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Fundamental Print Control

Timing Print Exposures

Expose for the highlights

The amount of light reaching a photographic emulsion must be controlled in order to ensure the right exposure. Exposing the film in the camera is typically done with a combination of lens aperture and shutter timing. The lens aperture, also called 'f/stop', controls the light intensity, and the shutter timing, also called 'speed', controls the duration of the exposure. The f/stop settings are designed to either half or double the light intensity. The shutter speed settings are designed to either half or double the exposure duration. This is accomplished by following a geometric series for both aperture and time. The 'film exposure control' table in fig.2 shows an example of typical settings used in modern cameras and lenses. Therefore, an f/stop adjustment in one direction can be offset by a shutter speed adjustment in the opposite direction. Experienced photographers are very comfortable with this convenient method of film exposure control and refer to both, aperture and shutter settings, as f/stops or simply, 'stops'.

In the darkroom, the need for exposure control remains. Splitting this responsibility between the enlarging lens aperture and the darkroom timer is a logical adaptation of the film exposure control. However, the functional requirement for a darkroom timer is different from that of a camera shutter, since the typical timing durations are much longer.

Film exposure durations are normally very short, fractions of a second, where typical enlarging times vary from about 10 to 60 seconds. Long exposure times are best handled with a clock type device which functions as a 'count down'. Some popular mechanical timers, matching this requirement, are available. More accurate, electronic models with additional features are also on the market. Some professional enlargers go as far as featuring a shutter in the light path. This gives an increased accuracy, but is only required for short exposure times.

fig.1 This image of old and worn piping was taken in the Botanical Garden on Belle Isle, just south of Detroit, Michigan USA. The final print exposure and the print manipulation were determined by the f/stop timing method.

arithmetic series a constant difference (here 5)	10	15	20	25	30	35	40
geometric series a constant ratio (here 2)	1	2	4	8	16	32	64

film exposure control										
aperture [f/stop]	45	32	22	16	11	8	5.6	4	2.8	2
time [1/s]	500	250	125	60	30	15	8	4	2	1

print exposure control										
aperture [f/stop]	45	32	22	16	11	8	5.6	4	2.8	2
time [s]	1	2	4	8	16	32	64	128	256	512

fig.2 The film exposure is controlled with the taking lens aperture and the shutter timing. Both sequences are geometric and not arithmetic in nature for good reason. The print exposure can be controlled in the same way with the enlarger lens aperture and a darkroom timer.

Arithmetic (Traditional) Timing

A typical traditional printing session is simplified in the following example. The enlarging lens aperture is set to f/8 or f/11 to maximize image quality and allow for reasonable printing times. The printer estimates from experience that the printing time will be around 25 seconds for the chosen enlargement. Typically, a 5 to 7-step test strip, with 5-second intervals, is prepared to evaluate the effect of different exposure times. A sample of such a test strip is shown in fig.3 and was used to test exposures of 10, 15, 20, 25, 30, 35 and 40 seconds. The test strip is then analyzed and the proper exposure time is chosen. In this example, a time of less than 20 seconds would be about right, and the printer may estimate and settle on an exposure time of 18 seconds. Now, a so-called ‘base exposure’ time is established. This sequence may be repeated for different areas of interest, for example textured highlights and open shadows. If they deviate from the base exposure, dodging and burning may be required to optimize exposure locally.

10s 15s 20s 25s 30s 35s 40s

fig.3 (right)
a traditional test strip in 5-s increments (arithmetic series)

8s 10.1s 12.7s 16s 20.2s 25.4s 32s

fig.4 (far right)
an f/stop test strip in 1/3-stop increments (geometric series)

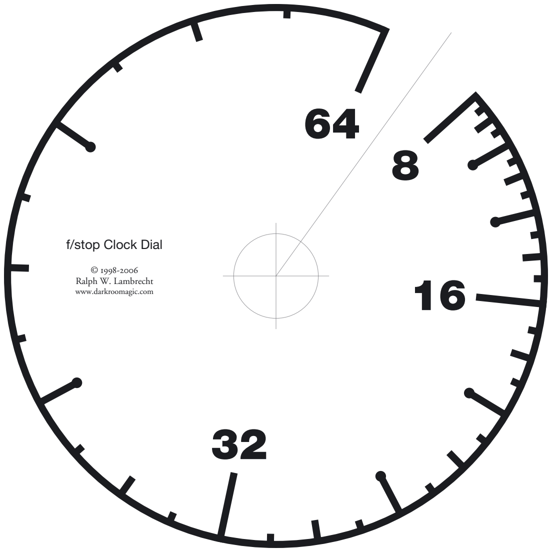

fig.5a (far left) A simple analog f/stop dial, from 8 to 64 seconds in 1/3, 1/6 and 1/12-stop increments, can be made and attached to any analog timer.

fig.5b (left) Here the f/stop clock dial was enlarged and temporarily taped to an already existing 'GraLab 300' timer.

This is a reasonable approach to printing, but it does not utilize some of the benefits of geometric, or f/stop timing. In the traditional, arithmetic timing method, uniform time increments produce unequal changes of exposure. As seen in fig.3, the difference between the first two steps is 1/2 stop, or 50%. However, the difference between the last two steps is only 14%, or slightly more than a 1/6 stop. Therefore, arithmetic timing methods provide too great of a difference in the light steps and too little of a difference in the dark steps of a test strip. This makes it difficult to estimate an accurate base exposure time for the print.

Geometric (f/stop) Timing

My involvement with geometric printing began when I met a fellow photographer and printer in the UK. He convinced me to give it a try. It did not take long to realize the major benefits of this very logical technique. After a small learning curve and the typical discomfort with any unfamiliar technique, geometric timing has now become the standard in my darkroom. It provides any darkroom practitioner with robust print control and the ability to predict repeatable results with confidence. I will explain the benefits of geometric timing in the chronological order of a typical printing session from the test strip, through the exposure adjustment for a work print, to the fine tuning with dodging and burning, but first some general notes.

Considering the typical design of darkroom timers, it is understandable why arithmetic timing has been the predominant method of exposing photographic paper. Nevertheless, it is worth considering geometric timing not just for film exposure but also for print exposure, because it has significant advantages when it comes to test strips, print control, repeatability and record keeping. Since lens aperture markings also follow a geometric progression, geometric timing is often referred to as 'f/stop timing'.

Fig.5 provides an analog version of an f/stop timing sequence, which helps to illustrate the effect. It is a continuation of the well-known camera shutter speed doublings from 8 up to 64 seconds, and it is subdivided first into 1/3 then 1/6 and finally 1/12 stop. These ranges were selected because times below 8 seconds are difficult to control with an analog timer, and times well above one minute are too time consuming for a practical darkroom session. Increments down to 1/12 stop are used, because that is about the smallest appreciable exposure increment. Anything less is really hard to make out. For normal paper grades, between grade 2 and 3, enlarging time differences of a 1/3 stop (~20%) are significant in tonal value, 1/6 stop (~10%) can easily be seen and differences of a 1/12 stop (~5%) are minute, but still clearly visible, if viewed next to each other. Smaller increments may be of use for paper grades 4 and 5 but are rarely required. The analog dial clearly shows how f/stop timing fractions increase with printing time. Fixed increments of time have a larger

dodging [f/stop] ←						base exposure	→ burning [f/stop]											
-1	-5/6	**-2/3**	-1/2	**-1/3**	-1/6		+1/6	**+1/3**	+1/2	**+2/3**	+5/6	**+1**	+1 1/3	+1 2/3	**+2**	+2 1/3	+2 2/3	**+3**
-4.0	-3.5	**-3.0**	-2.3	**-1.7**	-0.9	**8**	1.0	**2.1**	3.3	**4.7**	6.3	**8.0**	12.2	17.4	**24.0**	32.3	42.8	**56.0**
-4.2	-3.7	-3.1	-2.5	-1.7	-0.9	8.5	1.0	2.2	3.5	5.0	6.6	8.5	12.9	18.4	25.4	34.2	45.3	59.3
-4.5	-3.9	-3.3	-2.6	-1.9	-1.0	9.0	1.1	2.3	3.7	5.3	7.0	9.0	13.6	19.5	26.9	36.3	48.0	62.9
-4.8	-4.2	-3.5	-2.8	-2.0	-1.0	9.5	1.2	2.5	3.9	5.6	7.4	9.5	14.5	20.7	28.5	38.4	50.9	66.6
-5.0	-4.4	**-3.7**	-3.0	**-2.1**	-1.1	**10.1**	1.2	**2.6**	4.2	**5.9**	7.9	**10.1**	15.3	21.9	**30.2**	40.7	53.9	**70.6**
-5.3	-4.7	-4.0	-3.1	-2.2	-1.2	10.7	1.3	2.8	4.4	6.3	8.3	10.7	16.2	23.2	32.0	43.1	57.1	74.8
-5.7	-5.0	-4.2	-3.3	-2.3	-1.2	11.3	1.4	2.9	4.7	6.6	8.8	11.3	17.2	24.6	33.9	45.7	60.5	79.2
-6.0	-5.3	-4.4	-3.5	-2.5	-1.3	12.0	1.5	3.1	5.0	7.0	9.4	12.0	18.2	26.1	36.0	48.4	64.1	83.9
-6.3	-5.6	**-4.7**	-3.7	**-2.6**	-1.4	**12.7**	1.6	**3.3**	5.3	**7.5**	9.9	**12.7**	19.3	27.6	**38.1**	51.3	67.9	**88.9**
-6.7	-5.9	-5.0	-3.9	-2.8	-1.5	13.5	1.6	3.5	5.6	7.9	10.5	13.5	20.4	29.3	40.4	54.4	72.0	94.2
-7.1	-6.3	-5.3	-4.2	-2.9	-1.6	14.3	1.7	3.7	5.9	8.4	11.1	14.3	21.7	31.0	42.8	57.6	76.3	99.8
-7.6	-6.6	-5.6	-4.4	-3.1	-1.6	15.1	1.8	3.9	6.3	8.9	11.8	15.1	23.0	32.8	45.3	61.0	80.8	106
-8.0	-7.0	**-5.9**	-4.7	**-3.3**	-1.7	**16**	2.0	**4.2**	6.6	**9.4**	12.5	**16.0**	24.3	34.8	**48.0**	64.6	85.6	**112**
-8.5	-7.4	-6.3	-5.0	-3.5	-1.8	17.0	2.1	4.4	7.0	10.0	13.3	17.0	25.8	36.9	50.9	68.5	90.7	119
-9.0	-7.9	-6.6	-5.3	-3.7	-2.0	18.0	2.2	4.7	7.4	10.5	14.0	18.0	27.3	39.1	53.9	72.6	96.1	126
-9.5	-8.3	-7.0	-5.6	-3.9	-2.1	19.0	2.3	4.9	7.9	11.2	14.9	19.0	28.9	41.4	57.1	76.9	102	133
-10.1	-8.8	**-7.5**	-5.9	**-4.2**	-2.2	**20.2**	2.5	**5.2**	8.4	**11.8**	15.8	**20.2**	30.6	43.8	**60.5**	81.4	108	**141**
-10.7	-9.4	-7.9	-6.3	-4.4	-2.3	21.4	2.6	5.6	8.8	12.5	16.7	21.4	32.5	46.4	64.1	86.3	114	150
-11.3	-9.9	-8.4	-6.6	-4.7	-2.5	22.6	2.8	5.9	9.4	13.3	17.7	22.6	34.4	49.2	67.9	91.4	121	158
-12.0	-10.5	-8.9	-7.0	-4.9	-2.6	24.0	2.9	6.2	9.9	14.1	18.7	24.0	36.4	52.1	71.9	96.8	128	168
-12.7	-11.1	**-9.4**	-7.4	**-5.2**	-2.8	**25.4**	3.1	**6.6**	10.5	**14.9**	19.9	**25.4**	38.6	55.2	**76.2**	103	136	**178**
-13.5	-11.8	-10.0	-7.9	-5.6	-2.9	26.9	3.3	7.0	11.1	15.8	21.0	26.9	40.9	58.5	80.7	109	144	188
-14.3	-12.5	-10.5	-8.4	-5.9	-3.1	28.5	3.5	7.4	11.8	16.7	22.3	28.5	43.3	62.0	85.5	115	153	200
-15.1	-13.3	-11.2	-8.8	-6.2	-3.3	30.2	3.7	7.9	12.5	17.7	23.6	30.2	45.9	65.7	90.6	122	162	211
-16.0	-14.0	**-11.8**	-9.4	**-6.6**	-3.5	**32**	3.9	**8.3**	13.3	**18.8**	25.0	**32.0**	48.6	69.6	**96.0**	129	171	**224**
-17.0	-14.9	-12.5	-9.9	-7.0	-3.7	33.9	4.2	8.8	14.0	19.9	26.5	33.9	51.5	73.7	102	137	181	237
-18.0	-15.8	-13.3	-10.5	-7.4	-3.9	35.9	4.4	9.3	14.9	21.1	28.1	35.9	54.6	78.1	108	145	192	251
-19.0	-16.7	-14.1	-11.1	-7.9	-4.2	38.1	4.7	9.9	15.8	22.4	29.8	38.1	57.8	82.8	114	154	204	266
-20.2	-17.7	**-14.9**	-11.8	**-8.3**	-4.4	**40.3**	4.9	**10.5**	16.7	**23.7**	31.5	**40.3**	61.3	87.7	**121**	163	216	**282**
-21.4	-18.7	-15.8	-12.5	-8.8	-4.7	42.7	5.2	11.1	17.7	25.1	33.4	42.7	64.9	92.9	128	173	229	299
-22.6	-19.9	-16.7	-13.3	-9.3	-4.9	45.3	5.5	11.8	18.7	26.6	35.4	45.3	68.8	98.4	136	183	242	317
-24.0	-21.0	-17.7	-14.0	-9.9	-5.2	47.9	5.9	12.5	19.9	28.2	37.5	47.9	72.9	104	144	194	256	336
-25.4	-22.3	**-18.8**	-14.9	**-10.5**	-5.5	**50.8**	6.2	**13.2**	21.0	**29.8**	39.7	**50.8**	77.2	110	**152**	205	272	**356**
-26.9	-23.6	-19.9	-15.8	-11.1	-5.9	53.8	6.6	14.0	22.3	31.6	42.1	53.8	81.8	117	161	217	288	377
-28.5	-25.0	-21.1	-16.7	-11.8	-6.2	57.0	7.0	14.8	23.6	33.5	44.6	57.0	86.7	124	171	230	305	399
-30.2	-26.5	-22.4	-17.7	-12.5	-6.6	60.4	7.4	15.7	25.0	35.5	47.2	60.4	91.8	131	181	244	323	423
-32.0	-28.1	**-23.7**	-18.7	**-13.2**	-7.0	**64**	7.8	**16.6**	26.5	**37.6**	50.0	**64.0**	97.3	139	**192**	259	342	**448**

fig.6 The f/stop timing table, including adjustments for dodging and burning. Determine the base print exposure time, rendering significant print highlights to your satisfaction, and find this 'base exposure' in the center column. Base exposure times are listed in 1 stop (black), 1/3 stop (dark gray), 1/6 stop (light gray) and 1/12 stop increments. After adjusting overall print contrast, rendering significant print shadows as desired, find related dodging and burning times in 1/6 stop increments left and right to the base exposure to fine-tune the print.

Example: Assuming a base exposure time of 19.0s, exposure is held back locally for 2.1s to dodge an area for a 1/6 stop, and a 4.9s exposure is added locally to apply a 1/3 stop burn-in. Base exposure time and f/stop modifications are entered into the print record for future use. The exposure time must be modified if print parameters or materials change, but dodging and burning is relative to the exposure time, and consequently, the f/stop modifications are consistent.

effect on short exposure times and a smaller effect on long exposure times.

The numerical f/stop timing table in fig.6 is a more convenient way to determine precise printing times than the previous analog table. It also includes dodging and burning times as small as 1/6-stop increments. It can be used with any darkroom timer, but a larger version may be required to see it clearly in the dark. Base exposure times are selected from the timing table and all deviations are recorded in stops, or fractions thereof. This is done for test strips, work prints and all fine-tuning of the final print, including the dodging and burning operations. Now, let's get started.

1. The Test Strip

Assuming a typical printing session, select the following timing steps in 1/3-stop increments from the timing table: 8, 10.1, 12.7, 16, 20.2, 25.4 and 32 seconds. The resulting test strip is shown in fig.4. Please note that the range of exposure time is almost identical to the arithmetic test strip. However, a comparison between the two test strips reveals that the geometrically spaced f/stop version is much easier to interpret. There is more separation in the light areas and still clear differences in the dark areas of the test strip. After evaluation of the test strip, it can be determined that the right exposure time must be between 16 and 20.2 seconds. A center value of 18.0 seconds may be selected, or another test strip with finer increments may be prepared.

2. The Work Print

The next step is to create a well-exposed work print, at full size and exposed at the optimum base time. This base time is usually the right exposure time to render the textured highlights at the desired tonal value. In this example, the first full sheet was exposed at 18.0 seconds, developed and evaluated. I found this print just slightly too light and decided to increase the exposure by a 1/12 stop to 19.0 seconds, knowing that this would darken the print only marginally. I ended up with the almost same result as in the traditional timing method, but this time with much more confidence and control.

In a typical printing session, the print contrast would now be adjusted to render the important shadows at the desired tonal values, but this is covered in the next chapter. To simplify things for now, I will, therefore, assume that we already have the proper print contrast at grade 2. Consequently, we have at present a well-exposed work print with a base print exposure time of 19.0 seconds and good overall print contrast. A work print like this is the necessary foundation to successfully plan all subsequent print manipulations, with the intention to further optimize the image.

3. Dodging and Burning

Fine-tuning all of the tonal values, through dodging and burning, only takes place once the right base image exposure and good overall contrast have been found. I recommend to test strip the desired exposure times for all other areas of importance within the image and then to record them all as deviations from the base exposure time in units of f/stop fractions. The table in fig.6 provides dodging and burning times in relation to several base times.

In this case, I found it advantageous to dodge the center of the print for a 1/6 stop, or as read from the table, for the last 2.1 seconds of the base exposure time and recorded it as (-1/6) on a printing map. The final printing map is shown in fig.7 for your reference. A stubborn upper left hand corner needed an additional 1-stop burn-in (+1) to reveal the first light gray. According to the table, this was equivalent to 19.0 seconds. The top, left and right edges needed an additional 1/3 stop (+1/3) and the timer was set to 4.9 seconds to achieve that exposure. A minor adjustment for the bottom edge of 1/6 stop (+1/6) concluded the session, and the lead picture shows the final image.

The final printing map will be stored with the negative and can be used for future enlarging at any scale. A new base exposure time must be found, when a new enlarging scale becomes necessary, but the f/stop differences for dodging and burning always remain the same. This printing map will also remain useful even if materials for paper, filters and chemicals have been replaced or have aged. It will also be easier to turn excessive burn-in times into shorter times at larger lens apertures in order to avoid reciprocity failures.

Traditional printing has standard edge-burning times, such as 3 seconds, as an example. This can be a relatively large amount for a small print with short base exposure times, and it can be a very short time for a large print with a relatively long base exposure time. Adding a 1/3 stop to the edges is a far more consistent way to work.

Some experienced printers have adopted the practice of using percentages of the base exposure time for all dodging and burning procedures. This approach is not as consistent but very similar to f/stop timing, and these printers should have little or no trouble switching to f/stop printing, because they are already halfway there.

Hardware Requirements

You do not need any additional equipment to give f/stop timing a try. With the tables provided in this chapter and your current darkroom setup, you have everything needed to get started with this logical way to print. Any timer can be controlled to perform f/stop timing, especially when the exposure times are longer than 20 seconds.

Nevertheless, if you do not have a decent darkroom timer yet and if your budget allows, then go out and trade a bit of money for a lot of convenience and time saved, by investing in a good f/stop timer. There are only a few electronic f/stop timers available on the market. They usually provide f/stop and linear timing with a digital display. Some come with memory features to record the sequence of a more involved printing session.

Conclusion

In this chapter, it was shown that altering the print exposure time in an f/stop sequence is a logical adaptation of film exposure control. You are using it with your camera because it works. Why not use it in the darkroom too?

Two significant advantages are obvious. First, test strips become more meaningful, with even exposure increments between the strips, which allow straightforward analysis at any time, aperture or magnification setting. Second, printing records can be used for different paper sizes and materials without a change. After a little experience with the technique, it becomes second nature to visualize the effect of, say, a 1/3-stop print exposure, without worrying about the actual time. This is particularly useful for burning down critical areas or when working at different magnifications and apertures. Several well-known printers record image exposures in f/stops to describe their printing maps. Using f/stop timing makes printing easier, more flexible, and simpler to create meaningful printing records for future darkroom sessions.

f/stop timing has several advantages over traditional timing.

1. test strips have even exposure increments
2. straightforward test analysis at any time, aperture or magnification setting
3. print records are independent of equipment or materials

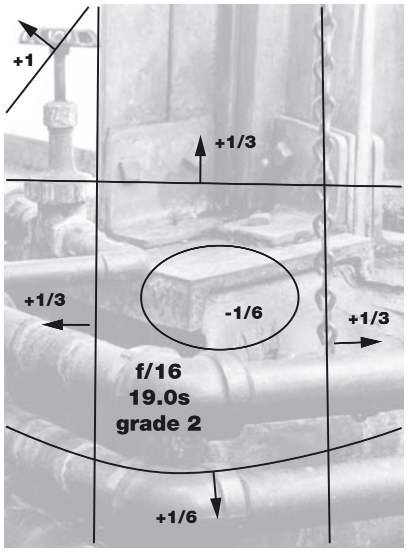

fig.7 Dodging and burning is recorded in f/stop deviations on the printing map. This map is stored with the negative for future enlarging at any scale.