# Simplified Stroboscopic Systems for Motion Pattern photography

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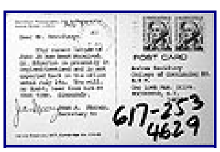
The photography and study of subjects in motion has been one of the fascinations of photographers since its invention. In fact, artists have dealt with this same subject since the time humans started to make pictorial records of their environment. With the development of photography, several workers devoted considerable personal effort into perfecting motion recording techniques. These people included Etienne Marey, Eadward Muybridge, Harold Edgerton, and others. Each had their "favorite" way of approaching the problems associated with their personal interests and all contributed greatly to our understanding of the world of motion around us. Many of the techniques that were developed and applied for motion studies were mechanical in nature as far as the photographic aspects of the techniques used. Even motion picture cameras can be classified among these solutions for dealing with recording and analyzing motion.

With the advent of the electronic flash and the electronic stroboscope, and primarily under the guidance of Harold Edgerton from the 1930's through the 1980's, the recording of subjects in motion onto a stationary film (and less well known, onto moving film) became almost the exclusive domain of electronic stroboscopes.

Modern photographic stroboscopy in its simplest form is a method whereby a subject in motion is lit by repeating flashes of light from the stroboscope while the shutter of the camera remains open for a period of time long enough to capture the subject in multiple locations during the time of exposure.

There are several factors that need to be considered, adjusted and controlled to end up with technically effective photographs made in this manner. These include a knowledge and the ability to adjust the flashing rate of the stroboscope, the influence of the background on the final image, the choice of exposure time and a knowledge of the output or power of the individual flashes produced by the stroboscope.




I will describe the basic parameters at work in a typical stroboscopic set-up by way of an example situation. Assume that the desire is to make a record of a golf club swing or the swing of a tennis racquet (such as depicted in this example by Harold Edgerton) or a gymnastic routine and that this record must be a single image (as shown here) illustrating the motion as opposed to a motion picture.

The procedure is quite straightforward. One first locates a stroboscope. This used to be fairly difficult as stroboscopes in the past were either too weak for practical applications or quite complex and considered specialized instruments and generally not available to non-specialists. These days the situation is much improved and it is becoming easier to buy or rent stroboscopes as flash manufacturers are even building a stroboscopic function into their flashes. Also, the entertainment industry uses stroboscopes on a regular basis to light up dance halls, etc.

For photography, the subject is placed in a suitable location and the camera distance adjusted to provide a desired image in the viewfinder. It is advisable to place the subject against as dark a background as possible since not doing so will likely lead to the subject looking transparent in those areas that are moving and thus which do not cover the same location in space throughout the camera exposure. Since the background will be black it is advisable for the subject to wear lighter colored clothing as dark parts of the subject may otherwise blend into the background.

The light level is measured for a single flash of the stroboscope and based on this information the lens aperture is adjusted appropriately based on the film speed used. With a flash type stroboscope one generally is not concerned with the exposure time of each flash, just the amount of energy or total light discharged during a single flash. Some photographers prefer to underexpose slightly for each flash so that wherever images overlap the density will not be excessive on negative materials.

Now, after you have made sure that your subject can perform the action that you want to portray in the allocated space, you open the camera shutter for a time that is roughly dependent on the time at which your subject starts to move and the length of time that elapses until the action you want to track is completed. You can do this by tripping the shutter set to a specific, estimated, exposure time or simply opening the shutter on "B' at the beginning of the action and closing it when it is over.

Note that, as shown in the illustration at the left with every flash of the stroboscope some parts of the subject will be in a different position and they will record on different location on the film. The human eye/brain combination can easily fill the gaps and make the connection from one image or position to the next to generate an impression of what the action looked like in detail.

The separation between moving parts of the subject will be governed by the frequency of the flash and the speed at which the subject moves. The faster the flash rate the closer and more separate images you will get for a given exposure time and the faster the subject moves the fewer images you will capture between the beginning and end of the action

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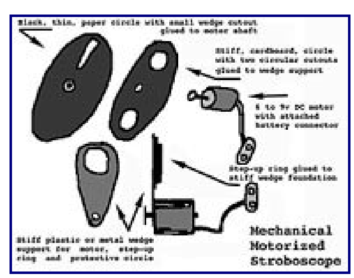
**Do-it-yourself stroboscopy**

Light or flashing stroboscopes are interesting but usually out of reach of the amateur's budget. I would like to suggest that a much more practical and inexpensive way to get into stroboscopic photography is to investigate the technique not with a flashing light but with a mechanical stroboscope.

A mechanical stroboscope consists of a rotating disc with a radial slot cut into it and the disc placed in front of a camera's lens in such a manner that each time the slot passes by the lens the camera sees the subject for a brief time interval.

This mechanical way to simulate a flash-type stroboscope is ideal for experimenting and it is quite adequate for initial work with the technique. In some cases it can yield more than adequate and useful results. In fact, the mechanical stroboscope has certain advantages over a flashing kind in that it can use the sun as a light source. This enables it to deal with large subject matter outdoors. The light flashing strobe can not be used outdoors effectively since it would have to significantly overpower the light from the sun!




To make a mechanical stroboscope take a look at the illustration to the right. The device can be even simpler than suggested here but I have found the following construction to be practical and useful in many situations.

You will need a small DC (battery) powered motor that will run at a good clip when attached to 6 to 9 volts DC. You will need to attach to it a slotted disc made out of a thin sheet of black paper (construction paper will do nicely). You will need a disc of stiffer material to act as a "protector" for the thinner, slotted disc. This can be heavy, black, cardboard stock. You will also need a step-up ring that will screw into your camera's filter thread to a filter size that is possible 5 to 10mm larger then the filter size your camera lens takes. So, if your camera takes 52mm filters you'd use an adapter ring that is maybe a 52 to 62 or even 52 to 72 mm in size. Finally, you will need a fairly stiff piece material to which you will attach "protector" disc and the motor allowing the shaft of the motor to protrude unimpeded through the cardboard disc.

You could make the larger, cardboard disc the device to which you also attach the motor but I opted for a separate, wedge shaped, "foundation" for the stroboscope. This is shown pictorially in the attached illustrations.

The step up ring is glued (use grey Epoxy glue that comes in 2 parts) to the stiff, strong, base, wedge at a distance of about 4 inches or so from the center of the motor shaft. A hole is cut in the support material allowing the camera lens to see through the support wedge and the attached cardboard disc.

The cardboard disc has cut into it a second hole about 180 degree on the other side of the hole where the camera lens "looks through". This second hole is there to allow you to visualize what the camera is recording even while the camera shutter is open and while the viewfinder of the camera is blocked.

The thin, construction paper, disc is then glued to the motor shaft at the center. You may want to buy a flange of some kind that you can attach to the motor shaft to make the gluing process easier than trying to glue to a narrow metal shaft.

The size of the slot that you cut into the construction paper disc should be about 10 degrees or so in size. The smaller it is the shorter the exposure times it will deliver. The larger the longer and the smaller aperture or less light you will need to use.

Once the stroboscope is assembled it is attached to the camera lens as shown in the illustrations. The motor will have a couple of wires hanging from it and when these are connected to a voltage source such a 9 volt transistor battery the motor and the slotted disc will start to turn. You might make the connection between the motor and the battery by way of a 9 volt battery clip.

I have found that I can power the motor using a "battery eliminator", a small transformer that you can plug in the house current and that will deliver adjustable voltages from 3, 4.5, 6, 7.5, 9 and 12 volts DC. The more voltage you supply the motor the faster it turns.

As far as making a traditional stroboscopic record of an object in motion, the procedures for using a mechanical stroboscope as opposed to a flashing one are not much different. One big advantage of the mechanical device is that your subject will be able to constantly see what it is that they are doing. With the flashing light stroboscope subjects sometimes loose their balance and coordination because it is easy to get confused while performing an action under a discontinuous light source.

For photography the subject is again placed against a dark background and when the photographer decides to start to record a sequence the shutter is simply opened while the slotted disc turns in front of the lens, with each turn of the disc making an exposure of the subject. The the end of the action the shutter is closed and the film processed. The result will be a series of images superimposed on each other where the subject did not significantly change positions but showing the moving extremities of the subject in several different locations in space. A true stroboscopic record.

To achieve proper exposure, one has to determine the approximate exposure time delivered by the rotating slot. It can be determined by dividing the size of the slot in degrees by the 360 degrees and multiplying this by the time it takes the disc to make one revolution. Lacking an accurate measurement of the time for one turn of the disc at a given voltage, it is probably appropriate to estimate this time.

For example, assuming that the disc is turning maybe 5 times a second, the time for one rotation is 1/5th second. Now if the slot measures 10 degrees, then the light goes through to the camera for 10/360ths of the time it takes the disc to make one turn. Or, 1/36th of 1/5th of a second. This is 1/180 of a second. To determine the aperture the camera needs to be set to, use a light meter to determine the aperture necessary for proper exposure given the film being used and an exposure time of 1/180 second. Approximately. time it

If you keep the shutter of the camera open for one second you will record 5 separate images of the moving subject. If the disc turns faster than 5 rps then you will get more. If less then fewer. It is all determined by the relationship between the number of times the slotted disc turns each second and the length of time the shutter remains open!

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**Calibrating your rotating disc stroboscope**

It is obvious that a general knowledge of the rotation rate of the stroboscopic disc, and thus the frequency of photography, is useful to arrive at predictable results. However, lacking suitable calibration and rotation frequency measurement instruments leaves one with nothing but an estimation of the actual stroboscopic frequncy of the device. This is better than nothing but there are simple and inexpensive ways of calibrating the device.

One way to do this would be to photograph the rotating disc with a camcorder particulary if one sets the shutter speed of the camcorder to a short exposure time. The camcorder, upon frame by frame playback, will display images on the TV monitor that are probably 1/60 second apart in time. It is a simple matter to track the position of the slot on the disc to determine the number of degrees that the slot turns between frames to arrive at the number of degrees per second that the disc is turning. Dividing this by 360 will give you the revolutions (or views) per second at the voltage that the stroboscope was being driven at when the recodring was made.

This methods works but it assumes that one has ready access to a camcorder and that the camcorder has a high speed shutter capability (most these days do).

Another, more "photographic", method is based on the fact, or realization of the fact, that the shutters on most cameras are themselves highly accurate timepieces. Also, it is useful to remember that a photograph is exposed for the time that the camera's shutter is open. These two facts point the way for using the very camera that the stroboscope will be mounted on as the instrument that will measure the rotation rate of the stroboscope.

This calibration process, based on the "hints" given above, can be done in several ways but the one that I am proposing here is to make an exposure of some subject, such as a golf ball rolloing down an inclined ramp, with the stroboscope operating at some given rate. The photograph should be made at a reasonably long exposure time, maybe 1 second.

After the rolling ball has entered the field of view of the camera the shutter (set to 1 second) is tripped. A second later the shutter closes. One simply needs to make sure that the shutter closes before the rolling ball exits the field of view of the camera on the other side.

After development it will be seen that the ball has left a "stroboscopic track" of its path as it rolled down the inclined ramp. This path will be made up of a number of separate or individual images of the ball since with each passage of the rotating disc's slot a picture of the moving ball (in a diferent location each time) was exposed on the film. This being the case, simply counting the number of separate images give one a clear measure of the disc's rate of rotation. If a one second exposure time was selected the rotation rate will be equal to the number of images of the ball per second.

It will be useful to draw a "performance curve" plotting rotation rate against voltage supplied to the motor so that in future photography sessions one will have a fairly good idea of what voltage one will need to supply to the motor to achieve a particular stroboscopic frequency. This will, of course, depend on what subjects one will be faced with at later times.

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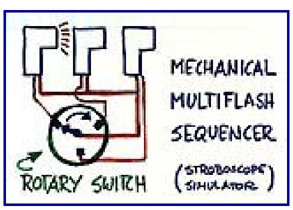
**Multiple Flash Based Stroboscope**

While I would definitely argue that there is a lot to be said for keeping things simple and reasonable in terms of cost, there is an alternative to a mechanical stroboscope. It is based on the use of multiple flash units operated in sequence.

The limiting factor that does not allow a standard electronic flash to fire in rapid succession, as a stroboscope would, is generally the fact that the power electronic flashes discharge per flash is quite high and it takes the circuit a considerable time to recharge the main capacitors.

To fire a flash in rapid succession, therefore, it is necessary to use a flash equipped with a thyristor switching circuit that allows the photographer to operate the flash at partial power levels, such as 1/16 or less. Once a flash is operated at 1/64th or 1/128th power generally the recycling time is reduced to a second or less. This means that if one had a device that would trigger the flash repeatedly one could conceivable operate the flash at a frequency of 1 flash per second and possibly even faster. This is not very high by stroboscope standards but it is a place to start with.

Triggering a flash by hand at frequencies of one flash a second or faster is not too easy and my suggestion is that one use an auxiliary device to simplify the switching procedure. The device I am suggesting is what is called a rotary swith. These are available at electronic parts supply stores. They are devices that close a series of contacts sequentially as the shaft of the switch is rotated.




If you attach a female PC socket to one of the switches in the rotary switch and a lever to the shaft, then it is a simple matter to rotate the shaft at a steady speed and have the powered-down flash operate in repeatable fashion at a steady rate. The shaft may be attached to something like a variable speed electric drill for motorized operation.

Realizing that the frequency that the flash can fire is limited by the recharging time, now it becomes obvious that one could increase the maximum frequency achievable by a single flash by connecting multiple flashes to the contacts of the rotary switch. For example, if one can achieve a maximum rate of 1 flash per second with a single flash, by connecting 4 similar flashes to 4 switch contacts located at 90 degree intervals on the switch, and rotating the shaft once a second, this will trip the 4 flashes sequentially at an equivalent flashing frequency of 4 flashes per second. This is starting to become interesting!

The flashes should usually be set to the lowest possible power they are capable. One can use automatic flash units by using a small reflector deflecting some of the light from the flash head of a given unit to its light detecting window. This makes the flash quench its flash very quickly and the result is that it operate at low power in this fashion.

If you do build a "sequential stroboscope" such as described here additional creative opportunities open up for the photographer. It is possible to vary the frequency of the stroboscope by simply altering the rotation rate of the shaft of the switch. It is also possible to place different colored filters over each flash and have these provide a multicolored sequence.

Finally a note of warning and a disclaimer. Please note that even with this procedure most electronic flashes are not designed to operate in continuously repeating mode for an extended time so please take the above suggestion with a good dose of caution by not operating the flash or flashes for more than a few seconds in repeating mode. The author can not be held liable for damage resulting to your flash unit if you attempt this method for simulating a stroboscope. The reason for this is that experimental conditions can vary widely and not all situations can be predicted from the author's position.

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**Stroboscopic photography with digital cameras**

Generally one is interested in photographing relatively long duration events (even though one may only be talking about a second or two!) because it is really pointless to to make a stroboscopic record while only recording the subject in two or three positions over time!

For example, to make a record of a golf swing or something similar, we would be looking to make a record over a time period of a second or so. During that time we might want to record our subject in maybe 20 to 100 different positions. This, of course would require a strobe flashing at a frequency of 20 to 100 flashes per second if we kept the shutter open for a second. An exposure time of 1 second is easy to accomplish with a regular camera but many digital cameras have a limited maximum exposure time. Sometimes this is as short as 1/8 or 1/4 second. This means that making stroboscopic records with such cameras is, in a way, limited to events of relatively short duration.

Well, recently I attached a mechanical stroboscope to a Kodak DC260 camera (which has a maximum exposure time of 4 seconds) and used an exposure time of one second to obtain the photograph shown here. The subject was placed against a large, black, velvet background. The lighting level was adjusted so that the results obtained were of an acceptable quality by making a few preliminary tests and judging the quality of the images on the LCD display screen of the camera. Very convenient and effective!

By the way, from this example made over a period of 1 second, the camera recorded about 17 separate images of my amateurish attempt to swing a golf club. From this it can be determined that the stroboscopic disc was turning at about 17 revolutions per second.

Note also that, as with traditional cameras, the background (which should have reproduced very dark since it was black velvet) and those parts of my body that remained essentially in the same position appear significantly overexposed because they reflected light to the same location on the CCD, while the moving club shaft was exposed in different positions on the CCD with every pass of the stroboscope disc. The moving club, therefore, is exposed only once on any given area on the CCD. One could improve slightly on the tonal range of the image by making the subject wear dark clothing while painting the moving club shaft with a highly reflective or white paint.

Finally, one of the major problems associated with making photographs with the DC260 and I assume with other consumer grade cameras as well, is the time delay involved between the pressing of the shutter release and the actual start of the exposure or opening of the shutter. Unlike regular cameras, this delay in digital cameras can amount to as much as a second and it makes it very difficult to synchronize and event and the operation of the camera's shutter. Fortunately the recording medium is reusable but still, it is frustrating not to be able reliably predict the start of the exposure. Often one needs to anticipate with too much lead time and this leads to unpredictable results.

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### Moving film technique

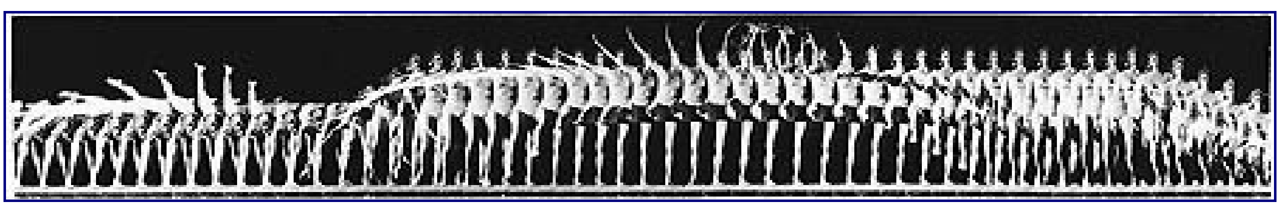
Traditional stroboscopic techniques generally have concentrated on simply opening the shutter at the beginning of the action and closing it at the end and recording the moving subject during the process. It becomes quickly evident that this approach has limits in terms of the length of time during which any given can be recorded because if the time is extended too far, too many images will superimpose on each other and it becomes impossible to determine the development or sequence of the action being investigated or visualized.

A method that allows one to examine a moving subject over an extended period of time is an extension of the techniques described above and it almost resembles a motion picture camera in its operation but the resulting images are displayed as flat, two dimensional, photographs instead of time-based, motion pictures that can usually not be reproduce in text form.

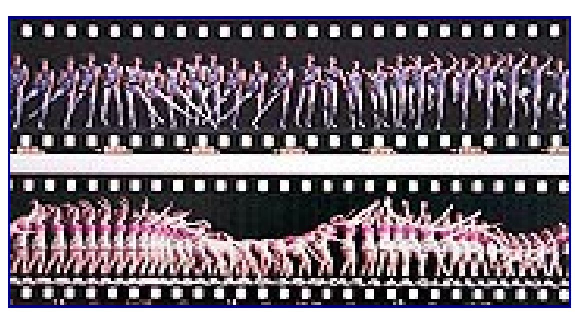
The basis for this extension of the stroboscopic technique depends on devising a way to place the subject on different locations on the film as the action develops or progresses. This places those parts of the subject that essentially remain motionless on different locations on the film and it also displaces the moving portions of the subject to other locations than those they would occupy if the subject exposed essentially the same location on the film with each exposure given by either the flashing light or the rotating slotted disc.

One way to achieve the displacement of the overall subject across the film is to rotate the camera or to laterally displace the stage upon which the subject performs its action across the field of view of the camera.

A very elegant solution to this same problem is to place the film in motion while the subject is moving and the stroboscopic light is flashing or the slotted disc is rotating in front of the camera's lens. A 35mm camera can be easily adapted to the task of moving the film by first advancing the film to the take-up chamber. This can be done by placing a lens-cap over the lens and then firing off the camera until the film supply is exhausted and is all located in the take-up side.



Now, the action stage is set and the lens aperture determined as explained above. The camera is placed on a tripod and aimed at the scene where the action will take place. At this time the shutter of the camera, set to "B", is tripped and locked in the open position with a locking cable release. Now the rewind release button is pushed up or activated, disengaging the sprocket drive from the internal gears in the camera. This frees up the film for rewinding. The film is now simply rewound back into the supply chamber.



Note that some cameras do not allow rewinding the film while the shutter is locked in the open position. These cameras are obviously not suitable for this technique. Also, another word of advice is this: if the camera seems to resist allowing you to rewind the film do not force the rewind knob. It might break if you apply enough force.

Do not force the mechanism to do something it clearly seems to resist.

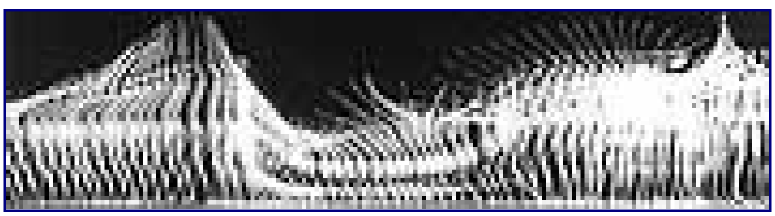
It is evident that periodically the slot of the rotating disc flashes an image onto the film, fixing the position of the subject at that time, and in the time the slot makes another turn, the subject changes position. In the same time, film has a chance to move within the camera so that when the slot again flashes an image of the subject onto the film, the image is recorded slightly offset from the first one. This process continues until the whole roll of film has passed through the camera. The result is typically a long series of exposures depicting the changing positions of the subject over a substantial period of time. The number of images thus recorded and the separation between them is now a function of the rotation rate (or flashing rate) of the stroboscope and the rate at which the film is transported through the camera by the rewind knob.

There is a "rule-of-thumb" relationship that allows a photographer to determine the length of time it should take to make the rewind knob turn once given the desired separation of images on the film and the rotation rate (or flashing rate) of the stroboscope.

It goes something like this: the time to turn the rewind knob once is equal to 50 divided by the product of the desired separation between images and the rotation rate of the slotted disk. (If you cut more than one slot in a disk then the disc rotation rate needs to be multiplied first by the number of slots cut into it.)

For example, assuming that the disc makes 5 turns each second and that we desire our images of the sequence to be about 4 mm apart (this would place about 9 images within a 36 mm length of film, or about 1 standard "frame") one would need to turn the rewind knob in 50/4x5 or 50/20 or about 2.5 seconds. For the images to be closer together the time to turn the rewind knob must be lengthened (the knob turned more slowly) or the disc must be turned more quickly. In any case, this does not mean that you will be turning the rewind knob only once! You essentially will be turning the rewind knob until you run out of film and will be generating an record of the action that extends from one end of the film all the way to the other, without frame lines or individuals "frames". A continuous "time" record of discrete instants in time, each showing your subject in different positions.

Make sure to inform you photofinisher that you are having special film developed and that it should not be cut into individual 35mm frames. It will be up to you to locate and identify interesting sections on the film and printing or saving those.



To print longer sections than those accommodated in a 35 mm enlarger you can enlarge the images in sections and assemble a long strip or you can print lengths of film up to about 5 inches long by using a 4x5 enlarger. It is best to use a glass carrier to hold the film flat and it is highly advisable to mask the carrier down to a 1 inch wide by 5 inch long opening so as to prevent enlarger flare from affecting your print's highlights or shadows (depending on whether you are printing negative or positive materials).

An alternative is to input or scan the film images into a computer using a slide scanner that can scan long lengths of film and then printing the image files as a long print. You might also scan in sections and assemble a long image file. Or, a truly esoteric alternative is to find a "strip" enlarger that accommodates long lengths of film and prints them onto moving paper.

Finally, the point to remember is that we should not think that we are limited to taking stroboscopic pictures onto stationary film, but that it is possible to to explore "time" by the simple expedient of setting the film in motion!

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