene point P is formed at image pixel P_1. Let the distance between P_1 and the image center O be r_1. Now, let us replace the regular lens with a wide-angle lens, as shown in Figure 70b. Since the wide-angle lens has to squeeze in a larger field of view onto the same sensor, it "squishes" the light rays toward the center of the image. This means that the point P, which would normally have been imaged at pixel P_1, will be now be imaged at a different pixel P_2, at a distance of r_2 from the center, but along the same direction

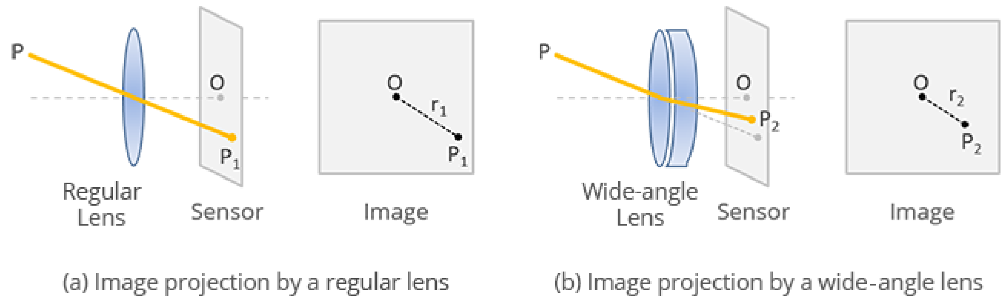


Figure 70: Radial distortion by wide-angle lens

from O as pixel P_1. This type of distortion is known as *radial distortion* [3].

To correct for this distortion (i.e., to move P_2 back to P_1), we need to first know the mathematical relation between P_1 and P_2. A common way to do this is by using a polynomial equation:

$$r_2 = r_1 + c r_1^3$$

where c is a parameter controlling the amount of distortion. When c=0, we get a regular perspective image (without distortions), and for positive values of c the image appears bulgy (distorted). If we know the value of c, correcting the distortion is straightforward. For every pixel in the desired (distortion-free) output image, we know its distance r_1 from the image center. By plugging this value in the above equation, we get the distance r_2 of the corresponding pixel in the distorted (input) image. The color values are then simply copied from the pixel at distance r_1 in the distorted image to the pixel at distance r_2 in the output image. This process is repeated for all the pixels in the output image.

Figure 71: Removing image distortion (Online demo)

The demo in Figure 71 shows distortion correction in action. The slider controls the distortion parameter c. When c=0, the output image is the same as the input image. As we increase the value of c, the amount of distortion is reduced.

USE

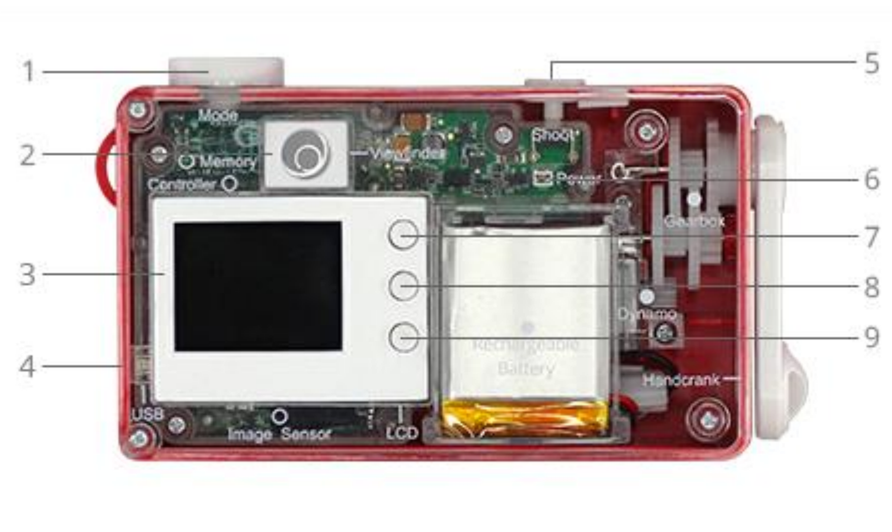
Getting Started

Identifying Camera Parts

Front of the Camera

1. Shoot button
2. Hand crank
3. Mode dial
4. Timer LED
5. Lens wheel
6. LED flash
7. Regular lens
8. Wide Angle lens
9. Stereo/3D prism

Back of the Camera



1. Mode dial
2. Viewfinder
3. Display
4. USB connector
5. Shoot button
6. Power indicator
7. Top button
8. Middle button
9. Bottom button

Safety Precautions

Always ensure that the camera is operated according to the instructions below, which are intended to prevent injuries to yourself and other persons, and to prevent damage to the camera.

WARNING: Possibility of serious injury

1. Do not trigger the flash in close proximity to people's eyes. Exposure to the intense light produced by the flash could damage eyesight. In particular, keep the camera at least one meter away from infants when using the flash.

2. Store the camera equipment out of reach of children younger than 8 years of age. It is dangerous if any of the components are swallowed. If this occurs, contact a doctor immediately. Putting the strap around a child's neck could result in asphyxiation.

3. Do not allow liquids to enter the camera. This could result in fire or electric shock. Do not use organic solvents such as alcohol, benzene, or thinner to clean the camera. If liquid or foreign objects come into contact with the camera interior, immediately turn the camera power off.

4. Use only USB outlets to recharge the camera. Use of other power sources could result in fire or electric shock.

5. Use only the provided battery. Use of other batteries could result in explosions, fire or electric shock.

6. Do not place battery near or in direct flame. Do not attempt to disassemble or alter the battery. Avoid dropping or subjecting battery to severe impacts. In the event that the battery leaks and the eyes, mouth, skin or clothing contacts these substances, immediately flush with water and seek medical assistance.

CAUTION: Possibility of injury or damage to the camera

1. Avoid using/storing camera in strong sunlight and high temperatures. These could cause leakage, overheating or an explosion of the battery resulting in electric shock, fire, burns and other injuries. High temperatures may also cause deformation of the camera casing and other components.

2. Do not sit down with the camera in your pocket. Doing so may cause malfunction or damage the LCD.

3. Do not put the camera and keys or other sharp objects into the same pocket. The camera lenses or LCD may get scratched.

Charging the Battery

Before you start using the camera, you will have to charge the battery. There are two ways to charge the battery: using a USB charger or using the hand crank. We suggest you use the first method whenever possible, and reserve the second method for when you do not have access to a computer.

Using USB charger

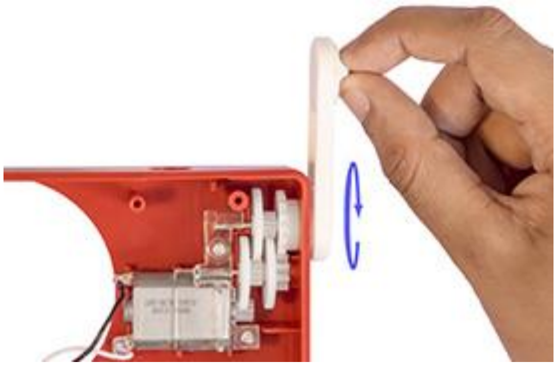
Connect the camera to your PC/Mac or a USB power source using the USB cable provided. Do not use force or attempt to insert the connectors at an angle.

The power indicator LED will start blinking green (if charge is low) or red (if charge is extremely low) to indicate the camera is charging.

Charging is complete when the power indicator stops blinking and turns solid green.

Using hand crank

Turn off the camera by setting the mode dial to OFF position. Gently rotate the hand crank clockwise as shown in the figure. Maintain a speed of 30 to 60 rotations per minute (rpm). The camera can take one picture for every 5 to 7 rotations. But it is better to rotate about 40 times so that multiple photos can be taken.



Warning: Rotating the hand crank at less than 30rpm will not charge the battery fast enough. Also, if you try to rotate faster than 60rpm and by applying greater force on the hand crank, you may damage the gear box.

Operate Bigshot

Mode Dial Settings

The mode dial allows you to turn on or off the camera, set the shooting mode and turn on camera playback.

Off

Turns OFF the camera. It takes the camera about 3 seconds to shut down

Auto-Flash

Automatically turns ON the camera flash if the light is too low.

Forced Flash

Always turns ON the camera flash while taking the photo.

No Flash

Always turns OFF the camera flash while taking the photo.

Timer Mode

Takes a picture 10 seconds after the shoot button is pressed. During this time, the buzzer will beep and the front LED will flicker.

Playback
View or delete photos stored in the camera.

Lens Wheel Settings

The lens wheel has three optical modules that allow you to take three types of photos.

Regular lens
Used to take normal perspective photos with a horizontal field of view of 40°.

Wide angle lens
Used to take wide angle photos with a horizontal field of view of 80°. The captured photos will appear bulgy, and must be processed using Bigshot's software to create panoramas.

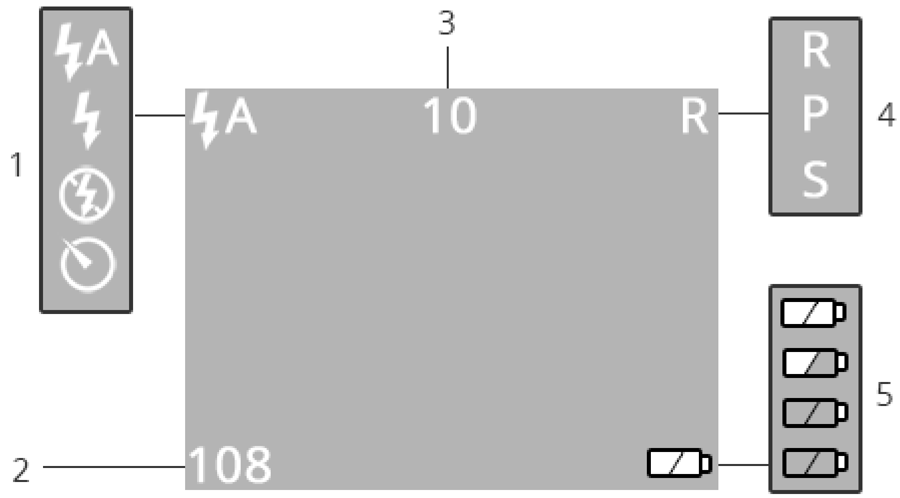
Stereo/3D prism
Used to take 3D photos with a horizontal field of view of 16°. The captured photos will have two side-by-side copies of the same scene, and must be processed by Bigshot's software to create anaglyphs (3D photos) that can be viewed using the provided red-cyan glasses. Wear the glasses such that the red filter covers your left eye.

Display

Camera Display

The following indicators may appear on the camera display during shooting and playback.

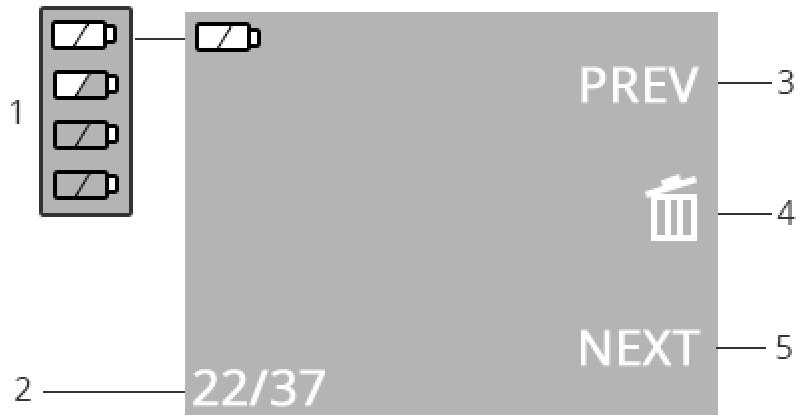
Shooting



1. Current shooting mode set by the mode dial
2. Number of photos remaining
3. 10 second counter during timer countdown
4. Current lens setting
5. Battery level

Additional indicators and messages may also be displayed. Details of special indicators are covered in the appropriate sections.

Playback



1. Battery level
2. Current displayed photo/Total number of photos stored
3. Go to previous photo
4. Delete photo
5. Go to next photo

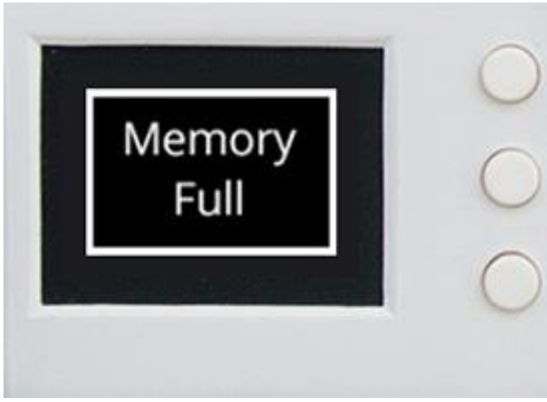
Additional indicators and messages may also be displayed. Details of special indicators are covered in the appropriate sections.

Memory

Camera Memory

The camera has sufficient memory to store approximately 120 photos.

When the mode dial is set to one of the four shooting modes, the number of photos that can be stored in the unused memory is displayed at the bottom-left corner of the display.



If no more photos can be stored in the camera, a "Memory Full" message is flashed on the display. At this point you cannot take any more photos. To take more photos, either transfer the photos on the camera to your computer or delete some of the photos stored in the camera.

Power Modes

Camera Power Modes

The camera has three power modes: normal, economy and sleep.

Normal Mode

In the normal mode, the camera is fully operational. That is, the battery has sufficient power to shoot and playback pictures. The power indicator is glows green. The battery level indicator on the display shows the amount of charge remaining.

Economy Mode

In the economy mode, the camera does not have enough power to operate the display. The camera can neither show live previews nor playback photos. However, it can still shoot photos. You will have to use the viewfinder to frame your pictures. Also, in this mode the flash is deactivated and hence good photos can only be taken of well-lit scenes. Before entering the economy mode, the camera flashes the "Economy Mode" message on the display and then turns the display off. The power indicator blinks during this mode. You should seriously consider recharging the camera now.

When the camera has no more power to take any photos, the power indicator blinks red a few times before the camera shuts down. You will have to recharge the camera to use it again.

Sleep Mode

When the camera is idle for more than 45 seconds, it automatically shuts down. You can turn it on again using the mode dial.

Shoot Photos

Shooting Photos

In this section we describe the simple steps that you need to follow to take pictures with your Bigshot camera.

Step 1: Set shooting mode

Turn mode dial to the desired shooting mode:

- Auto Flash
- Forced Flash
- No Flash
- Timer (10 seconds)

Step 2: Choose the lens

Gently rotate lens wheel to the desired lens setting:

- Regular
- Panoramic
- Stereo/3D

Step 3: Confirm Settings

The display will confirm your mode dial and lens settings. Check battery level to make sure there is sufficient power to take photos. Check number of photos remaining to make sure there is sufficient space to store the photos you plan to capture.

Step 4: Frame the picture

Hold the camera steady with both hands. Look through the viewfinder or the display to frame the scene you want to capture. Make sure your hands or fingers do not block the camera lens or flash.

Step 5: Shoot

Hold the camera steady and gently press the shoot button. You will hear a shutter sound and see a green LED glow in the viewfinder during exposure.
Note: If the camera is set in the Timer mode, it will wait for 10 seconds before taking the picture. During this time, the buzzer will beep and the Timer LED will blink.

Step 6: Review photo

Right after the photo is captured, the display will show the photo for three seconds for a quick review. You can continue to take pictures after that or go to playback mode to review the photos you have taken.

Using a Tripod

For darker scenes the camera will tend to use longer exposure times during which it may be hard for you to hold the camera steady. The resulting photos will tend to have strong motion blur due to hand shake. To reduce motion blur, you can mount the camera on a tripod using the tripod mound provided at the bottom of the camera.

Playback

Playback Captured Photos

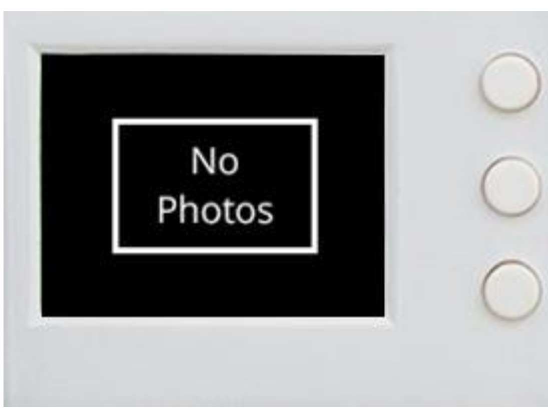
The photos stored on the camera can be viewed on the display when the camera is not in economy mode. Follow these steps to view the captured photos.

Step 1: Set playback mode

Turn mode dial to playback mode.

Step 2: Navigate photos

The display will show the latest captured photo. Press the top button to view the previous photo and the bottom button to view the next photo.



If the memory is empty, then a "No Photos" message is displayed.

Deleting Photos

Deleting Photos from Memory

Often you will want to delete unwanted photos on the camera to make room for new ones. Follow these steps to delete photos.

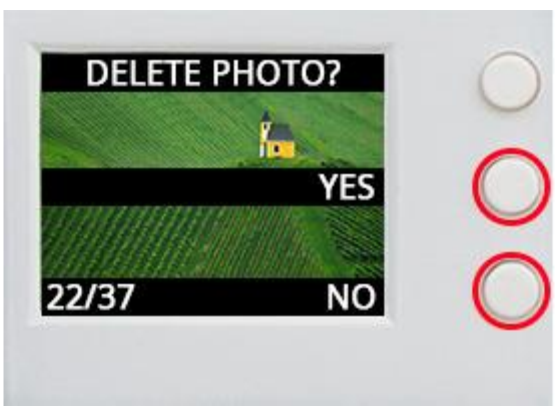
Step 1: Set playback mode

Turn the mode dial to playback mode.

Step 2: Delete photo

Step forward or backward to the photo you want to delete and press the middle button.

Step 3: Confirm deletion



Press the middle button to confirm the deletion. You can cancel the deletion by pressing the bottom button.

Process Photos

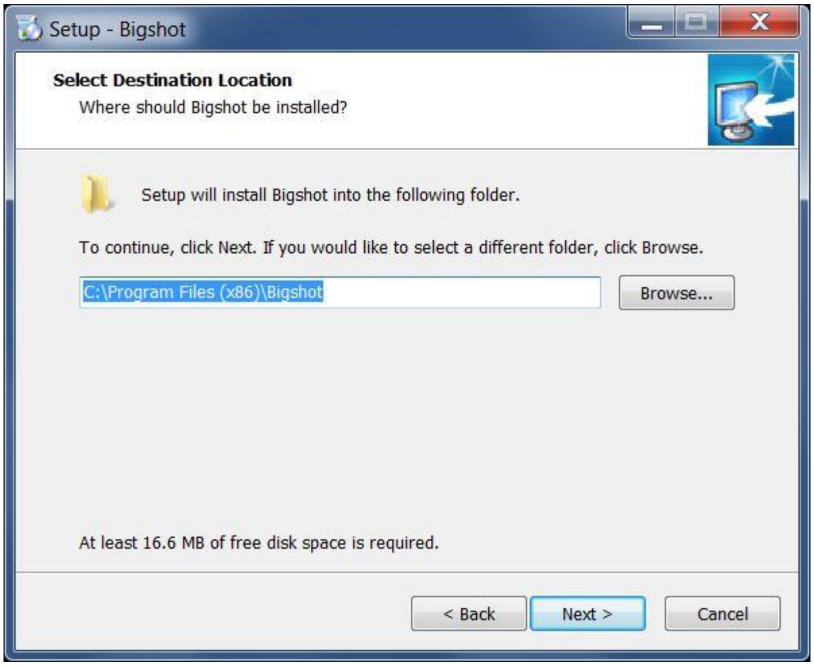
Download Bigshot Software

Download the Bigshot software from http://www.bigshotcamera.com/camera/software

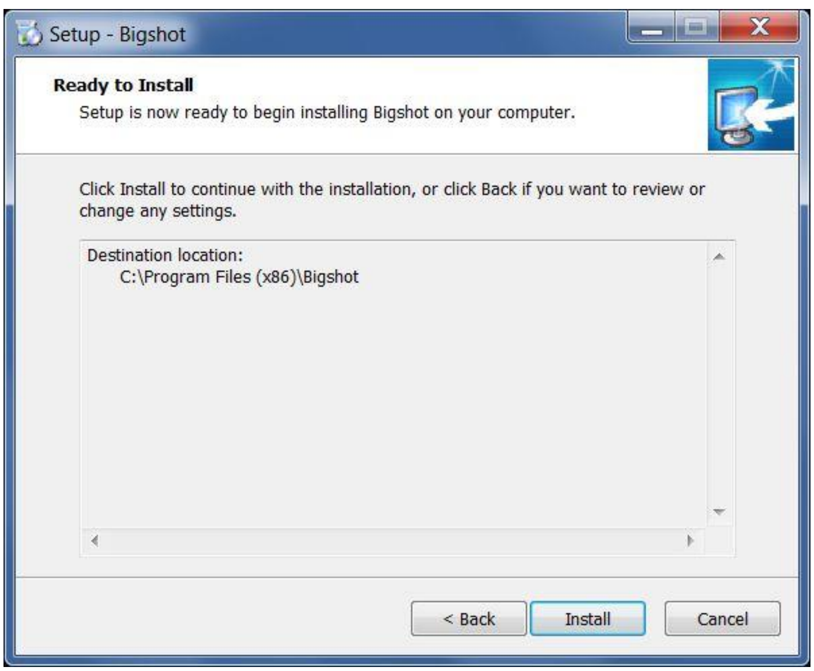
Install Software on Windows

1. Double-click on the downloaded installation file. The computer may ask for your permission to install the software. Click Yes.

2. The installer will then ask for your permission to install the software. Click Next.



3. Select the location where you would like to install the software. If you are not sure, click Next.



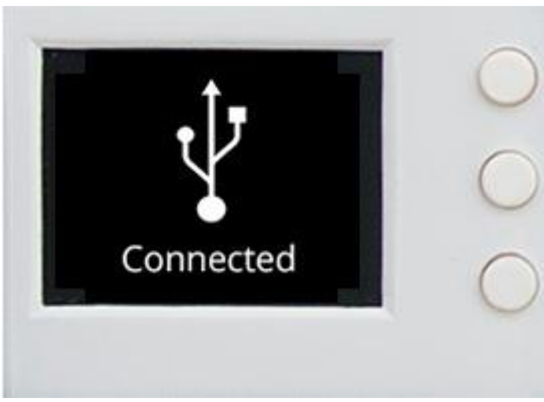
4. Click Install to complete the installation process.

Installing Software on Mac OS X

The Bigshot app is packaged as a bundle. Just extract the downloaded zip file and launch the app by double-clicking on it.

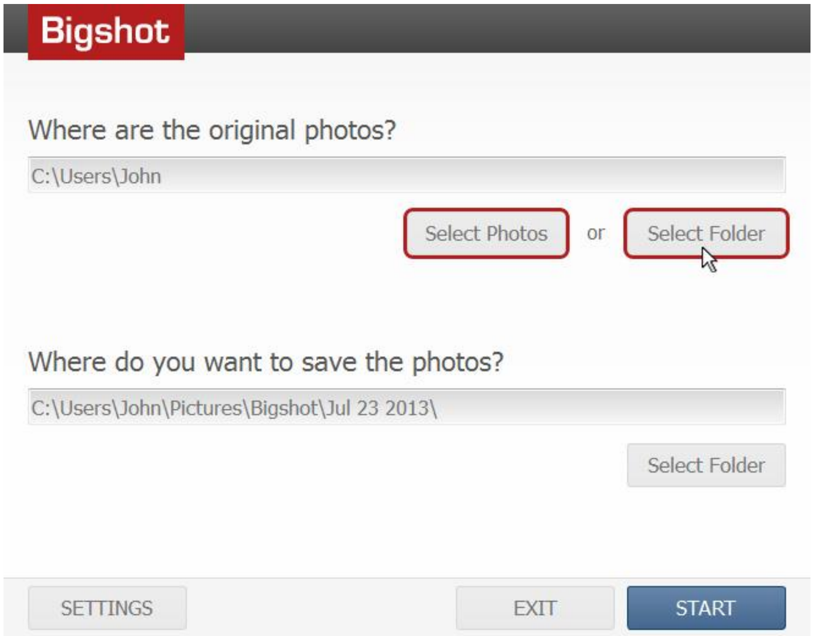
Connecting Bigshot to Computer

Connect the camera to your PC/Mac using the USB cable provided. Do not use force or attempt to insert the connectors at an angle or with the opposite polarity.

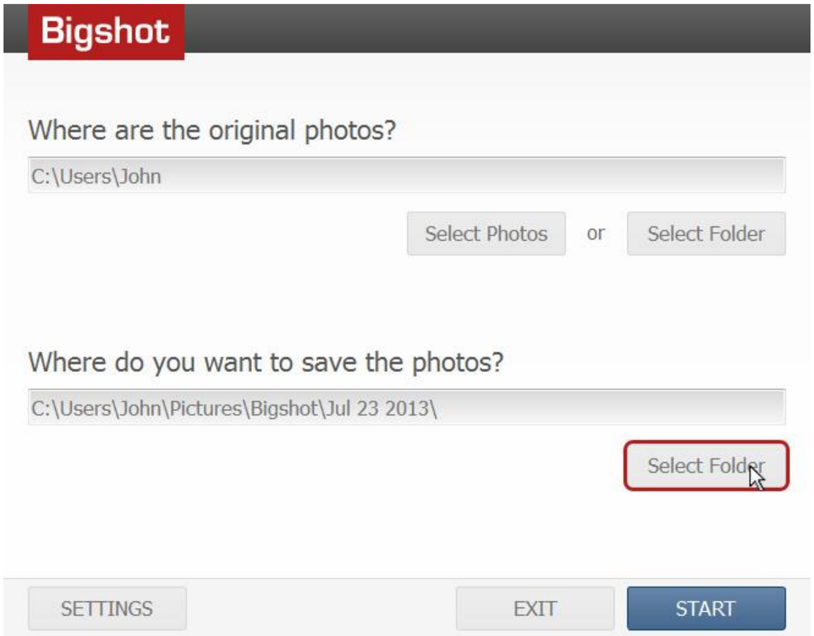


The computer will detect the camera. The computer may automatically install the required drivers the first time you connect the camera. When successfully connected, the camera display will show the "USB Connected" message. At this time, the camera's battery will also start recharging.

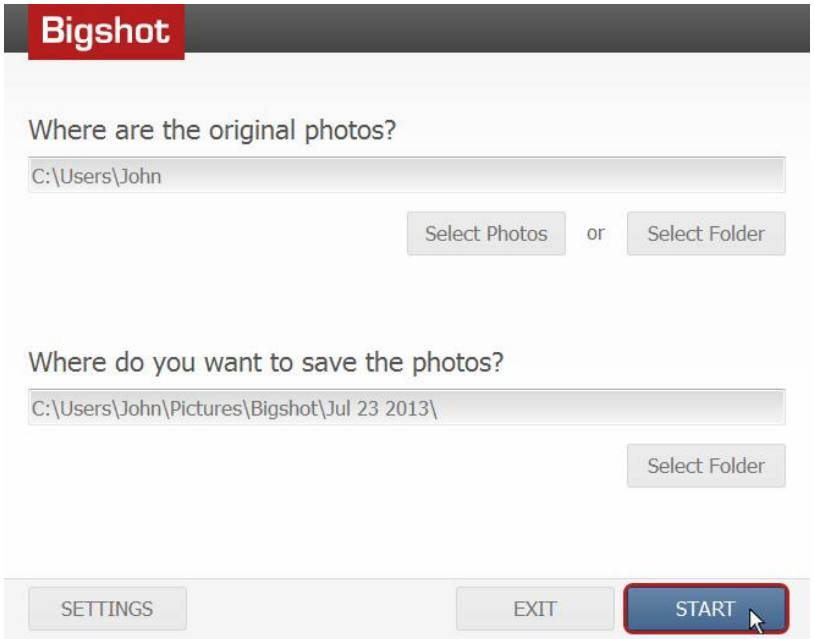
Process Photos



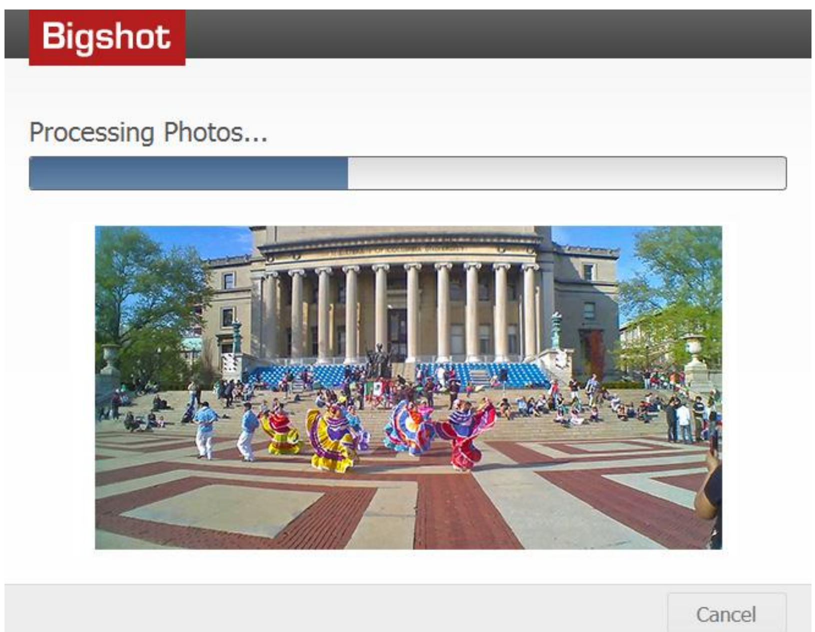
1. If the Bighot camera is connected to the computer, by default, the software will select all the photos on the camera for processing. However, you can either select individual photos or an entire folder in another location for processing.



2. Select where you would like to save the processed photos. By default, the software saves the photos in your picture library.



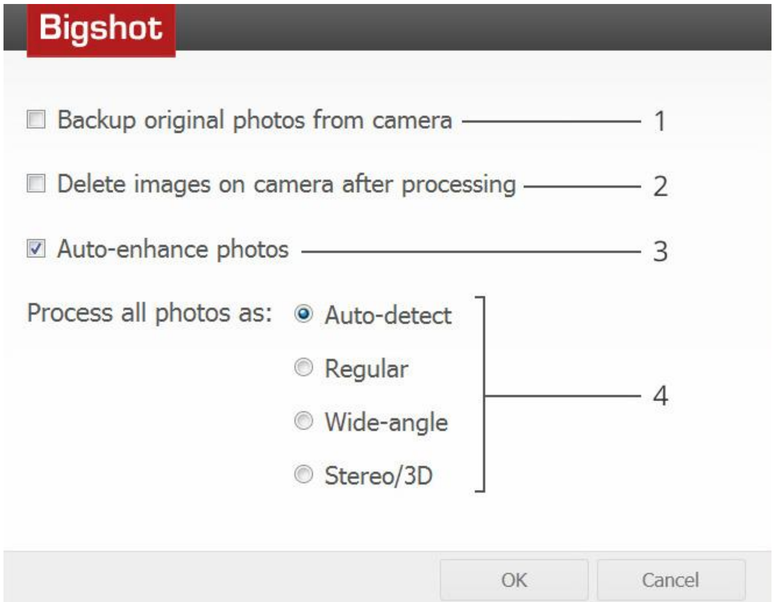
3. Click Start to start processing the selected photos.



4. For each photo, the software will automatically detect its type and apply appropriate processing. When done the computer will launch a window with all the processed photos.

Software Settings

Click on the Settings button to view the software options.



1. Backup

Enable this option to save a copy of the original photos on the Bigshot camera to the computer.

2. Delete photos on camera

Enable this option to delete the original photos on the Bigshot camera after processing them.

3. Auto Enhance

Enable this option to automatically enhance the appearance of the photos.

4. Auto-Detect Photo Type

You can either let the software detect the type of photo (Regular, Wideangle, Stereo) automatically before applying appropriate processing or you can override the auto-detection and force the software the process the them as a particular type.

Take Good Photos

Experiment, Experiment, Experiment

Many of the photos we shoot of subjects tend to look similar. This is because we approach subjects in much the same way with every shot. Eventually these photos will start to look uninteresting. Here are some of the things you can vary while taking photos.

Shoot from different perspectives

From high up

From low down

From high up

Image Credit: Flickr/Mike Baird

From low down

Image Credit: Flickr/Mike Baird

Get in close or step back

From a distance

Up close and personal

Try different lenses

With regular lens

With wide angle lens

Play with lighting

In the morning

After sunset

Without flash

With flash

Take as many photos as you like. Remember, there is no charge for storing extra photos. So forget about the photo count and keeping shooting. Be patient and you will get some great shots!

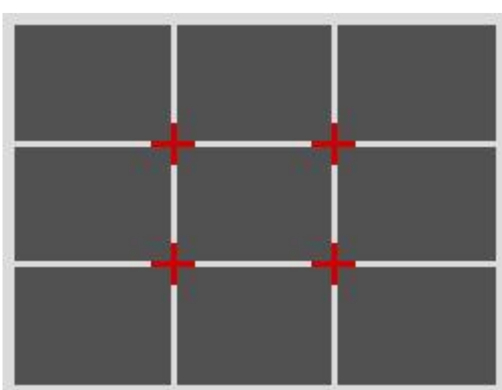
Get Images Straight

What is wrong with this photo? Yes - you guessed right. The photo is tilted. The horizontal lines and vertical lines are not aligned properly. While it is a simple task to align the lines, people often make the mistake of not holding the camera straight.

Before taking a photo, take a moment to observe the straight lines through the viewfinder or display. Try to align the horizontal and vertical lines with the borders of the viewfinder or display, unless you intentionally want the photo to be tilted.

Rule of Thirds

The rule of thirds is one of the basic, yet very effective, rules that one can follow while composing a photo.



Consider the photo to be divided into nine equal parts by two horizontal and two vertical lines as shown in the figure. The rule of thirds encourages one to compose a photo such that an "object of interest" is placed either at the intersection of two lines (shown in red) or along one of the four lines.

Studies have shown that when viewing photos our eyes naturally concentrate on one of the intersection points rather than the center [1]. The rule of thirds works with this natural way of viewing an image.

Below are a few shots composed following the rule of thirds. Observe that interesting objects are placed near the intersection points and all major lines are aligned with one of the four lines.

Image Credit: Flickr / Guru Krishnan

Image Credit: Flickr / Michael Miller

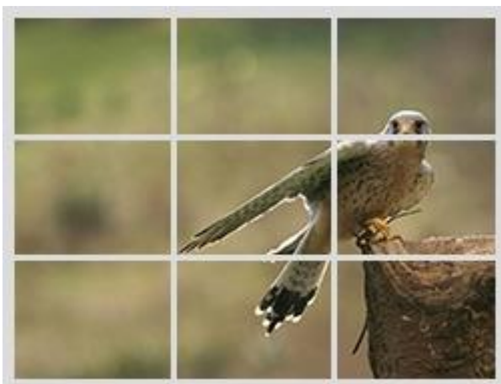


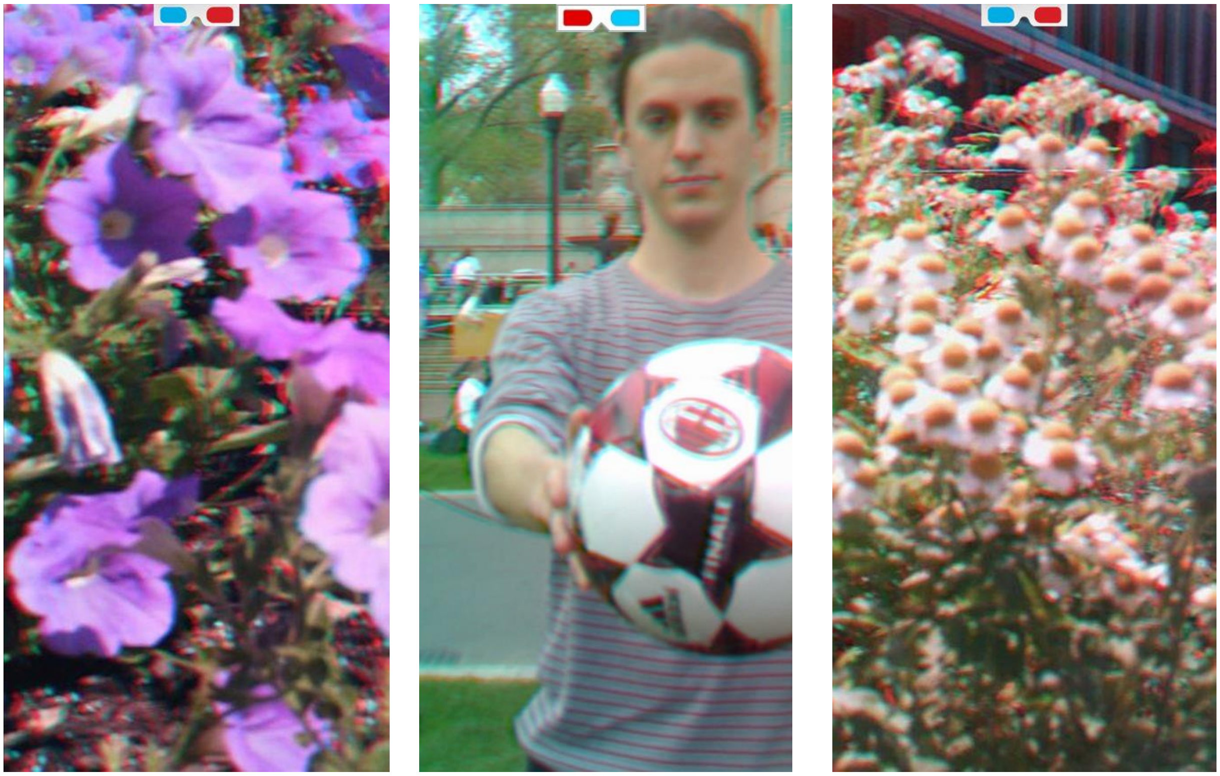
Image Credit: Flickr / Alan Cleaver

Image Credit: Flickr / Guru Krishnan

In order to follow the rule of thirds, before taking a photo ask yourself these two questions [2]:

- What are the points of interest in this shot?
- Where should I intentionally place them?

Shooting 3D photos with Bigshot



Bigshot allows you to explore another dimension - the third dimension - than most cameras. You can take 3D photos! These three photos above were taken using Bigshot's 3D prism. Wear your red-cyan glasses (with red covering your left eye) to view these scenes. **To achieve a strong 3D effect, shoot 1–4 feet away from the subject.**

References

[1] D. W. Dudley, Handbook of Practical Gear Design, CRC, 1994.

[2] C. S. Siskind, Electrical machines, direct and alternating current, McGraw-Hill, 1950.

[3] E. Hecht, Optics, Addison Wesley, 2001.

[4] "The Photoelectric Effect," ScienceTrek, [Online]. Available: http://www.colorado.edu/physics/2000/quantumzone/photoelectric.html.

[5] D. Litwiller, "CCD vs. CMOS: Facts and Fiction," *Photonics Spectra,* January 2001.

[6] H. Helmholtz and D. L. MacAdam, "Physiological Optics – The Sensations of Vision," in *Sources of Color Science*, Cambridge MIT Press, 1970.

[7] B. E. Bayer, "Color imaging array". United States of America Patent 3971065.

[8] L. Stroebel and R. D. Zakia, The Focal Encyclopedia of Photography, Focal Press, 1996.

[9] M. J. Kidger, Fundamental Optical Design, SPIE Monograph, SPIE Press, 2002.

[10] "Charles Wheatstone," Wikipedia, The Free Encyclopedia, [Online]. Available: http://en.wikipedia.org/wiki/Charles_Wheatstone. [Accessed 4 10 2009].

[11] K. Sayanagi, "Stereoscopic photograph system using a stereoscopic attachment to a camera". United States of America Patent 3674339, 4 July 1972.

[12] D.-H. Lee, I. S. Kweon and R. Cipolla, "A Biprism-Stereo Camera System," in *IEEE Conference on Computer Vision and Pattern Recognition*, 1999.

[13] W. J. Smith, Modern Optical Engineering: The Design of Optical Systems, McGraw-Hill, 1990.

[14] E. N. Marieb and K. Hoehn, Human Anatomy & Physiology, Benjamin Cummings, 2006.

[15] "Image warping," Wikipedia, The Free Encyclopedia, [Online]. Available: http://en.wikipedia.org/wiki/Image_warping. [Accessed 4 10 2009].

[16] "Distortion (optics)," [Online]. Available: http://en.wikipedia.org/wiki/Distortion_(optics). [Accessed 4 10 2009].