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Software Enhancement for Creative Video Production and Photography with Digital Cameras

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Magic Lantern is an open source software addon for Canon digital single reflex cameras (DSLR). The purpose of the thesis is to showcase what this open framework can offer in professional video production and photography. It shows what features Magic Lantern gives and where it could be used.

The goal set for the thesis was reached through research, testing, and documenting the main features selected for the study, and through utilizing them in every day scenarios, which comprise of interior and outdoor scenes.

The thesis as a whole provides a good summary for home professionals, semi professionals, professionals, and people who want to have control over their digital cameras. The thesis will help beginners who want to use Magic Lantern know its capabilities. Moreover, for enthusiasts that are on a limited budget this software enhancement is by far the best solution.

Keywords	Firmware, Magic Lantern, video production, photography, Canon, camera, open source

Contents

List of Abbreviations

DSLR	Digital single reflex camera
GPL	General Public License
SD	Secure Digital
SDHC	Secure Digital High Capacity
SDXC	Secure Digital Extended Capacity
CF	compact flash
ExFAT	Extended File Allocation Table
ML	Magic Lantern
ROM	Read Only Memory
M mode	Manual mode on digital cameras
RAW	Camera image file, file format, uncompressed file
MLV	Magic Lantern video
JPEG	Joint photographic experts group
FPS/ p	Frames per second
H.264	Compressed Internet video codec
ProRes	Lossy video compression format by Apple
Take	A particular shot that is filmed
HDR	High dynamic range

ISO	International Standards Organization
ETTR	Auto exposure to the right
ADTG	Analog/ digital timing generator
DNG	Digital negative
CinemaDNG	Cinema digital negative
CMOS	Complementary metal-oxide semiconductor
CCD	Charge-coupled device
EV	Exposure value
ARM	Advanced RISC Machine/ Instruction set
GUI	Graphical user interface
NLE	Non-linear editing system
SNR	Signal to noise ratio
OS	Operating system
API	Application program interface
LCD	Liquid crystal display
HTML	Hyper text markup language
RGB	Red, Green, and Blue channels
sRGB	Color space
LUT	Look up table

MLP	Magic Lantern Processor
F-stop	Aperture value
GB	Gigabyte
MB/s	Megabytes per Second
ERR	Camera malfunction warnings

1 Introduction

In a course of a few decades, cameras have become more advanced, having the latest technologies, and they are becoming frequent tools in production works. There is a lot of competition in the digital camera industry to make the best products that perform well in low light, being able to capture images at high quality and speed, and being able to record full high definition video. These digital cameras are being in use in Hollywood movies along side high-end cameras like the Arri camera, and this is because of their size and weight.

Magic Lantern, being amongst software enhancements for digital cameras, brings complete control over the Canon digital single reflex cameras (DSLRs) with increased functionalites. Canon digital cameras are classified into cameras for beginners, enthusiasts, and professionals. The prices are high, especially with the professional model Canon DSLRs, and there are differences of course with the hardware and features available.

Magic Lantern is a great solution when it comes to working with small budget productions, indie films, and photography. The purpose of this thesis is to demonstrate the features available on Magic Lantern, and how an end user with a Canon DSLR at their disposal can start incorporating this open source software enhancement onto their creative work. Since Magic Lantern and most of the applications used during this project are open source, it makes Magic Lantern an affordable alternative to the expensive cameras.

2 Magic Lantern

At the moment, Magic Lantern is supported on the following Canon camera models: 1100D, 500D, 550D, 60D, 50D, 600D, 650D, 700D, 7D, 6D, 5D Mark ii, 5D Mark iii, and EOS M (Mirrorless). The following models are still in progress: 100D and 70D. The 5D and 40D models are inactive with the latter not working at all. [1.]

The Magic Lantern team have moved away from the stable version of their firmware release and have since provided downloads using only nightly builds. Nightly builds are automatically compiled binaries that are generated daily from the latest source codes once changes are made. The nightly builds utilized during this project were the 'Nightly.2014Aug20.60D111', and 'Nightly.2016Jan14.60D111' was used for demonstration purposes. Although the latest nightly builds have more added features, the older nightly builds seem to be more stable.

2.1 Legality

Magic Lantern is legal, free, and licensed under the general public license (GPL). The GPL licence allows end users to download, share, and even modify the Magic Lantern firmware. It is legal in the case of fair use under interoperability.

Laws in Europe and the United States of America (USA) have allowed reverse engineering for interoperability without needing any permission for the owner. Reverse engineering is necessary to attain interoperability. In the case of Magic Lantern, the main developers have not found any public documentation by Canon; hence reverse engineering is allowed. [2.]

Magic Lantern only runs alongside the Canon software. Whenever the camera is started, Magic Lantern is loaded from the card slot. Magic Lantern took this advantage of being able to run software from the memory card.

2.2 Installation

To start using Magic Lantern for the first time, it is recommended to use a formatted secure digital (SD) card, and to update the camera to a required Canon firmware version. It is important to always remember to wait for a few seconds before removing the SD card from the camera. This applies also when the camera is turned off, and the reason is to avoid any camera freeze because the Canon firmware is still accessing the SD card. A few other preparations to go through are to remove any battery grips and speedlights attached to the camera and to restore the camera settings to default. [3.]

Magic Lantern was already installed on my Canon 60D. Both the first time installation and updating have similar steps to follow. It is always a safe step to backup the Magic Lantern files that are currently on the SD card. A link to the nightly builds can be found on the downloads page of Magic Lantern.

Once the backup is done, the next step is to follow the instructions as provided on the downloads page which is simply to format the SD card and replace the new files in it. Thereafter, from the camera menu, an update should be done. Figures 1 and 2 below show the on-screen process as Magic Lantern is being installed.

Figure 1. An image split showing the processes for installation.

The image on the left in figure 1 shows the formatting of the SD card with Magic Lantern (ML) being removed. Pressing the button Q on the camera will instead keep ML.

The right-hand side image in figure 1 shows the stage at which the firmware update is done. The new nightly build files have been copied to the SD card prior to this. The process that continues after pressing the OK option can be seen below in figure 2.

Figure 2. An image split showing the processes for installation.

The left-hand side image in figure 2 shows Magic Lantern installing the files placed on the SD card. The installation process continues on the right-hand side image in figure 2 where ROM0 and ROM1 are backed up, and at this stage during the installation, the boot flag is set, and this process makes the SD card bootable. Finally, the last step is to restart the camera. After the camera has restarted, the installation is finished. Prior to installation, it is recommended to have the camera batteries charged fully, to turn the camera mode wheel to manual (M), and to use memory cards such as SD, secure digital high-capacity (SDHC), secure digital extended-capacity (SDXC), and compact flash (CF) instead [4]. Once Magic Lantern (?) is installed, pressing on the trash icon button will show the Magic Lantern menu.

2.3 Official Website

The Magic Lantern official website provides all content and information related to the open source software. On the homepage, there is basic information about what the software offers and about the features that are available in a nutshell. The homepage holds links to other pages such as downloads, forum, support, and the about page.

The downloads page has links to the nightly builds which are binaries compiled automatically once changes occur. Magic Lantern has also provided the source code of the firmware for any person who wants to start compiling code. The forum page is where the Magic Lantern community lives. Users ask questions and share their creative work achieved using Magic Lantern. The forum has up to date releases, a help section with questions and answers, workflows and usage of the features, a developer section with feature requests, and general discussion where users and admins help each other to solve problems and share their tips. [1.]

By Monday 29th of February 2016, 155,486 posts had been posted on the forum and there were around 47,689 members registered. The support page has information regarding further questions, legality, installation and setup, and a user guide for the features. Finally, the about page has a section for donations where users can make donations in bitcoins to support the developers, to contact the Magic Lantern team, and to view photo and video galleries from the community. [1.]

3 Video Features of Magic Lantern

Magic Lantern has really stepped it up with their video features. The RAW video and HDR video are among the two main features that have made Magic Lantern popular. Non Linear Editing (NLE) systems have even had to release updates to support the file types extracted. It is great that there are open source applications to make workflows better.

3.1 RAW Video

For digital cameras, RAW files have only been associated with photos. The RAW image files from the digital cameras are unprocessed, and compared to joint photographic experts group (JPEG) image files. In addition, the RAW images files can be processed further to obtain high quality image output, and this is because RAW files have more bits of data to work with, such that everything can be later changed while post-processing except for the shutter speed, f-stop, and ISO value. [5, 24.]

The H.264 compressed video format that Canon utilizes on its digital cameras for taking videos was mainly intended to be used for the purpose of sending and sharing with others via the internet as this format is compressed and is smaller in size [6]. Generally, the H.264 video consists of JPEG frames, which are not suitable for post-production work as there is not much detail to work with. A solution for this is either increasing the bitrate using the H.264 bitrate controls available with Magic Lantern, which to some extent helps, or RAW video.

In the mid-year of 2013, Magic Lantern was able to, in theory, come up with a way to achieve 12-bit RAW video at full high definition (HD) on the Canon 5D Mark iii while the Magic Lantern team was investigating RAW data for overlay graphics, and this was a big milestone for the Magic Lantern team and the community of cinematographers. [7.]

3.1.1 How RAW Video Works

The RAW video is captured from reading the RAW data straight from the camera's sensor and eventually the data is saved on the card in any way possible [7]. Depending on the Canon camera model, the buffer size can vary. For example, the Canon 60D

has fairly large buffer size. Another thing is that the SD card limits the writing to around 21 Megabytes per Second (MB/s), and this limits the amount of frames saved on the SD card. Figure 3 below shows the Magic Lantern RAW Video menu.

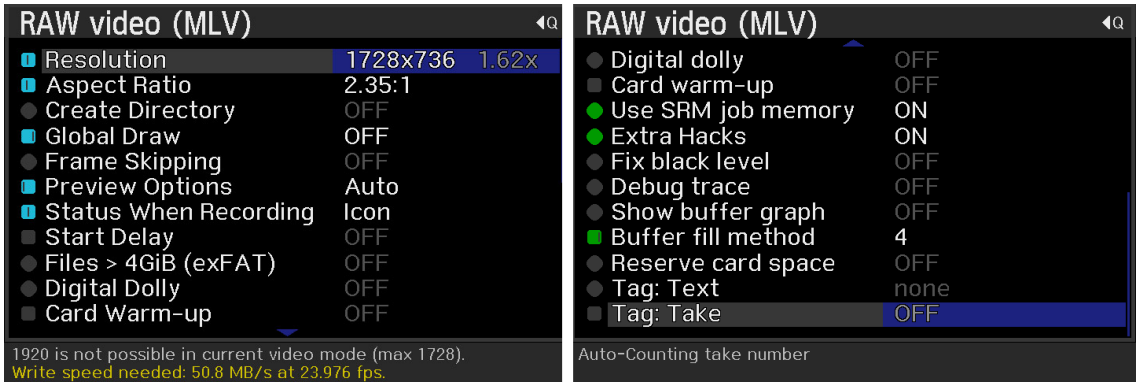

Figure 3. Screenshots showing menus for the RAW video on the left-hand side and MLV based RAW video on the right-hand side.

In the screenshot on the right in figure 3, the resolution option gives a list of dimensions to choose from, and for the Canon 60D, the option is able to capture RAW video at a maximum width of 1728 pixels with an aspect ratio of 2.35:1. The combination of aspect ratios with resolutions greatly affects the writing speeds.

The create directory option will save the video files in separate folders. Since the global draw uses some of the camera's processing power, turning the global draw off might help with performance. Frame skipping is used when the cards tend to be slow, and this means that a selected number of frames will be skipped in order to save the file on card. The start delay option can be set to on if the recording should start with a delay. When enabling the 'Files > 4GB extended file allocation table (exFAT)' option, the recorded file will not be split when exceeding 4 gigabytes, and this is only for exFAT formatted cards. There is a card warm-up option that writes a large file onto the card so that the card would perform a bit faster. The fix black level option helps remove and fix any color casts that may appear due to the available light condition. The debug trace option is used for purposes of detecting any errors that may occur during a video recording. The buffer fill method affects how the card will perform and different values may change the writing speed of the card. The 'reserve card space' option is somewhat similar to the card warm up option. Finally, on the very last option, it is possible to rename and number the recorded files. [4.]

3.1.2 Cababilities of RAW Video

Magic Lantern has came up with their own RAW format that supports audio recording and is placed within the .MLV files generated after recording RAW video. The other RAW video module that saves the video into the .RAW format does not record any audio. The earlier versions of RAW video consisted of bugs like the camera crashing down, file error upon converting the RAW video files, and captured frames containing hot pixels and pink frames as seen in figure 4.

Figure 4. An image crop showing hot pixels on the left and pink frames on the right as found on the extracted RAW file.

The application for converting RAW videos was constantly improved with regular testing and changing lines of codes. Once a single Canon DSLR starts to work, the other developers use the available codes to port into other Canon DSLRs models. Eventually, most of the Canon DSLRs using Magic Lantern are able to use this RAW video feature, though with limitation on hardware for some camera models.

For example, a difference between the Canon 60D, which can achieve a continuous recording at 24p at a resolution of 960x540, and Canon 5D Mark iii, which can achieve a continuous recording at 24p at a higher resolution of 1920x1080, is that the latter has higher writing speed of 100 MB/s for the CF slot and an additional 20 MB/s for the SD slot. Comparison of other Canon camera models can be seen in appendix 1. In figure 5 below, a frame comparison between the RAW video and regular H.264 is made to show how easy it is to fix things like color casts, contrast, and highlights in post-processing.

Figure 5. An image showing comparison between a RAW video and an H.264 frame.

The ability to edit the RAW video in a similar fashion like editing RAW images is a good option. Similar workflows are kind of used with high-end cameras intended for cinema works, and these cameras typically record in high quality formats like the ProRes. At the moment, Magic Lantern is working on a way to make a newer RAW video format called MLV Lite, which is a cross between the .RAW and .MLV formats [8].

3.1.3 Drawbacks of RAW Video

RAW video is surely overwhelming at first, as it needs a bit of learning beforehand to understand the workflows and get acquainted with the tools available. One thing to take into account is the size of the files. For example a 1600x900 resolution video of 10 seconds, which consists of 235 frames has a size of about 594 MB, and each extracted DNG frame has file size of about 2.6 MB. This means that a 9 minutes RAW video will fill up a 32 gigabyte (GB) SD card.

Moreover, with such longer workflows that take time and hard disk space, it is definitely worth the effort compared to the amount of details, sharpness of the footage, and the capabilities available in post-production. On the one hand, these open source applications available are getting frequent updates and are being improved by the Magic Lantern developers.

3.1.4 RAW Video Workflows in Post-production

Working with RAW video files is tedious, as they occupy a lot of space and can take longer times to convert. On the other hand, the results that are achieved with RAW video are worth the effort. There are currently many tools available online that can be used to help with the workflow, and these go from command line tools to nice graphical user interface ones. Developers aim at creating tools that can in some way improve the RAW video workflow, for instance how to reduce the time it takes to convert files. Different kinds of applications will be discussed and mentioned in this section.

MLRawViewer

MLRawViewer is a cross-platform application that is used for viewing and converting RAW video – both the .RAW and .MLV files format into a higher quality video format like the ProRes or cinema digital negative (CinemaDNG). In addition to viewing and converting the RAW video, it is possible to add both 1D and 3D look up tables (LUTs) and to change the debayering qualit, which is used for recreating the full color image from the RAW file. [9.] Figure 6 shows a screenshot of MLRawViewer being used to review an .MLV file with sRGB (color space) curve applied.

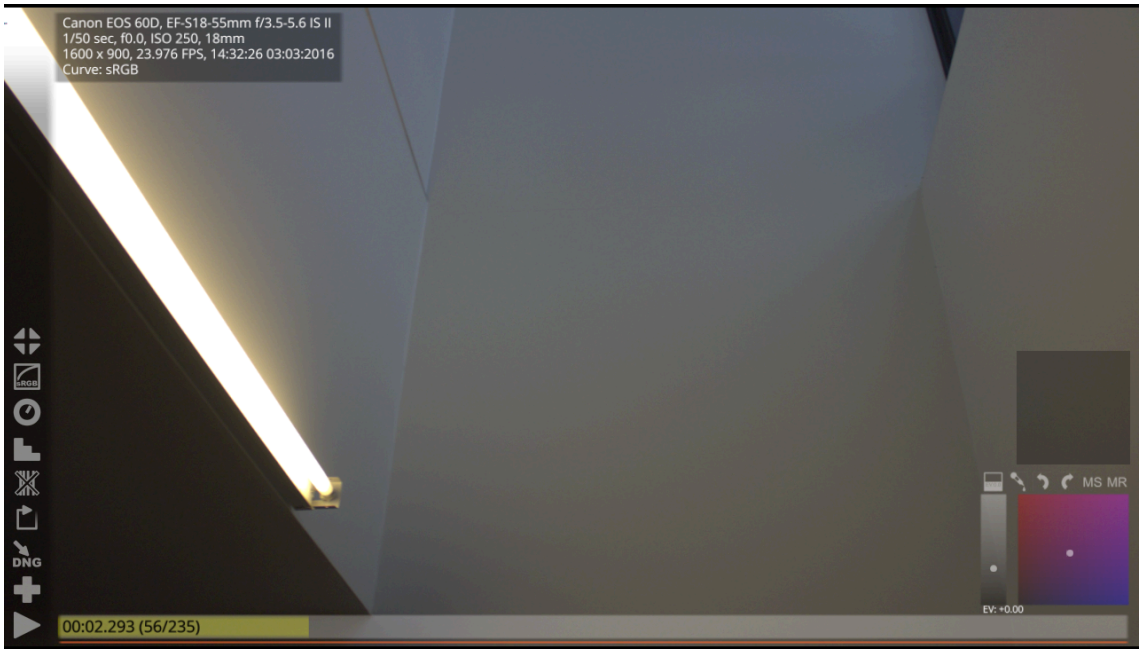

Figure 6. A screenshot of MLRawViewer in action.

For the RAW video seen in figure 6 above, the Magic Lantern RAW video settings were set to a resolution of 1600x900 with an aspect ratio of 16:9. The number of frames achieved was 235, and this equates to around 10 seconds of footage on a 23.976 frames per second (fps) sequence. It is possible to also fix the white balance and exposure straight from MLRawViewer before converting by using the available tools on the bottom right corner. Moreover, after the RAW video has been converted to either ProRes or cinemaDNG frames, further editing can be done in an NLE system.

Alternative Open Source Applications

There are other options available when it comes to extracting frames from the RAW video files. A few notable applications amongst others include raw2dng, raw2cdng, and Magic Lantern processor (MLP – previously cr2hdr-r).

The MLP can process different file types including dual ISO and HDR conversions. When compared to MLRawViewer, raw2dng, and raw2cdng, MLP was able to convert the recorded RAW video file fairly fast compared to the others. A side-by-side comparison is made between the RAW video and the Canon H.264 [10].

Both DNG and cinemaDNG are good standard formats for images and videos. These two formars are recommended by Adobe since their development team have agreed to support these open source formats in the future. [11,11-12.] Following the Adobe documentations, developers have made these cross platform tools for easy RAW video workflows. [12.]

3.2 High Dynamic Range (HDR) Video

HDR is among the features that are popular with video on Magic Lantern. This is somewhat closely related to dual ISO that is discussed in section 4.1 but implemented in a different way. As in the photography side, HDR is a method used for capturing a scene with the highest possible dynamic range available within the digital cameras. Usually what happens is that multiple images are captures of the same scene using different exposure values. Magic Lantern has made it possible to capture videos using this feature as seen in figure 7, and the output file is of an H.264 format.

Figure 7. A frame from HDR video after the Enfuse process.

As seen in figure 7 above, it is typical that the light bulb gets overexposed, and to compensate for these overexposed areas, the exposure would have to be dialled down, but then again the shadows will become darker. With HDR video, it is possible to achieve enough details in the dark and bright areas.

3.2.1 How HDR Video Works

HDR changes the ISO values in such a way that it captures exchanging frames at two ISO values. When the footage is previewed, it looks as if it has a flickering effect. The HDR menu is simple with just two options, namely ISO A and ISO B. Figure 8 below displays the HDR video menu found on Magic Lantern.

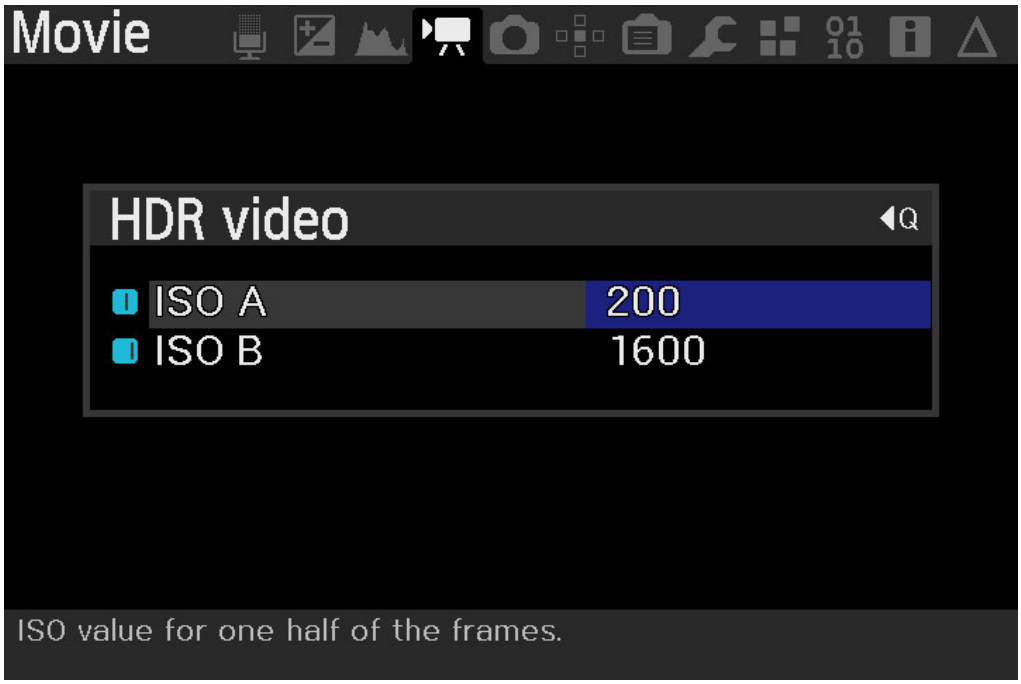

Figure 8. A screenshot showing the HDR video menu.

The options available on the HDR video are fairly straightforward. The ISO A is set for half of the frames and ISO B is set for the other half of the frames. [4.] During post-processing, different application can be used to separate these two exposure values – A and B – and then the frames in between are interpolated.

3.2.2 Post-processing for HDR Video

Open source applications like the MLP and scripting methods like Enfuse, Avisynth, and VirtualDub are among a few post-processing tools used for creating the HDR video. There are also other plugins and scripts that can be used inside NLE systems to separate the frames and blend them together. Figure 9 below shows the original frames from the HDR video file and how it looks like after processing.

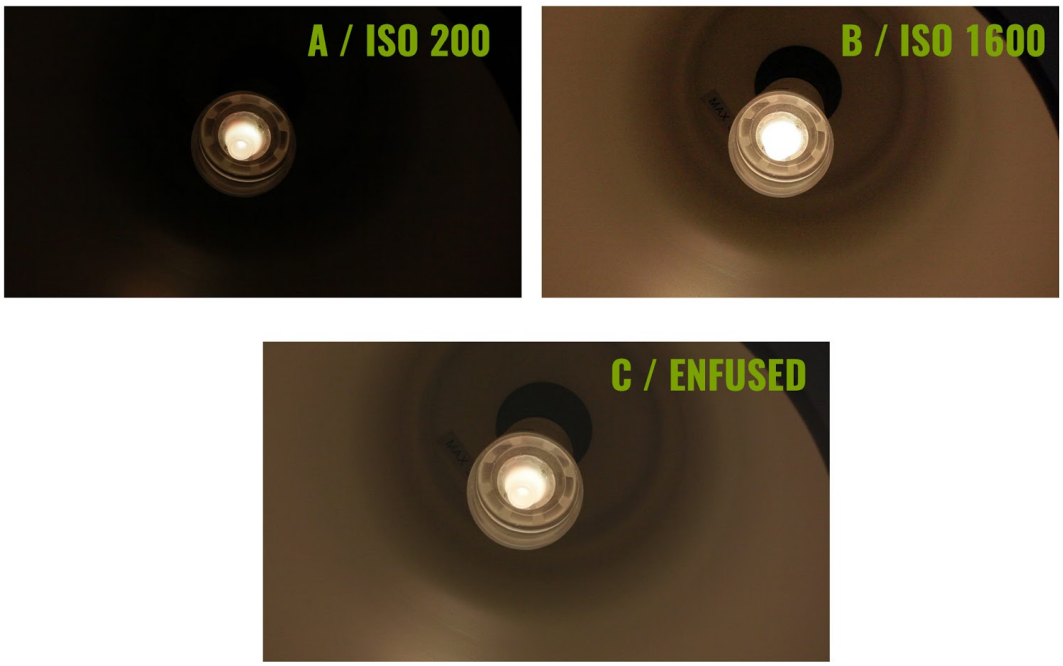

Figure 9. An image showing the stages in creating HDR video.

When the HDR video file is being processed, the Avisynth will split the footage into dark and bright frames, namely A and B, as seen in figure 9. The two separate frames A and B will be blended together with Enfuse to create a combined output C as seen in figure 9. Thereafter, VirtualDub will be utilized to post-process and export the footage. [13.]

4 Photography Features of Magic Lantern

Magic Lantern has a good list of features available for photography. The features that will be focused on in this chapter are dual ISO, auto exposure to the right (ETTR), advanced bracketing, intervalometer, and silent pictures.

4.1 Dual ISO

Dual ISO is a feature available on the nightly builds that and it is constantly being improved. This feature captures an image at two different ISO values, that is, changing the ISO for every other line pair horizontally on an image. It samples half of the sensor at the lowest ISO set by the user, and the other half at a higher ISO set by the user, and then mixes these two together. The final result is an almost noise free image with a much better dynamic range, and not so harsh shadows and highlights on the image. However, scripts and plugins are needed to post-process the images taken with dual ISO [4].

4.1.1 How Dual ISO Works

Canon DSLRs previously used charge-coupled device (CCD) image sensors, but due to the CCDs using a lot of electrical power, being slow, and having high manufacturing costs, Canon changed to the complementary metal-oxide semiconductor (CMOS) image sensors that utilize less power and that are less expensive. In general, Image sensors are used in digital cameras to turn light into electrons. [14.]

The Magic Lantern development team has expected that the analog/ digital generator (ADTG), which is a chip located inside the Canon DSLR, to be partly responsible for turning the CMOS analog sensor values into digital values and to control its clock. Moreover, the CMOS registers are used for tweaking the low-level sensor timings and parameters like the ISO and scan lines. [15.]

On hooking a callback function in the existing Advanced RISC Machine (ARM) code using a breakpoint, the Magic Lantern developers obtained register values. Different CMOS register values were noticed on the register #0 while changing ISOs on the Canon 5D Mark III DSLR. In the CMOS register #0, it was seen that the ISO value of

100 had a register value of 0x003, and also the ISO value of 1600 had a register value of 0x443. Changing this register to 0x403 or 0x043 turned out to enormously improve image quality and the sensor was able to scan half of the lines at the ISO value of 100 and the other half at the ISO value of 1600. Separating the two exposures was done by obtaining separate dark and bright lines, and for the missing lines, obtaining them using an interpolation method. [16.]

On the Lightroom plugin used during post-processing, there are two interpolation methods available to obtain the missing line, which are AMaZE (amaze-edge) and mean 23 (some sort of bilinear method), of which the AMaZE is considered the best.

4.1.2 Drawbacks of Dual ISO

Dual ISO is a good feature and provides us with an image that is less noisy in the shadows. On the other hand there are a few drawbacks, for instance ending up with aliasing and moiré due to line skipping. The other downside of dual iso is that final image has less vertical resolution in the shadows and highlights, and this is due to the black areas that are saved along with the RAW image file that can be used for noise analysis [16]. The full image size captured on my camera was 5344x3516. After a decrease in the vertical image resolution, the active area is now 5202x3465. In post-processing, it is a bit time consuming though not too much. One image took about 4 minutes to convert to the digital negative (DNG) format. Computer space can be an issue, as RAW files are typically large.

4.1.3 Post-processing for Dual ISO

There are a number of methods to post-process the images taken with dual ISO that are available for free, and for different operating systems. For post-processing the images taken, a free Lightroom plugin was used. This Lightroom plugin works on both Windows and Mac operating systems and requires a minimum of Lightroom version 4. For the image seen in figure 10, the camera settings were ISO 100, an aperture of f8.0, and shutter speed of 1/800.

Figure 10. An image with dual ISO disabled.

Moreover, with dual ISO enabled as seen in figure 11, the recovery ISO was set to ISO 1600. This indicates that a dynamic range gain of 2.1 EV with a midtone overlapping of 6.9 exposure value (EV) can be achieved.

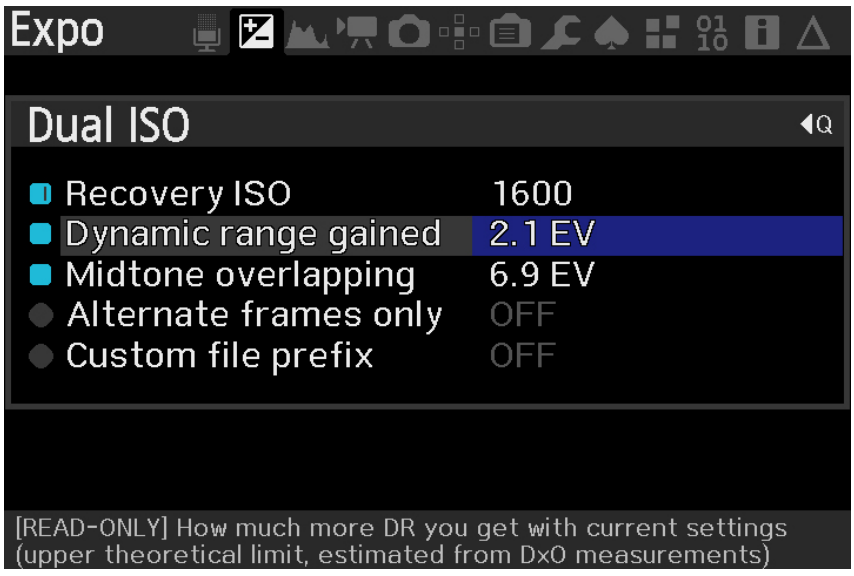

Figure 11. A screenshot showing the dual ISO menu.

Inside the Lightroom application, the dual ISO files can be easily exported by selecting export then choosing the dual ISO Converter (cr2hdr) option. In general, this opens up a dialogue box where different settings that affect how the image is merged together can be edited. Figure 12 shows a portion of the default settings available on the Lightroom plugin. The plugin exports a DNG file with a separate text file that includes all the information concerning the dual ISO file. These two files were placed in a folder named ‘dng_new’ as it was a default option in the Lightroom plugin.

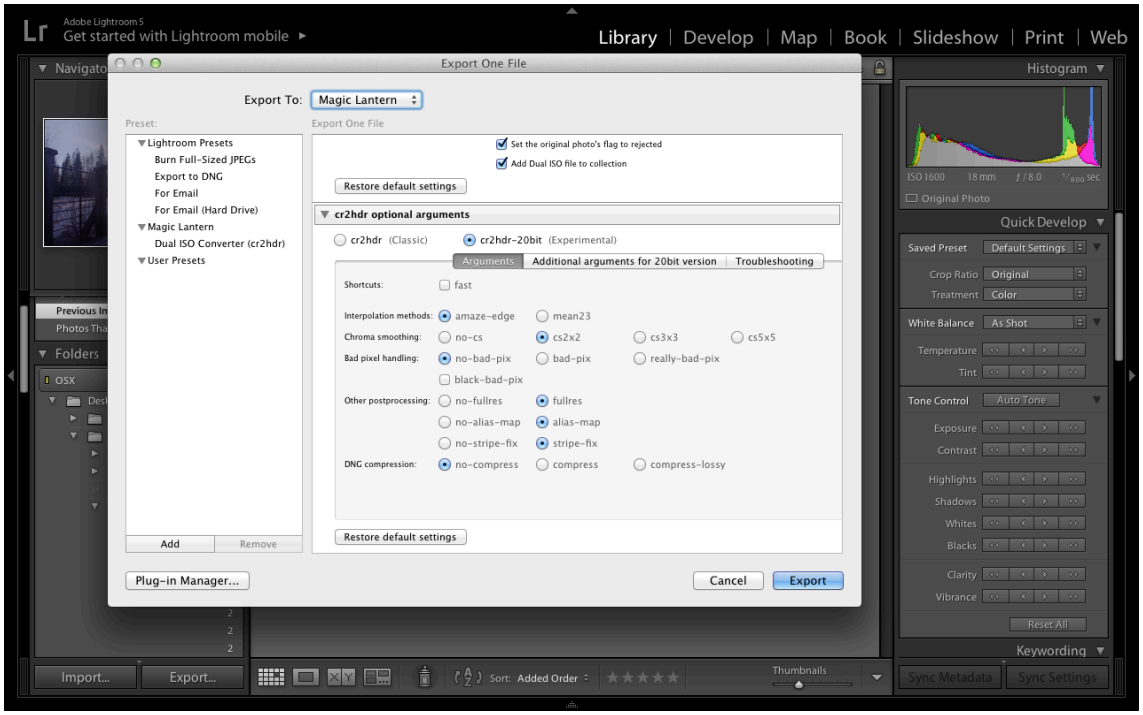

Figure 12. The Lightroom plugin with its options for exporting dual ISO images.

From the DNG file obtained, the folder inside Adobe Lightroom needs to be refreshed in order for the new image to sync. Afterwards, editing proceeds similar to any normal image, difference being that now there are details in the shadows, less noise, and overall the image is looking better as seen in figure 13.

Figure 13. An image with dual ISO enabled.

Moreover, a side by side comparison zoom of the two images was made, one with dual ISO disabled, and the other one with dual ISO enabled as seen in figure 14 to show the differences in noise and details overall, and these two images have the shadow option on Lightroom set to a value of 100%.

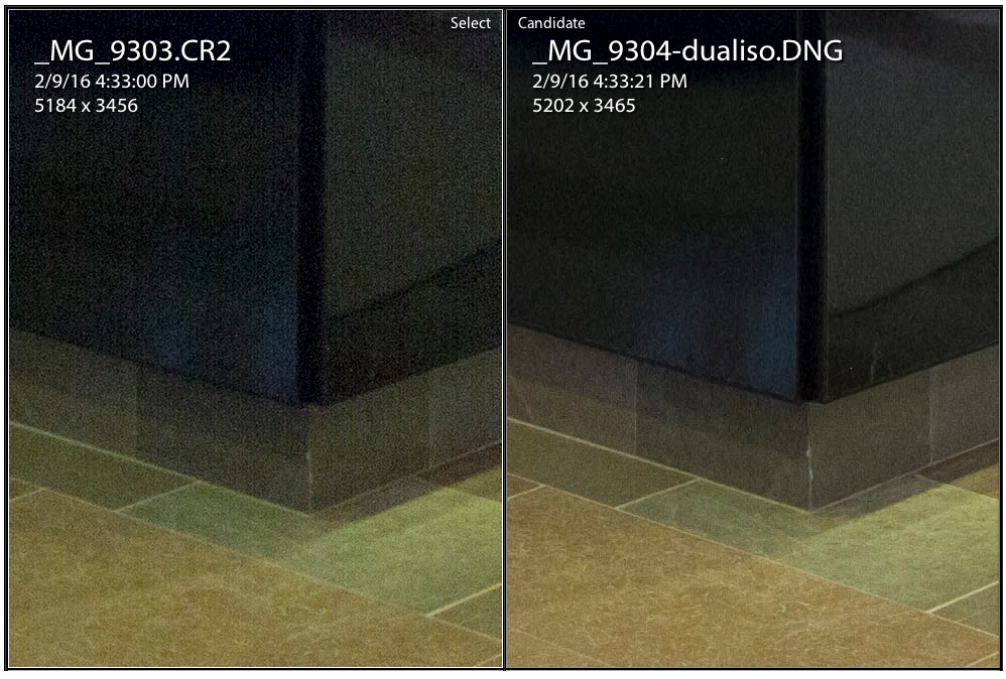

Figure 14. A side by side comparison zoom showing an image without dual ISO on the left-hand side, and with dual ISO enabled on the right-hand side.

Finally, apart from the Lightroom plugin that is available on both the Windows and Mac operating systems, there are other post-processing applications available. These are BarracudaGUI (for Windows) and MLP (for both Windows and Mac operating systems) [17]. It is also possible to record RAW video using dual ISO. The post-processing would have the same idea as talked about in handling RAW video that after extracting the frames, the frames would be dragged into a preferred application and then the two exposures would be merged into one. Thereafter, exported again to frames and onto a non-linear editing (NLE) software such as Adobe Premiere.

4.2 Auto Exposure to the Right (ETTR)

The main goal when taking a photograph is for it to be properly exposed, that is, neither too bright and nor too dark. The reason is that when an image is underexposed, it is perceived to be too dark and the shadows in the image have no details at all. The same goes for an overexposed image that the image is considered too bright and the brighter areas are clipping. Figure 15 shows examples of images taken with their respective histograms to show what the same image looks like when underexposed, overexposed, and normally exposed by using the in-camera histogram, and also what the image looks like when the auto exposure to the right (ETTR) feature is used.

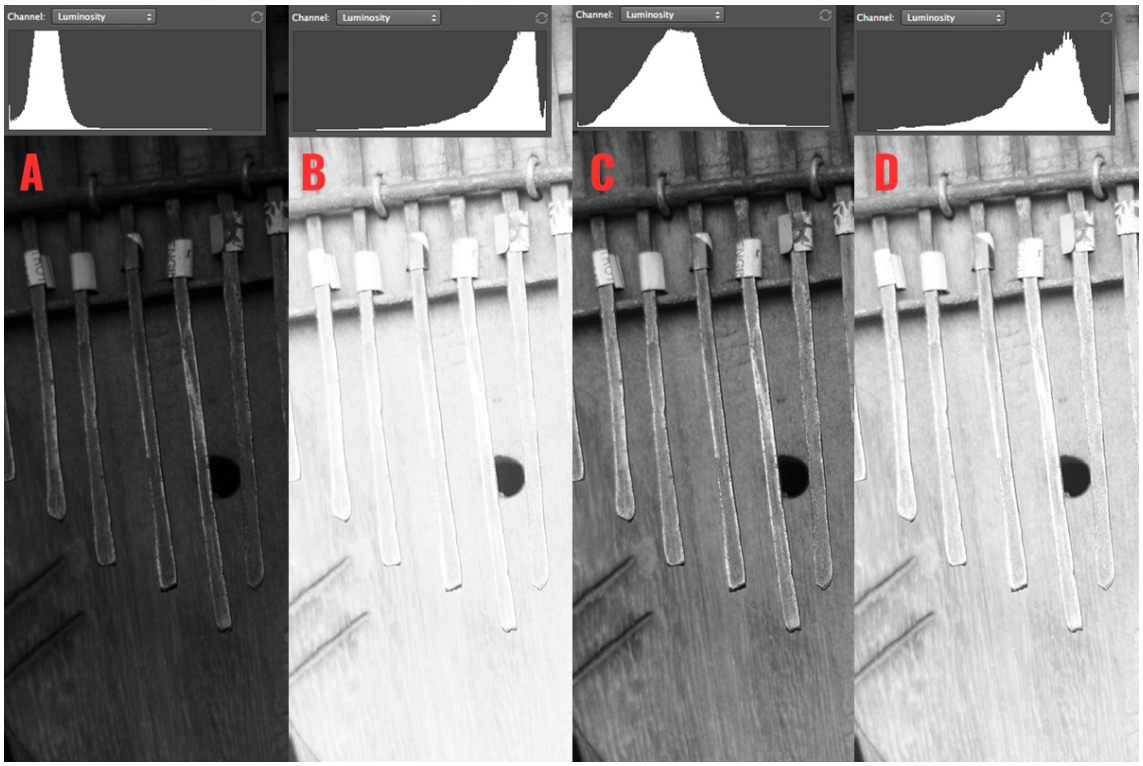

Figure 15. An image comparison showing different exposures.

As seen in figure 15, image A shows an image underexposed, image B shows an image overexposed, image C shows an image normally exposed using the in-camera histogram, and image D shows an image taken using the auto exposure to the right (ETTR) feature. Image C is neither too bright nor too dark. I have utilized the in-camera histogram as guidance.

4.2.1 How ETTR Works

ETTR, as already mentioned, is auto exposure to the right, although others term it as automatic exposure to the right with the abbreviation of AETTR. This feature uses a technique where it moves the exposure of the scene as far to the right as possible without overexposing the image. ETTR tries to get as many details out of the scene as possible. [18.] Similar to other Magic Lantern features, ETTR is loaded from the modules tab and the camera needs to be restarted to start using this feature. The auto (ETTR) has two sets of options, a simple mode that is best for beginners and an advanced mode that is suited for experts. Figure 16 below shows the settings used for achieving image D that was correctly exposed in figure 15.

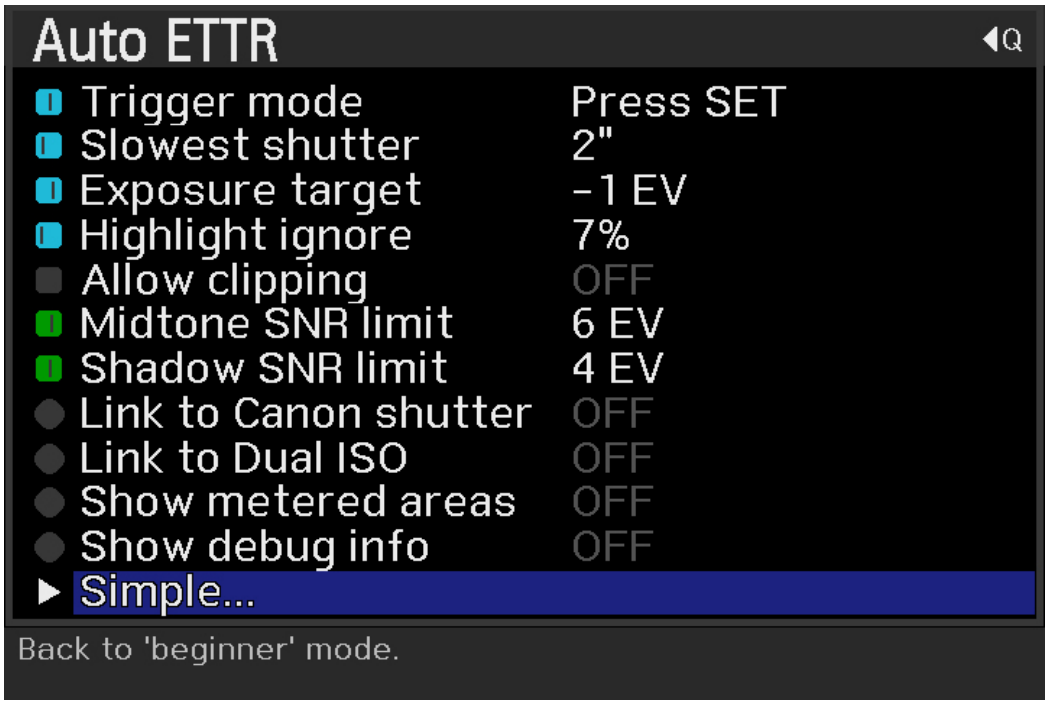

Figure 16. A screenshot displaying the auto exposure to the right (ETTR) menu.

First off, there is the trigger mode option that determines how this feature is set off, and it has the following options: ‘Always ON’ that is continuously active when taking a photo in LiveView, ‘auto snap’ that calculates if another photo is needed after taking a photo, ‘press set’ that is activated when pressing the set button during LiveView, and ‘halfs dblclick’ that requires pressing the shutter halfway twice to activate ETTR. The slowest shutter option is the minimum value allowed for ETTR, and it can be used together with the link to the Canon shutter option that uses the scroll wheel on the camera to adjust the shutter, which makes it faster as compared to changing the shutter all the time from the Magic Lantern menu. [18.]

The exposure target is a general target for the scene, similar to exposure compensation. When it is set to for example -1 EV, the scene will become darker. There is the highlight ignore that has a value from 0% to 50%, and this is the amount of pixels allowed above the target level. The ’allow clipping’ option that is set to off by default can be used to allow a certain color channel to be clipped. [18.]

Moreover, there are two options available for the signal to noise ratio (SNR) limit that are for midtones and shadows. A higher signal to noise ratio is vital so as to get images with less noise, and it is among the requirements when talking about image quality.

Signal to noise ratio is the ratio of the signal and also the noise that may be measured for a given light input. [19.] For more information on the calculations results of the scene while using ETTR, the show debug info should be turned on. Finally, the show metered areas will display in LiveView using the zebras (overlay graphics) to show areas of shadow, midtone, and highlight.

4.2.2 Drawbacks of ETTR

The thing with auto exposure to the right (ETTR) is that it has a learning curve to it, and at times more than one image and tweaking of the settings available within ETTR should help. Furthermore, a tripod would be needed because ETTR will mostly go for higher ISO values and slower shutter speeds, and ETTR will indicate that it has reached the limit when the slowest shutter speed and the highest ISO values are met. A solution for this, depending on the scene, is either achieving enough details in the midtones and highlights and fixing the shadows that have less noise in the editing software or using the dual ISO feature.

4.2.3 Comparison between ETTR and Dual ISO

Both ETTR and dual ISO are great features when it comes to capturing images with as many details as possible. Dual ISO would be the quicker method since it captures two different ISO values in a single click. On the other hand, auto ETTR in most cases would require a tripod since it seems to favour high ISO values and lower shutter speeds. Auto ETTR has an option to link to dual ISO. After analyzing the scene, it will decide if dual ISO is required or not.

4.3 Advanced Bracketing

Advanced bracketing is used in creating images with a higher dynamic range. This is generally done by taking a number of photos at different exposures values, for example a three bracketed photo consisting of -3 EV, 0 EV, +3 EV. These photos will then be imported into editing software for aligning and merging into an HDR image. [20, 195.] However, a number of users dislike the effect of HDR because of its unnatural look and halos beside objects. Instead, these users merge the photos with exposure fusion that combines the best pixels from each image and fuses them together.

Advanced bracketing was included in the older stable version of Magic Lantern, and also now in the nightly builds. A similar feature is available within Canon DSLRs by default and it is named auto exposure bracketing. The only issue is that not all Canon DSLRs have a dedicated bracketing menu. For example, Canon 60D has a limit of +/- 3 EV with increments of either one half or one third with only three bracketed shots, while Canon 5D Mark iii has a dedicated menu option with up to seven bracketed shots. These limits can be by passed using Magic Lantern. Figure 17 shows the menu for advanced bracketing.

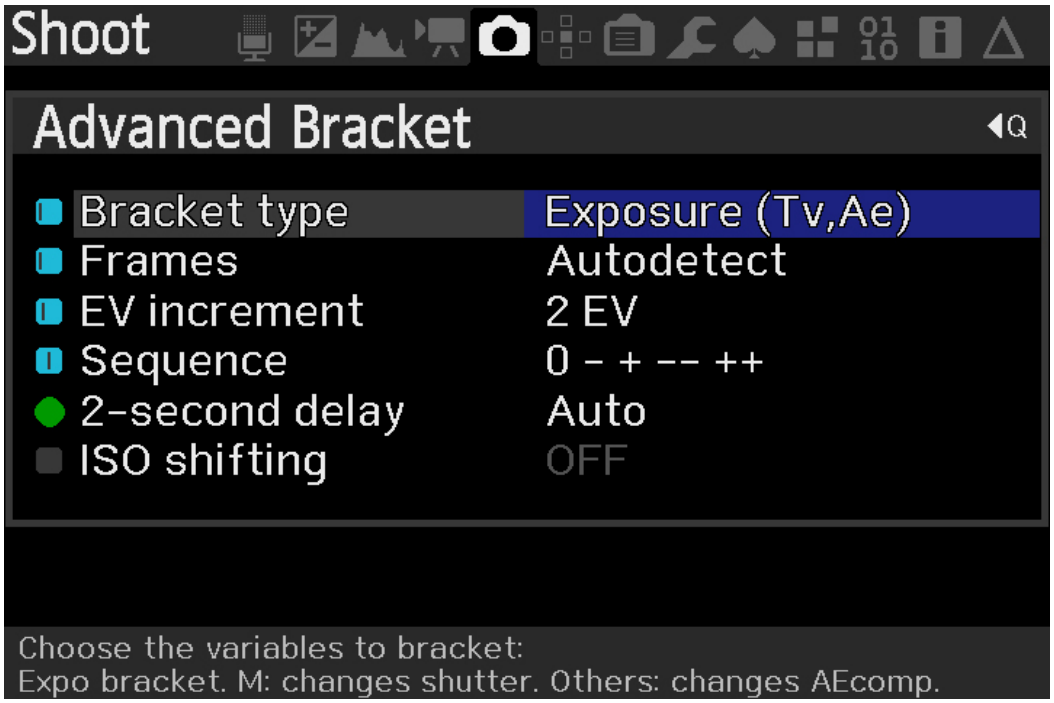

Figure 17. A screenshot showing options available on the advanced bracketing feature.

As seen in figure 17, there are options such as bracket type, where it is possible to choose the type of bracket, and this affects which variable is being bracketed. There are three options available, changing the shutter, flash exposure compensation, or the aperture. Unlike the limit of only having a few frames to bracket, this enables up to 12 frames including an auto detect option that will take an image and analyze if more frames are needed. It can achieve an EV increment from 0.5 EV to 8 EV with three available sequences that define in which order the images are bracketed. A 2-second delay will set the camera to take photos two seconds after the shutter has been pressed. The last option is the ISO shifting that uses the ISO as a variable. [4.]

There are a handful of software, both commercial and open source that can be utilized in merging these images. The final output images achieved will be shown using a few selected software such as Adobe Photoshop, Luminance HDR, and Enfuse.

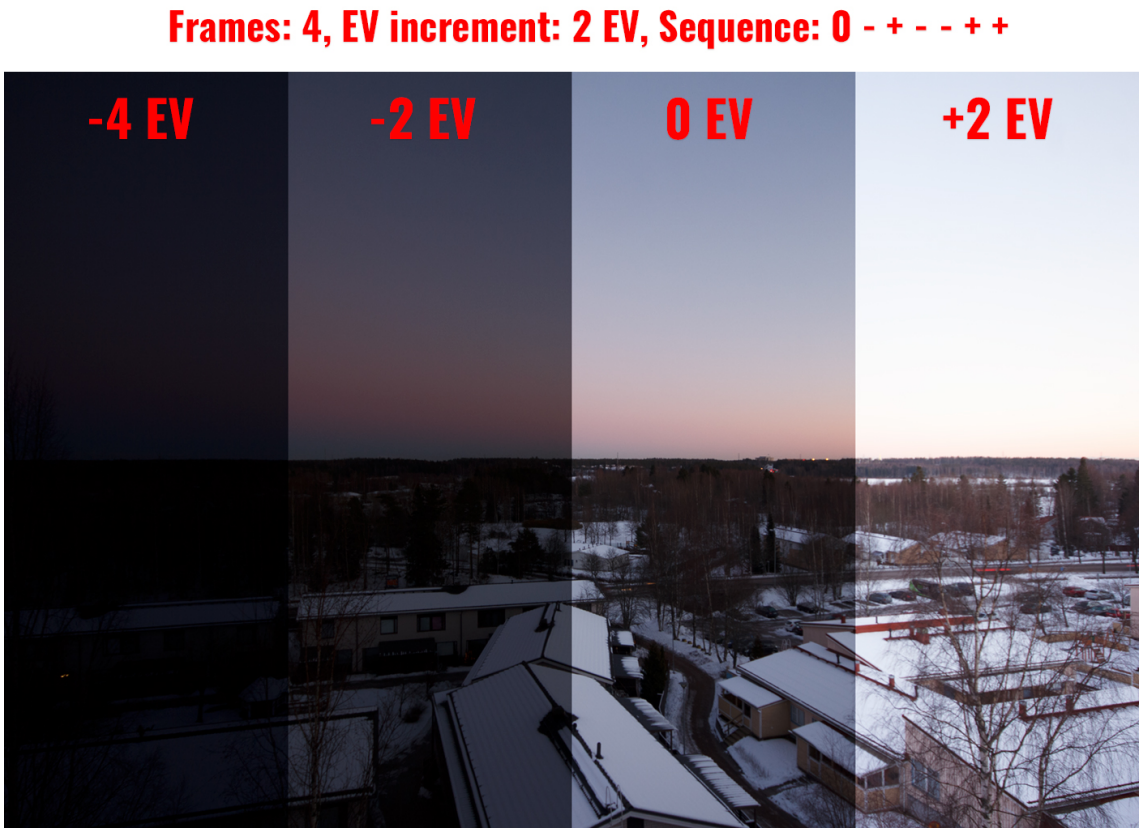

Figure 18. A comparison showing four bracketed frames.

Adobe Photoshop has a feature called ‘merge to HDR Pro’ that can be used to create the photorealistic look of HDR. The menu for HDR has built-in presets and it is possible to edit parameters like the shadows, details, saturation, and strength to achieve a certain look. [20, 197.] Figure 19 below shows what was achieved using Adobe Photoshop.

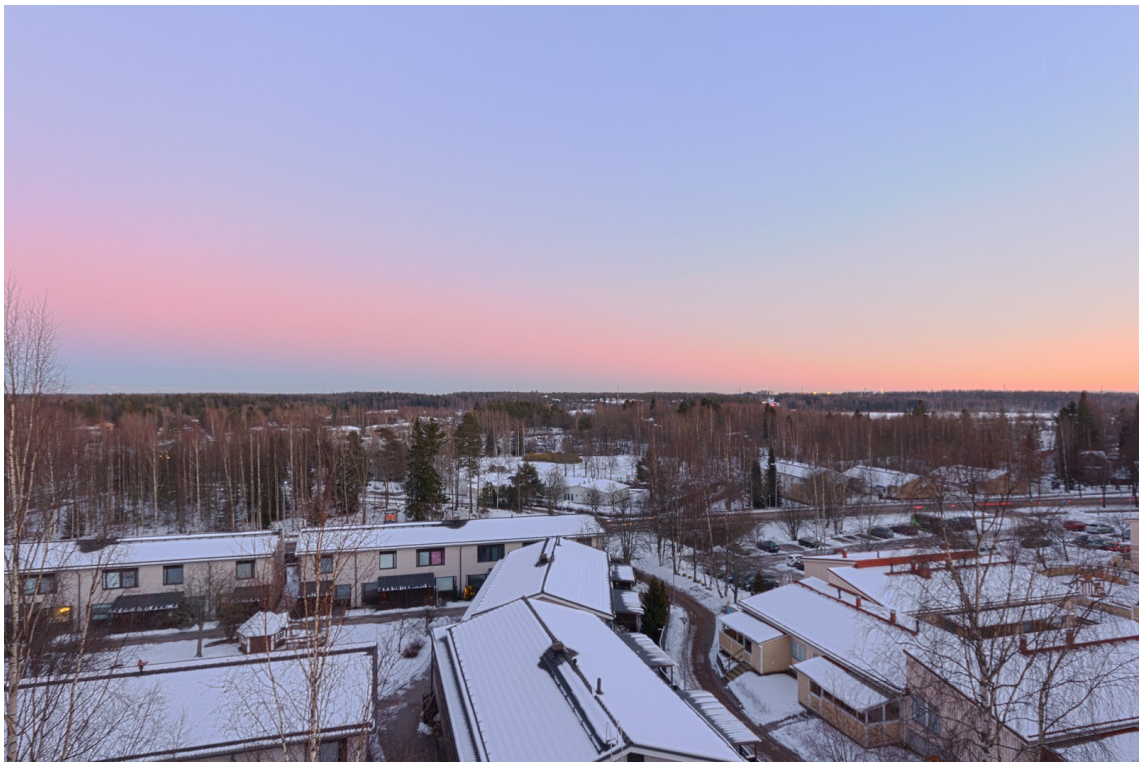

Figure 19. An image that is merged using Adobe Photoshop's merge to HDR Pro.

Another software that can be utilized to merge the images is Luminance HDR. This software is an open source project for HDR photography. It supports creating of HDR images from a number of different file formats, basic editing, and tone mapping. Figure 20 shows the same image merged using the tone mapping technique available on this software. [21.]

Figure 20. An image that is merged using Luminance HDR.

Whilst photographing the bracketed images, there is an option to create a post script file that can align and enfuse the images together using command line. An open graphical user interface (GUI) and panorama stitcher application known as Hugin also provides other command line tools, and amongst the tools available, enfuse and align image stack are included [22]. Once the application is downloaded, the tools are found inside the HuginTools folder. After the bracketed images are placed into a directory, I then simply applied “align_image_stack -a TEST_ IMG_*” and “enfuse --output test_final.tif TEST_*”. The image named test_final.tif will be created and be ready for further post-processing. Figure 21 shows the final blended image with a bit of post-processing in Adobe Lightroom to increase the shadows a little.

Figure 21. An image that is merged using the Enfuse command line.

Moreover, there is an application called ImageFuser that has a graphical user interface for Enfuse and the align image stack and that is available for Mac OS as an open source. There are other good alternatives for Windows and Linux, and a few of them are multi platform [22]. It is also possible to view the bracketed images within the camera by switching on the exposure fusion in the image review settings as shown in figure 22.

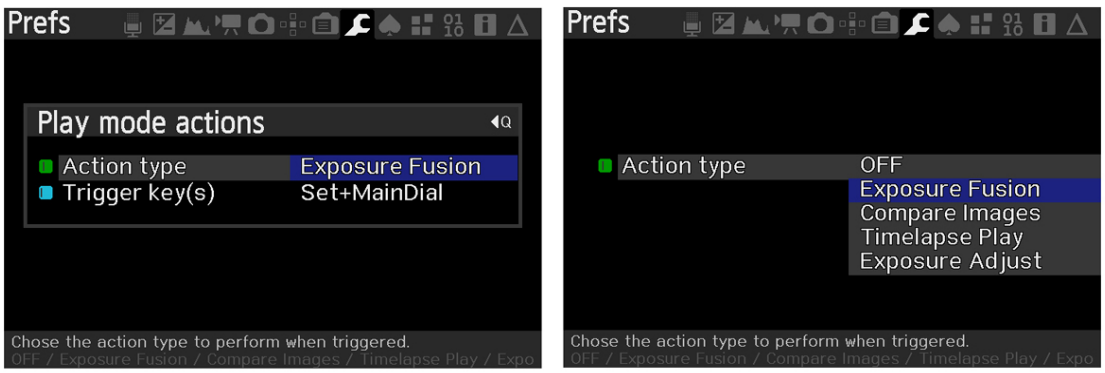

Figure 22. A screenshot showing play mode action on Magic Lantern.

4.4 Intervalometer

Usually when taking timelapses, a dedicated remote would be needed. A timelapse is generally done by taking a certain amount of photos over time, and when played at normal speed, the timelapse will look fast. Examples of timelapses can show sunrises, sunsets, clouds passing by, cars moving around, people walking, and so on. Magic Lantern makes this easy with its intervalometer feature as seen in figure 23 below.

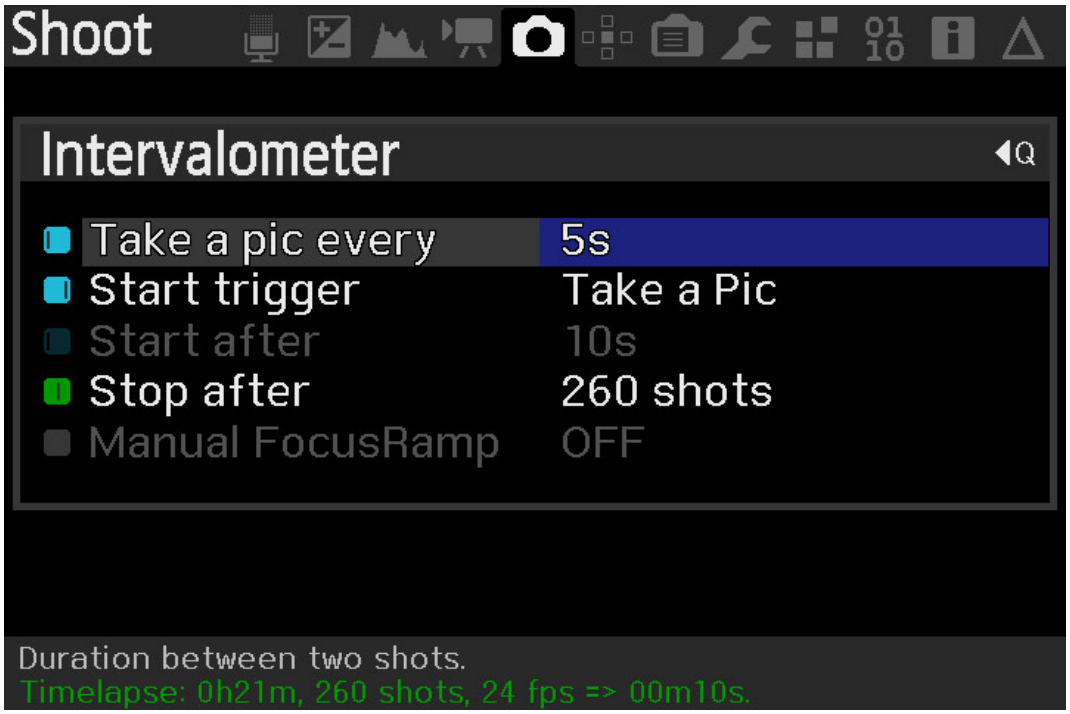

Figure 23. A screenshot showing the intervalometer menu.

The options available for intervalometer are not hard to grasp. First off, is setting the intervals between images, and this comprises of durations from split seconds up to 8 hours. The ‘start trigger’ is how the intervalometer process is initiated, and there are methods such as leaving the menu, pressing the shutter halfway, or taking a picture. The ‘start after’ option is when the intervalometer should begin, and this can be anything from zero seconds up to eight hours. The ‘stop after’ option is when the intervalometer should stop, and this option can be set to either take photos until the SD card is full or stop after a specific set amount. Finally, there is the manual focus ramp that has both negative and positive steps, and this is used for adjusting focus white taking the timelapse. [4.]

The lower part of the intervalometer menu gives valuable information and changes as the settings are edited, and in this case it tells that the camera will take 21 minutes to complete the timelapse, that 260 frames will be captured, and that the final video length of 10 seconds will be achieved at 24 fps. Figure 24 below shows a Canon 60D performing a timelapse of 260 frames.

Figure 24. An image showing the intervalometer process.

The 10 second timelapse was captured using the intervalometer settings as seen in figure 24. The image type was changed to JPEG so as to reduce the size. Once the process had finished, the 260 frames were saved on the computer and made into a sequence ready to export. [23.]

As longer timelapses take time, the camera drains the battery and may heat up a bit. To avoid this problem, it is better to use the power saving option within Magic Lantern to either dim the display or turn the liquid crystal display (LCD) off, and the card led will blink to show that it is alive.

4.5 Silent Pictures

Digital cameras in general have a shutter count. A high shutter count indicates that the shutter release button on the digital camera has been pressed a number of times for either taking photos or videos. As cameras have a lifespan, taking silent pictures can significantly reduce the shutter count.

The silent picture feature simply takes an image without moving the shutter, and this occurs during LiveView. This feature captures the images in DNG format. An older version of silent picture saved files as a .422 uncompressed file type that later needed to be converted into a more commonly used image file type. For viewing the images within the camera as seen in figure 25, the file manager and picture viewer modules need to be activated. On the other hand, post-processing is done on the computer [4].

Figure 25. An image taken using the silent picture feature as viewed on the camera.

The silent picture feature is able to capture the image using different available modes as seen in figure 26. For testing purposes, the mode was set to simple, and the captured image will be saved at a low resolution. The other modes are burst that captures as many photos until the memory gets full, then saves afterwards. The second burst mode with ‘end trigger’ is similar to the burst mode but it only saves the last few photos

on the SD card. The ‘best shots’ mode captures as many photos and saves the focused ones. Finally, the silt-scan mode captures the images with a funky distorted effect. The image that was captured using the simple mode is 1734x1156 pixels and about 3.76 megabytes.

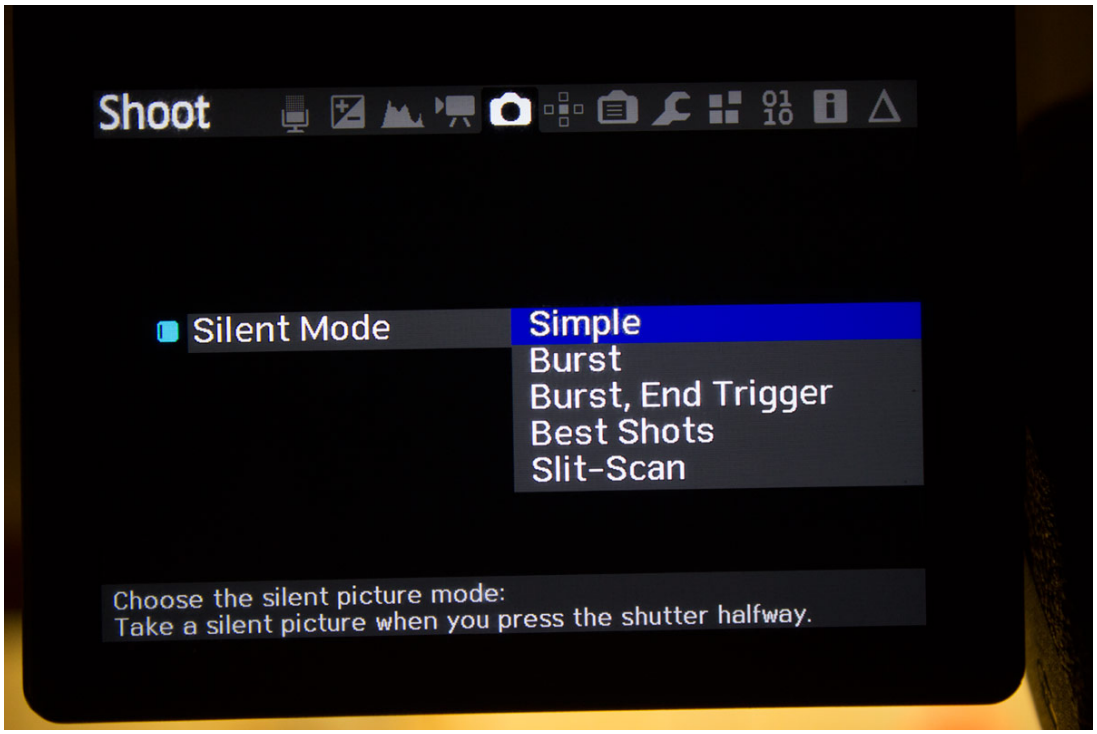

Figure 26. A screenshot showing the silent picture menu.

Figure 27. A two image split showing the silent picture process.

Figure 27 shows the step process that occurs when the camera is capturing the frame and saving it on the SD card. It also displays the folder path where the DNG file can be located.

Post-processing for Silent Pictures

As the current module of the silent picture saves the image as a DNG file, it is much easier to edit this kind of image type on editing software such as Adobe Photoshop, as seen in figure 28 below.

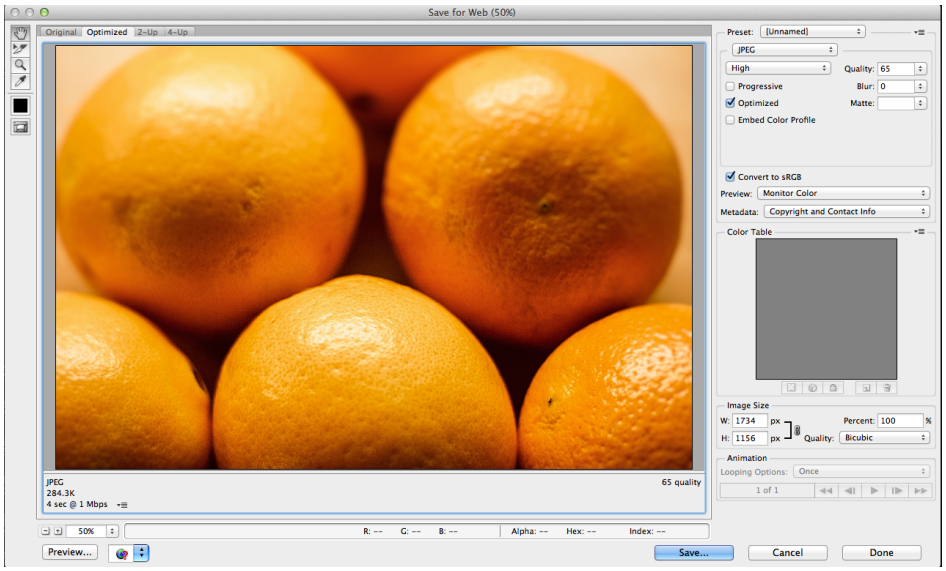

Figure 28. An image processed using Adobe Photoshop.

Furthermore, on the latest Magic Lantern nightly builds, there is a newer module of silent picture that can capture full resolutions, and save the files in DNG format [24]. As seen previously, the intervalometer eats a lot of the shutter count. This newer silent picture module can capture timelapses when using the intervalometer feature, which is a huge saver.

5 Overlay Graphics

Overlay graphics are useful guides that help to achieve proper exposure of the scene, to check if an object is in focus, to avoid clipping of the RGB channels, or to simply use cropmarks to compose a shot well. In this section, focus peak, spotmeter, and zebras will be discussed.

5.1 Focus Peak

Focus peak is feature that is found on some expensive external monitors used together with the DSLRs, but Magic Lantern has incorporated this feature within the overlay graphics. When taking an image in LiveView or a video, zooming in and out is mostly what is done. Focus peak helps to know if an object is in focus by highlighting it with color. Figure 29 shows what options are available in focus peak.

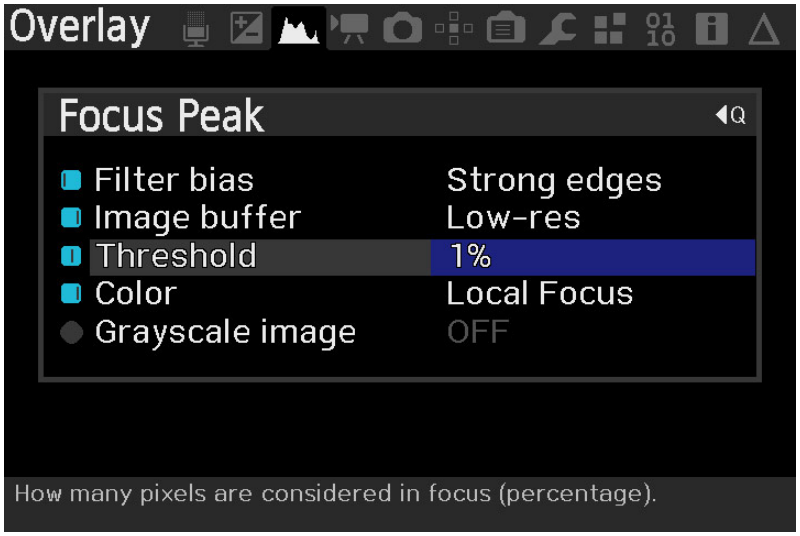

Figure 29. A screenshot showing the focus peak menu.

The options within focus peak can be adjusted to better suit the scene. The filter bias has three options, which are strong edges, balanced, and fine details. All these three detection algorithms affect how the focus peak shows up. Strong edges works great when in low light scenes. In a situation where there is a lot of light, the fine detail algorithm is best suited, and with everything in between with somewhat strong edges and fine details, the balanced algorithm is the one to choose. Setting the threshold lower will decrease the number of pixels. The higher the threshold is, the more pixels are

affected. Moreover, colors can be chosen for the highlighted pixels. [4.] Figure 30 shows an image that has a ‘focus peak’ option set to a threshold of 1% and the color option to local focus. Local focus displays color by intensity.

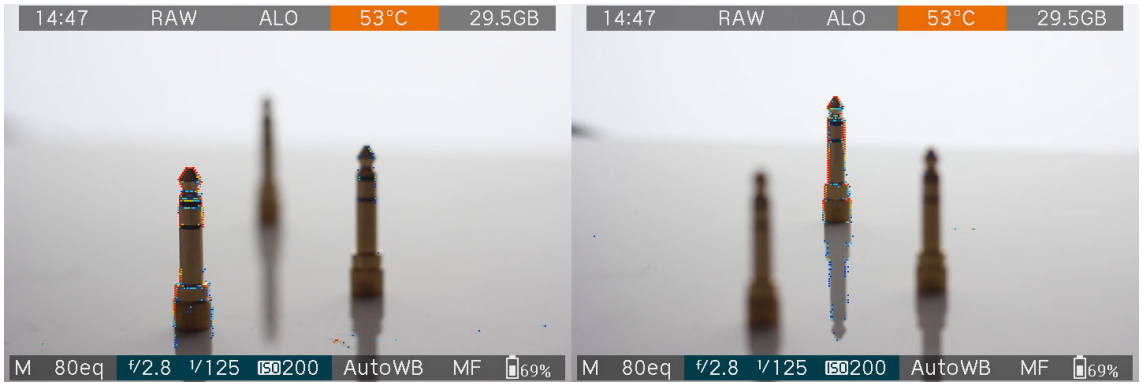

Figure 30. A screenshot showing the focus peak being used to get correct focus. The image on the left is focused on the closest object, and the image on the right is focused on the farthest object.

5.2 Spotmeter

The spotmeter shows a value on a certain point within the scene, and this value can be changed into other types of units. It is easier to know a value, for example the value of a point in the sky by moving the focus box to that desired point on the scene. Spotmeter helps to avoid overexposure and underexposure of a shot.

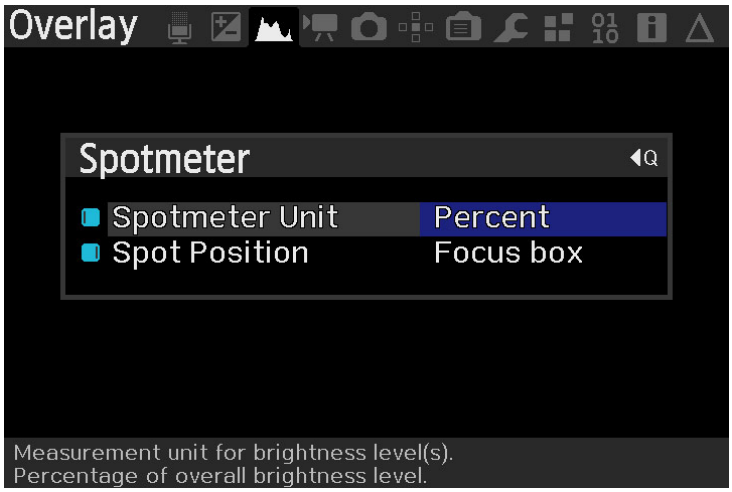

Figure 31. A screenshot showing the focus peak menu.

Spotmeter has two options available, which are the spotmeter unit and spot position. The spotmeter unit describes the type of unit to be shown. The spotmeter unit can be set to different types. There are units in percentages that have a value from 0 to 100 and shows brightness levels. An 8 bit RGB level that has a value from 0 to 255. There is another RGB level that shows values in hyper text markup language (HTML) color codes. Lastly, a RAW based value in EV that shows the amount difference from over-exposure. The other option is spot position, and this enables choosing how the values are read. It can be either with a focus box that can be moved to any 'x,y' position on the screen. Apart from the focus box, it can be set to center, and it simply reads the value on the center. [4.]

Figure 32 below shows percentage values of a white balance card with a grey value of 52%, a black value of 13%, and a white value of 84%. If there is any change in the camera settings such as the shutter speed, these values will change accordingly.

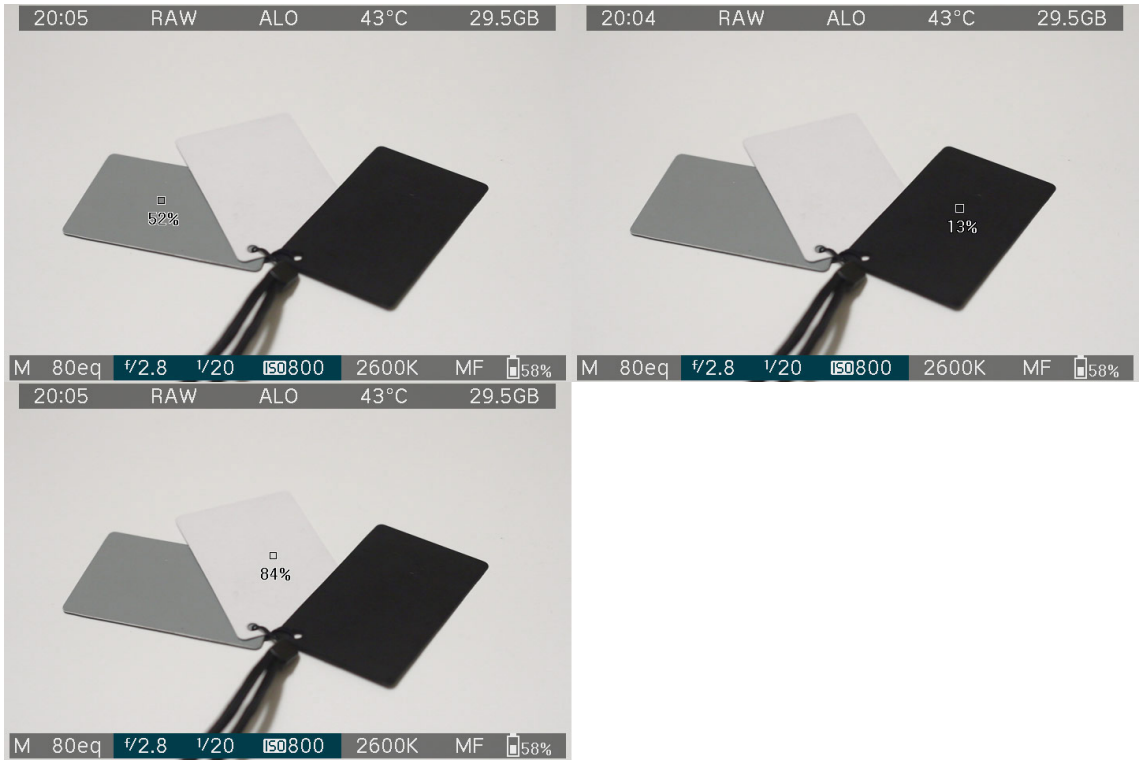

Figure 32. A screenshot comparison showing spotmeter percentage values.

5.3 Zebras

The zebras help to achieve a better exposed image. This feature has different options available to so as to avoid taking an image that is underexposed or overexposed. Figure 33 shows a screenshot of the zebras inside the Magic Lantern menu.

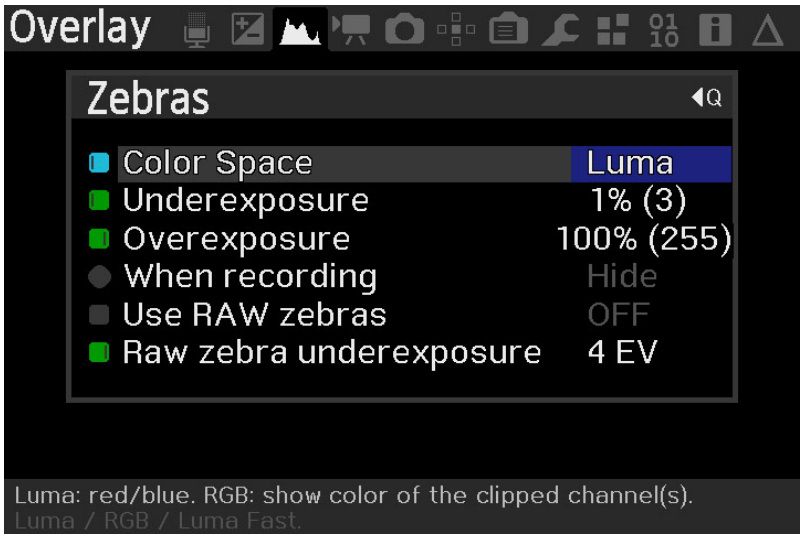

Figure 33. A screenshot showing the options available inside zebras.

There are different color spaces available, which are luma (which shows the Y channel, also known as brightness) and RGB (red, green, and blue channels, and luma fast). These affect how the zebras are displayed. When the color space is set to RGB, the zebras will show in opposite colors. For example a white area on the scene will be highlighted in black, red colors will be highlighted in cyan and so on. When the color space is set to luma, the zebras only show in one color. It is possible to also change the threshold of underexposed and overexposed areas. Moreover, instead of the color space, it is possible to use the RAW zebras. This gives a more accurate reading since RAW data is not at all affected in the same way as JPEG data. [4.] Figure 34 below shows how zebras show up on an overexposed and underexposed scene.

Figure 34. A screenshot showing zebras on an overexposed scene on the left, and an underexposed scene on the right. The underexposure value was set to 1%, and the overexposure value was set to 100%.

6 Advantages and Disadvantages of Magic Lantern

Magic Lantern offers many great features at the moment. A camera user may feel overwhelmed and not want to use this open source firmware for many reasons. On the one hand, the advantages that come with Magic Lantern are as follows:

- Overlay graphics that assist in obtaining correct exposure and focus, and with RAW data that is not affected in the same way as the JPEG processor.
- Headphone monitoring comes in handy when filming and this enables the camera operator to know if the audio is either clipping or within safe range.
- The fact that this third party software is open source makes it even better because anyone can start compiling and use the developer's application program interface (API) provided by Magic Lantern.
- More frequent updates utilizing the rolling release development model. The previous stable version of Magic Lantern was removed due to being old, whereas now the nightly builds are considered somewhat stable and are compiled automatically every day.
- Supported on all the consumer level Canon DSLR models and a few prosumer level Canon DSLR models.

On the other hand, this third party firmware may have the following issues:

- There is a possibility that the camera may get bricked, meaning that due to some corruption or problem, the camera may no longer function. Magic Lantern states that they are not responsible for any damages that occur [3].
- The camera may seem to generate heat. The heating can occur, for example when recording video for a longer time, and this process puts strain on the camera. On the Magic Lantern menu there is a tab that shows the internal temperature of the camera, and it is best to let the camera cool down in case of any temperature warnings.
- It may occur when using Magic Lantern that the camera freezes. It is best to switch off the camera, removing and inserting the battery back. Then the camera should work as normal when switched back on. Moreover, there are errors that may print on the camera LCD, such as ERR70, ERR80, and ERR99. These errors are related to a malfunction, and should be easy to fix as mentioned previously [26].
- Lastly, Magic Lantern may void the warranty although there are two sides to this point. The first is that Canon may not take in the camera if it is known that a malfunction was caused by third party firmware. Secondly,

> Magic Lantern does not modify any hardware on the cameras, and this should not affect the warranty. [27.]

The older stable version of Magic Lantern has been downloaded approximately 300,000 times. This is a huge number because of the fact that it is third party firmware [7]. Although there are rarely any reports of the Canon digital cameras failing to work because of using Magic Lantern, the Magic Lantern team and other members are willing to help find a solution and help out in case a user has had difficulties during the usage of Magic Lantern.

7 Scope and Future

The Magic Lantern team could not imagine that a Canon DSLR would produce for example 14-bit RAW video. The footages achieved from the Canon DSLRs using RAW video have been compared to in quality with the high-end cinema cameras like the Red digital cinema cameras, Blackmagic design cameras, or even the most expensive Arri cameras. Most of these features came about as a result of testing and reverse engineering.

In about five years, Magic Lantern will have achieved a massive amount of improvements on the Canon digital cameras. It is hard to image what they will do next. At the moment, the Magic Lantern development team are also helping out on the AXIOM Beta project in which they are developing together with the Apertus team. Figure 35 shows a prototype of an open source camera. The AXIOM Beta team want to make this technology free and open source [28].

Figure 35. AXIOM Beta camera. Copied from [28].

8 Conclusion

The purpose of this thesis was to showcase a selected number of features found on the Magic Lantern open source firmware, showing what kind of workflows and post-processing methods are available. The Magic Lantern features can be used in conjunction with production works, and this assures confidence to achieve appealing results. It has now gotten easier to achieve images with a higher dynamic range and great details.

In production work, a small amount of equipment is ideal, which means that the extra cost would be put for good usage. Digital cameras have a rated life span for the shutter actuations. The ability to take longer timelapses without moving the shutter mechanism is a great deal. This thesis project is a good reference for an enthusiast wanting to start using Magic Lantern or simply experimenting with it. This open source firmware runs alongside Canon firmware and it can be easily removed at any moment. Magic Lantern has a lot to offer. The video and photography features discussed in this thesis are amongst some of the features.

During the course of this project, I utilized a Canon 60D DSLR camera that had Magic Lantern initially installed. A second camera, a Canon 600D DSLR was utilized to take behind the scene pictures when the screenshot of the main camera could not be used. For post-processing, both Mac OS and Windows OS were used so as to show at least some tools on both platforms. Similarly, Linux OS can be used for post-processing but it was out of reach in this project. The Canon 60D DSLR camera experienced some freezing a couple of times when filming RAW videos. This problem was fixed by turning the camera off, removing the battery and placing it back again.

This is not the first time digital cameras have been reverse engineered to achieve impressive results and to understand how they function. Apart from Magic Lantern, there are similar software enhancements for other digital cameras where developers have achieved to bypass limits not included within factory settings. Magic Lantern has truly transformed the way Canon DSLRs are used.

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[ML] Canon EOS Features Comparison – Raw video support [25]

	Comments	Card type / max write speed	Buffer size	Sensor size	Aliasing	Low light	Max resolution 1:1 Liveview no crop	Max resolution 1280x720 50/60fps	Max resolution in crop mode [2]	Max res for 24p continuous rec	Max res for 30p continuous rec	Record time at 16:9 almost 1080p 24fps no crop	ExFAT		Raw buffer size 640x480 crop	Raw buffer size 1920x1080
5D Mark III	Best choice, expensive	CF+SD, 100+20 MB/s	32x4 32x6 hacked	Full-frame	Almost none	Very good	1920x1280	1920x672, 1.61x	3584x1320	1920x1280	1920x1080	1920x1080 continuous	yes			3584x1320
5D Mark II	Fairly good	CF, 75 MB/s	26x5+29+19		Bad, VAF	Good	1880x1250	N/A	2144 x 1076 jun 29 NB 334 frames	1880 x 940	1600 x 900 jun 27 nb	1856x1004, continuous	no			
6D	Good low light, but slow SD UHS	SD, 40 MB/s	32x7			Very good	1808x1216	1792x568, 1.62x	2560x944	?	? (30p!)	1792x1008, 120 frames	yes			
50D	Cheapest with CF card	CF, 70 MB/s	27x6	APS-C		Average	1584x1058	N/A	2000x1080	1584x1058	1440x810	1584x894 continuous	no			
700D, 100D	slow SD card has UHS though	SD, 40 MB/s	2 X 30 + 26 + 4 ?				1728x1158	1728x694	2496x1080	1280x720	1152x648	1728x972, 102 frames	yes			
650D	slow SD card has UHS though	SD, 40 MB/s	2 X 30 + 26 + 4				1728x1150	1728x694	2512x1076	1280x720	1152x622	1728x972, 64 frames				
60D	SD card bottleneck, but large buffer	SD, 21 MB/s	32x8+25				1728x1156	1728x694, 1.67x	2512x1080	960x540 card speeds are identical	864x484 card speeds are identical	1728x972, 137 frames			752x424 of 1610x623 (or 960x479 ?)	
600D	SD card bottleneck		30 + 31 + 12 + 28 [3]									1728x972, 45 frames				
550D			2x32 + 8									1728x972, 26 frames				
500D	SD card bottleneck, 20fps		2x27 + 20		Bad, no VAF		1584x1060 20p	1584x636 30p 1.67x	2000x838 22p			1584x636, 92 frames				
EOSM	slow SD card has UHS though	SD, 40 MB/s	~30x3				1728x1158 [4]	1728x672, 1.71x	2496x1056	can record FullHD only when also recording H.264						
1100D	Very small buffer	SD, 21 MB/s	?				?	?	?	?	?	continuous				
7D	Fairly good	CF, 80 MB/s	5x32+27		Bad, VAF		1728x1156	1728x694	2512x1200	1728x972	?	1728x972, continuous	no			
40D	Possible, but nobody seems interested in it.		?		Bad, no VAF		1600x680?	N/A	?	?	?	?	no			
5D classic	No LiveView	CF	N/A	Full-frame	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			

Legend :
- best
- good
- not bad
- average
- bad
- not working

[1] VAF: optical anti-aliasing filter, http://www.mosaicengineering.com/products/vaf/5d2.html

[2] Press the zoom button. Zoom factor = horizontal CR2 resolution / horizontal video resolution (around 3x for 1920x1080)

[3] set ML->Shoot->PicQuality:SRAW

[4] https://bitbucket.org/hudson/magic-lantern/commits/c2a01891156ed4084f36a7b83517cf38e4cbacf0