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The automation of solar eclipse photography

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In this paper I describe the evolution of a system for automatically photographing a total eclipse of the Sun using several cameras. The paper also describes the final Psion Organiser-based solution and how this can interface to ordinary cameras.

Introduction

Many who have seen a total eclipse of the Sun will say that no camera can ever capture the majesty of the event. That doesn't stop people like me trying to capture aspects of the event using more than one camera.

Cameras

For eclipse photography I have only used the cameras that I already had for "normal" photography and so my experience is obviously limited to these. A suitable camera must have the facility to automatically wind on the film. I have a pair of Pentax ME Super cameras (circa 1982) and two power winders that screw on underneath, one Pentax and one Soligor. Both winders have a socket to remotely fire the camera and the Soligor has an internal "intervalometer" function (for taking sequences of pre-set exposures at a given interval). The exposure mode is either manual or auto. The manual exposure of these Pentax cameras is adjusted via up and down buttons, quite a novelty at the time compared with the conventional dial marked with 1000, 500, 250 etc. I also have two Canon EOS 100 autofocus cameras (circa 1994). Manual exposure is adjusted via a thumbwheel and other features include Auto Exposure Bracketing and a multiple exposure facility.

I cannot claim that these cameras are the optimum choice for what I wish to do - they are merely the ones I already had before embarking on this project. There are other cameras that are equally or even better suited for this exercise. If one had *no* camera to start with then other options present themselves, in particular the use of a Command Back available for some top-of-the-range cameras such as the Canon EOS1. These can be programmed to do virtually any sequence of exposures at any time. These cameras and Command Backs are usually reassuringly expensive!

Chile 1994

For the eclipse visible from Chile I decided I wanted to record the passage of the lunar shadow with one camera, as well as record the corona and the chromosphere with another. I didn't have enough hands. However, by using the "intervalometer" on the Soligor power winder, the camera could take pre-set exposures every 5 seconds as the shadow passed by. All I had to do was switch it on just before second contact and the camera would do the rest until it ran out of film or I switched it off. The cold at an altitude of about 14,000 feet slowed the camera down somewhat but I was rewarded with a nice sequence of shots, showing the shadow moving across the cirrus cloud that was present, particularly at third contact.

India 1995

While the intervalometer was successful, the minimum period was fixed at 5 seconds. This was going to be rather long compared to the duration of the eclipse at Fatehpur Sikri, near Agra, a mere 55 seconds. Unfortunately there was no way of directly altering the exposure interval. However, the power winder was also fitted with an electrical trigger - short the terminals and the camera would fire. Thus the next generation of intervalometer was born (home-made this time), based on a 555 timing chip. A small unit was built by a colleague Ken Cobb. By choosing the appropriate RC time constant the 555 timer would switch a small double-throw relay on and off. This could then trigger two cameras fitted with wideangle lenses. A cycle time of about 2.7 seconds was used and the device worked successfully. The only difficulty found was in determining when to switch it on - it needed to be switched on before second contact but not so early that the camera ran out of film before third contact. I wasted about 6 frames by switching on too early, then realising that the eclipse still had some time to go before second contact and temporarily switching off to preserve the remaining film.

Mongolia 1997

While the device used for India was successful, the interval between exposures was fixed. The interesting pictures tended to be at the beginning and end of the total phase - all the ones in the centre part of totality looked very similar (although the cost of the wasted film is trivial to the cost of being there to see the eclipse!). What was wanted was an intervalometer with a variable interval. The next generation controller needed to be centred on some form of computer that would control the trigger function. At around this time I found an article on automated eclipse photography on the internet[1]. This described variable exposure control of a single camera, using a portable Macintosh computer.

Mongolia also brought with it a special problem - the cold, projected to be about -20°C. At that temperature film can be brittle and the capacity of batteries is dramatically reduced. I decided that the solution for me, given the battery-powered cameras that I already had, would be to prevent the Latent Heat of the cameras from escaping. This was accomplished by building customised cardboard boxes containing pre-cut slabs of 25 mm expanded polystyrene sheet. Small blocks of wood would connect and insulate the camera bodies from the metal tripod heads. These boxes would be taken in kit form and reassembled in Mongolia. The viewfinder for alignment would be accessible via a small plugable hole in the back of the box and the lens would peep out of a larger hole in the front. For the longer focal length lenses that need to be focused, the barrel would extend out of the front of the box and be insulated from the cold air with many layers of "expanded polystyrene wallpaper" found in DIY stores.

In the end the automation project was too ambitious for the time available and a backup plan was used. As each of the cameras was in a closed polystyrene insulated box, some form of trigger from the outside world was required. An electrical connection to the power winder for one of the Pentax cameras would use the 555 timer box, with a longer interval of about 5 seconds to record fixed exposures of the lunar shadow passing by. One Canon camera had a push solenoid, on a wooden support inside the box, positioned over the fire button. This was connected to a 12V battery (kept in a warm internal pocket) via a simple push button control box for making fixed exposures for second and third contact. Another Canon had an air release on another support positioned over the trigger and used the Auto Exposure Bracket facility to record the corona, 1 picture at +2f stops, 1 at the nominal setting and 1 at -2f stops (a limited choice but better than nothing). The second Pentax camera had a mixture: one button on the control box to advance the film via the power winder and one button to take pictures on the "B" setting with a push solenoid. This was set to record the eclipsed Sun and comet Hale-Bopp on a 28mm lens, so different exposures of several seconds at a smaller aperture could be done manually.

So much for the plan - on the day we stood by the snow-covered roadside north of Darhan in Mongolia and saw the sky go dark but the Sun was invisible behind clouds in an overcast sky. Two of the cameras didn't even leave the bus. The main record of the event was recorded with the ultra-wide angle lens and the 555 timer.

Development of "Widget"

The key requirement was the need to control several cameras, each via a simple trigger. The solution was developed with a colleague, David Butler, centred on a parallel printer port. If a control device can send a single 8 bit character, it would be possible to control 8 independent slave devices that only understand the binary on/off. The control device chosen was a personal organiser, a Psion 3c with an optional parallel lead interface. The Psion has its own programming language, OPL, has a large display screen and it is possible to write directly to the parallel port from an OPL program. The Psion has an advantage over a portable PC or Mac - weight (only 10 oz) and cost (as I didn't own any of them in the first place).

The key component of the interface box is a 74LS373 Octal D-type flip-flop that gives TTL compatible outputs. It is a latch for the 8 bit characters that come from the parallel port, enabling the Psion to switch 8 sealed reed relays, chosen for their low current consumption. Those reed relays can then switch all sorts of devices, limited only by the speed needed and the power being switched. The box, containing the power supply, chip and the reed relays, has never got past being called “Widget”.

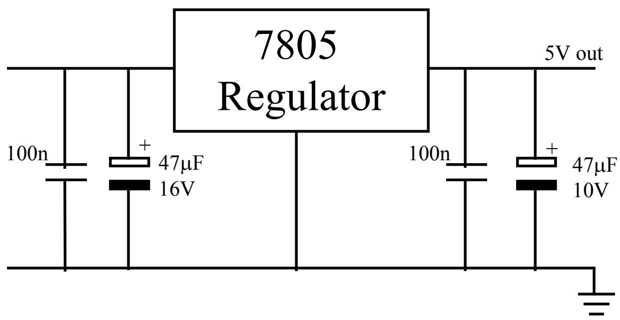

Figure 1. The power supply. I used a L78M05CV but many others are suitable.

The power supply’s prime function, Figure 1, was to supply 5V to the chip. The voltage regulator can handle a wide range of voltages, but here a 9V PP3 battery was used.

Figure 2 shows the connections to the chip, which remembers the data present on the connector pins 2-9. As the Psion Organiser expects to see a printer, the handshakes are simulated using the wiring arrangement shown. The chip never talks back to the controller and the Psion does not know if the chip is active. The switch S1 (Output Enable Control) is closed after the Psion opens its communication port. If S1 is closed before the Psion has opened its port, all the disabled outputs are pulled high, firing any cameras connected.

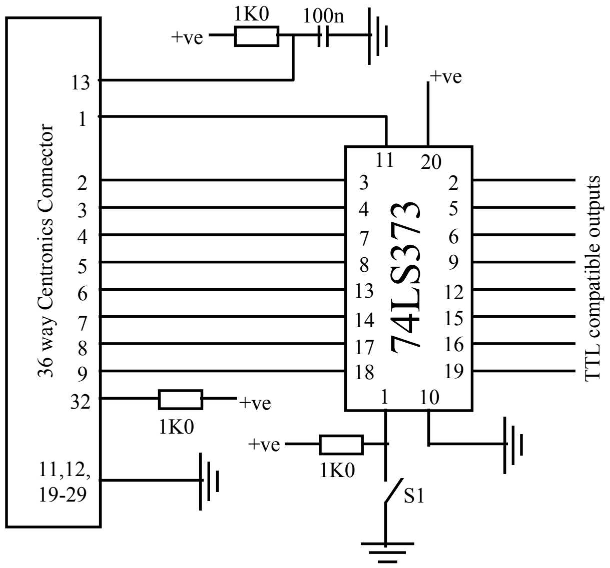

Figure 2. The heart of Widget. The additional components are to simulate the handshakes a printer is expected to generate. The Psion has a proprietary port connector so the Psion Parallel Port Interface is also needed

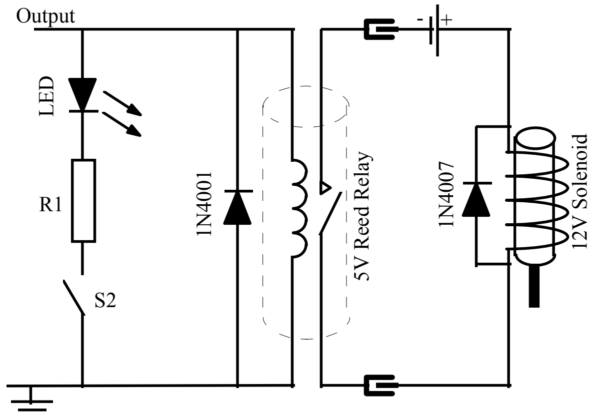

Figure 3 An example of the output options. The LED and the reed relays are in a box with the control chip. The battery and solenoid are connected to the reed relay via a 3.5 mm jack, shown as separate connections for clarity.

Figure 3 shows a variety of output options. Only one port has been drawn yet up to 8 are possible. One option is an LED that lights up when the high 5V output is across it. This is particularly useful to see what is happening when developing the data tables for the control program. The optional switch S2 can be common for all 8 output LEDs so that the LED need not waste power when not used. The value of R1 is chosen so as not to damage the LED with excessive current.

The central and key feature is a 5V sealed reed relay. When the coil is energised, the contact inside the glass envelope is closed. (It is possible to use double reed relays that contain two sets of contacts, enabling two instruments to be controlled, but obviously they would be controlled in an identical manner.) The flexibility is in what the reed relay is connected to.

In Figure 3, a 12V solenoid is connected to a battery to push on the trigger of one of the Canon cameras. The force generated with 12V was not enough to guarantee operation with my Canon equipment, so 15V was used. Solenoids can be operated at greater than their (100%) rated voltage provided that voltage is not continuous. The force that a solenoid will exert is also dependent on how much of the Iron core is within the solenoid as well as the battery voltage. The highest force occurs when the core is fully within the coil. The amount of travel of the shutter trigger is only 1-2 mm so the solenoid must be held at the correct distance so the strongest part of the thrust is used. The solenoid I used would give a maximum force of about 400 g. Remember that only sufficient force to reliably fire the trigger is needed - 400g could cause damage if applied to the "wrong" camera. An estimate of the force required can be made using a set of analogue/digital kitchen scales. Push the inverted camera trigger with something like a pencil onto the measuring pan and see when the camera fires.

An alternative connection is a pair of unpowered wires to the electrical terminal on the Pentax power winder. For a Canon EOS 100 camera this is not possible as it does not have electric contacts or use a conventional cable release - an infrared remote trigger is available. Squeezing a button on the remote control shorts two contacts inside, sending an IR pulse train to fire the camera. To use this for an electrical remote control, the unit was broken open (**obviously invalidating any guarantee**), two thin wires were soldered to these contacts under the button and the wires extended out of the body to a small connector. This could then be attached to the reed relay terminals. When the reed relay coil was energised the terminals inside the remote control were shorted and an infra red signal sent to the camera to fire. All cameras would be used with constant manual shutter speeds.

Obviously different ports of the chip can be connected to different devices.

The Control Program

A listing of the control program is provided on the BAA Journal World wide Web site[2] or may be obtained from the author. The control program is effectively a means of sending a series of 8 bit characters very slowly. Numbers in the range 0 to 255 are sent out using the CHR$ function. In OPL the ";" character is important in a print statement. "LPRINT CHR$(65);" sends the letter "a" (0100001) and suppresses the LF character CHR$(10) that normally automatically terminates a sequence. CHR$(65) is held until another character is sent. By using a PAUSE function, each character from a predefined list is slowly sent to Widget. I use 0.5 second for the duration, as some equipment, for example the power winders, need a certain minimum duration of pulse. It also makes the planning of a firing sequence easier to draft out. The result is a data file, of numbers (0 to 255) and pause durations, that is sent to Widget once the program calls it. A program to create a data file and another to read the completed file are given in Appendix B and C respectively.

One of the advantages of something with an internal clock is that it can start events relative to that clock (such as eclipse photography!). So how do you determine when that is? That is determined from a knowledge of where you are and predictions of the times of second and third contact for that position. For the accuracy needed here the position can be measured using a GPS receiver. The local circumstances can be calculated from the Besselian Elements of the particular eclipse. For the August 1999 eclipse these are available[2]. These contact times can be calculated to ridiculous accuracy if required. However, it must be remembered that the published eclipse predictions assume a spherical Moon - the mountains and valleys of the real Moon modify those predictions by up to several seconds either way. More accurate times of the total eclipse are obtained using a set of "limb corrections"[2], which actually slowly vary as the shadow of the Moon sweeps over the Earth. The prediction calculated using the Besselian Elements therefore have to be manually amended. Anyway, an accuracy of 1 second is sufficient for our purposes (particularly as the Psion internal clock can only be interrogated with a resolution of 1 second).

Note that the sequence for recording the eclipse does not have to start at second contact time - it can start a pre-set interval beforehand. The same applies to third contact. As I cannot guarantee with sufficient accuracy beforehand exactly where I will be located, I cannot accurately determine the duration of the eclipse. seconds. I therefore have two main data files, one for use relative to second contact that finishes before mid-totality and another one for third contact that starts after mid-totality. (There are two others described later). It is important that each file finishes before the next one is required due to the way the program runs.

Curaçao 1998

Four automated cameras were taken to Curaçao in the Caribbean. The two Pentax cameras were set to record the passage of the shadow across the landscape with ultra wide-angle lenses, a 17 mm and a 16 mm fisheye. One Canon EOS 100 was set to record second and third contact through a 1000 mm lens using the modified infra red remote control.

The second Canon EOS 100 was set for something new - a multiple exposure of the partial phases through a solar filter and a clear exposure of the totality - a "multisun" shot. A third data file, with just one line in it, was created to fire this one camera, the interval between each shot being controlled by the main program. Various studies were carried out beforehand to choose the exposure for the partial phases, the totality exposure, the interval between exposures and the focal length of the lens. 80 mm was chosen and about 29 exposures would extend diagonally across a 35 mm frame. With an essentially empty sky, there is nothing for the autofocus mechanism to use, so the camera will not work in auto focus mode. The lens was focused on infinity, taped in position and the camera set to manual focus. The infra red remote trigger is an option that resets itself if not used within 4 minutes 20 seconds. I wanted 5 minute intervals and had to use a solenoid over the trigger instead. Canon EOS 100 cameras have a maximum of 9 exposures on a single frame. This can be increased part way through the multiple exposure by entering the multiple exposure option and increasing the remaining value. The exposure for the mid-totality shot is adjusted manually after the last partial phase shot just before second contact. A fourth data file was used to fire the "multisun" camera at that time as well as some of the other cameras. One feature I totally underestimated is how to work out where the Sun will be 1-1½ hours ahead and point the camera at that point. In Curaçao the Sun pivots around a point 12 degrees above the horizon, completely different to the 52 degrees at home. My first attempt at recording the partial phases was a complete failure - the Sun drifted out of the field of view rather than in! Fortunately this was discovered in time and the camera realigned.

So how did it all go? Figure 4 5 and 6 are examples of what was obtained. My plans in Curaçao were upset by the wind, tending to blow solar filters off. Improvements will be made to prevent a reoccurrence.

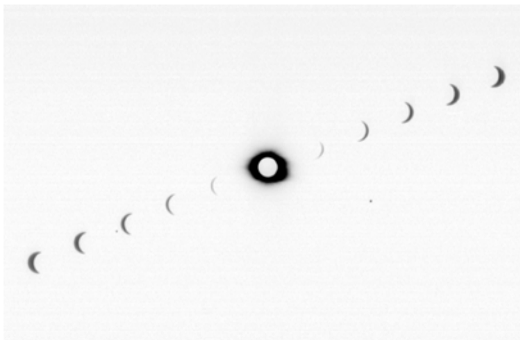

Figure 4. The successful (second!) attempt at recording the partial phases and the total phase on one frame. This eclipse was also fortunate with Mercury (on the left) and Jupiter (on the right) close to the Sun. Kodachrome 25, 80mm, f/5.6 - Partial phases 1/60 second through a Thousand Oaks Mylar filter - Totality 2 seconds no filter. Shown in negative form.

Figure 5 One frame from the sequence taken with the 16 mm fisheye lens showing the wonderfully clear sky. The eclipsed Sun, 62° above the horizon, is rather small at such a scale. In the original, Venus is about 20° above the horizon and Jupiter and Mercury are also visible next to the eclipsed Sun. On one of the boats moored in Knip Bay, one couple were married during totality! Fujichrome 100, 16 mm, f/2.8, 1/4 second.

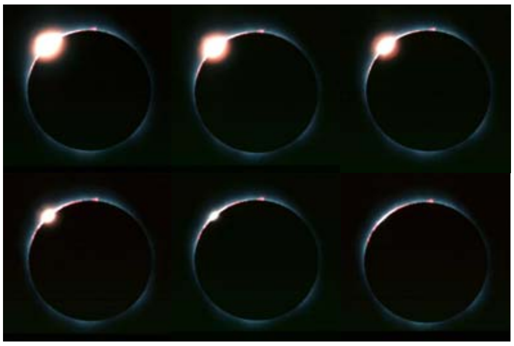

Figure 6. The sequence taken at 2 second intervals during second contact. Kodachrome 64, 1000mm, f/10, 1/60 second

August 1999

So what will I be doing in August 1999? I found that a pan and tilt head can be quite difficult to use with long lenses, particularly when the Sun is as high as it was in Curaçao (62°). Next time I will use a Vixen mount to automatically "track" the Sun. Alignment to Polaris does not have to perfect, particularly as I will have to do this during the day, but it should minimise the amount of effort required to follow the Sun.

All the plans so far have involved fixed exposures in all the cameras. The multiple Sun picture required me to manually adjust the exposure at the right point - it was not automatic. Some thought has been made as to how to automatically adjust the camera speed. I am neither confident nor reckless enough to open a perfectly good camera to get at that part of the mechanism. One method is to use the "B" setting and to vary the duration that the solenoid is held down[1]. This was not found to be suitable for the cameras and solenoid used by me. The minimum shutter attainable speed seemed to be about 1/10 second. However, I have made a working prototype using the Pentax ME Super and the power winder. The remote socket will fire the shutter for whatever duration the manual speed is set to. The manual speed is then adjusted by a solenoid mounted over the "up" speed adjustment button. For a Pentax ME Super a 6V battery through a 12V solenoid is sufficiently strong. (Other means of not stabbing the camera to death include using a resistor in series with the solenoid or positioning the solenoid so that the core is further out of the body of the solenoid) The duration has to be just right to increase the duration by just one stop. To go "down" another solenoid does not easily fit in the space. Fortunately, the shutter speeds scroll round in a loop and the next step from 4 seconds is 1/2000 second. So only one solenoid is needed.

So, my proposed set up will be:- 1 camera for second and third contact, 1 camera for the corona at various speeds (both roughly tracking the Sun), 1 camera for the passage of the shadow and one for a multisun. I realise I will still have to amend the shutter speed for totality of the multisun, but during totality I won't be taking a single picture! *(Famous last words!)*

Anything else needed? Oh, yes - clear skies!

Acknowledgements

Thanks are given in particular to Ken Cobb and Dave Butler for their help.

References

[1] Schneider G "Umbraphile"
http://balder.prohosting.com/stouch/UMBRAPHILE.html

[2] http://www.star.ucl.ac.uk/~hwm/evans.htm

[3] Espanak F Anderson J "Total Solar Eclipse of 1999 August 11" NASA Reference Publication 1398

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