

COMPRESSION LEVEL ANALYSIS:  
EXAMINING VIDEO RECOMPRESSION LEVELS  
FOR FORENSIC EXAMINATION

by

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B.S, University of Colorado Denver, 2013

A thesis submitted to the  
Faculty of the Graduate School of the  
University of Colorado in partial fulfillment  
of the requirements for the degree of  
Master of Science  
Recording Arts

2015

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Compression Level Analysis: Examining Video Compression Levels from Commercial Software

Thesis directed by Dr. Catalin Grigoras

### **ABSTRACT**

With more digital devices such as cameras, smartphones, and tablets currently in use than there are humans in the world, forensic analysis of videos is here to stay. While there are many tools available to forensic examiners to determine the authenticity of a video, this document focuses on the Compression Level Analysis of videos recorded on different digital cameras. This study will examine videos recorded on 30 different devices including digital cameras, smartphones, and tablets. The acquired test videos were recompressed using multiple programs including Adobe Premiere Pro, HandBrake, FFmpeg, QuickTime Player 7 Pro, as well as YouTube. The recompressed videos were processed with MATLAB to generate data showing the Compression Level Analysis. The data will provide the differences between recompression generations from each program. Also, this data will discover visual cues left behind during the recompression process, which were created by the programs used.

The form and content of this abstract are approved. I recommend its publication.

Approved: Catalin Grigoras

## **ACKNOWLEDGEMENTS**

I would like to thank my professors Catalin Grigoras and Jeff Smith for the assistance with this thesis and their outstanding instruction throughout the graduate program.

Also, I would also like to thank my parents and grandparents for all of their encouragement and help, both mentally and financially, during my entire college career. I would not be where I am today without the love and support you have afforded to me.

Finally, I would like to thank my loving wife who has also provided me with her love and support over the last few years. You helped me stay motivated when I needed it the most. I'm excited to see where we go from here!

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# **CHAPTER I**

## **INTRODUCTION**

### **1.1 Background**

With the rise in popularity of digital cameras in the early 2000s and the addition of cameras on mobile phones, the use and availability of videos to record daily events is continuing to grow. According to an article published in late 2014 by The Independent, “The number of active mobile devices and human beings crossed over somewhere around the 7.19 billion mark.” [1] This means there are more active devices than humans.

With the ever-increasing number of digital devices, it’s safe to say some videos will be recorded, which contain crimes or subject matter that can be used in a court of law. In order for these videos to be admitted into evidence, an analysis sometimes needs to be conducted to determine authenticity of the recording. One method used to evaluate authenticity is the Compression Level Analysis or CLA.

When a video is an original or was provided directly from the source, the CLA produces little or no signs of recompression depending on the device.

Recompression occurs when a video is loaded into a video editing software or uploaded to YouTube and resaved or downloaded.

In order to fully understand how CLA works, it is important to note how video compression works. Popular video codecs such as H.264, MPEG-2, and MPEG-4 use motion estimation to compress a file. “Motion Estimation (ME) and compensation techniques, which can eliminate temporal redundancy between adjacent frames effectively.” [2] This is accomplished when information is extracted to become represented by a motion vector. “The motion vector indicates the displacement of a pixel

or a pixel block from the current location due to motion. This information is used in video compression to find best matching blocks in reference frame to calculate low energy residue to generate temporally interpolated frames.” [3] All of this is used to find redundancies that can be exploited to reduce the file size. The compression process can leave behind traces that can be seen on a CLA test.

In order to produce a CLA plot, the video needs to complete a few steps to generate a proper reading. This can include frame averaging, which will create one averaged image that contains all of the frames from the video. The image is then analyzed using the Discrete Cosine Transform coefficients, which looks at the quantization values of the image. [4] The recompression of the video (which is a lossy process) creates periodicity in the DCT. The CLA examines the second derivative of the DCT coefficient. The plots produced usually have a larger center spike with smaller spikes on each side. Each new generation should produce smaller spikes to the left and right of the center spike. [5]

When using the CLA test, the analyst cannot see what has changed, however, the test can give you a good idea as to what has happened before it was received. This is important information to determine the authenticity of the file or to possibly determine which program was used to recompress the file.

## **1.2 Scope and Intent of Thesis**

The purpose of this thesis is to analyze how the Compression Level Analysis can be tied to a specific video editing/encoding software and YouTube. Every time a video is recompressed, the editor or website will add artifacts that, in most cases, can be detected upon visual inspection of the CLA plots. Recognizing those visual markers will help the

analyst be able to determine the video software that was used to recompress the video. In addition to identifying the visual markers, this thesis examines the reliability of determining the number of recompressions created from the original video with the same software. This will help the examiner gain a better understanding of the data handling before it reaches their desk.

This thesis will use a testing pool of 30 different video devices, which include digital cameras, smartphones, and tablets. All of these cameras had the ability to record digital videos. The video resolution was reset to the default setting before each test recordings was created.

The next component of this test dealt with the different software and YouTube that was utilized to recompress the test videos. It was decided to use a commercial video editing software (Adobe Premiere Pro), three video transcoders including one commercial program (Apple Quicktime Pro), two freeware programs (FFmpeg and HandBrake), and finally YouTube. YouTube was included in this test because of the documentation about the encoding process that is unique to the popular video-sharing website. While each video program mentioned above has multiple output options that can change the video container and video coding options, I decided to use the very popular .mp4 container and H.264 video codec across all of the programs. In most cases, this was the default setting for the program.

In order to see the changes that occur from each generation of video recompression, each video will recompress five times, which creates five generations from the original video. This is an important test to help determine how many times the video might have been altered before it was received by the examiner.

Finally, each camera was used to record two digital videos used for analysis. The first video was used as the control to show CLA results directly from the device. The second video was used to create the different generations in each of the software/websites listed above. All of the created videos were then analyzed using a custom MATLAB script designed to provide the CLA results.

## **CHAPTER II**

### **TESTING PARAMETERS**

#### **2.1 Cameras/Smartphones/Tablets**

With so many different digital cameras, smartphones, and tablets available today, I decided it was important to try and generate a diverse testing group consisting of many different makes and models of digital cameras. This is because one never knows what kind of camera a criminal or an eyewitness to a crime would use. Therefore, the greater the test group, the larger the database created from which to compare the results. I was fortunate to have acquired a wide range of test cameras.

These cameras included older point and shoot cameras like the Olympus Stylus 710, which at the time of its release in February 2006 [6] only had the capability to record low resolution videos. At the other end of the spectrum, I was able to gather videos from a professional Blackmagic Pocket Cinema camera that had the ability to record HD RAW videos. The rest of the cameras fell in-between these two cameras either as a professional, “prosumer”, or consumer quality.

In addition to the digital cameras tested, I was also able to acquire test videos from a variety of different smartphones and tablets. With the convenience of having a camera on most mobile phones or tablets, the amount of potential video sources is significantly increased. However, maintaining an updated database for mobile phone images would prove challenging due to constant model updates and releases. In addition to new mobile phone releases, the version of the software running on each device can have an effect on the outcome of a CLA analysis.

The following tables break down the make and model of the mobile phone or camera that was used for testing based upon the default resolution after reverting the settings back to factory defaults.

**Table 1: Cameras used with a resolution of 320x240**

320x240		
Make	Model	Release Date
Olympus	Stylus 710	June 2003
Olympus	Stylus 790SW	February 2008
Olympus	X-560WP	September 2007
Sony	DSC-S930	February 2009

**Table 2: Cameras used with a resolution of 640x480**

640x480		
Make	Model	Release Date
Canon	D10	May 2009
FujiFilm	Z30	February 2009
Samsung	BL103	Mid 2009
Sony	DSC-W80	March 2007

**Table 3 Video Camera with a resolution of 720x480**

720X480		
Make	Model	Release Date
JVC	Everio GZ-MG630RU	February 2009

The JVC video is one of three cameras in this test group that is a dedicated video camera. This camera was relevant to testing, since unlike its older predecessors, it records videos to an internal hard disk drive to store the media verses recording videos to a tape on older cameras.

Cameras in the next two tables record digital videos in what is considered high definition or HD. HD videos have better image quality when compared with the cameras previously listed.



**Table 4: Cameras with a resolution of 1280x720**

1280x720		
Make	Model	Release Date
Canon	SD3500	April 2010
Samsung	HZ50W	May 2010

**Table 5: Cameras with a resolution of 1920x1080**

1920x1080		
Make	Model	Release Date
Blackmagic	Pocket Cinema*	July 2013
Canon	EOS 5D Mark II	November 2008
Canon	EOS 7D	October 2009
Canon	Rebel T3i	February 2011
FujiFilm	S9400W	January 2014
GoPro	Hero4 Silver*	October 2014
Kodak	Zi8	September 2009
Panasonic	Lumix DMC TS5	March 2013

\* These cameras are the other two cameras that are dedicated video cameras meaning their primary function is to record videos verses taking pictures as well as recording video.

The smartphones become more challenging to categorize for a few reasons. First, if two different phones that are the same make and model have different versions of an operating system, the CLA might produce different results. Secondly, two smartphones that look identical will have different model numbers that are specific to the carrier they are compatible with. The following tables will provide information about the different smartphones and tablets that were used during testing.

**Table 6: Smartphones/Tablets with a resolution of 1280x720**

1280x720			
Make	Model	Operating System Version	Hardware Release Date/OS Release Date
Apple	iPhone 4 MC608II/A	7.1.1	June 2010/April 2014
Apple	iPhone 4 MD127LL/A	6.1.3	June 2010/March 2013
Apple	iPod Touch MC544LL/A	6.1.3	September 2010/March 2013

**Table7: Smartphones/Tablets with a resolution of 1920x1080**

1920x1080			
Make	Model	Operating System Version	Release Date/OS Release Date
Apple	iPad Mini MD533LL/A	8.4.1	November 2010/ August 2015
Apple	iPhone 5 MD646LL/A	8.4.0	September 2012/ June 2015
Apple	iPhone 6 Plus NGAU2LL/A	9.0 Beta	September 2014/ July 2015
LG	G2 LG-D801	4.4.4	September 2013/ June 2014
LG	G3 LG-D850	5.0.1	May 2014/ December 2014
Samsung	Galaxy Note 4 SM-N910T	5.0.1	October 2014/ December 2014
Samsung	Galaxy S5 SM-G900A	Unavailable	April 2014/ Unavailable
Samsung	Nexus 10	5.1.1	April 2015

## 2.2 Video Creation Parameters

In order to complete the CLA for this thesis, test videos needed to be created for the research. In order to control some of the variables that can accompany video recording, some steps were taken to minimize those variables. It was decided each video would be approximately ten seconds in length. Since most cameras default to 30 frames per second (a few defaulted to 24 frames per second and one had a default of 60 frames per second) each video would have about 300 frames that would be averaged together. Most people don't know the intricacies of manual settings on a digital camera; therefore, all of the cameras were reset to factory default settings.

The second controlled parameter was the type of content to be recorded. As I was not able to gather test videos from all the cameras at the same time, it was decided the best video content would be a white wall. White walls are easy to find and they create

consistent content that can be easily recorded. However, there is another good reason why white walls were most suitable for this test. Due to white's color profile, it will pass through all of the primary colors of red, green, and blue in the color filter array of the camera before reaching the image sensor.

In order to compare the results of each generation with the original video taken from the camera, two 10-second videos were created with each camera. The first video was left unchanged while the other video would be used as a starting point to create the new video generations with the different software and uploaded/download from YouTube. A CLA was performed on the original video to provide a baseline result for each camera.

### **2.3 Method to Create Each New Video Generation**

As mentioned earlier in the previous section, two videos were created; one to provide a baseline for the CLA test and the other to create new videos. The process of creating each new generation is fairly simple, however, it is time consuming. Most are a one step process, but the videos recompressed using YouTube required an extra step.

To create each new generation, I started with the second recording from each camera, as designated for this purpose. This video was loaded into the program. Then without editing or altering the video, I immediately exported the video as a new file. Special consideration was taken to ensure the resolution matched the original video; and also, I made sure the program exported as an .mp4 file using the H.264 codec. Next, the soon to be recompressed video was labeled and finally exported. The process was then repeated with the newly created video to produce another recompressed generation. This process was repeated five times for each program.

Since YouTube is a web-based video sharing site, a few extra steps were required to create multiple recompressed generations. The video designated for recompression from each camera was uploaded to YouTube using the file “upload” section of the website. Unlike the other programs where the examiner is required to export the video and chose the settings, YouTube automatically compressed the video upon upload. Once uploaded to the site, a YouTube video downloader was used to download the videos. The downloaded videos were labeled and saved for later analysis.

After the videos were downloaded and saved, they were re-uploaded to create a new generation. Like before, the process was repeated to generate five recompressed generations of the original video.

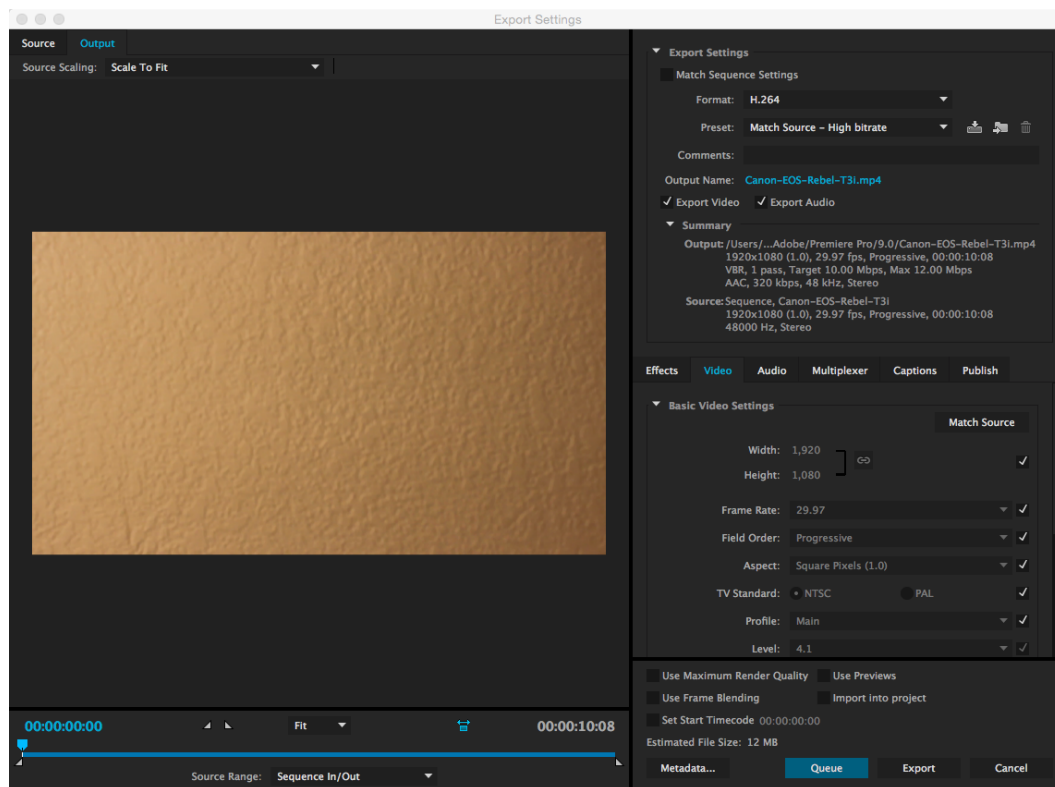
## **2.4 Software and YouTube Overview**

While the cameras are vital to the success of this thesis, they are only one part of the equation to complete the testing. The second and equally important part of the testing was the different software and YouTube used to create the different generations of videos from the cameras. The following outlines the different settings used for each program when the examiner created each new generation.

## **2.5 Adobe Premiere Pro CC**

Adobe Premiere Pro Creative Cloud 2015 is Adobe’s answer for video editing. This program can hold its own against other popular video editing software and had no problems handling the easy task of video recompression. Out of all the software I had access to, this was the only true video editing software that was used. Since this program has more editing features, there were also a lot of options that could be changed when exporting. As mentioned earlier, careful consideration was taken to ensure the resolution

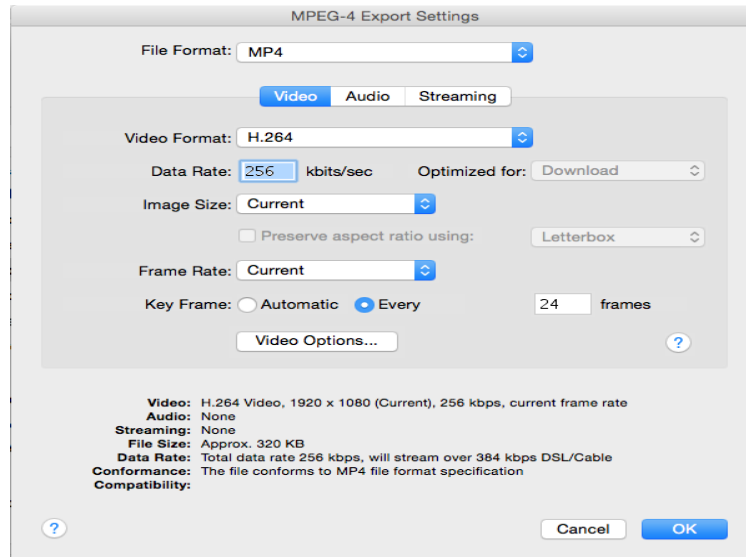
was identical to the original video, as well as setting the .mp4 container with the H.264 codec.



**Figure 1: Example of export settings for Adobe Premiere Pro CC**

## 2.6 QuickTime Player 7 Pro

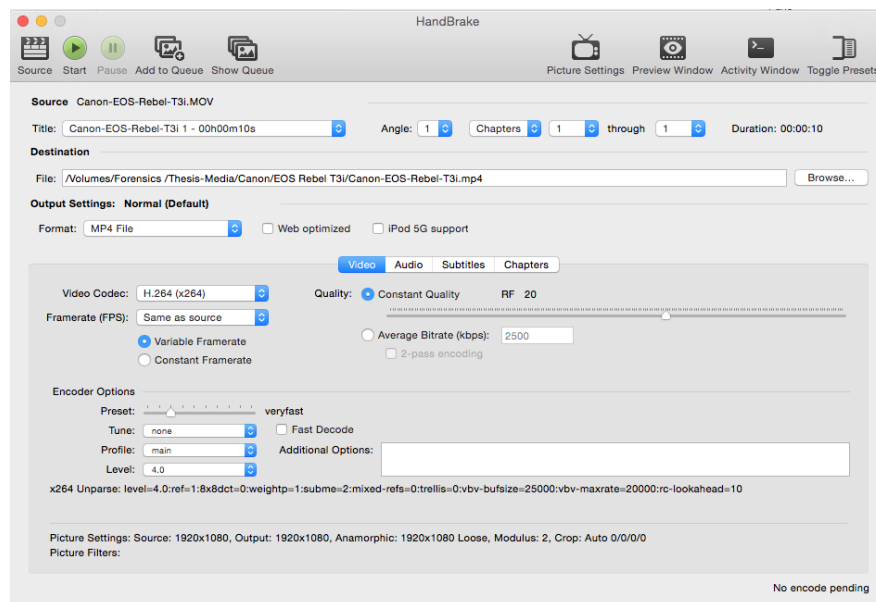
Created by Apple, QuickTime Player 7 Pro is an affordable solution for basic video tasks. The advantage of this program over many of the others is its simplicity. This program lets you record, convert videos, and perform basic edits, while exporting to popular video standards.



**Figure 2. Example of export settings used for QuickTime Player 7 Pro**

## 2.7 HandBrake

HandBrake is a very popular freeware program that is used to convert videos from a wide variety of formats to popular common video codecs. While HandBrake is easy to use, it also has numerous advanced options that can be used when converting videos. Below is an example of the settings used for this thesis.



**Figure 3. HandBrake export settings**

## 2.8 FFmpeg

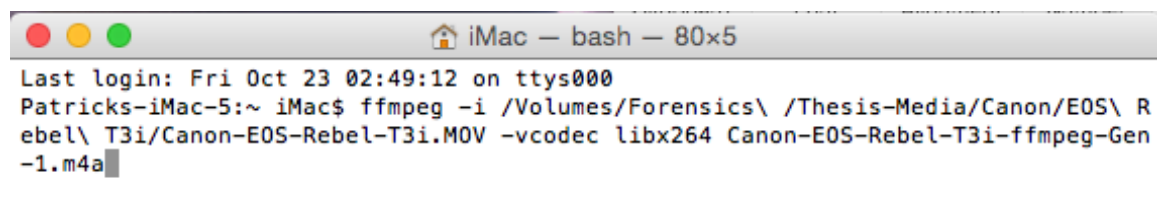
FFmpeg is another freeware that requires the use of Command Prompt in Windows or Terminal on an Apple machine. Since it is not a standalone program, this was the most complicated converter used during the testing. Even though it might be more complicated to operate, it provided an amazing amount of conversion and playback options for both audio and video. In order to recompress the videos using this program, I had to adapt a previously acquired script to run FFmpeg so as to provide the desired results. The following FFmpeg command was used to convert the videos.

**Table 8. FFmpeg recompression command**

<code>ffmpeg -i Input-File.MOV -vcodec libx264 Output.mp4</code>
--

Breaking down the different components of the script include:

- -i Input-File.mov = the directory and desired original file to be converted
- -vcodec libx264 = this specifies the resulting video will use the H.264 codec
- Output.mp4 = This is where the new video file is named and the output file's container is specified, which in this case is .mp4



```
iMac — bash — 80x5
Last login: Fri Oct 23 02:49:12 on ttys000
Patrick's-iMac-5:~ iMac$ ffmpeg -i /Volumes/Forensics\ /Thesis-Media/Canon/EOS\ R
ebel\ T3i/Canon-EOS-Rebel-T3i.MOV -vcodec libx264 Canon-EOS-Rebel-T3i-ffmpeg-Gen
-1.m4a
```

**Figure 4. Example of full FFmpeg command**

It should also be noted that FFmpeg is used as the core makeup or converter engine in many different programs. According to the FFmpeg website, FFmpeg is incorporated into programs or software including Google Chrome, HandBrake, and VLC, just to name a few. Due to the wide use of FFmpeg, if the settings that use FFmpeg are

selected on a program such as HandBrake, the results from a CLA will be very similar, if not the same, which makes determination of the specific program much harder.

## **2.9 YouTube**

Unlike the programs that have been previously discussed in this section, YouTube is the only one tested where one doesn't have control over the conversion settings. In order for the user uploaded videos to have optimum playback online, the popular video sharing site makes the tough decision about proper settings for all of us. An article by Wiger van Houston and Zeno Geradts states, "When the uploaded (natural) video content has a resolution lower than the maximum resolution from YouTube, there is no change in resolution." [7]. In order for the video to playback on the website, every uploaded video is encoded but the video will not be upsized to a larger resolution and will remain at its maximum resolution.

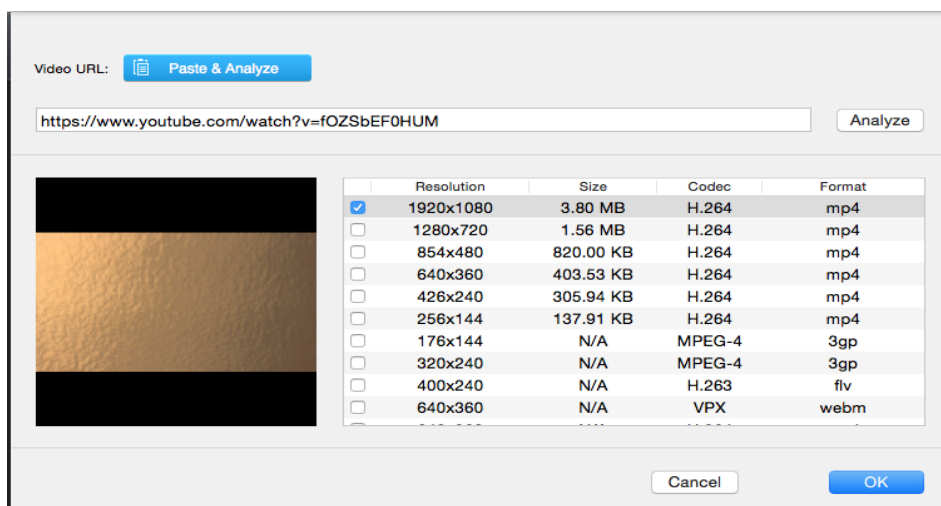
Normally, when a forensic investigator is downloading a video, careful consideration is given to the resolution of the video. The downloaded video should have the same resolution as the original to avoid any recompression or encoding. However, during Zac Giammarrusco's research, he found, "The video will always re-encode regardless if the dimensions are identical upon upload and download." [8] This is important to remember when analyzing a video from YouTube.

In order for YouTube to provide better streaming, it utilizes dynamic adaptive streaming over HTTP (DASH). It works by letting the video playback with different bit rates and resolutions, so there isn't any buffering. Since this is the protocol that YouTube uses, a screen video recorder should not be used when trying to recover a video for forensic analysis.



Downloading videos directly from YouTube isn't possible, so there are many different freeware, command lines, and software that can be used to download a video. While there are many different programs available, I chose to use MacX YouTube Downloader. This is a freeware program created for Mac, which provides the ability to download the videos. Once again, the research by Zac Giammarrusco shows MacX yields the same results as YouTube Downloader by GreenTree Applications. "This tool uses FFmpeg licensed under the LGPL v3." [8] This illustrates the versatility and wide use of FFmpeg in many different applications.

In order to download a video, the URL of the video needs to be copied and pasted into the program. The program then provides the user with all of the available format options for download. An example of the resolution and codecs available for download is shown below in Figure 5. I chose the highest resolution available for download, which happened to be the same as the original resolution. Once the resolution is selected, the user can choose the destination folder and download the video.



**Figure 5. YouTube downloader resolution options**

## **2.10 MATLAB**

The third and final component to complete the data gathering for this thesis required the use of MATLAB for the purpose of generating a CLA for each video created with the 30 cameras. The custom script combined multiple functions, which included reading.mp4 files and analysis of the RGB color layers. The results from this part of the research provided a very useful charts and plots for analysis. Those include histograms and CEPSTRUMs (which is a numerical value of the spectrum of the image.) All of this information is combined to help provide a visual and numerical representation of the CLA for each video.

## **CHAPTER III**

### **RESULTS**

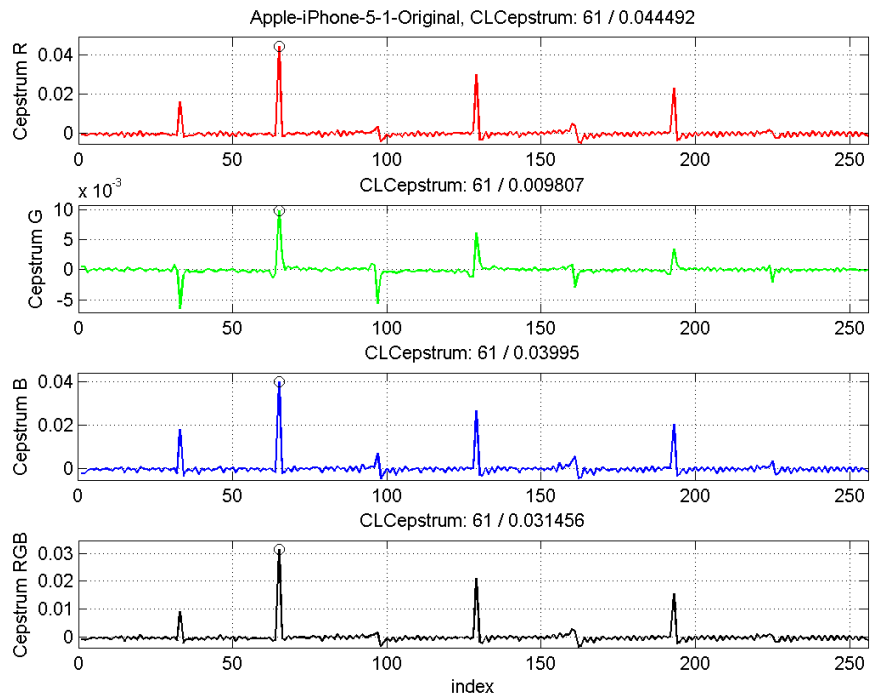
#### **3.1 Overview**

Upon analyzing the data gathered from the experiments outlined in this thesis, many different findings emerged. While I was able to draw conclusions on my original questions, I was also able to report unexpected findings. When looking back through the data, these additional findings helped to answer more questions and solidify answers to the original questions. The next few sections will explain the results from the testing.

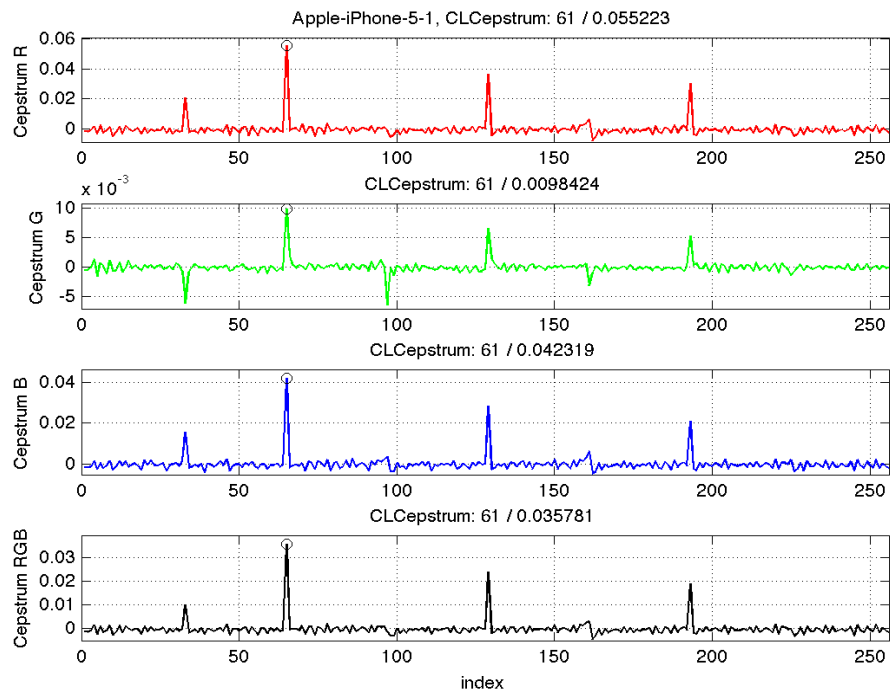
#### **3.2 Original Video Comparison**

In order to help validate the results below, CLA plots were generated for the two original videos recorded with each camera. One would expect the CLA results of each video to look very similar to each other, since they were recorded with the same camera, same settings, and same scene.

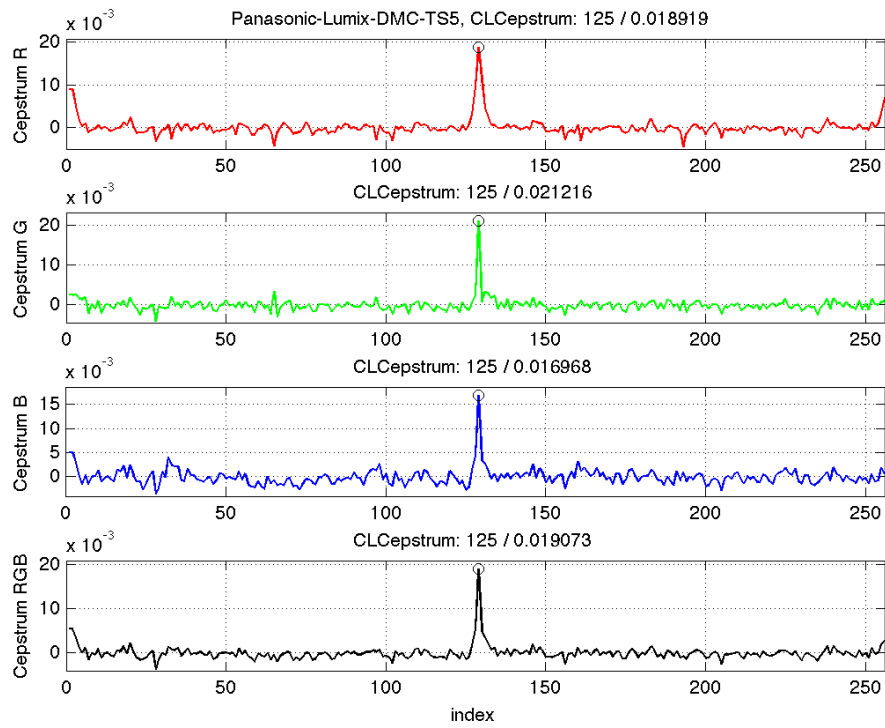
As expected, the results from the original videos look almost identical. Since all of the test videos were shot without the use of a tripod and many had natural lighting, there were slight variations between the two. However, the subtle variations can be expected and could be a result of camera shake or different angles when recording. The following figures illustrate the similarities between the two original videos.



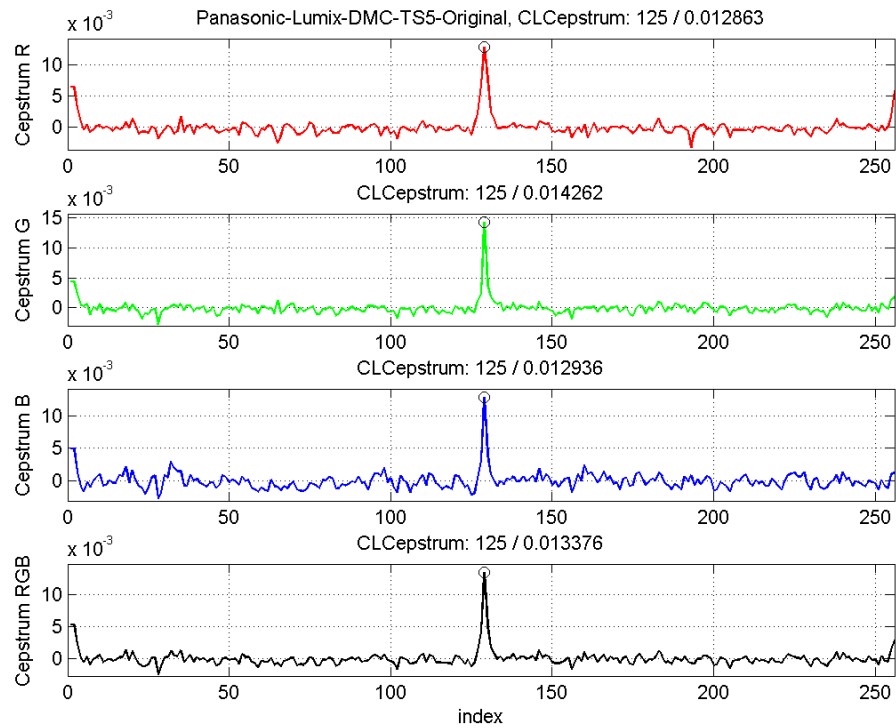
**Figure 6. Apple iPhone 5 Original Video 1**



**Figure 7. Apple iPhone 5 Original Video 2**



**Figure 8. Panasonic Lumix DMC-TS5 Original Video 1**



**Figure 9. Panasonic Lumix DMC-TS5 Original Video 2**

### 3.3 Video Resolution

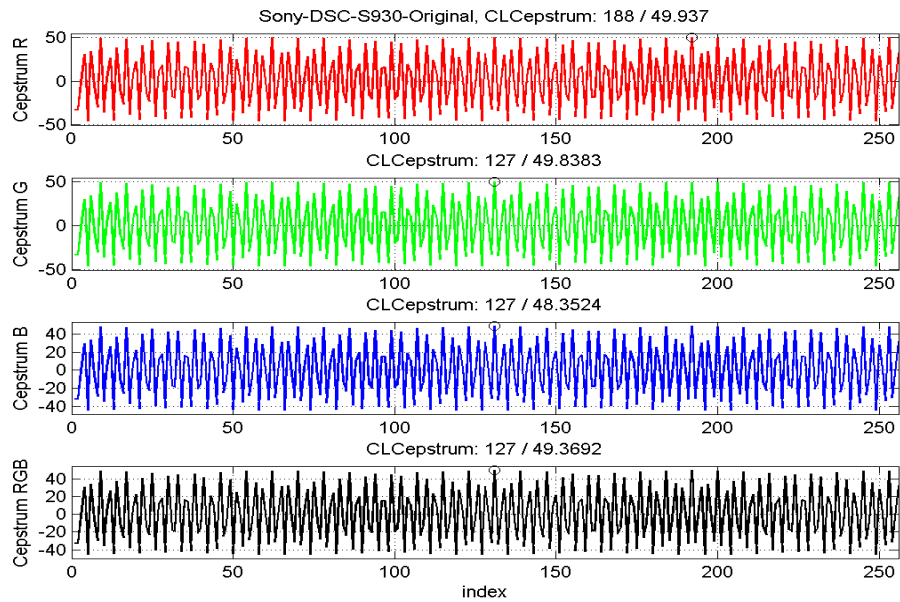
Fortunately, for this test I was able to gather videos from cameras that had a wide range of resolution extending from 320x240 to 1920x1080. This wide range helped to illustrate a point when resolution starts to affect the results of the CLA.

My research found four cameras that recorded video at the 320x240 resolution when returned to factory defaults. The camera would default to this resolution due to the amount of space available on memory cards in the mid to late 2000s. While there were larger memory cards available at that time, the price was very high. According to a press release from the Consumer Electronics Show in January of 2007, Sony announced it would be doubling its 4 GB memory card (released the prior year at CES) to 8 GB. The press release stated 8 GB cards would sell for \$300 at the time of release [9]. Also, according to Olympus archives, the largest available memory card for their Stylus cameras was 2GB.

**Table 9: Older camera information**

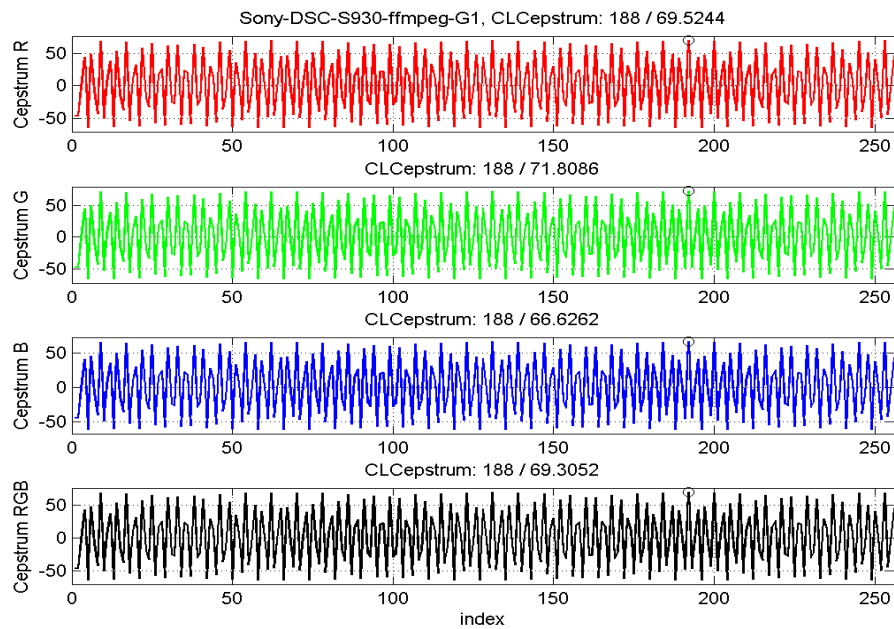
Camera Specifications (Oldest to Newest)		
Make	Model	Release Date
Olympus	X-560WP	June 2003
Olympus	Stylus 710	February 2007
Olympus	Stylus 790SW	September 2007
Sony	DSC-S930	February 2009

Since the amount of space was limited when these cameras were released, they also used higher levels of compression when recording on the camera to save space on the card. The figures below illustrate how the Sony DSC-S930 already begins with a high compression level.

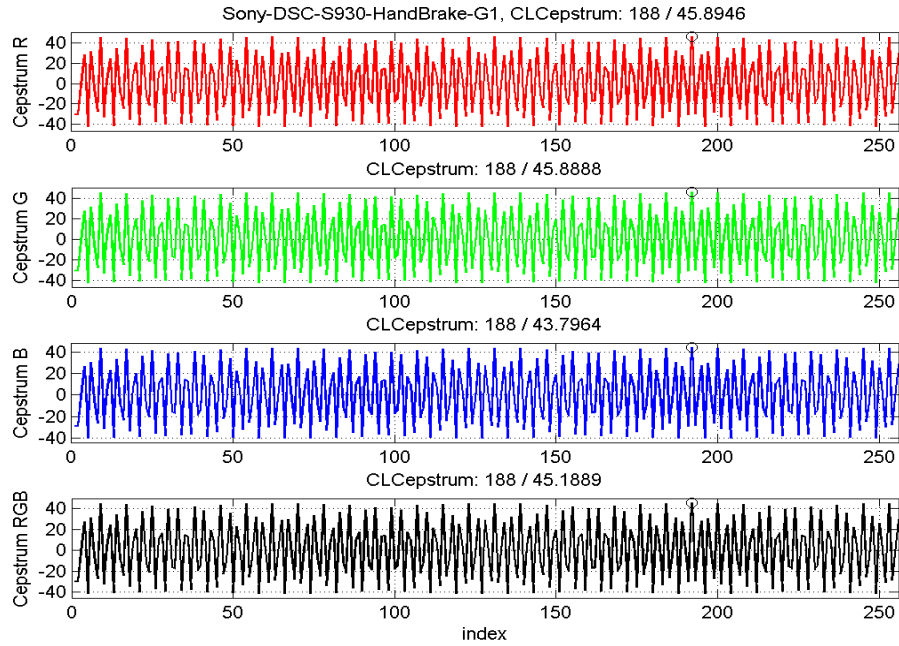


**Figure 10. Original CLA for the Sony DSC-S930 showing high starting compression level**

Once this video was run through the programs outlined in this thesis, the visuals didn't change very much. The only way the examiner could tell if there was recompression was by the corresponding numbers for each color and scale of the plot.

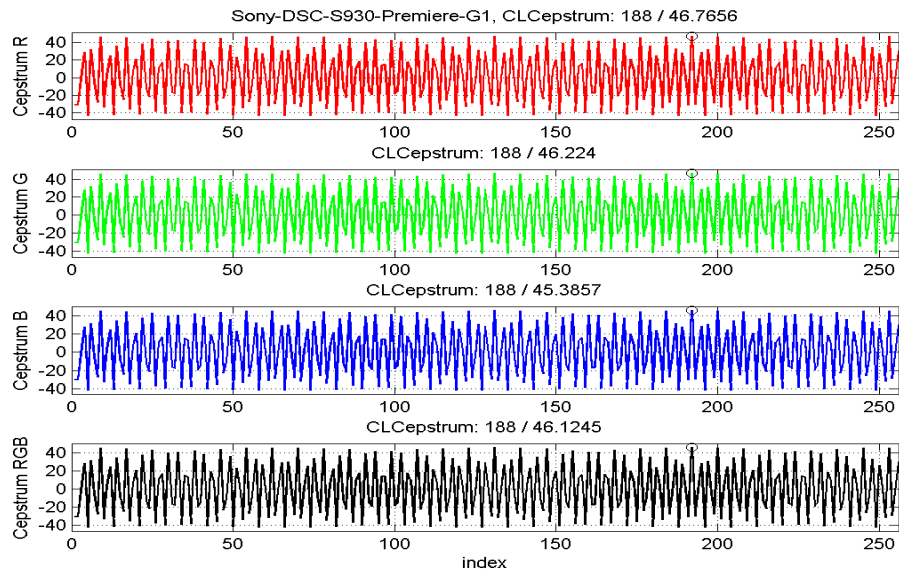


**Figure 11. CLA results from FFmpeg Generation 1**



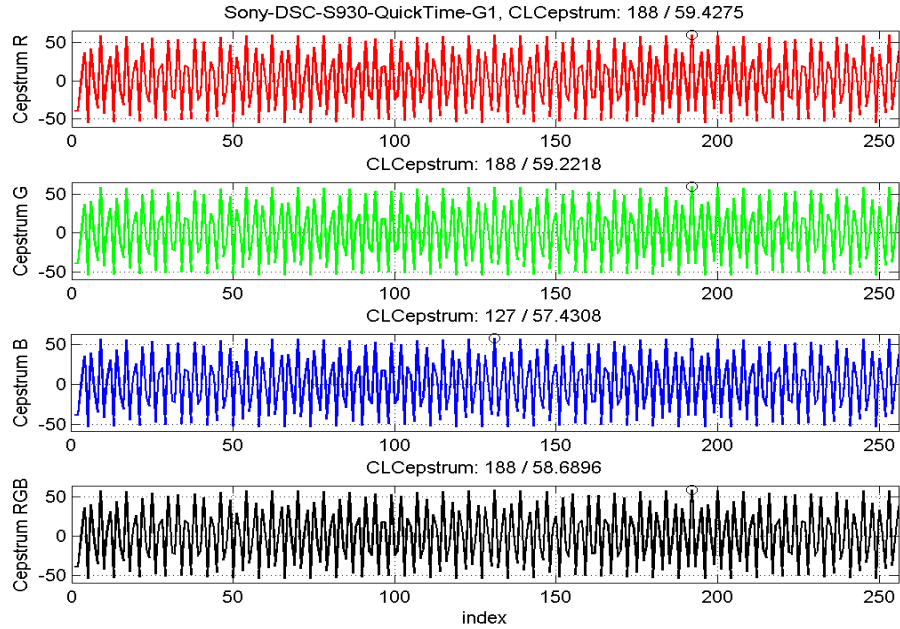
**Figure 12. CLA results from HandBrake Generation 1**

Figure 12 illustrates the change in the scale from the original plot to to the HandBrake Generation 1. This would tell the examiner there was recompression, but only if the examiner could compare it with an original video from the same device.

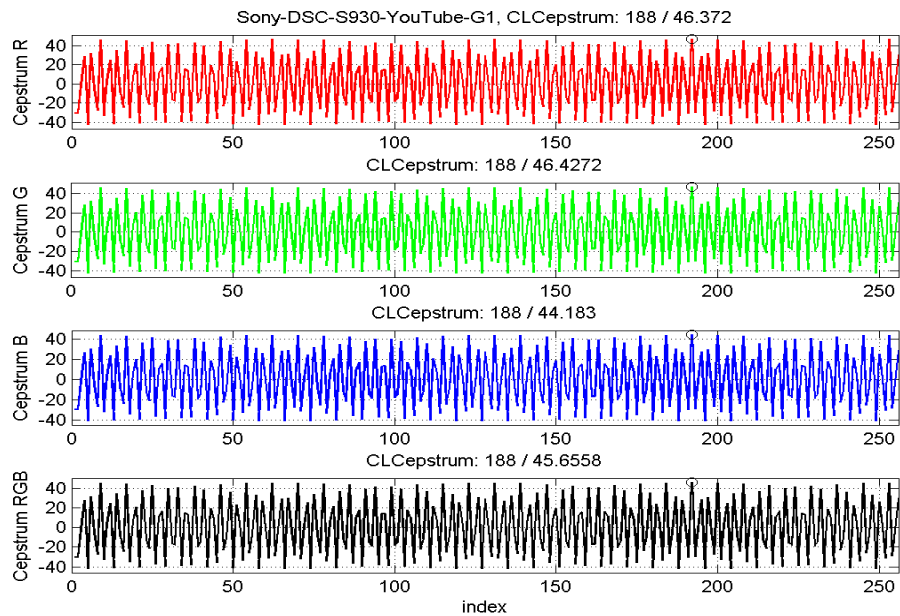


**Figure 13. CLA results from Adobe Premiere CC 2015 Generation 1**





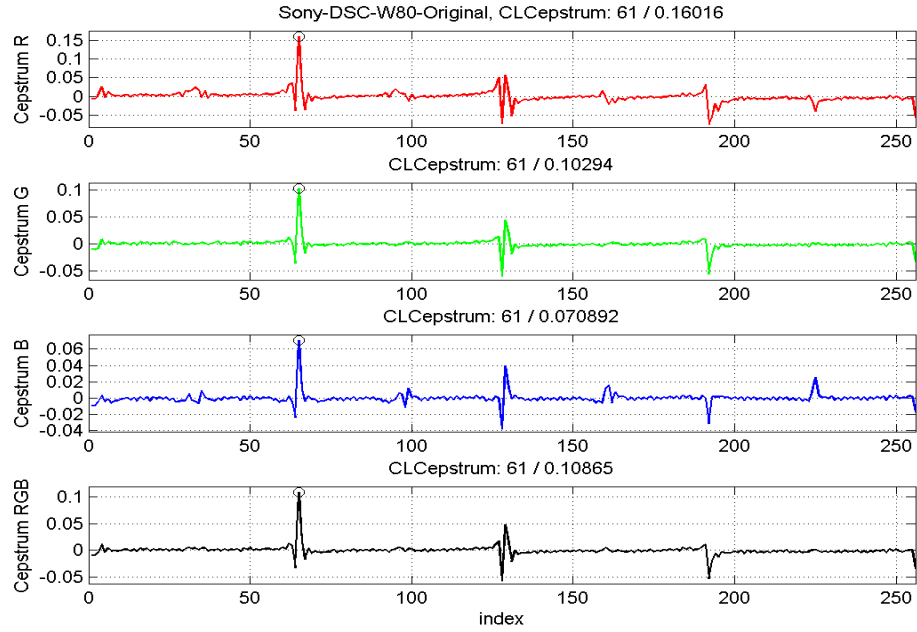
**Figure 14. CLA results from QuickTime Player 7 Pro Generation 1**



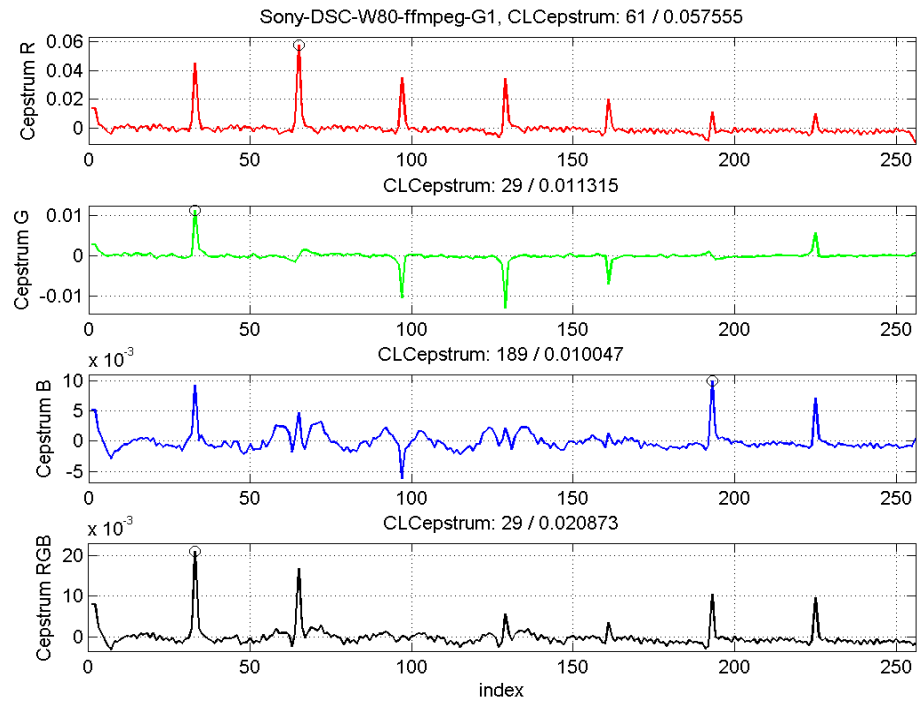
**Figure 15. CLA results from YouTube Generation 1**

As demonstrated in the previous figures, the CLA test on a video with a resolution of 320x240 will not provide much useful information for the analyst. However, better

results can be more prevalent with videos that have a resolution of 640x480 or higher, as shown in Figure 16 and 17.



**Figure 16. CLA from Sony-DSC-W80 with a resolution of 640x480**

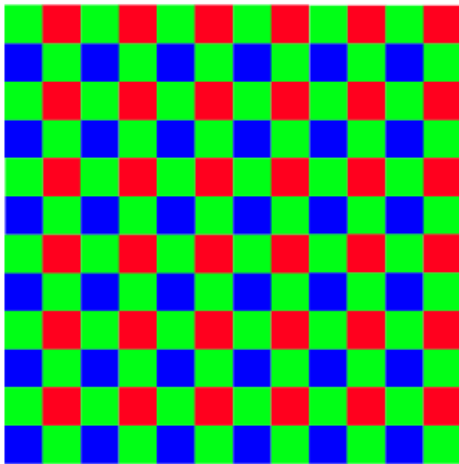


**Figure 17. CLA results from FFmpeg**

As one can perceive in the previous two charts, there is a clear difference between the original and FFmpeg Generation 1 showing recompression.

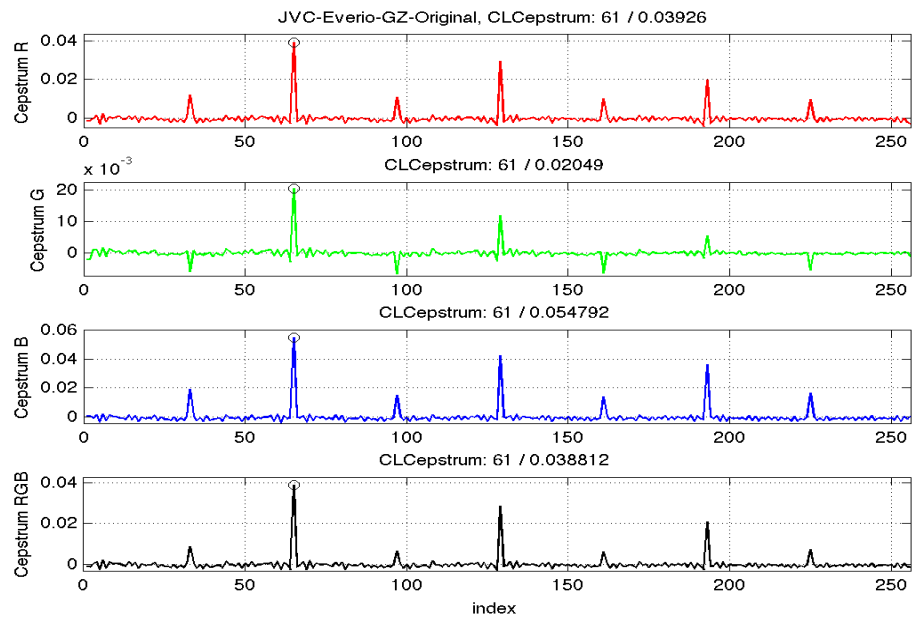
### 3.4 More Change in Green and Blue Levels

Another interesting finding from the testing is more change in the green and blue levels as opposed to the red. The change in green is easy to explain. Human eyes are more sensitive to the color green when compared to red and blue. Consequently, camera manufactures try to mimic how the human eye sees color with color filter arrays. The most popular CFA is the Bayer Array. The design of this array is laid out in a grid pattern, which consists of red, green, and blue filters. To mimic the ability of the human eye to see green, there are twice as many green filters as opposed to red and blue filters.

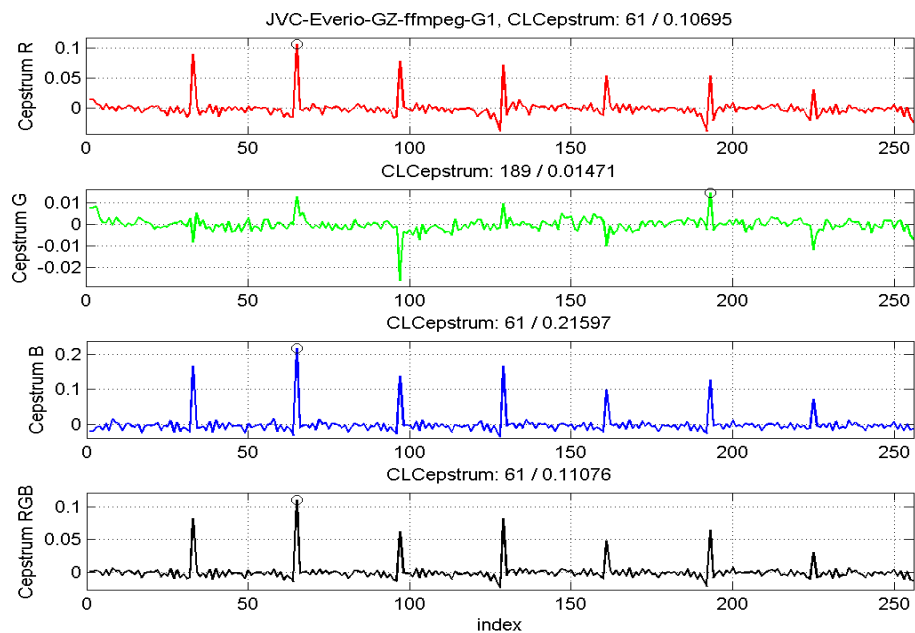


**Figure 18. Example of a Bayer CFA [10]**

Most of the results from recording a white wall included stronger green and blue levels. This can lead to a great change in those colors during the CLA tests. The following figures are the best examples of change in either the green or blue analysis.



**Figure 19. CLA of original video from JVC Everio**



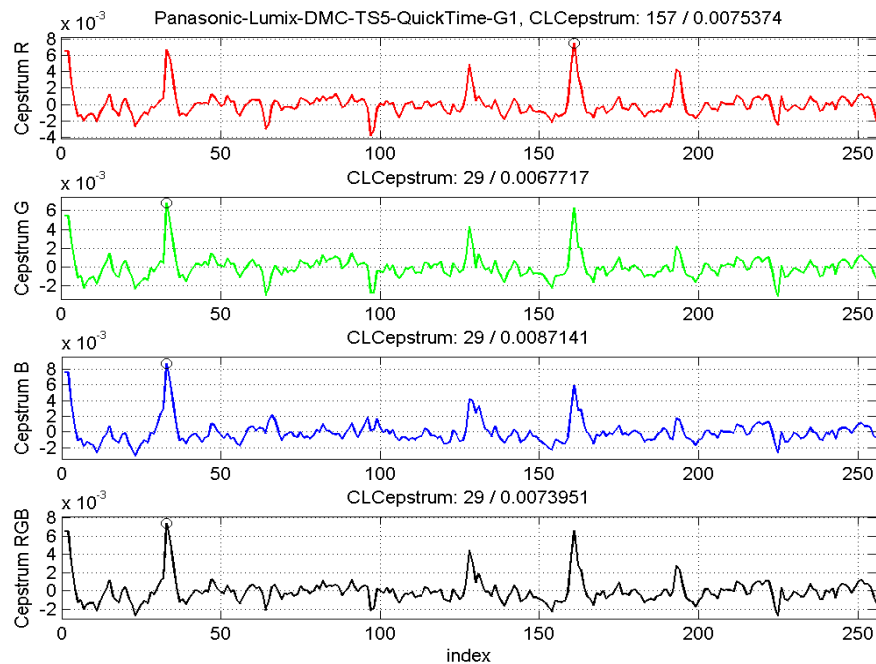
**Figure 20. CLA after first recompression**

When viewing the two charts above, one can see a noticeable difference in the red and green layers. However, when considering the peak value numbers and location for those color layers, there is minimal change. While the analysis number for the green layer

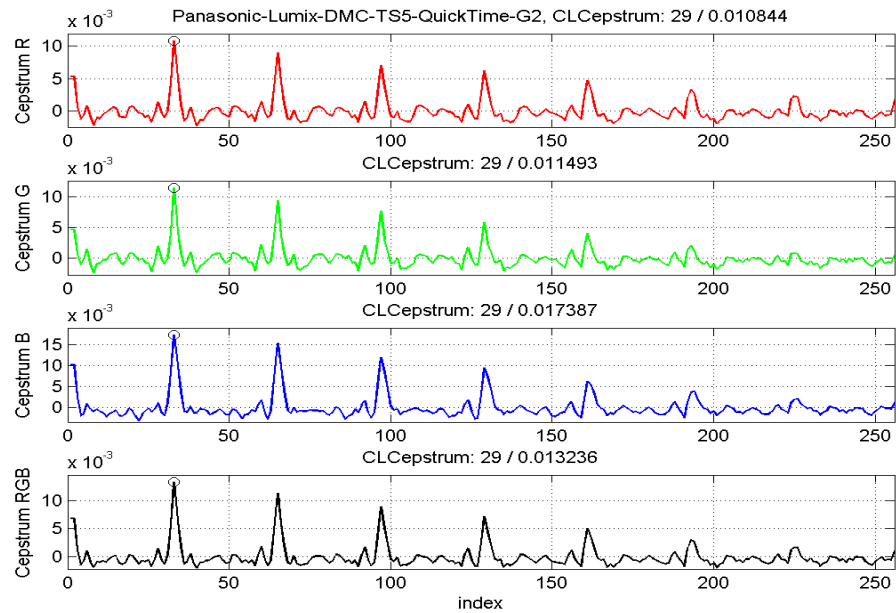
might seem small as well, the location of the central spike and the scale between the two are vastly different. Further analysis on the changes in the green and blue layers will be discussed later in this section.

### 3.5 Differences Between Generations

Since it is well known in the industry that video compression works to reduce redundancies in the video data for the purpose of reducing overall file size, the CLA script used in MATLAB is able to show the original file with a central spike and some smaller spikes to the left and right. With each subsequent generation, the compression level should show an increase after the initial conversion. Figures 21 and 22 illustrate the difference between HandBrake Generation 1 and 2 from the Panasonic Lumia DMC-TS5.

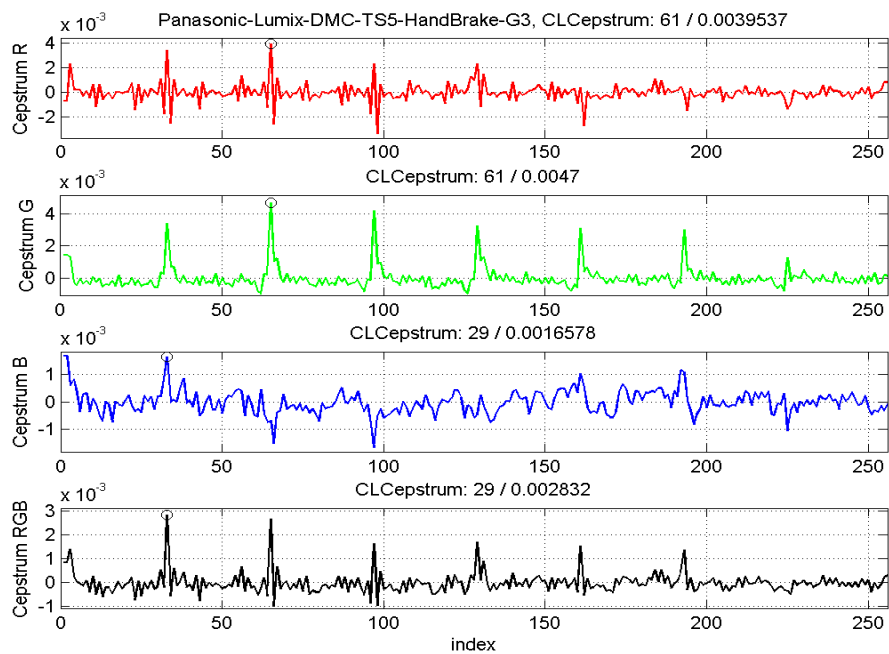


**Figure 21. Handbrake Generation 1**



**Figure 22. HandBrake Generation 2**

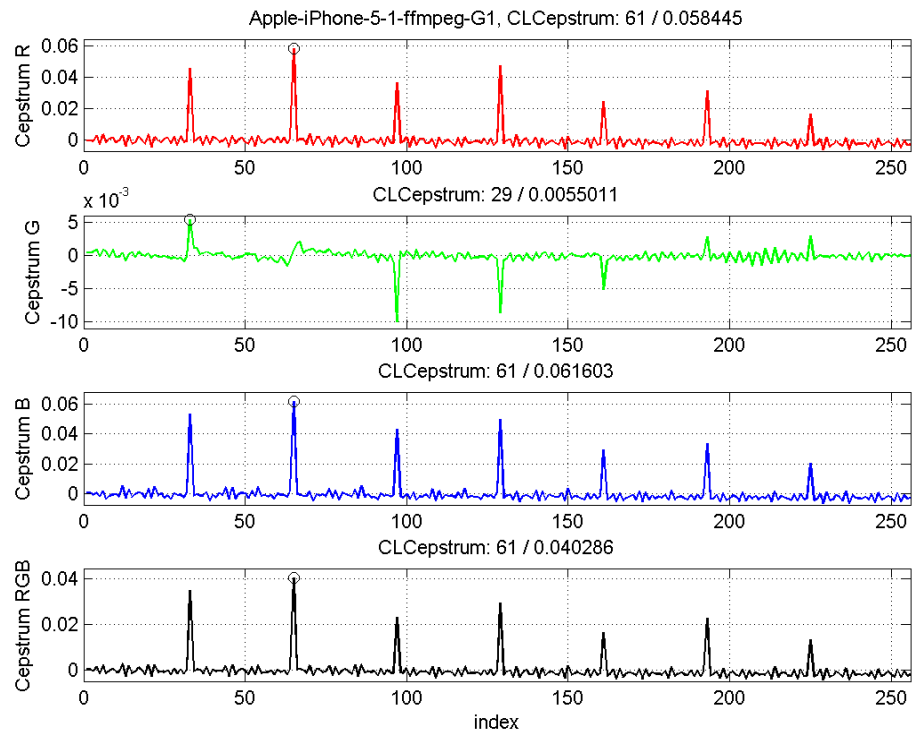
As you can see, there is an increase in the maximum point for each color layer between the first and second generation. There is even a noticeable difference between generation 2 and 3.



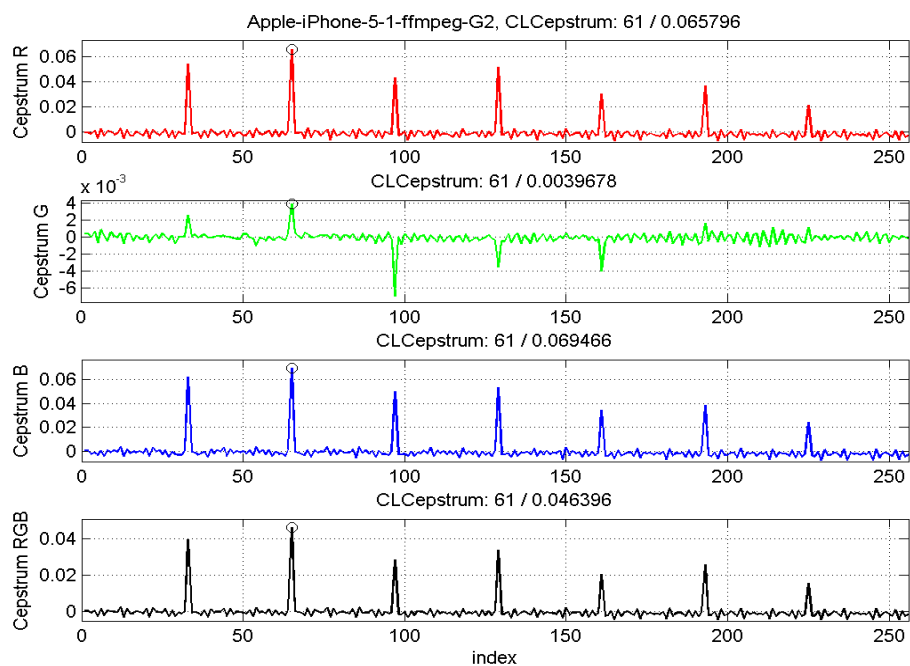
**Figure 23. HandBrake Generation 3**

The generations beyond generation 3 start to yield poor results. Some of the color layers in generation 4 and 5 began to stabilize out, while others had odd jumps where the peak value changed significantly. However, these types of results did not occur consistently with all 30 cameras.

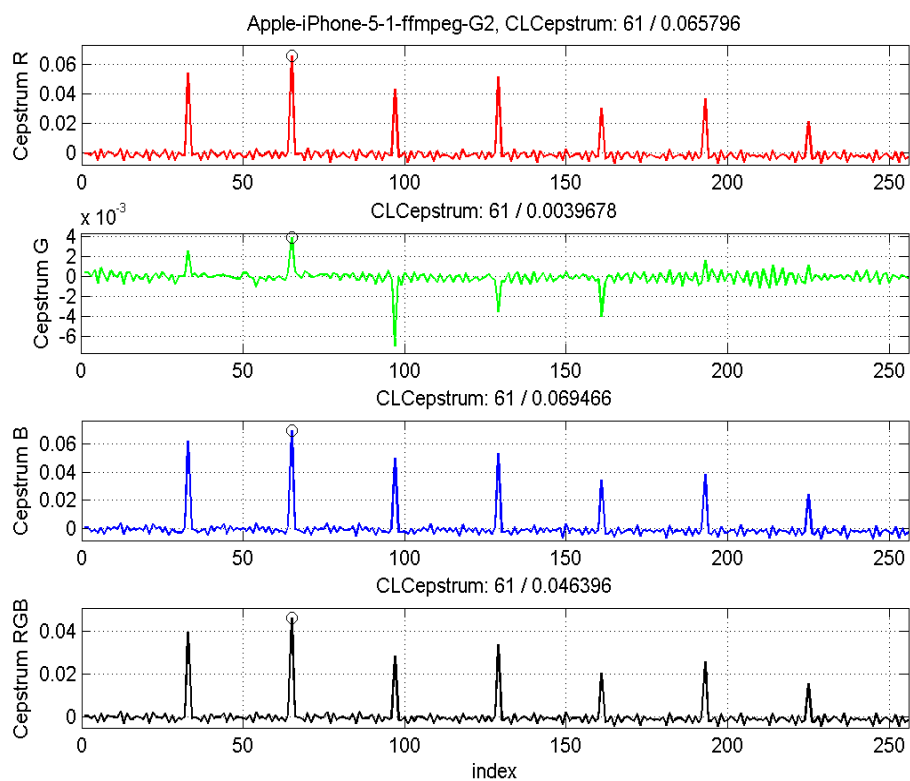
For example, the Apple iPhone 5 had increases in the maximum peak value between the first three generations on the red and blue layer, while the green layer decreased then increased.



**Figure 24. Apple iPhone 5 Generation 1**



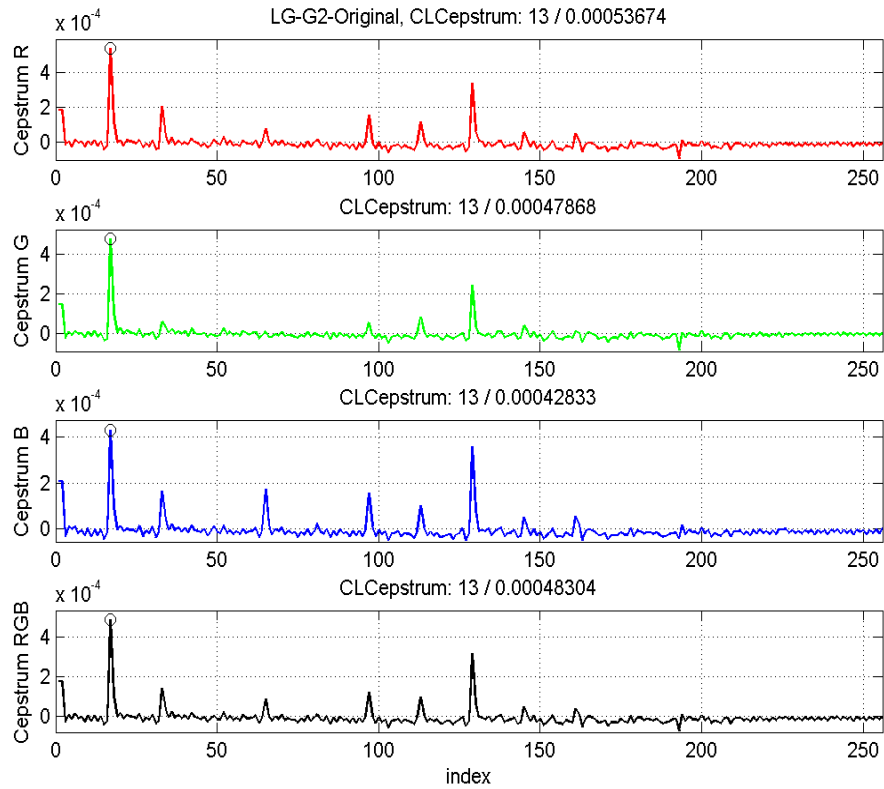
**Figure 25. Apple iPhone 5 Generation 2**



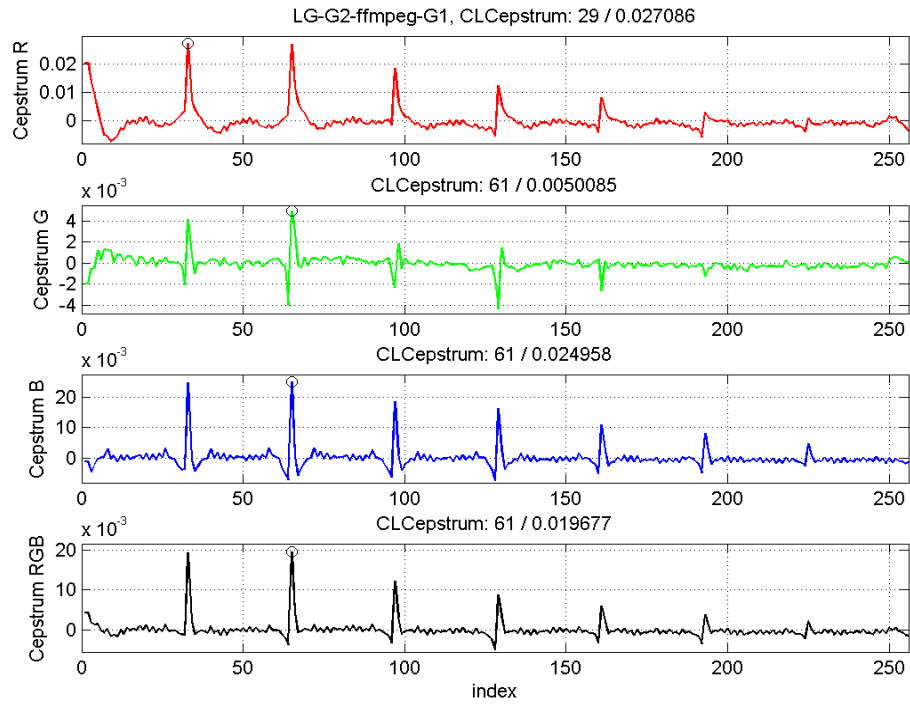
**Figure 26. Apple iPhone Generation 3**



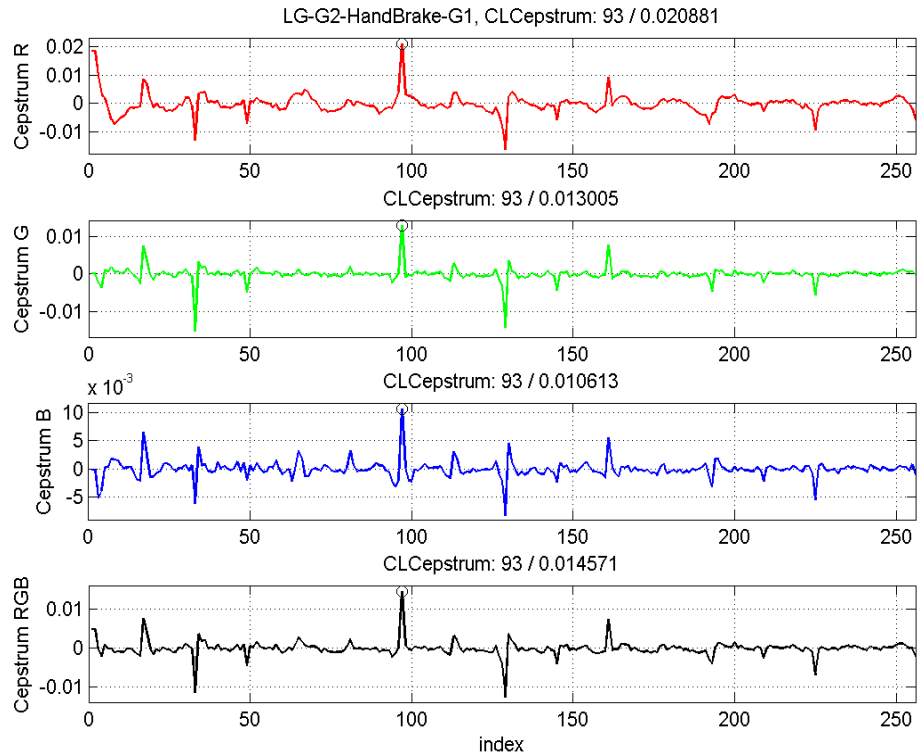
While the difference between the different generations may not always be clear, there is a clear difference between the original file and every generation 1 recompressed video. The only exception was the cameras with a lower resolution, as discussed earlier in this chapter.



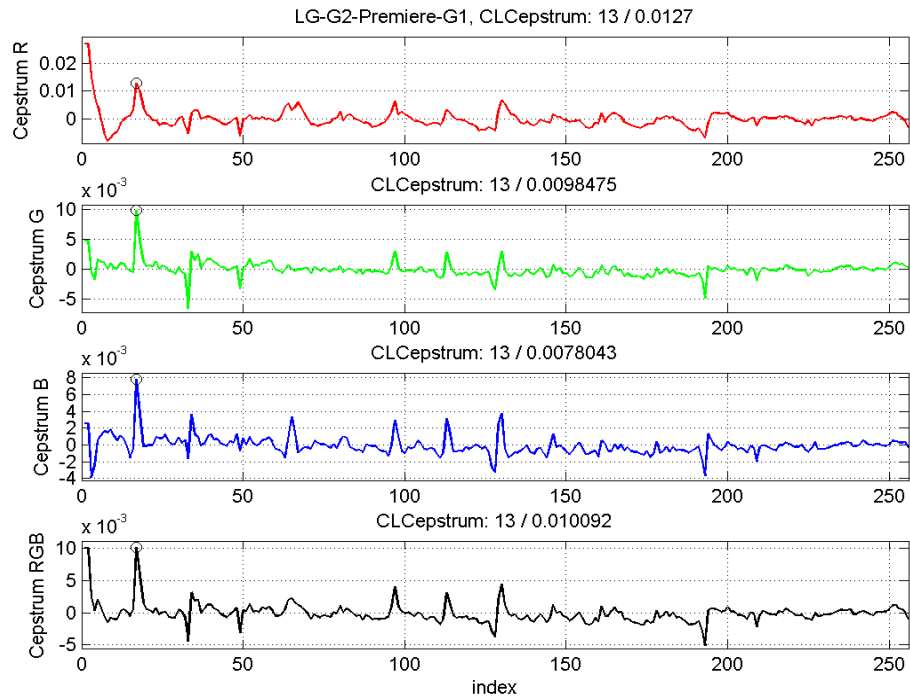
**Figure 27. LG G2 Original CLA**



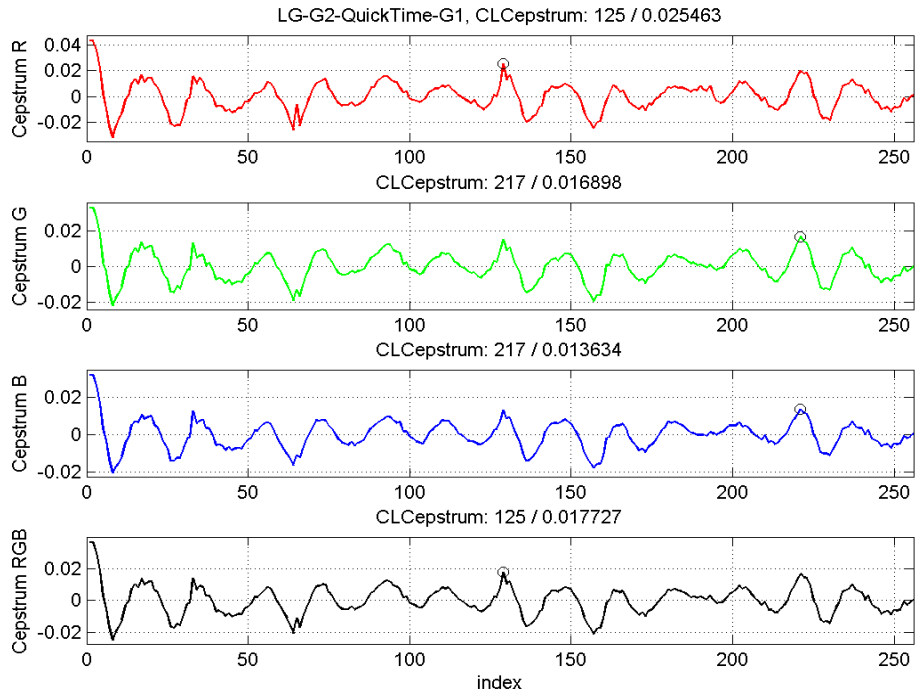
**Figure 28. LG G2 FFmpeg Generation 1**



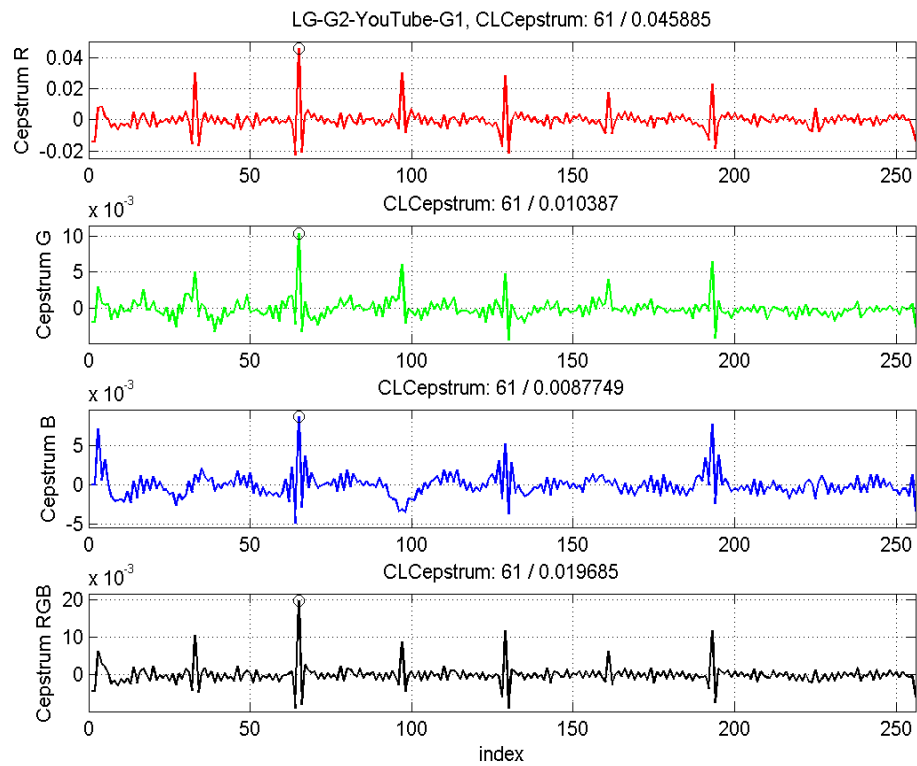
**Figure 29. LG G2 HandBrake Generation 1 CLA**



**Table 30. LG G2 Premiere Generation 1 CLA**



**Table 31. LG G2 QuickTime Player 7 Pro Generation 1 CLA**



**Table 32. LG G2 YouTube Generation 1 CLA**

The initial difference between the original and the first generation of each program and YouTube is seen on almost all of the cameras, smartphones, and tablets used during this test.

### 3.6 Visual Cues to Determine Software Used Overview

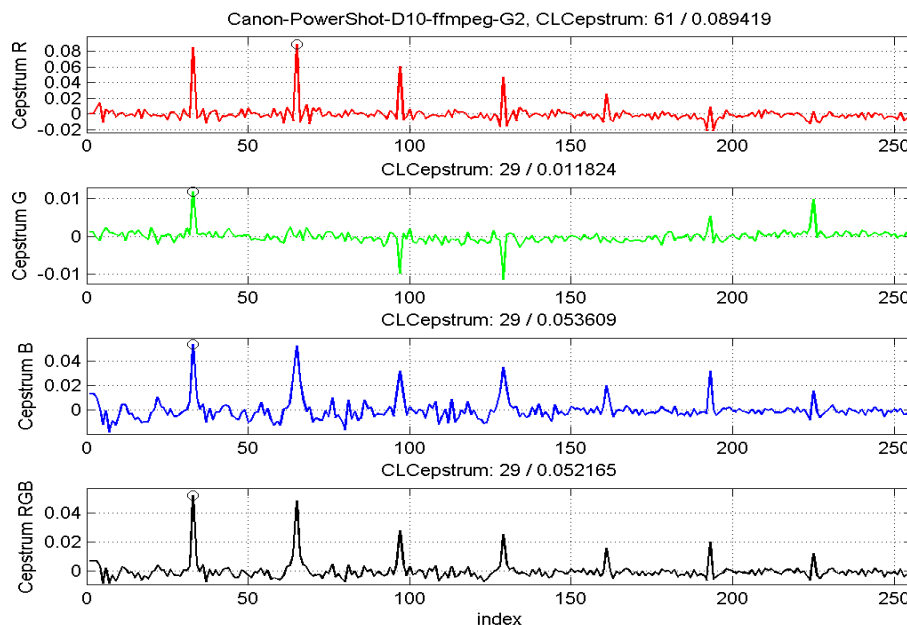
One of the primary questions tested was the determination of any visual cues that could lead a forensic examiner to determine the program used to recompress the video. While these different visual cues may be subtle due to the content of the video, original compression from the camera, and/or recompression generation, a pattern began to emerge that linked the CLA charts to the program.

### 3.7 Visual Cues for FFmpeg

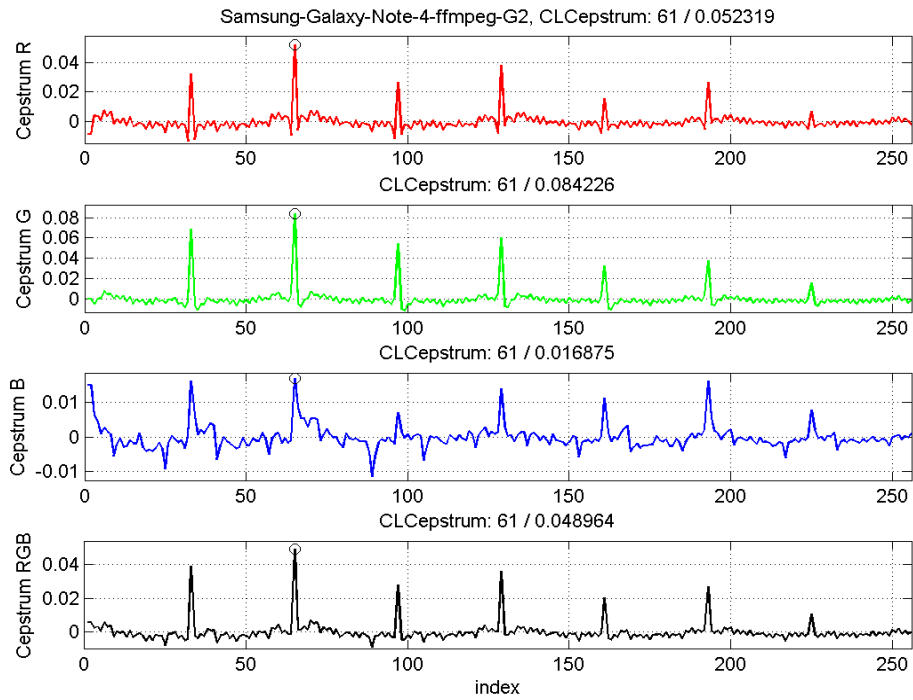
While analyzing the data repeatedly, FFmpeg always stood out as the most uniform CLA with each subsequent generation created. At first, I didn't notice this uniformity but soon discovered this was the unique trait for FFmpeg.

With almost every video, FFmpeg would result in a CLA chart with noteworthy narrow peaks or valleys. Further, the content between the narrow peaks or valleys nearly flattens itself along the 0 line of the plot. These next few examples show the characters of a video that was recompressed with FFmpeg.

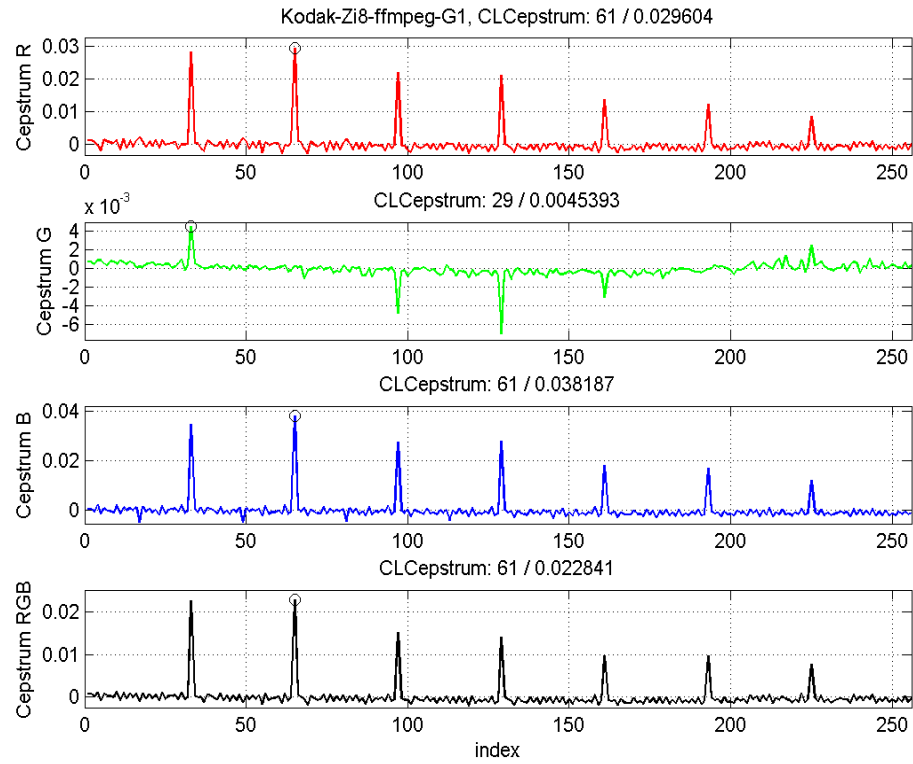
It is important to point out the camera used for the CLA in Figure 33 is one of the cameras with a lower resolution of 640x480. Even though the original CLA plot has more movement to a lesser extent than what was seen in section 3.2, FFmpeg still transformed it to its familiar characteristics.



**Figure 33. Canon D10 FFmpeg CLA**



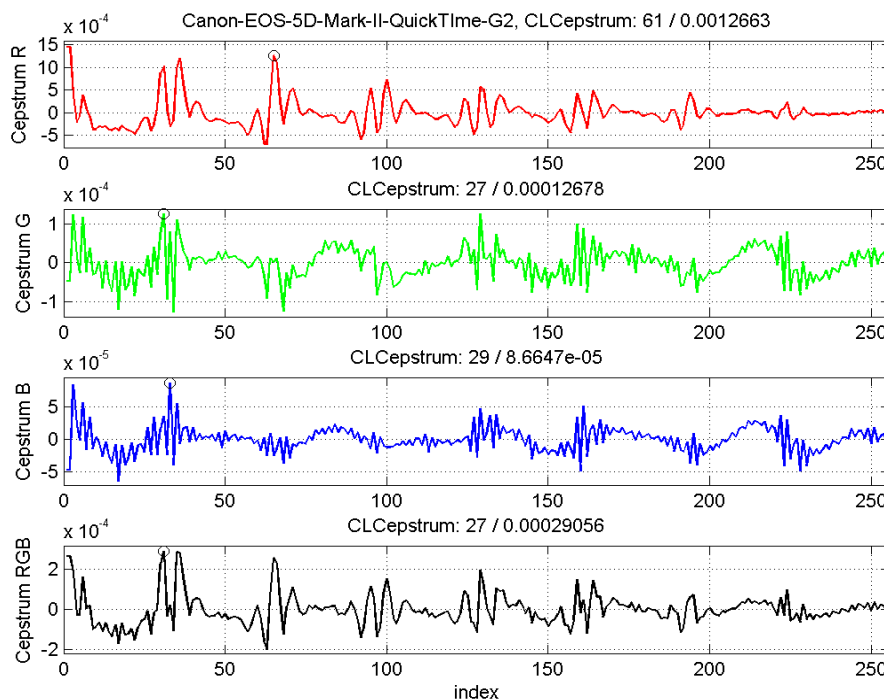
**Figure 34. Samsung Galaxy Note 4 FFmpeg CLA**



**Figure 35. Kodak Zi8 FFmpeg CLA**

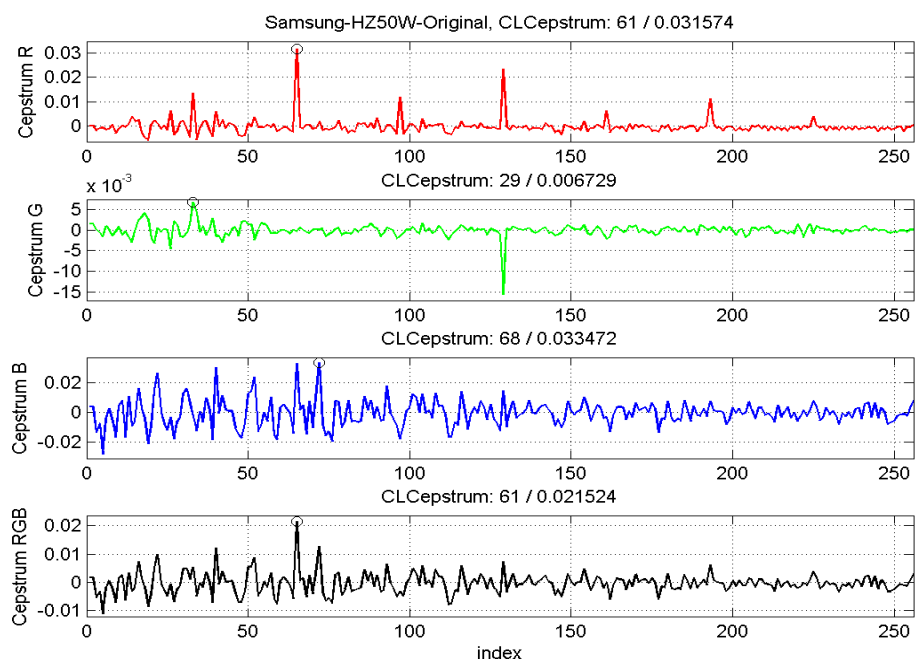
### 3.8 Visual Cues for QuickTime Player 7 Pro

Unlike the narrow peaks and valleys created with FFmpeg, the characteristics of QuickTime Player 7 are quite different. In fact, they are the opposite. QuickTime seems to generate wider peaks and valleys. Additionally, the data between the peaks and valleys creates an almost wavy shape by rolling positively and negatively off of the 0 line. These visual cues help to identify QuickTime Player and the software used in these next few examples.

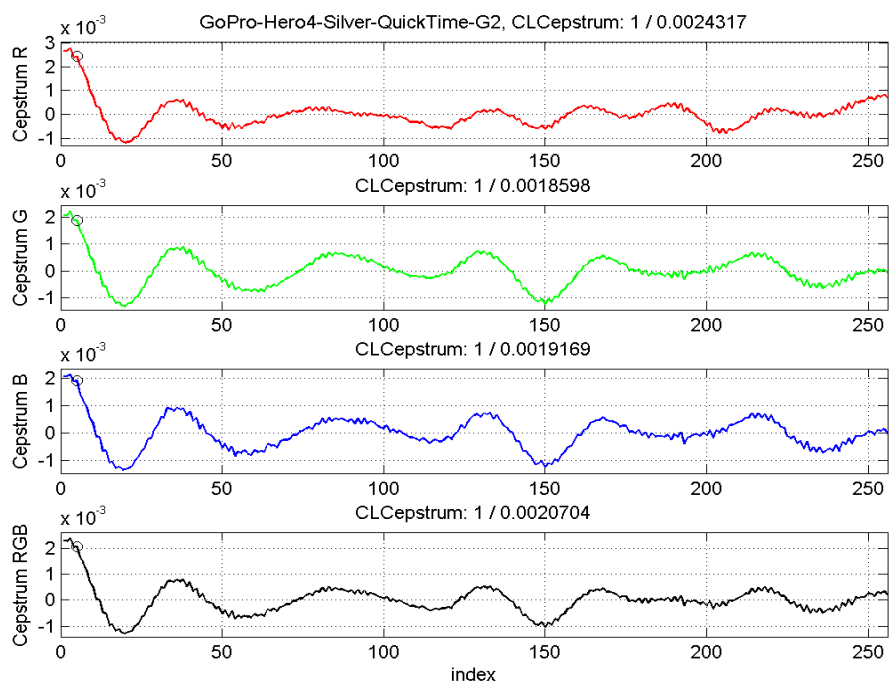


**Figure 36. Canon EOS 5D Mark II QuickTime Player CLA**

At this point, it is important to note the visual artifacts generated from QuickTime Player became more noticeable with each generation. This means generation 2 will show more of these traits when compared to generation 1.



**Figure 37. Samsung HZ50W QuickTime Player 7 Pro CLA**



**Figure 38. GoPro Hero4 Silver QuickTime Player 7 Pro CLA**

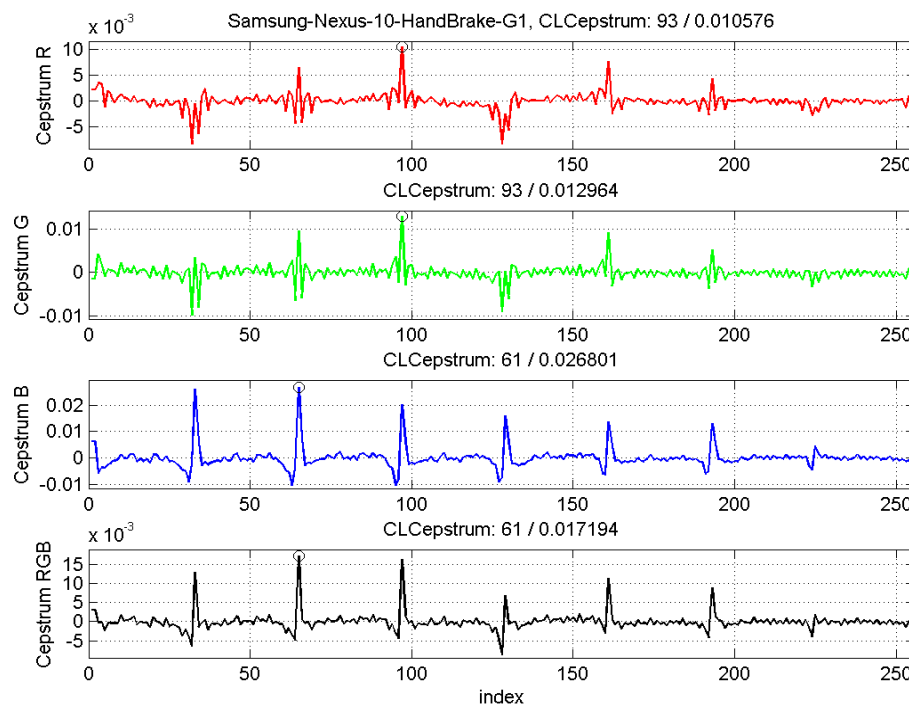
The QuickTime CLA for GoPro exhibited the most extreme example of these characteristics. Since it was so extreme, the CLA results from the other programs were



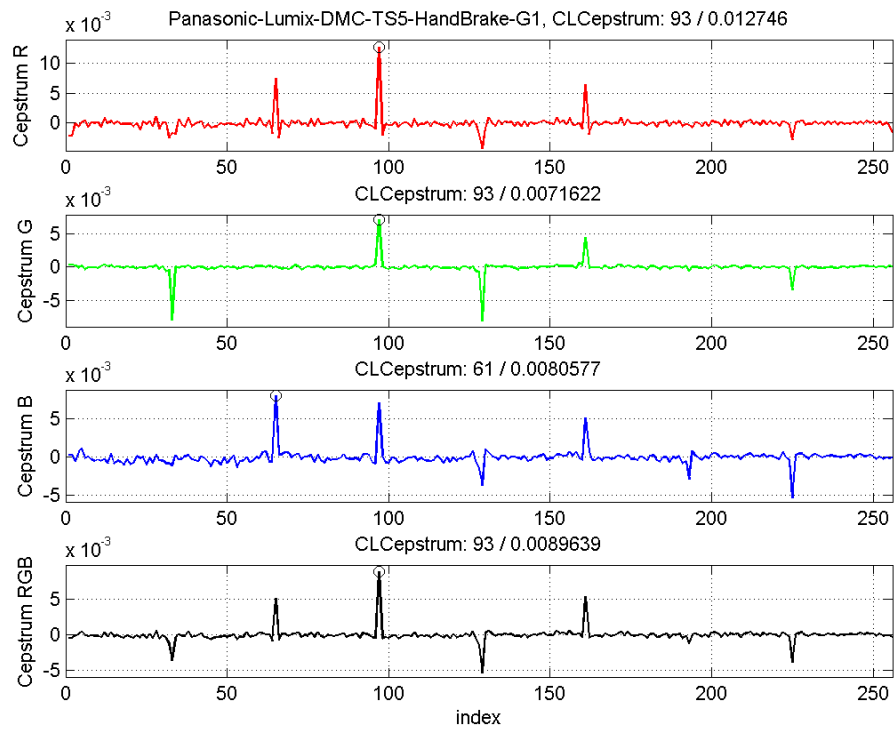
checked to see if the original compression could have caused this type of shape across the board. By analyzing the other CLA results, I was able to determine the original compression did not create this type of extreme shaping.

### 3.9 Visual Cues for HandBrake

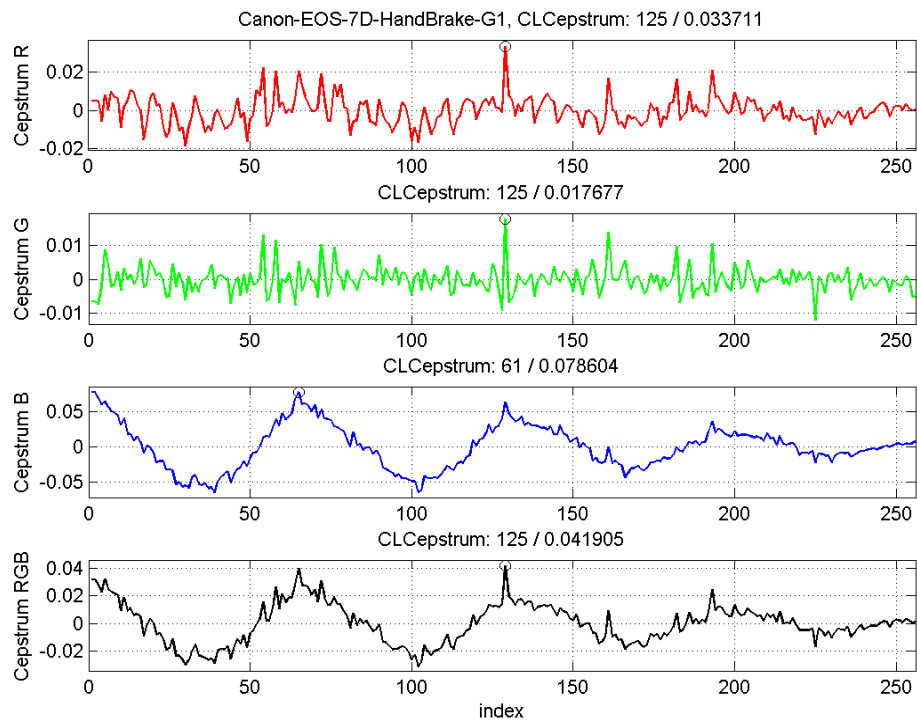
The visual cues for HandBrake were a little more difficult to decipher. I finally determined this was a result of the program's effect on two of the three color levels and not three as in the previous programs. After analyzing the CLA plots from the videos, there was a pattern that started to emerge. HandBrake generated more drastic changes in the blue and more dominate green color layers. In order to really notice these changes, an examiner needs look at the scale of the plots, as well as the shape of the plot. In most cases, the scale and shape for the red color layer stayed almost identical to the original video, while the green and blue layers had extreme changes.



**Figure 39. Samsung Nexus 10 HandBrake CLA**



**Figure 40. Panasonic Lumix DMC-TS5 HandBrake CLA**



**Figure 41. Canon EOS 7D HandBrake CLA**

### **3.10 Visual Cues for YouTube and Adobe Premiere**

While the visual cues for the other programs began to stand out after looking at the data, I had issues with the cues for YouTube and Premiere. When comparing the CLA from the original image and the results from these programs, there are noteworthy differences. However, there is nothing consistent about the shape, reduction, or gain of the peak values for each color level.

Like the other programs, I would imagine with further research and analysis, traces and patterns would start to emerge, which could be used as identifiers for the use of YouTube or Adobe Premiere.

## **CHAPTER IV**

### **CONCLUSION**

Overall, there are many positive and interesting conclusions that can be derived as a result of this research. The results reiterate the understanding that Compression Level Analysis is a positive method for identifying video compression. When comparing the CLA results from the original video to the results from all of the recompressed videos, the visual differences between the CLA plots are easily identifiable. When comparing the first three generations from any of the programs used, there are clear indications showing the recompressions of the video. However, the results from generation 4 and generation 5 start to yield inaccurate results due to the high levels of compression.

It was interesting to discover how much the resolution of the original video affects the CLA results. For the most part, any analysis at a resolution of 320x240 would be undesirable to draw a conclusion. Next, the ability to tie specific visual cues to most of the programs creates an advantage for the examiner. This will save time during the analysis phase and help produce detailed information. It was unfortunate conclusions could not be drawn for YouTube and Adobe Premiere, but with further research and analysis, perhaps a conclusion will be determined.

While Compression Level Analysis may still not be useful as a sole method for forensic video authentication, it's results when combined with other authentication methods can help the examiner draw a scientifically valid conclusion. Finally, the original test videos will help add to the database of videos and images that can be used as references during forensic examinations.

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