



TROUBLESHOOTING HDMI WITH 840HXL

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Overview

The 840Hxl is a new Pattern Generator by Kramer Electronics. The 840Hxl replaces the 840H in the Kramer Line. The 840H was a simple pattern generator that allowed you to choose a pre-defined resolution, and then sent a number of different HDMI test patterns. The new 840Hxl can be used not only as a pattern generator, but as a true HDMI troubleshooting device.

Via the front panel or through PC software, the 840Hxl gives the user the ability to control the pattern being outputted, the resolution of the HDMI signal (whether HDCP is on or off), the color depth, and the color space of the video output. The 840Hxl provides full audio support allowing the user to change the sampling frequency and bit depth.

Combine all these features together into a single generator and you have a powerful product that can be used to determine where the problems are in HDMI environments. Read below for a description of each of these features and how they could help.

Resolutions

Like most signal generators, the 840Hxl has a predefined list of selectable output resolutions. These resolutions include:

- | | | |
|-----------------|------------------|-------------------|
| » 640x480@60Hz | » 1360x768@60Hz | » 1280x1024@75Hz |
| » 720x480@60Hz | » 1440x900@60Hz | » 1920x1080@60Hz |
| » 800x600@60Hz | » 1400x1050@60Hz | » 1920x1200@60Hz |
| » 1024x768@60Hz | » 1280x1024@60Hz | » 720x480i@60Hz |
| » 1280x720@60Hz | » 1680x1050@60Hz | » 1920x1080i@60Hz |

This is great; however, with EDID becoming more and more popular, having a predefined bank of resolutions will not always work in every situation. For this reason we added 8 more resolution spaces. Seven of these spaces are user-defined and will allow you to create any resolution you like based on a set of detailed timing numbers. The last space is called "Output Native Resolution" which reads the detailed mode line of the Native Resolution of the display's EDID, and sets its output to exactly what the display is looking for. This feature makes our pattern generator much less like a generator and more like a computer graphics card with the ability to adapt to anything you plug into it.

In today's world of non-standard resolutions and every display manufacturer doing something a little different, having a generator that can adapt to the EDID of any display is imperative.

See Appendix 1 for more details on Resolutions and EDID.

HDCP

The 840HxL has another very powerful feature, the ability to turn HDCP On and Off.

We all know HDCP is the 4-letter word that we love to hate. It quietly adds that extra level of complexity to our HDMI signals which can sometimes be the difference between getting a picture or not. Testing for HDCP compliance can be hard because it usually requires switching sources. For example, when I want to test with an HDCP compliant source I will use the Blu-Ray player, and when I want to test a non-compliant source I will use my PC. Even though this method works well, problems arise when the Blu-Ray doesn't work. It is difficult to know if the problem is actually HDCP, Color Space, Color Depth, or something else.

Using the 840HxL to toggle HDCP on and off is very important, because with one button you can individually isolate the HDCP signal. By isolating the HDCP signal, you can identify the reason the source isn't working without changing anything else.

Color Depth

HDMI 1.3 introduced something called Deep Color which adds color depths of 30-bit, 36-bit, and 48-bit into the HDMI standard. These color depths are higher than the existing standard of 24-bit color. These higher color depths were added so HDMI sources could send more colors than the human eye can discern. This would eliminate any potential color banding artifacts that could be seen when there are not enough color shades to properly display certain images.

One thing to be careful of with Color Depth is how much it affects the total Bandwidth of your HDMI signal. If one product or cable in the signal path is not capable of this bandwidth, it will result in no picture on the screen. Here you can see the differences between different color depths at 1080p60Hz:

- » @24bit Color Depth: Data Rate = 1.540Gbps
- » @36bit Color Depth: Data Rate = 2.156Gbps
- » @48bit Color Depth: Data Rate = 2.772Gbps

With the 840HxL, you can toggle the HDMI output between 24-bit, 30-bit, and 36-bit color depths (48-bit color is currently not implemented in any standard HDMI equipment). Color Depth can also be set to Auto, which will set the color depth of the output according to the EDID it reads from the downstream device.

Sources that output Deep Color will be Blu-Ray players or Media Players for the most part.

See Appendix 2 for more details on Color Depth.

Color Space

HDMI is capable of supporting 2 main color spaces, RGB and YUV (aka. YCbCr). Different sources will output different color spaces depending on the type of source and also depending on the EDID of the downstream device.

RGB color space sends a full value of all three primary colors (Red, Green, and Blue) and is completely un-compressed. In YUV color space black and white information is being sent over the Y channel and the chrominance, or color, is being sent over the U and V channels.

The 840HxL has the ability of outputting these two different color spaces in 3 different forms:

- » **RGB** – The standard color space of HDMI and DVI. Common sources of this color space include PC's.
- » **YUV 4:4:4** – YUV (YCbCr) color space in which the Y, Cb, and Cr are all weighted equally, and is also un-compressed.
- » **YUV 4:2:2** – YUV (YCbCr) color space in which the Cb and Cr carry half the weight as the Y signal. 4:2:2 uses a mathematical compression technique in which weights of colors are calculated based on the color accuracy of the human eye to optimize picture while reducing overall bandwidth.
- » **Auto** – In this mode, the color space being outputted will be selected based on the EDID of the downstream device.

HDMI / DVI

One option on the 840HxL is switching between an HDMI and DVI signal mode. What you are basically doing is telling the generator whether you would like to output audio or not. Based on experience, I can tell you that when certain "DVI" monitors receive embedded audio, they do not know what to do with it and crash showing no picture at all and others will just ignore the audio and show the video. DVI is in quotations because the fact that a display has a DVI connector does not always mean it does not support audio. Some manufactures will use a DVI connector just for the locking mechanism while the EDID provides audio support.

The 840HxL has 3 settings for this feature:

- » **HDMI** – Which will output embedded audio with the set Audio Sampling Frequency and Audio Bit Depth Selected.
- » **DVI** – Which will output a digital video signal without embedded audio.
- » **Auto** – When in Auto Mode, the 840HxL will use the EDID of the downstream device to determine whether to send audio or not. It will only send out what the destination supports.

The 840HxL will output 2-channel PCM audio when audio is being embedded. Now let us take a look at the audio capabilities of the 840HxL.

Audio Sampling Frequency

PCM Audio

Pulse Code Modulation (PCM) Audio is a method of digitally representing an analog audio signal. It uses both a Sampling Frequency and Bit depth to convert a continuous analog voltage into a series of 1's and 0's.

Audio Sampling Frequency

The audio sampling frequency is defined as the number of measurements taken on the X-axis of an audio signal per unit of time (usually per second). During the conversion from analog audio, a higher sampling rate will result in a more comprehensive recording, especially in the higher frequencies of the original signal. The Nyquist theorem states that the minimum sampling frequency must be at least 2x as high as the maximum frequency of the audio being recorded. The human ear can hear frequencies up to 20kHz which is why CD's chose a sampling frequency of 44.1kHz, slightly higher than 2x the ability of the human ear.

The 840HxI allows you to output audio in 6 common sampling rates:

» 44kHz » 48kHz » 88kHz » 96kHz » 176kHz » 192kHz

There is also an Auto Mode which will set the Sampling Frequency base on the EDID of the downstream device.

See Appendix 3 for examples of Sampling Frequency.

Audio Bit Depth

Bit Depth for Audio is essentially the number of binary digits used to represent each audio sample on the Y-axis (very similar to Color Depth in video). The greater the bit depth of your Digital Audio, the more accurate your measurements will be resulting in higher dynamic range.

The 840HxI allows you to choose between 3 different Bit Depths for the audio output:

» 16bit » 20bit » 24bit

It also has an Auto mode which will select the Audio Bit Depth based on the EDID of the downstream device.

See Appendix 4 for examples on Audio Bit Depth.

PC Control Software

Using the free PC control software you can easily connect to the 840HxI via USB or RS-232, providing easy access to all the controls described above. See a screen shot of the software below.

Kramer 840HXL Controller

Device Reset About

Disconnect

Resolutions

Common

1	VGA	640x480 60Hz
2		720x480 60Hz
3	SVGA	800x600 60Hz
4	XGA	1024x768 60Hz
5		1280x720 60Hz
6		1360x768 60Hz
7		1440x900 60Hz
8	SXGA+	1400x1050 60Hz
9	SXGA	1280x1024 60Hz
10	WSXGA+	1680x1050 60Hz
11	SXGA	1280x1024 75Hz
12	HD 1080	1920x1080 60Hz
13	WUXGA	1920x1200 60Hz
14	UXGA	1600x1200 60Hz
15		720x480i 60Hz
16	HD 1080	1920x1080i 60Hz

User Defined

17	Label1	2048x1080 60
18	Label2	720x480 60
19	Label3	1280x720 60
20	Label4	1920x1080i 60
21	Label5	1440x480i 60
22	Label6	1440x240 60
23	Label7	2880x480i 60
24	Output Native Resolution	

Patterns

1	100% Color Bar	17	Square
2	75% Color Bar	18	White Dot
3	Gray Bar 8-step	19	Alternate Pixels
4	Red Screen	20	White HScroll
5	Green Screen	21	White VScroll
6	Blue Screen	22	Multiburst
7	Yellow Screen	23	Vertical Split
8	Cyan Screen	24	Horizontal Split
9	Magenta Screen	25	Red Ramp
10	Gray Bar 16-step	26	Green Ramp
11	White Screen	27	Blue Ramp
12	RGB Ramp	28	Bounce
13	Crosshatch Black	29	4 Line Border
14	Crosshatch Red	30	Window
15	Crosshatch Green	31	Target Circle
16	Crosshatch Blue	32	Moving Ball

Output Settings

Signal Mode (H/D)

HDMI DVI AUTO

HDCP

HDCP No HDCP

Color Space (CS)

RGB YUV 444 YUV 422 AUTO

Color Depth (DC)

24 Bit 30 Bit 36 Bit AUTO

Audio Sample (ASF)

44 KHZ 48 KHZ 88 KHZ 96 KHZ

176 KHZ 192 KHZ AUTO

Audio Bit (ASD)

16 Bit 20 Bit 24 Bit AUTO

Status Of Connected Display

HDCP: Not supported

Type: DVI

DeepColor: Not Supported

Load Status: HPD

Status Of Output

HDCP: No HDCP

Signal Type: Auto

Audio Freq: 48K/s

Audio Bit: 24 bit

Color Depth: 24 bit

ColorSpace: RGB444

Summary

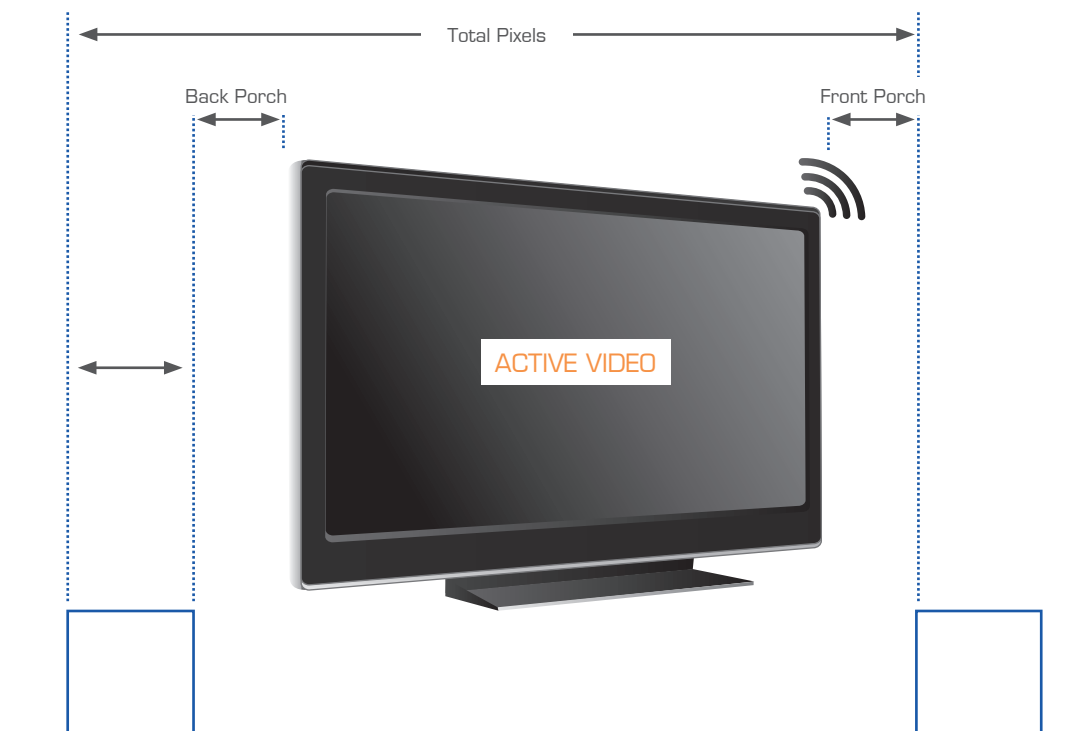
As described here the 840HxI is much more than a simple pattern generator, it is a tool that when used properly can assist to narrow down issues in HDMI systems. By having one source that can toggle all of these options, it is simple to single out individual issues in an HDMI system. What really makes this box unique is its ability to react to the EDID of the device it is connected to. This will allow the generator to behave less like the generators we are used to, and more like a real world source.

Appendices

Appendix 1 - Resolutions

If you're like me, when you mention a computer resolution it is simply described using its viewable or active pixels such as 1920x1080. However, as you could have guessed, there is more going on in a computer signal other than the number of active pixels being sent (See Figure 1). In the past, the active pixels alone were enough to describe a resolution, because you were referring to an existing standard that was followed by the industry. Resolutions like 1024x768 and 1600x1200 are in this category. Every monitor that supported 1024x768(XGA) supported the exact same previously defined standard version of XGA. Also, every computer, when you choose 1024x768 as your output resolution, outputted the same standardized version of XGA. This made all devices instinctively compatible with each other. Today, with the rapid acceleration toward High Definition and widescreen display devices, standardization has been pushed aside and reliance toward communication between the display and source has become necessary.

Figure 1: Make-Up of a Computer Resolution (Horizontal Only)



Looking above at Figure 1 you will see that a resolution is certainly more complicated than only active pixels. Every resolution has these set of parameters, all of which are needed to achieve a perfect image. Through EDID, a display is able to show the source all of these numbers in the detailed timing section. It can be displayed by what we call a mode line. This is an example of a mode line for 1024x768:

Detailed timing #1..... 1024x768p at 60Hz (4:3)

Mode line..... "1024x768" 65.000 1024 1048 1184 1344 768 771 777 806 -hsync -vsync

Beginning with 65.000 which is the Pixel Clock for this resolution, we then have four numbers that describe horizontal timing, four numbers that describe vertical timing, and finally the polarity of the sync pulses themselves. Remember, if displaying XGA is your goal then this mode line communication through EDID is overkill because every display and computer supports this XGA mode line.

Knowing that the standardization problem exists mostly in widescreen resolutions, let's look at an example revolving around 1920x1080. These mode lines were read from the EDID's of the VGA inputs of different 1080p monitors.

» **LG LCD**

Detailed timing #1..... 1920x1080p at 60Hz (16:9)

Modeline..... "1920x1080" 148.500 1920 2008 2052 2200 1080 1084 1089 1125 +hsync +vsync

» **Westinghouse LCD**

Native/preferred timing.. 1920x1080p at 60Hz (16:9)

Modeline..... "1920x1080" 138.500 1920 1968 2000 2080 1080 1082 1087 1111 +hsync -vsync

» **Samsung LCD**

Native/preferred timing.. 1920x1080p at 60Hz (16:9)

Modeline..... "1920x1080" 138.500 1920 1968 2000 2080 1080 1083 1088 1111 +hsync -vsync

» **Panasonic Plasma**

Detailed timing #1..... 1920x1080p at 60Hz

Modeline..... "1920x1080" 148.500 1920 2008 2052 2200 1080 1084 1089 1125 -hsync -vsync

» **Vizio LCD**

Native/preferred timing.. 1920x1080p at 60Hz

Modeline..... "1920x1080" 136.500 1920 1952 1984 2048 1080 1081 1084 1111 +hsync +vsync

You can clearly see that while all these monitors claim to be 1920x1080 monitors, they all support a different version of 1920x1080. Now it is clear that describing active pixels alone is not specific enough to define a resolution. Display manufacturers are able to get away with this because each of their specific timings is completely described in the EDID of that monitor. When a computer is connected directly to any of these monitors, the mode line is read by the PC and the PC modifies its output to comply with that display.

Appendix 2 - Color Depth

What is Color Depth?

Every HDMI signal has a color depth associated with it. Color depth basically defines how many different colors can be represented by that HDMI signal. A normal HDMI signal has a color depth of 8 bits per color. This may also be referred to as 24-bit color (8-bits per color x 3 colors RGB). The number of bits refers to the amount of binary digits used to determine the maximum number of colors that can be rendered. For example, the maximum number of colors for 24-bit color would be:

111111111111111111111111(binary) = 2^{24} = 16777216 = 16.7 million different colors.

Color depth is very important in HDMI signals because the more colors you send, the higher the bandwidth of your HDMI signal.

Deep Color

HDMI 1.3 introduced something called Deep Color which adds color depths of 30-bit, 36-bit, and 48-bit into the HDMI standard. These higher color depths were added so HDMI sources could send more colors than the human eye can discern. This would eliminate any potential color banding artifacts that could be seen when there are not enough colors to properly display certain images.

Maximum Colors:

- » 30-bit: 1.073 Billion Colors
- » 36-bit: 68.71 Billion Colors
- » 48-bit: 281.5 Trillion Colors

Calculating HDMI Bandwidth

Since all HDMI products are hardware limited to a maximum bandwidth, it is important to know how to calculate the bandwidth of source signals to make sure all downstream devices are compatible. There are many factors that determine bandwidth like Resolution, Refresh Rate, and Color Depth. The first thing to determine is the pixel clock of the desired resolution. Pixel Clock is the number of pixels being sent every second by the source.

Pixel Clock = Total_Horizontal_Pixels * Total_Vertical_Pixels * Refresh_Rate

Common Pixel Clocks

- » 1080p@60Hz: approximately 154MHz
- » 1080p@24Hz: approximately 74.275MHz
- » 1080i@60Hz: approximately 74.275MHz
- » 720p@60Hz: approximately 74.275MHz

Once the Pixel Clock is determined, the bandwidth can be calculated with the following formula:

Bandwidth = Pixel_Clock * (bit_depth_per_color + 2)

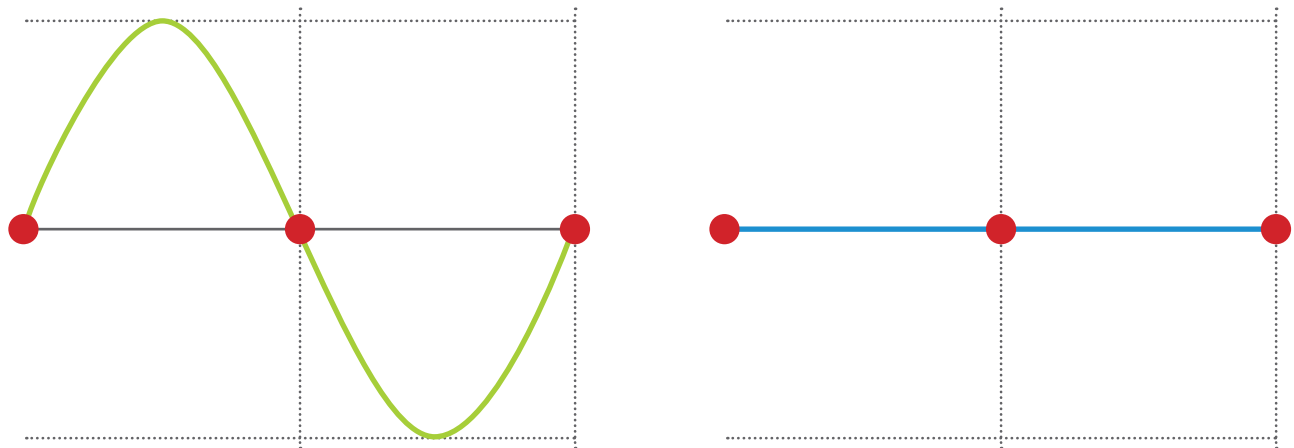
Common Bandwidth Calculations

- » 720p/1080i@60Hz Pixel Clock = 74.275MHz
 - @36bit Color Depth: Data Rate = $74.275 * (12 + 2) = 1.039\text{Gbps}$
 - @48bit Color Depth: Data Rate = $74.275 * (16 + 2) = 1.336\text{Gbps}$
- » 1080p@24 Pixel Clock = 74.275MHz
 - @24bit Color Depth: Data Rate = $74.275 * (8 + 2) = 742.75\text{Mbps}$
 - @36bit Color Depth: Data Rate = $74.275 * (12 + 2) = 1.039\text{Gbps}$
 - @48bit Color Depth: Data Rate = $74.275 * (16 + 2) = 1.336\text{Gbps}$
- » 1080p@60Hz Pixel Clock = 154MHz
 - @24bit Color Depth: Data Rate = $154 * (8 + 2) = 1.540\text{Gbps}$
 - @36bit Color Depth: Data Rate = $154 * (12 + 2) = 2.156\text{Gbps}$
 - @48bit Color Depth: Data Rate = $154 * (16 + 2) = 2.772\text{Gbps}$

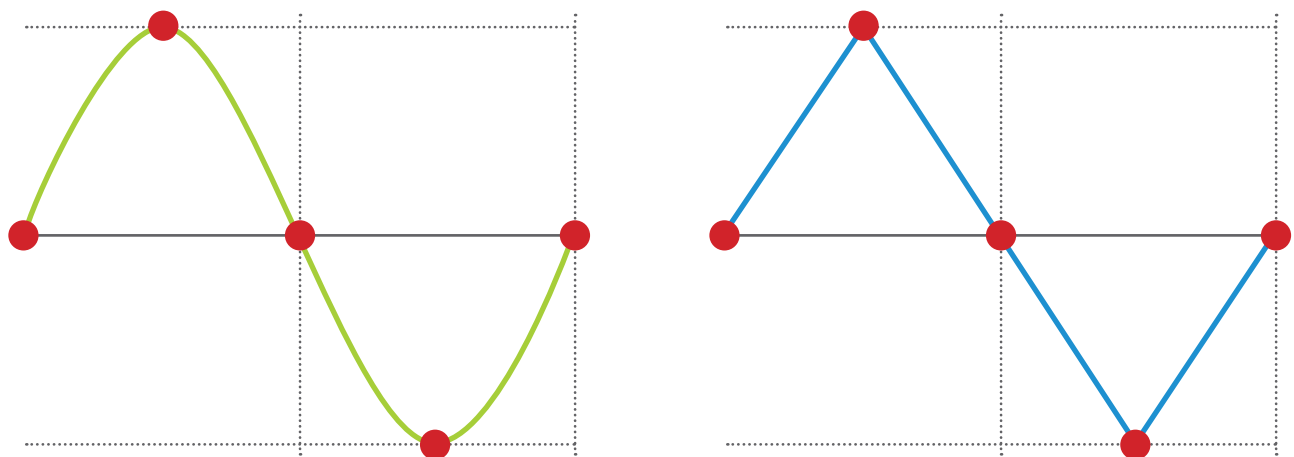
Appendix 3 - Audio Sampling Frequency

The frequency of the original analog audio is 2 units in all examples. Also, in the digital representations, sufficient bit depth is assumed.

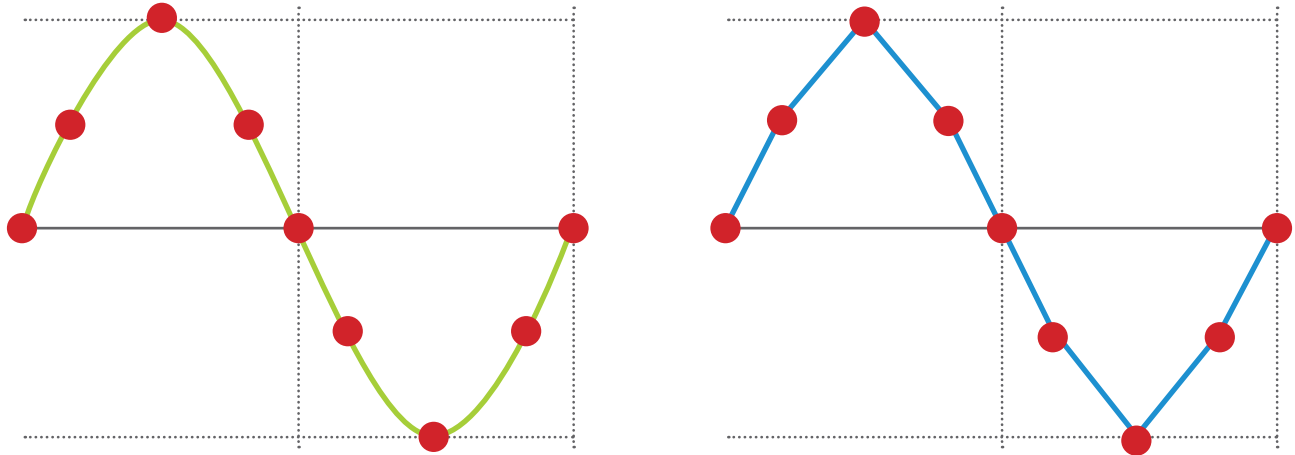
In the example below, on the left, the analog audio signal will be sampled at a rate of 2, which is below the Nyquist Rate. The image on the right is a representation of your digital signal based on this sampling rate. In this case, because I am below the Nyquist Rate, much of in the audio information is lost (in this case ALL).



In the example below, on the left, the analog audio signal will be sampled at a rate of 4, which is at the Nyquist Rate. The image on the right is a representation of your digital signal based on this sampling rate. In this case, because I am at the Nyquist Rate, the basic shape of the original sine wave is still intact. It may not be as smooth as the analog wave but all the highs and lows are accounted for.



In the last example below, on the left, the analog audio signal will be sampled at a rate of 8, which is twice the Nyquist Rate. The image on the right is a representation of your digital signal based on this sampling rate. You can see that the more samples I take, the more my digital signal start to become like the analog signal. These crude examples could be applied in theory to all audio signals.



Sampling Rates are not the only thing creating your digital waveform. Ultimately, sampling rates are only telling you where to measure on the X-axis. Read on to Bit Depth to determine how to measure the Y-Axis.

Appendix 4 - Audio Bit Depth

Now that we know how to sample an analog signal, we need to learn how to create it. Audio Bit Depth is the last piece of that puzzle. Bit Depth is the value of the analog audio at each sample. The greater the bit depth, the more binary digits you have to make the reading more accurate.

- » 1-bit – 2 Potential Values. 0 or 1
- » 2-bit – 4 Potential Values. 00, 01, 10, or 11
- » 4-bit – 16 Potential Values. 0000-1111
- » 24-bit – 17million Potential Values. 000000000000000000000000-111111111111111111111111

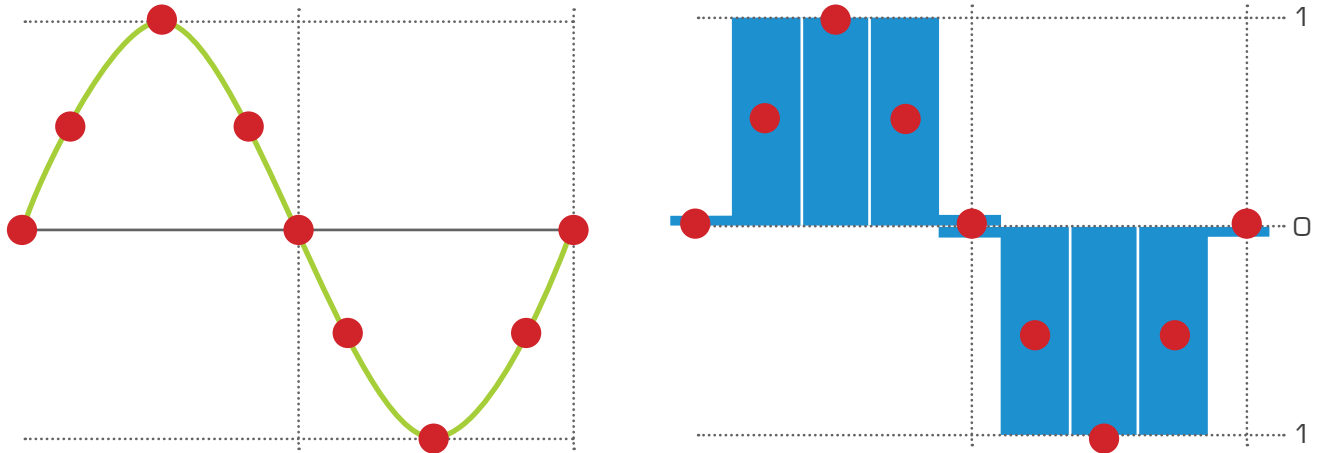
Looking at the examples you will see how bit depth alone can play a large part in creating the digital signal. To isolate bit depth, in the examples, the frequency of the original analog signal and the Digital Sampling Rate will be constants.

- » Analog Audio Frequency = 2 units
- » Digital Sampling Rate = 8

Example 1

Bit Depth = 1

Potential Values of Each Sample = 0 or 1

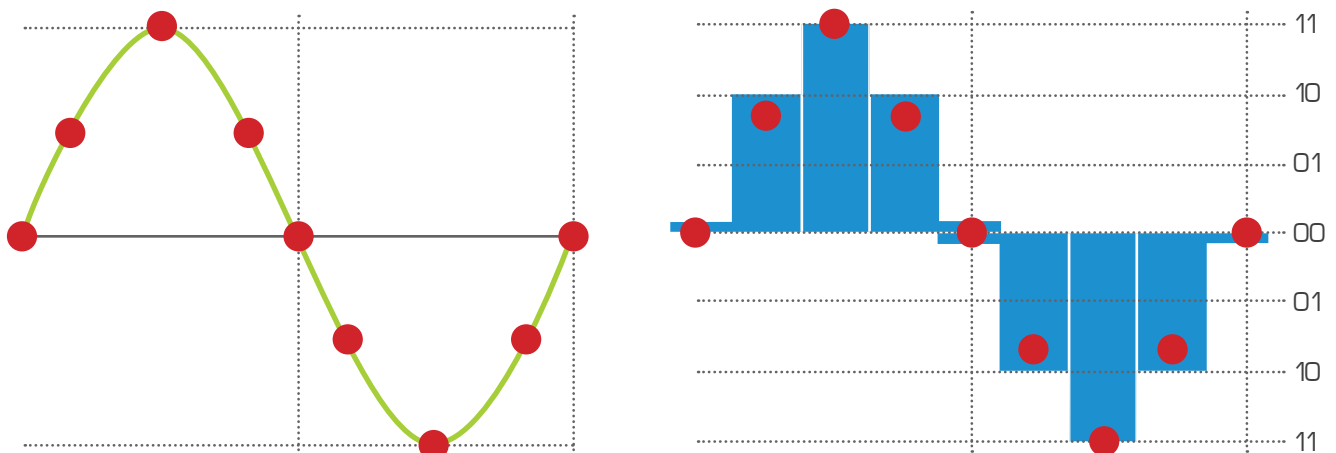


On the left diagram below, you can see the original analog signal along with where the sampling points are. The right hand diagram shows the resulting digital representation of that signal with a Bit Depth of 1 bit. Since the bit depth is so low, each sampling point must be either a 0 or a 1. For samples 2, 4, 6, and 8 you can see that we are forced to round up to 1 resulting in a digital signal that looks nothing like the original analog one.

Example 2

Bit Depth = 2

Potential Values of Each Sample = 00, 01, 10, 11



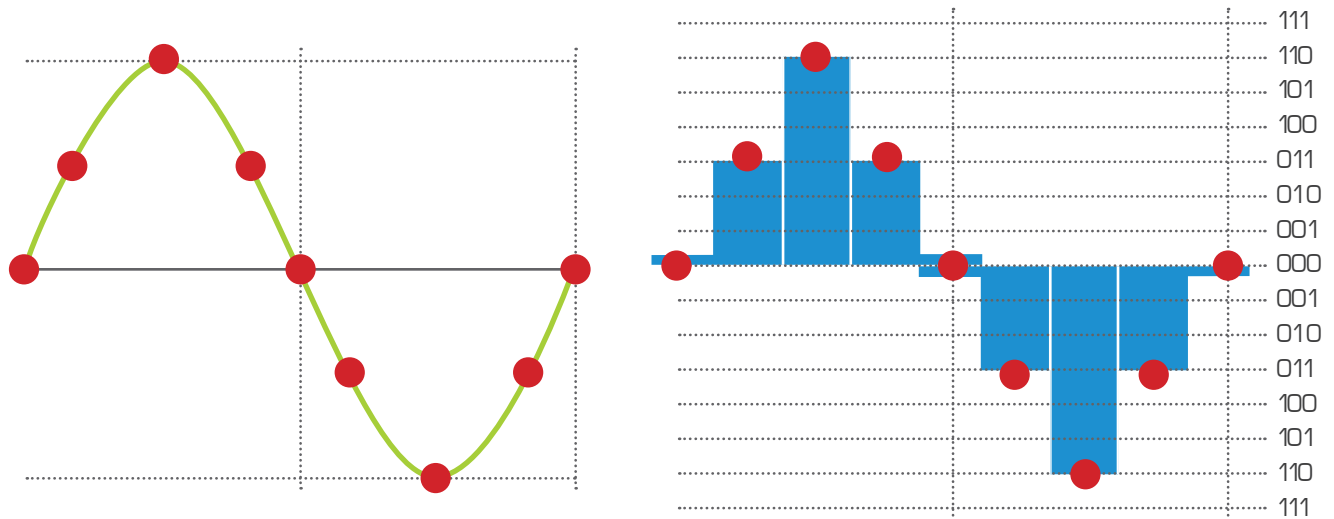
On the left diagram below, you can see the original analog signal along with where the sampling points are. The right hand diagram shows the resulting digital representation of that signal with a Bit Depth of 2 bits.

Now that we have more values to choose from, we don't have to round up quite as much for samples 2, 4, 6, and 8. This results in a digital signal that is starting to look more and more like its analog cousin.

Example 3

Bit Depth = 3

Potential Values of Each Sample = 000, 001, 010, 011, 100, 101, 110, 111



On the left diagram below, you can see the original analog signal along with where the sampling points are. The right hand diagram shows the resulting digital representation of that signal with a Bit Depth of 3 bits. Again you can see that now with even more selections we are able to become more accurate in our sample measurements. It seems the sampling rate is now, for the moment, the limiting factor to making this digital signal better.



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