

ARDMS Topic:  
Ultrasound Instrumentation

# Unit 14: Ultrasound System

Sononerds Ultrasound Physics  
Workbook & Lectures

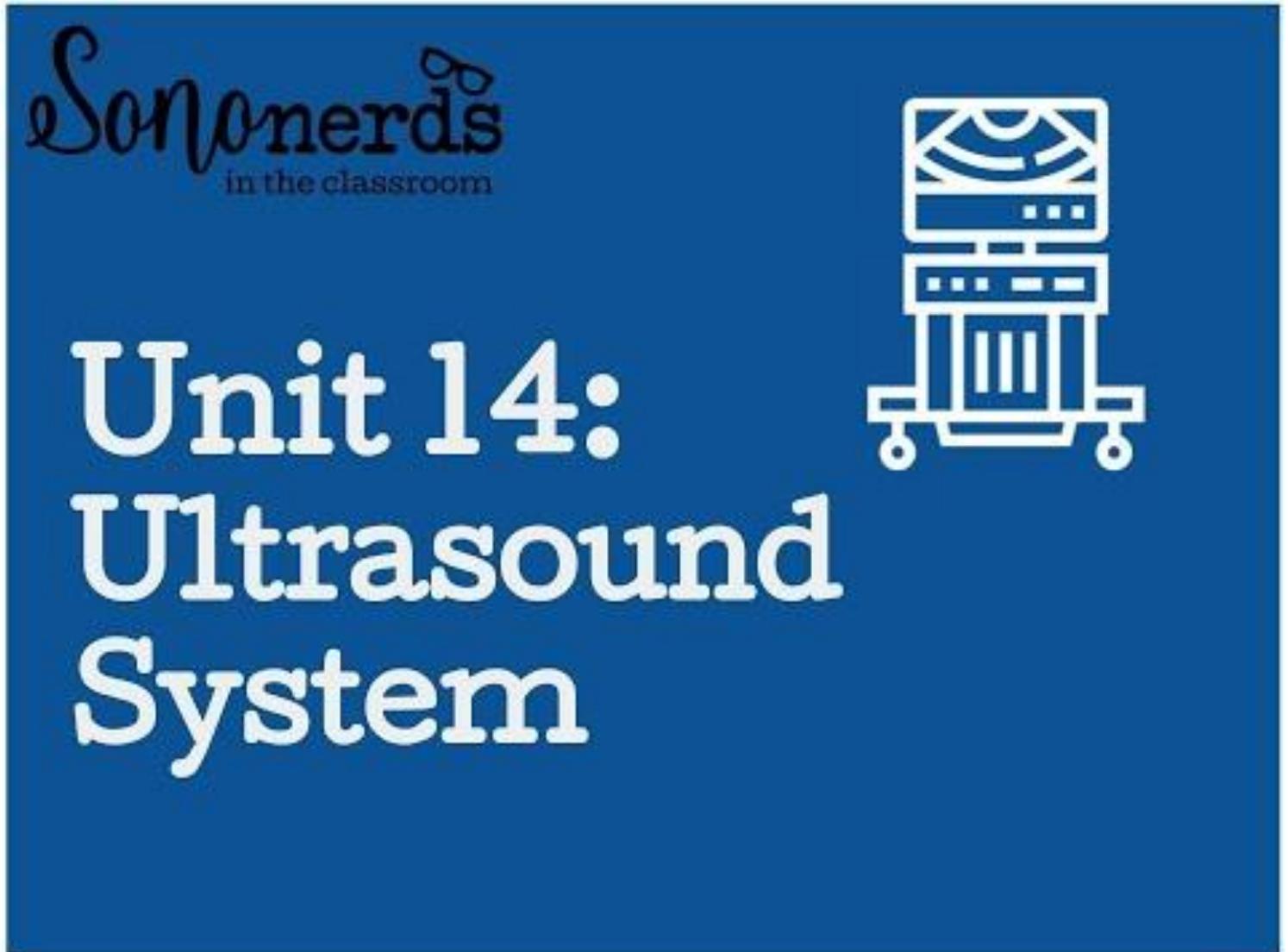
# Unit 14: Ultrasound System

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# Unit 14: Ultrasound System

[Entire Unit 14 Lecture:](#)



Did you know you can time jump to each section by using the “chapters” in the YouTube video playbar OR timestamps in the video description?

# Unit 14: Ultrasound System

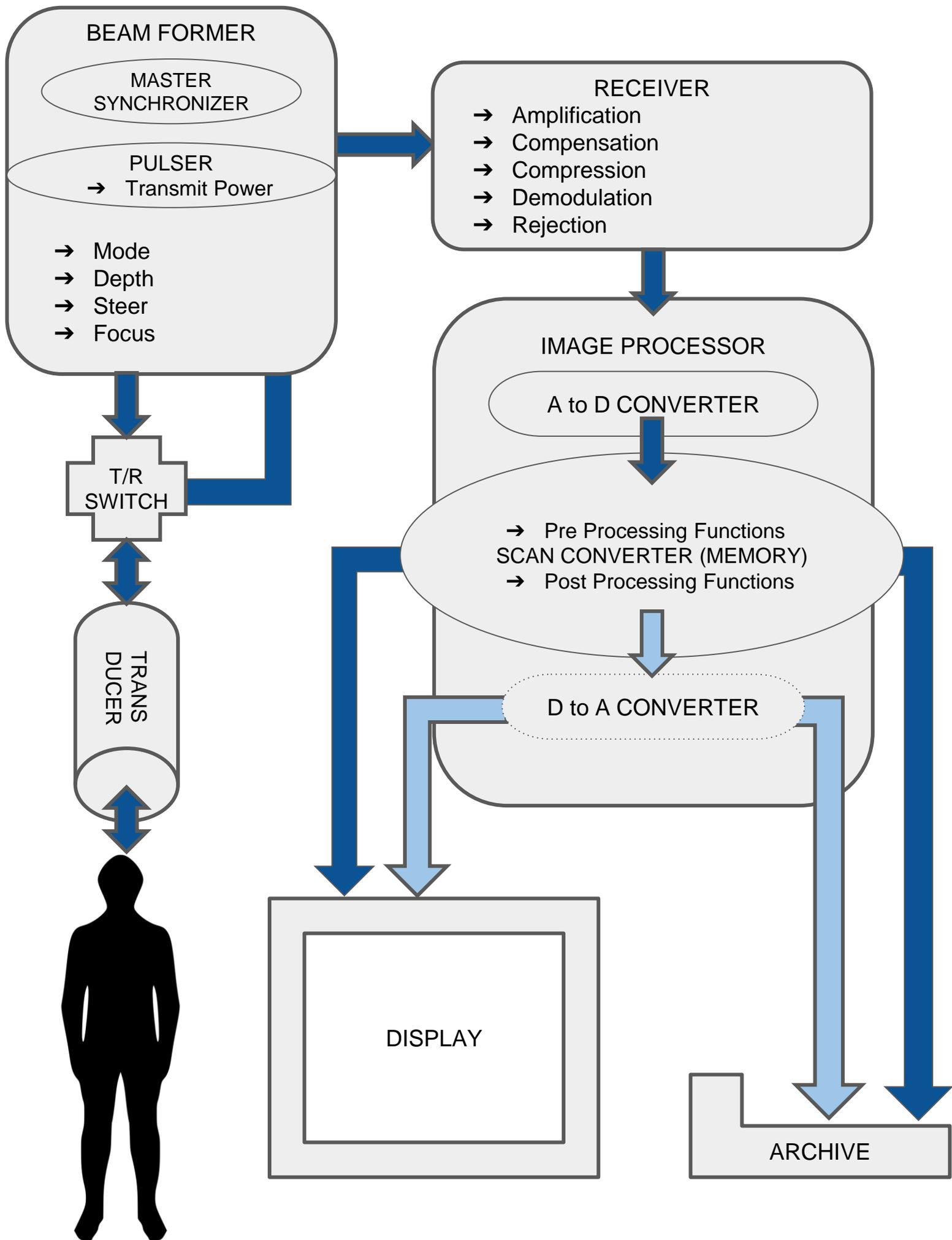
The ultrasound system is the computer, transducer and display of the unit. The ultrasound system performs very complex activities. As a sonographer, you should know, in general, how the machine creates the images.

This unit will follow all the way through the system from beam formation to display on how the image is created and also discuss some details related to each step.

Focus on the the parts of the system, what they are responsible for, and how a sonographer can interact with them.

The next page will show you a “map” of the ultrasound system and all the components we will discuss in this unit.

Some of these topics will be discussed further in their own units. Discussion surrounding modern technologies and more resolution will also be discussed in a subsequent unit as well.



# Section 14.1 Beam Former

The beam former is the main force behind creating an ultrasound beam. When using a continuous wave transducer or a single element transducer. Only the master synchronizer/pulser are needed. When using an array, there are multiple components /jobs of the beam former:

- **Master Synchronizer**
- **Pulser**
- **Pulse Creation**

## 14.1.1 Master Synchronizer

A big reason that ultrasound is capable of creating images is because of the pulsed ultrasound and the “off time.” If the machine did not wait for echoes to return from each pulse, the machine would not be able to differentiate where and when echoes are coming from.

The master synchronizer is responsible for the waiting. It takes into account the depth and modes being used and times when a pulse can be created.

Remember the depth is directly related to the PRP and inversely related to the PRF. As the sonographer changes the depth, the master synchronizer works with the pulser to make sure pulses are sent appropriately.

- **The master synchronizer makes sure that pulses do not overlap.**

## 14.1.2 Pulser

- **The pulser creates the voltage delivered to the transducer, thus controlling the amount of power the patient is exposed to.**

The pulser is responsible for creating the voltage that will be dispersed to the transducer crystals during **transmission**.

More voltage, means more power, which may increase the patient’s risk of bioeffects. However, more power usually means an improved image. Let’s take a closer look at these concepts.

## Output Power

When a system puts out a voltage, the stronger the voltage, the stronger the ultrasound power. When you start with stronger power, the echoes that return are also stronger.

**Low voltage = weak ultrasound power = weak echoes = dark image**

**High voltage = strong ultrasound power = strong echoes = bright image**



The power emitted by the ultrasound Transducer is monitored by the machine by the Mechanical and Thermal Indices. (This will be discussed more when we talk about bioeffects). But, as we increase power, we increase the risk of causing bioeffect. Either little bubbles destroying cells or heating up tissue.

→ **The output power is adjustable by the sonographer.**

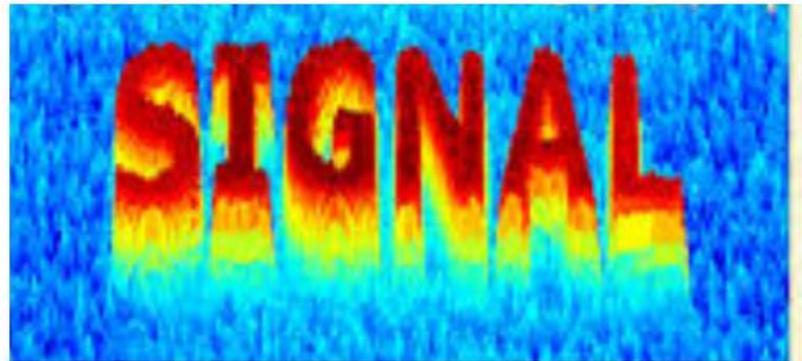
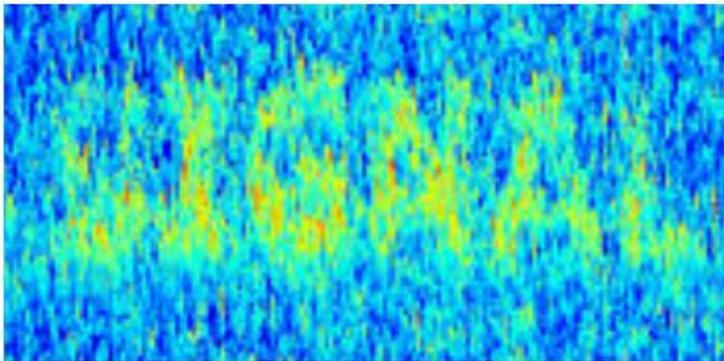
The output power can be adjusted from 0 volts to 100 volts on most systems. When the power is increased, **all echoes** returning from the body are stronger. When the power is decreased, **all echoes** returning from the body are weaker. As a sonographer you want to balance having an optimized image with reducing the patient's exposure to excessive ultrasound energy.

Increasing the power cannot make an image uniformly bright, however it does improve the **signal to noise ratio**.

- **Noise is unwanted echoes that can obscure the signal (anatomical echoes) in an image.**
- **The signal to noise ratio is the amount of noise compared to the meaningful echoes.**

Noise will be in the images regardless of the power put out by the machine and transducer. When the voltage is low and the transducer sends out weak waves, the noise might overpower the weak signals.

When the power is increased, the signals coming back are stronger and therefore improve signal to noise ratio as the signal is stronger than the persistent background noise.



### **Increased output power:**

- **Increases strength of ultrasound wave**
- **Increases brightness of image**
- **Improves SNR**
- **Improves penetration depth (less attenuation occurs)**
- **Increases risk of bioeffects**

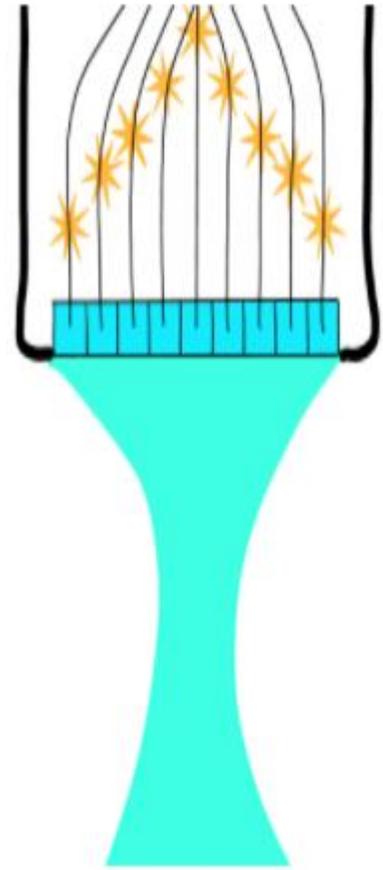
## 14.1.3 Pulse Creation

The other function of the beam former is to distribute the voltages to the elements. This varies depending on the mode or modes the ultrasound machine is using and what type of transducer is attached.

→ **The beam former is responsible for phasing the voltages for electronic focusing and electronic steering.**

Modern ultrasound systems use digital beam formers to calculate the phasing patterns to achieve the desired focal depth, beam steer and apodization as well as producing the pulse patterns to create B-mode images or adding in Doppler. All of this happens during **transmission**.

The beam former is also integral during **reception**. During reception, the beam former adjusts for dynamic receive focusing and dynamic aperture.



## Section 14.2 T/R Switch

The "T" stands for transmit and the "R" stands for receive. The T/R Switch is responsible for diverting voltages in the correct direction. When in transmit mode, the strong voltages need to be sent to the transducer. If they were to be diverted to the very sensitive receiver, the system may break.

When on T, the voltages are directed to the transducer and when on R, the returning voltages are directed to the receiver.

## Section 14.3 Transducer

We have already spent many units on the transducer, but to place in the pathway, it receives voltages from the beam former and then returns voltages to the beam former and then to the receiver.

The voltages coming back from the transducer are a result of echoed sound waves interacting with the PZT crystals. The echoes that return are VERY weak, and the voltages are proportional.

## Section 14.4 Receiver

The receiver, as the name suggests is going to get the echo voltages. The receiver is also known as the **signal processor**. When echoes return from the transducer they go through a variety of manipulations to not only be able to work with the returning voltages, but to represent sonographer settings and compensate for the physics of ultrasound. Once manipulated, they are ready to go to the machine's memory for display.

**There are 5 key steps that occur in the receiver.**

- **Amplification**
- **Compensation**
- **Compression**
- **Demodulation**
- **Rejection**

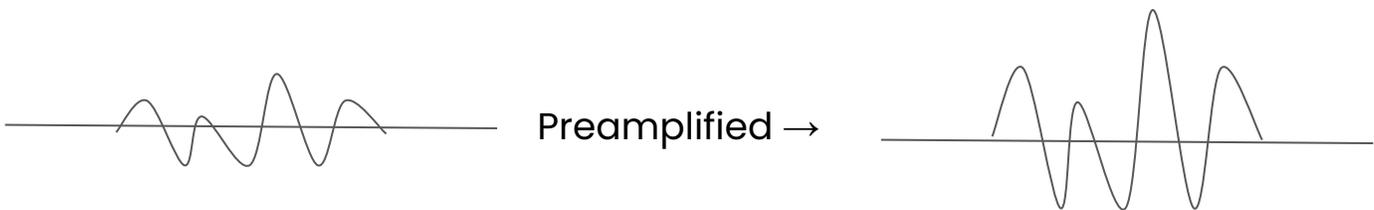
All 5 functions occur with each pulse that is sent back, preparing the scan line for display. The 5 steps need to occur in this order, so take note of the order the functions are listed. Also take note of which ones have are automatically applied by the machine, which ones can be adjusted by the sonographer and which undergo both.

## 14.4.1 Amplification

There are a couple types of amplification that occur when voltages return.

- **Preamplification**
- **Amplification**

When the echoes come back, some literature has it showing that they head directly into the receiver, but some have that they go into beam former for preamplification. Regardless of location (beam former or receiver) **preamplification must occur to make the weak voltages big enough for the machine to be able to manipulate.** This initial amplification is an automatic function of the machine and is not dictated by the sonographer.



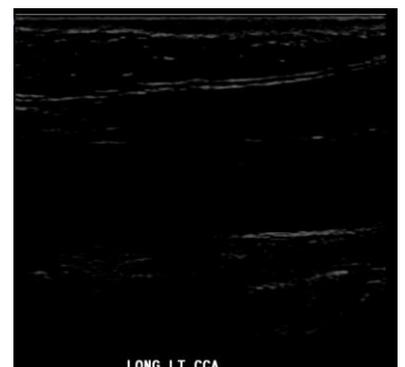
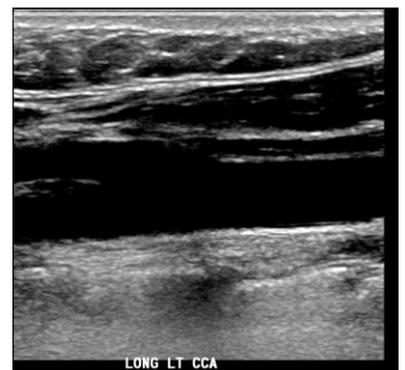
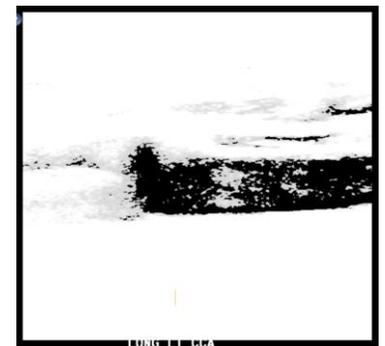
Amplification, also known as **2nd amplification** is adjustable by the sonographer. There is a knob on the machine that when turned will change the **gain** applied to the image.

- **Gain identically effects all echoes.**

If the sonographer increases the gain in the image, ALL of the echoes will be amplified or become brighter. And ALL means all, noise and signal. Unlike power, **gain does not improve the SNR.** BUT gain does not pose any risk to the patient for bioeffects because it only changes the data AFTER it's returned from the patient.

- **Amplification is measured in decibels (dB)**

Amplification typically indicates an increase in in decibels, which remember is a comparison value. It is comparing the initial value of the voltage when it came into the receiver to what it is leaving the receiver.



Both power and amplification (gain) are adjustable by the sonographer and both can make the whole image brighter. But....

Increasing power increases risks for bioeffects. Increasing gain has NO effect on bioeffects.

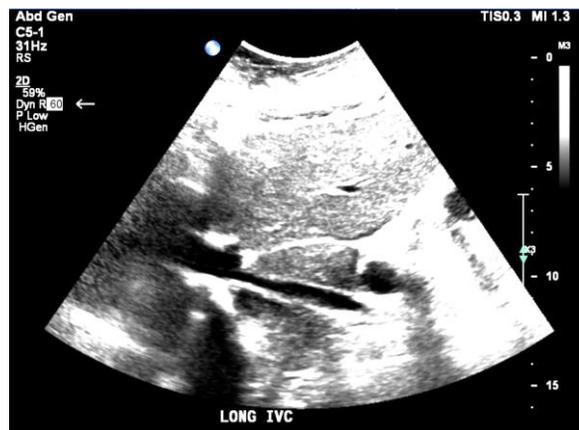
To follow the principle of **ALARA - As Low As Reasonably Achievable** is to understand that we should reduce power to as low as diagnostically correct and opt to adjust gain before power.

Most modern systems won't allow you to adjust power very easily and if you can find it, it won't allow you to adjust power to a dangerous level.

However, you should pay attention to the presets you select. A 1st trimester preset is going to use less power than an adult abdominal penetration preset.

In theory then

If your image is too bright, reduce output power first.



If your image is too dark, increase gain first.



If part of your image is too bright or too dark in one area, use compensation (next section).



## 14.4.2 Compensation

The second function of the receiver is compensation.

→ **Compensation can make an image uniformly bright.**

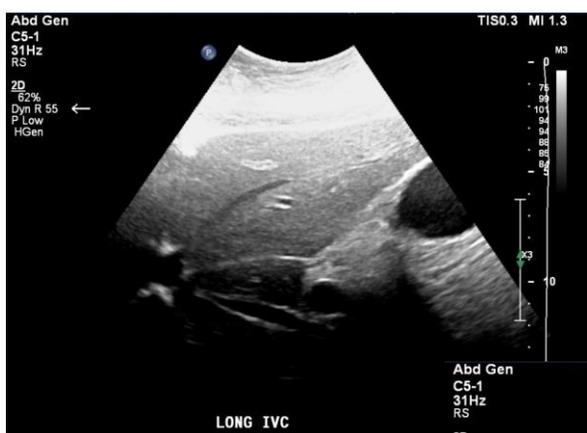
As the sound travels through the body it attenuates. Compensation allows the machine and sonographer to account for the attenuation. Compensation (like amplification) occurs in two steps:

- 1st compensation
- 2nd compensation

First compensation is automatically performed by the machine. The machine (and us now too!!) know that as sound travels, it attenuates. Attenuated signals are usually weaker and therefore appear darker on our image. So the machine does a 1st compensation to increase the brightness of the echoes in the far field. The effect is minimal and the sonographer doesn't control this one.

→ **Second compensation is adjustable by the sonographer.**

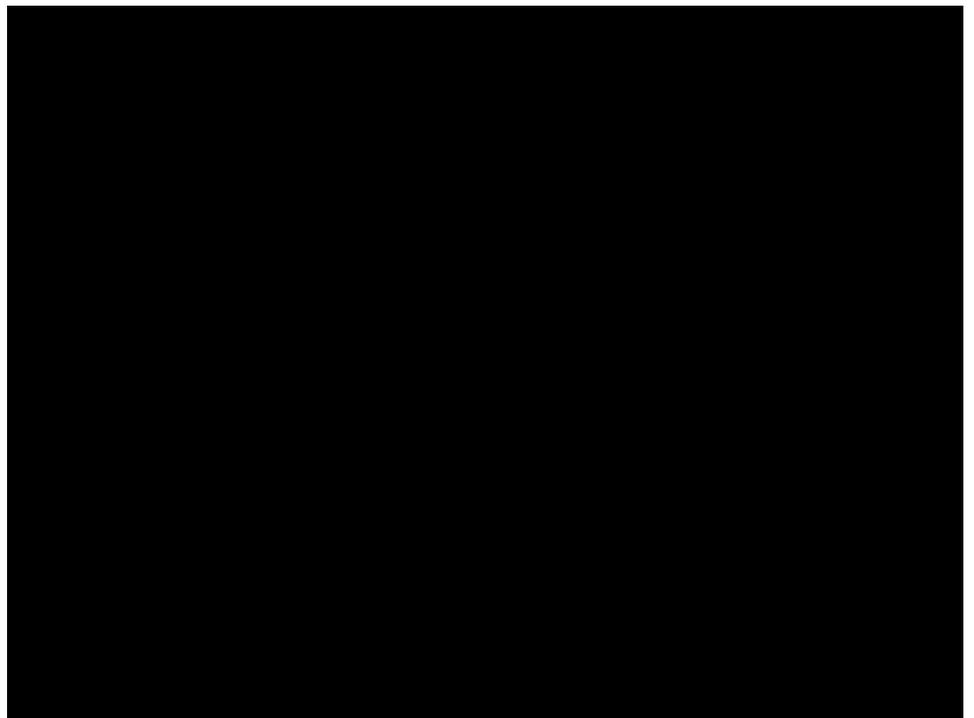
This is where some of the art of ultrasound comes in. An uncompensated image will not be uniformly bright from top to bottom. As a sonographer, you should use your knowledge of attenuation to either decrease the brightness of the echoes in the near field or increase the brightness of the echoes in the far field to make it even throughout.



→ **The sonographer uses the Time Gain Compensation sliders to adjust the image brightness.**

The Time Gain Compensation sliders or TGCs are a set of sliders on the machine. Each slider is responsible for a horizontal section of the image. Sliding the toggle to the right increases the gain and sliding to the left decreases the gain.

Some systems have physical sliders on the console and some newer systems and handheld systems are transitioning to touch screen sliders.



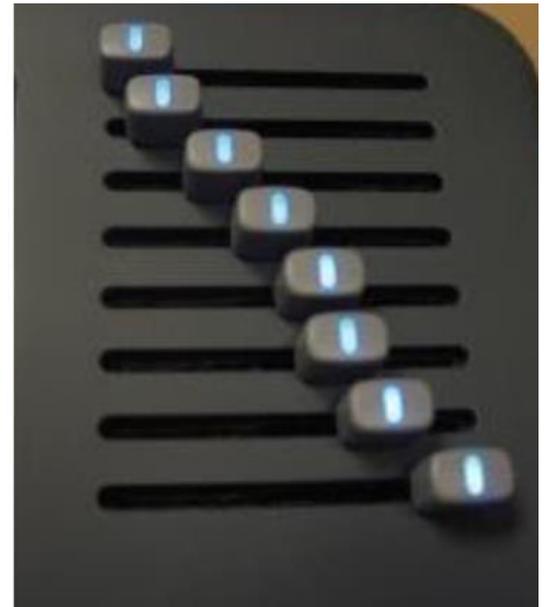
Regardless of the TGC format, the goal is to use them in a gentle curve or slope to compensate for the attenuation. **Avoid zig-zagging or moving one slider over.** This will create “stripes” in the image and does not improve the quality of the picture.

The compensation that occurs in newer machines is pretty phenomenal. The images, in general are just better than previously, with better penetration of sound and less obvious effects of attenuation. However, in older machines, almost all images needed to be compensated for with the TGCs. The very standard TGC configuration looked similar to this:

Little to no compensation in the near field

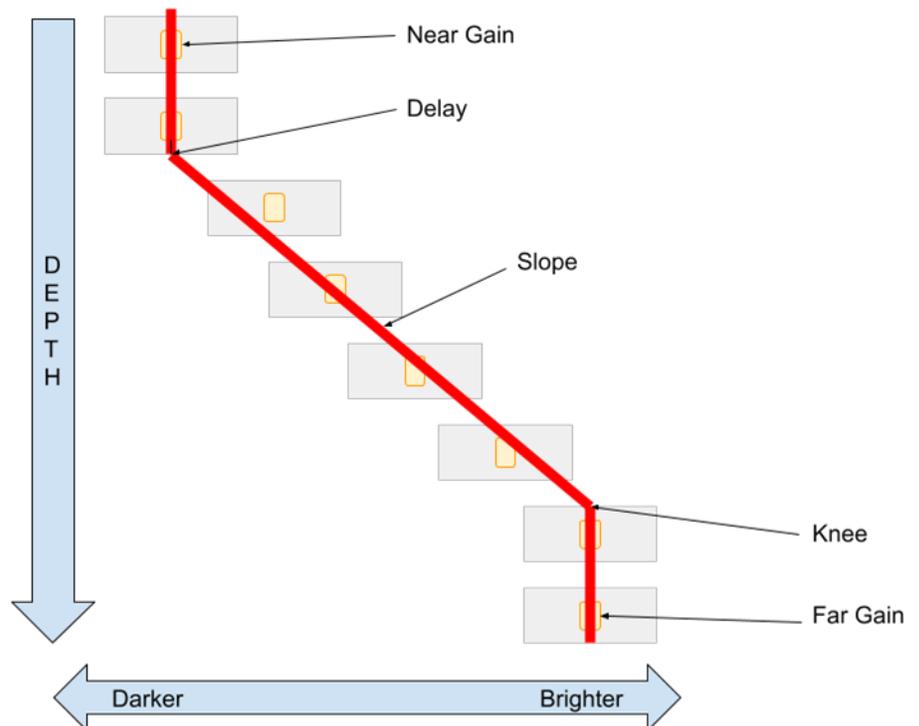
Gradual compensation through the middle

Maximum compensation in the far field to make the weak, attenuated echoes brighter.



This is known as the TGC slope and has key attributes:

- Near Gain
- Delay
- Slope
- Knee
- Far Gain



TGCs should be used when part of your image is too bright or too dark and not adequately seen. Remember that TGCs can change the image brightness in accordance to depth where gain would change the whole image.

Remember that attenuation is directly related to frequency. High frequency transducers will need more compensation than low frequency transducers.

- **TGCs are also known as DGCs (depth gain compensation) and swept gain.**
- **TGC adjustments are a special type of amplification, so they too have a decibel unit.**

### 14.4.3 Compression

The third function of the receiver is compression.

- **Compression reduces the number of grays in the display.**

The information that the transducer is getting back is A LOT. All the little echoes and voltages are sent to the receiver for processing. The information that comes back is way more than the receiver can handle, so it needs to compress that information into a usable range. **First compression is the reduction of information and automatically occurs.** During this reduction, nothing is changed about the value of the information, it's just recalibrated for the machine component

A hypothetical example of this would be a machine that is capable of sorting candy. One machine might be able to tell the difference between a chocolate bar, chocolate/caramel, chocolate, nougat & caramel, and chocolate, nougat, caramel & peanuts. It can also tell the difference between fruity candy - chewy/crunchy, sour/sweet, sucker/non-sucker etc. This machine is your transducer. It is very good at parsing out detailed information about the echoes returning from the body



The next candy sorting machine might only be able to sort plain chocolate from chocolate with other stuff and fruity candy that has sticks and those that don't. The machine is still correctly sorting candy, but reduces the options. This is your receiver. It doesn't all of a sudden mistake a lollipop for a chocolate bar, it just can't handle all the detail from the transducer. The receiver needs to reduce the information to be able to process the signal correctly.

If the transducer sends back 1000s of voltages that could be sorted into 1000s of different grays, the receiver can't handle it, so it will sort those 1000's of voltages into 100's of grays. The largest signals are still the largest and the smallest signals are still the smallest, there are just less options in between.

→ **Second compression is adjustable by the sonographer.**

Like the other functions, compression has a first and second stage. The second stage is adjustable by the sonographer by a knob called compression or **dynamic range**. By changing the dynamic range, the sonographer is telling the machine to reduce the number of gray options being displayed.

When there is low dynamic range, there are few choices and the image becomes more black and white with more contrast.

When there is high dynamic range, there are more choices and the image becomes less contrasted, with more of a gray appearance.

Notice how the top image has a lot of gray in it. Blacks are still black and white is still white, but there are many more gray options in between.

The bottom image has the dynamic range decreased and the image appears more black and white.

→ **Units for compression are also in decibels.**



## 14.4.4 Demodulation

The fourth function of the receiver is demodulation, also known as **detection**. For a wave to modulate, it means that it changes amplitudes. So demodulation aims to even out the amplitude changes.

→ **Demodulation is an automatic process and not controlled by the sonographer.**

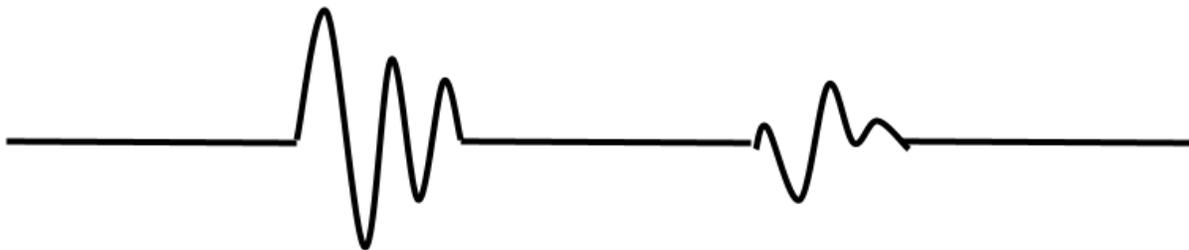
There are two steps to demodulation:

→ **Rectification - turning negative amplitudes into positive**

→ **Smoothing - average out the amplitudes in the pulse into one. (also known as enveloping)**

Demodulation has no effect on the image, but rather gets the signal ready for the system's memory and display.

Original Signal:



After Rectification:



After Smoothing / Enveloping:



## 14.4.5 Rejection

The last function of the receiver is rejection.

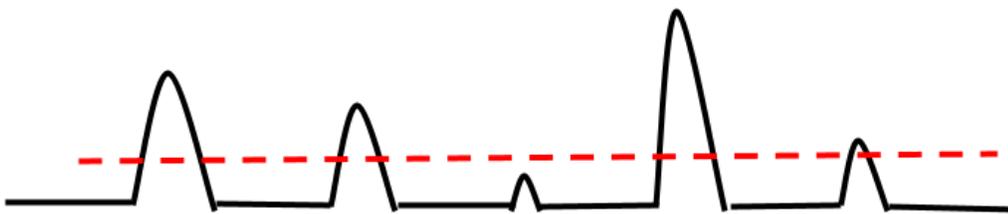
→ **Rejection allows the machine to ignore the low level echoes.**

After demodulation, the amplitudes of the signal are all above the baseline. Rejection is the process by which the machine will decide what echoes to get rid of because they are considered too weak.

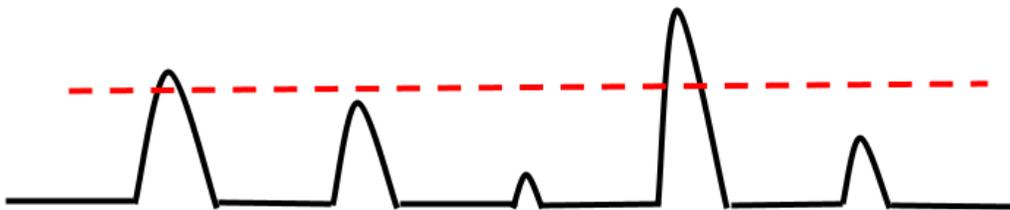
First rejection will get rid of echoes that just add noise to the image. First rejection is not controlled by the sonographer and happens automatically.

→ **Second rejection is controlled by the sonographer.**

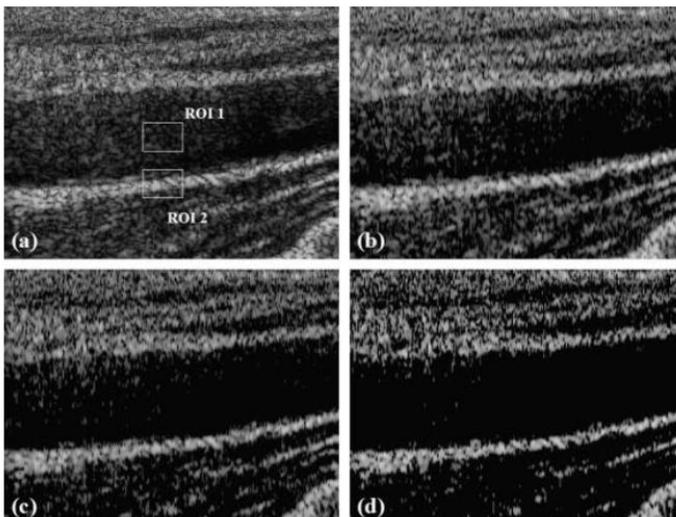
Also known as **Threshold or Suppression**, there is a knob on the machine that can be used to increase or decrease the rejection.



This rejection threshold only eliminates the weakest echo from the signal.



This rejection threshold eliminates the three weakest echoes. This reduces the low level echoes in the image, making it appear cleaner.



## 14.4.6 Receiver Review

|               |                                 |  |
|---------------|---------------------------------|--|
| Amplification | Adjustable - gain knob          | Makes all echoes bright or darker              |
| Compensation  | Adjustable - TGCs               | Evens out an image to make it uniformly bright |
| Compression   | Adjustable - Dynamic Range knob | Changes the amount of grays displayed          |
| Demodulation  | Not Adjustable                  | No effect                                      |
| Rejection     | Adjustable - Rejection knob     | Gets rid of low level echoes                   |

# Section 14.5 AD Converter

The signals leaving the receiver are still in analog form. To process the signals in the digital memory, the data must be converted from analog to digital. This is done in the **analog to digital converter (ADC) also known as the digitizer**.

When converting the analog waveform to digital, it is converted into a number that the digital memory can process further.

## 14.5.1 Analog vs. Digital Values

### **Analog numbers have infinite possibilities...**

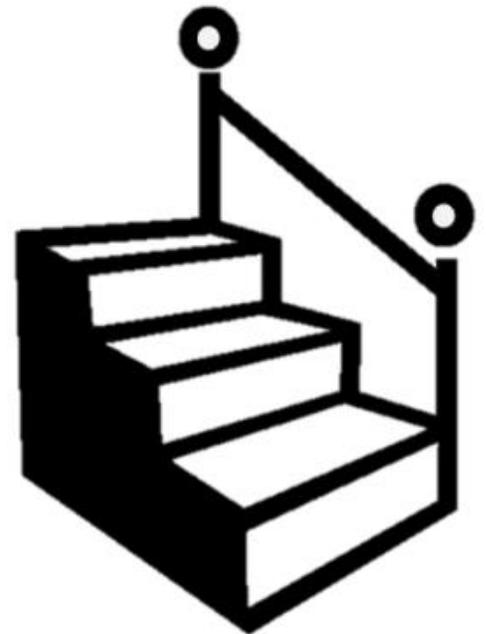
Think about a ramp. You can be anywhere on that ramp and it will have a defined number, moving just an iota in one direction creates a new value.



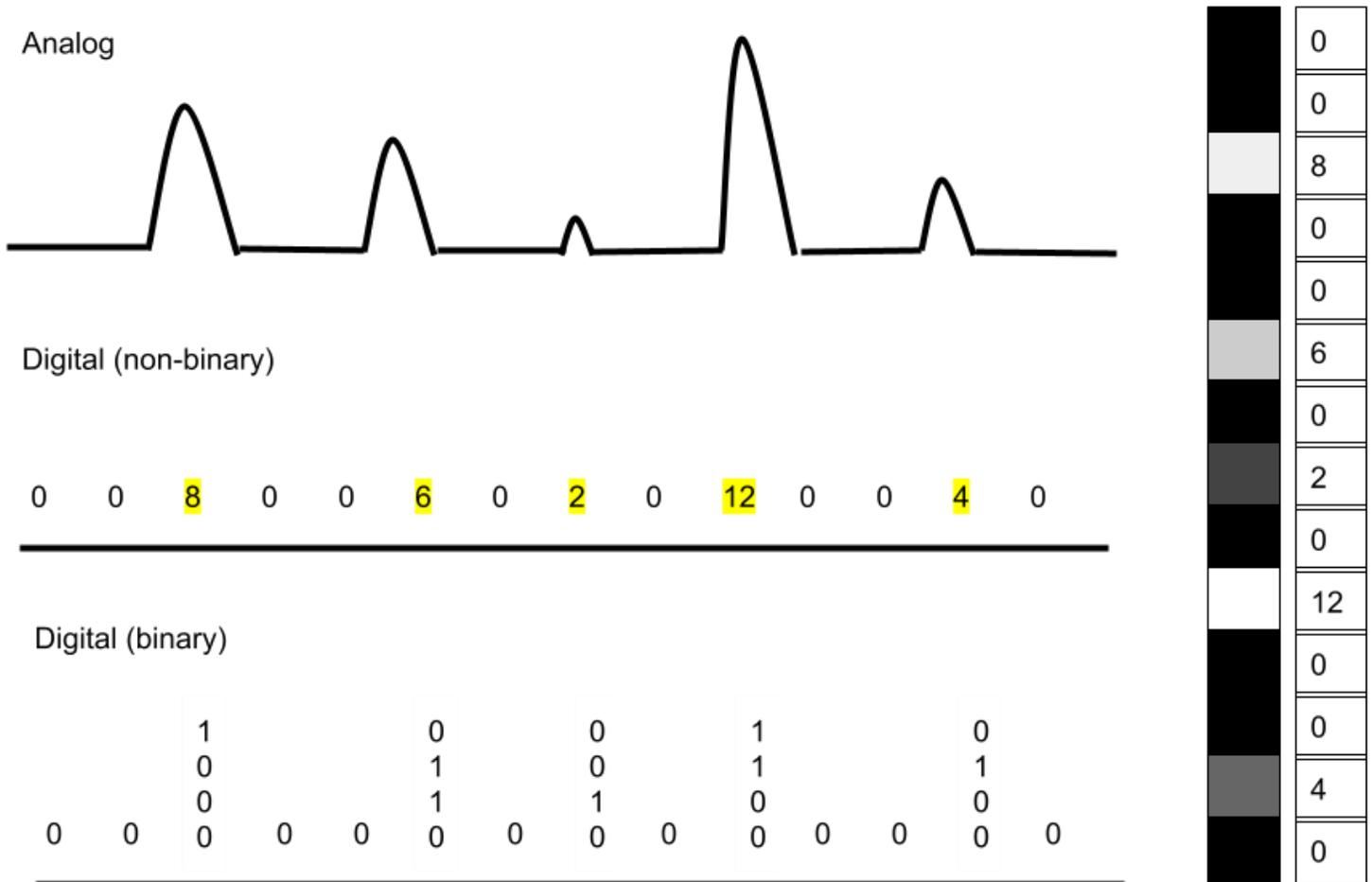
### **Digital numbers are finite.**

Think about stairs, you are either on stair 1 or stair 2 or 3...there is no in between.

You can also think about analog clocks and digital clocks. An analog clock can show you any moment from 1:59 to 2:00. But, a digital clock won't change until it is actually 2:00. You don't see the in between infinite possibilities in digital. This is why analog can be considered real life, where digital numbers are discrete.



To get ready for the scan converter the ADC changes those “real life” values into discrete digital values. These values are usually represented in binary to the memory. If this line of information are the final echoes for one scan line, the scan converter will match the discrete numbers to a value of gray that the system can process.



→ **The summer is responsible for combining all of the information into the scan line information for the scan converter.**

# Section 14.6 Scan Converter

Once digitized, the scan line information is sent to the scan converter. No image is created yet - the machine is still acquiring each scan line for the final display. The scan converter is yet another place that the information can be processed, but now it is manipulation of digital information.

The scan converter is part of the whole image processing component of the machine that handles pre-processing and post-processing functions.

The final part of image processor/scan converter is to reformat the information for the display. This may include a step to convert back to analog values.

Important things to remember are that:

- **The scan converter is also known as memory.**
- **Preprocessing functions occur in the working memory (while the machine is live scanning)**
- **Post-processing functions occur in the stored memory (when the image is "frozen.")**
- **The DA converter is only necessary when the display is analog**

\*\*\*Image processing functions will be discussed in Unit 15a.

## 14.6.1 Analog Scan Converters

Original scan converters on a machine were analog scan converters, meaning they could take the information from the receiver and process it. No AD converter was needed.

The converter was a vacuum tube, shaped as a funnel. At the narrow end sits an electron gun. The gun would stream electrons (carrying image information) down to the other end where a dielectric matrix or silicon wafer sat. The matrix is basically millions of dots, with an electron bucket in each.

When the electron strikes the matrix, the electron bucket stores the electron where it will be read later.

→ **Spatial resolution is EXCELLENT with analog scan converters.**

However, there were a lot of problems with analog converters. They were very insatiable and the image and component itself would deteriorate over time. Thus the digital scan converter became the new normal.

## 14.6.2 Digital Scan Converters

The digital scan converter uses computer technology to convert the image information into numbers. This is called digitizing.

The image information is stored in the memory, which looks like a giant checkerboard. Is "square" is assigned a string of 0s and 1s, representing a digital number. The number for the square is then processed into a level of gray when being displayed on the monitor.

The digital scan converter offer many improvements over the analog scan converter. They are very fast, accurate and durable.

The digital scan converter spatial & contrast resolution are limited by two factors:

1. The number of pixels in the scan converter
2. The number of bits assigned to each pixel

## 14.6.3 Pixels

The pixels in the scan converter are arranged in a grid. Each pixel holds information. For our purposes, the pixels are going to hold information about our ultrasound image.

The word pixel is derived from **picture & element**.

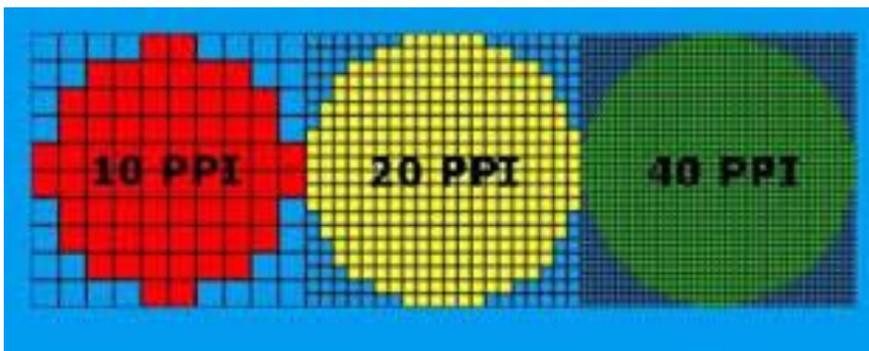
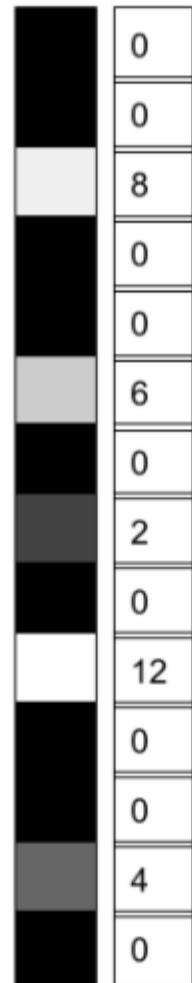
→ **Each pixel can only display ONE shade of gray at a time.**

We saw this image earlier when talking about the ADC. It shows us that each pixel is assigned a number, each number is assigned a gray. There can only be one gray per pixel, you can't split a pixel in half or more.

This concept plays into the detail that the scan converters can display. The more **pixels per inch**, the more detail that can be displayed.

In the image below, all three "scan converters" have been tasked with creating a circle. Remember that a pixel is either on or off, and if on, can only display one color. In the 10 PPI (red) circle, we can see that it isn't very smooth. It has a *pixelated* appearance. Compared to the 40 PPI, the edges appear smoother.

→ **Pixel density improves the spatial resolution of an image.**



High Pixel Density in the Scan Converter:

- High PPI
- Small pixels
- Improved detail

## 14.6.4 Bit

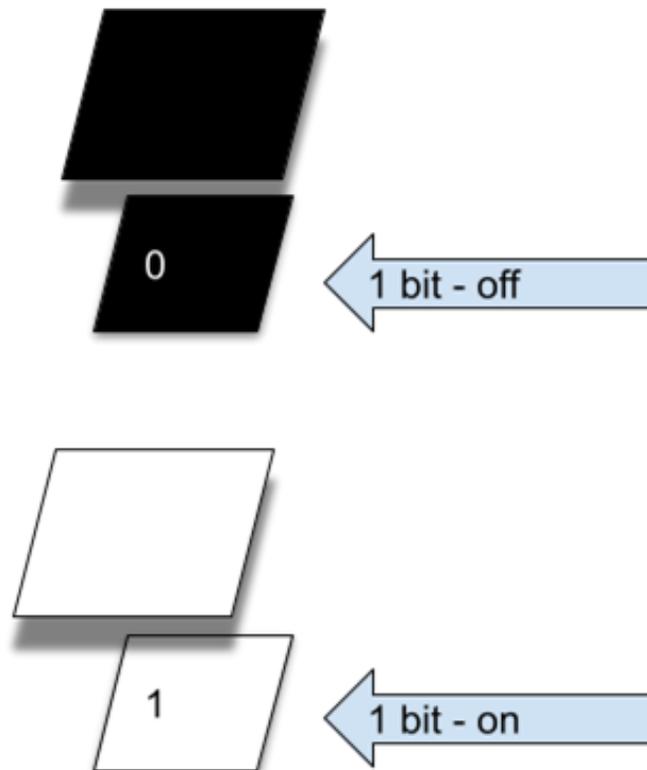
The bit is also a special word made from **binary & digit**.

→ **A bit is the smallest amount of memory that can be assigned to a pixel in a scan converter.**

A bit is bistable - meaning it can either be ON or OFF. In digital word that means it is either assigned a 0 or a 1.

→ **For every bit of memory assigned to a pixel, more gray shades can be displayed.**

The amount of grays that can be displayed are related to the binary number created from turning bits on or off.



1 bit of memory can display 2 shades of gray. ( $2^1 = 2$ )



By knowing how binary numbers work, then we can see how the bits are assigned either a 0 or 1, adding bits together can make more shades of gray and there is a finite amount of combinations, therefore a finite amount of grays that can be displayed. By turning a bit on or off and the pattern it makes with the other bits makes new numbers, therefore making a new shade of gray.

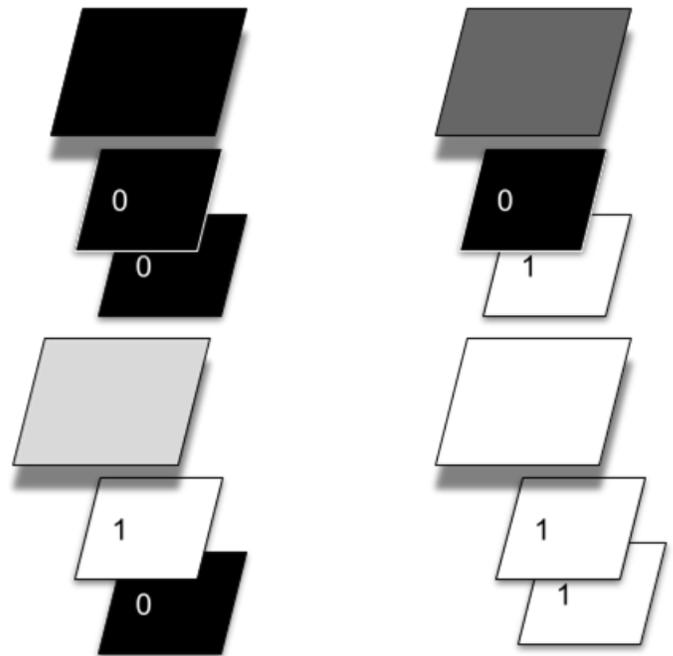
The number of shades of gray a system can make can be calculated by taking the number 2 and raising it to the the number of bits.

A machine with 4 bits can display 16 shades of gray:

$$2^4 = 16 \quad (2 \times 2 \times 2 \times 2 = 16)$$

|          |   |           |
|----------|---|-----------|
| 0000 = 0 |  | 1000 = 8  |
| 0001 = 1 |  | 1001 = 9  |
| 0010 = 2 |  | 1010 = 10 |
| 0011 = 3 |  | 1011 = 11 |
| 0100 = 4 |  | 1100 = 12 |
| 0101 = 5 |  | 1011 = 13 |
| 0110 = 6 |  | 1110 = 14 |
| 0111 = 7 |  | 1111 = 15 |

| Number of Bits of Memory | Number of Grays |
|--------------------------|-----------------|
| 1                        | 2               |
| 2                        | 4               |
| 3                        | 8               |
| 4                        | 16              |
| 5                        | 32              |
| 6                        | 64              |
| 7                        | 128             |
| 8                        | 256             |



2 bits of memory can display 4 shades of gray. ( $2^2 = 4$ )

→ The number of grays that can be displayed determines a system's contrast resolution.

The more grays, the better the contrast resolution is.

- Most modern systems are 8 bits which displays 256 shades of gray.
- Most humans can only see about 30 shades of gray.



1 Bit



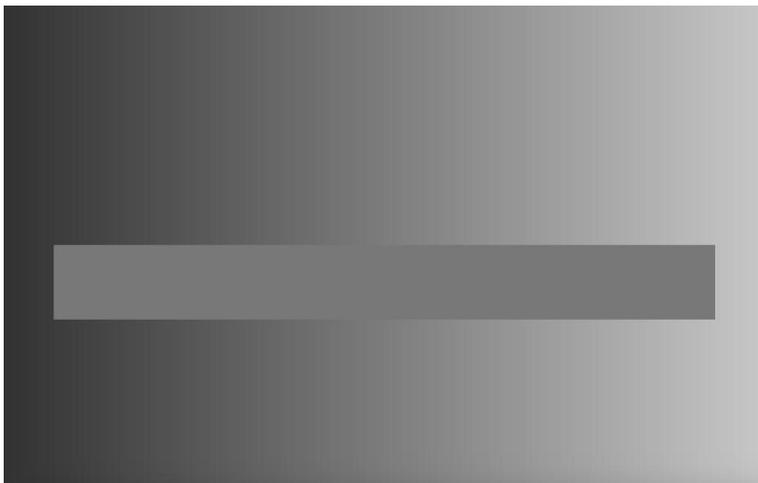
2 Bits



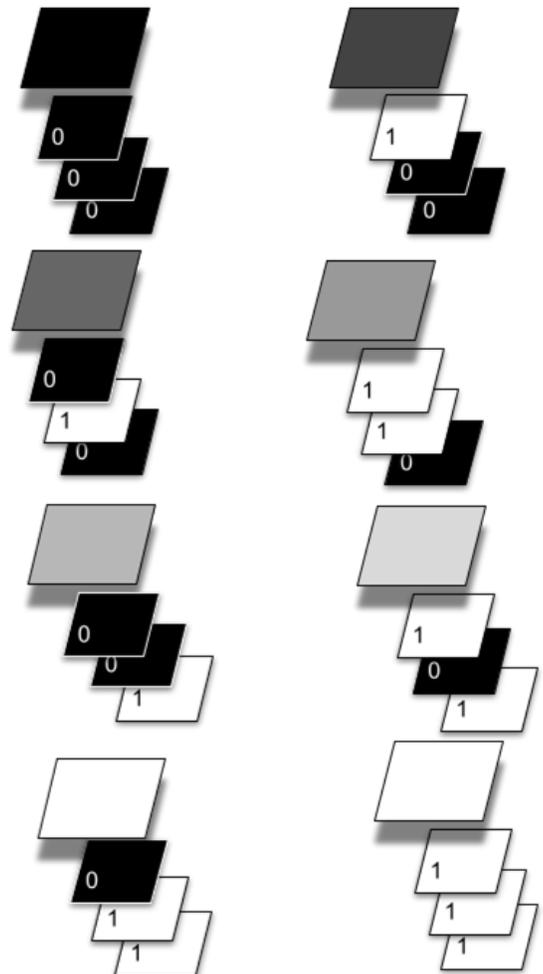
4 Bits



8 Bits



30 shades of gray



3 bits of memory can display 8 shades of gray. ( $2^3 = 8$ )

## 14.6.5 Pre-Processing & Post-Processing

Pre-processing and post-processing are both steps in digital information manipulation that allow the sonographer and system to alter the data.

### **Pre-processing occurs when the scanning is still live.**

If you are scanning and change a parameter,, you are changing how the machine is scanning and it is immediately reflected in the image on your display. Since these are changes made before the image is frozen, these are considered pre-processing functions.

### **Post-processing occurs when the image is frozen.**

Up until the image is frozen, the information regarding the scan lines is continually written over in the scan converter. Once the image is frozen, the machine stops acquiring new data and the scan converter displays the image information as it has it.

There are some functions that can occur after this point and are considered post-processing functions. Post-processing (unlike pre-processing) functions can be reverted back to the original digital data if needed.

In Unit 15a, we will cover more detail on image processing functions.

## 14.6.6 DA Converter

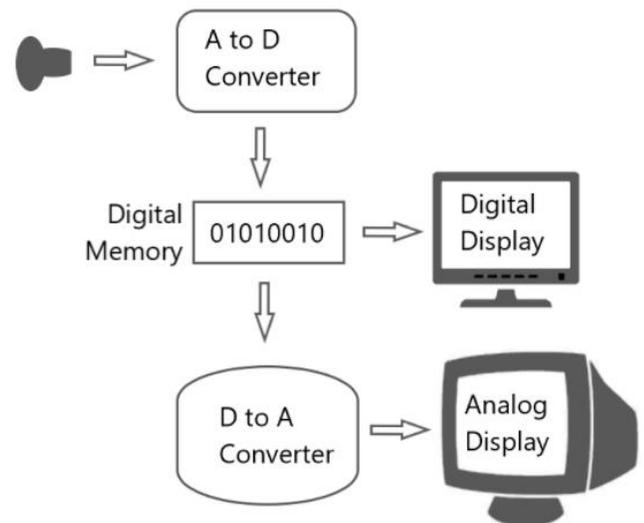
When the information comes back from the transducer, the voltage is VERY weak. Typically, it will go through amplification in the receiver, but it is still susceptible to being contaminated by outside electrical interference.

→ **Changing the information from analog to digital reduces the susceptibility, making it more stable as it is processed.**

Depending on the system, the data may have to be converted back to analog before being displayed.

The process of changing the information from Analog, to digital and back to analog is a 5-step process:

1. Analog information from the transducer is processed by the ANALOG-to-DIGITAL CONVERTER (A to D)
2. The digital information is temporarily stored in the memory, if it is changed (gain, compression, etc.) the information is written over. This is all PREPROCESSING, up until the “freeze” button is pushed.
3. Once the “freeze” button is selected any changes that happen now are POSTPROCESSING.
4. If the display is digital, this information is read from the scan converter as is and displayed, skipping this step...however, if the display is analog, the digital number must be processed again through a DIGITAL-to-ANALOG (D to A) CONVERTER
5. The signal should now be in the appropriate form for the display and an image is created.



# Section 14.7 Display

The evolution of the display or monitor has helped to improve the use of ultrasound.

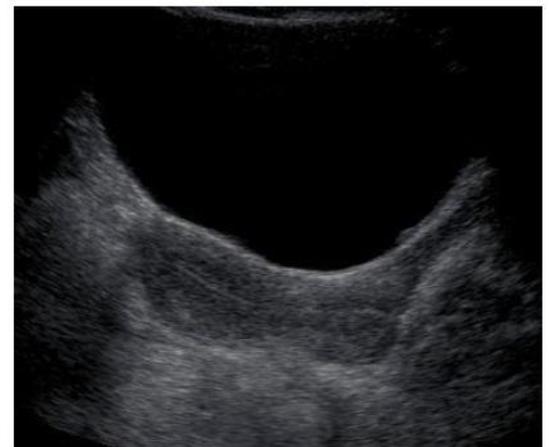
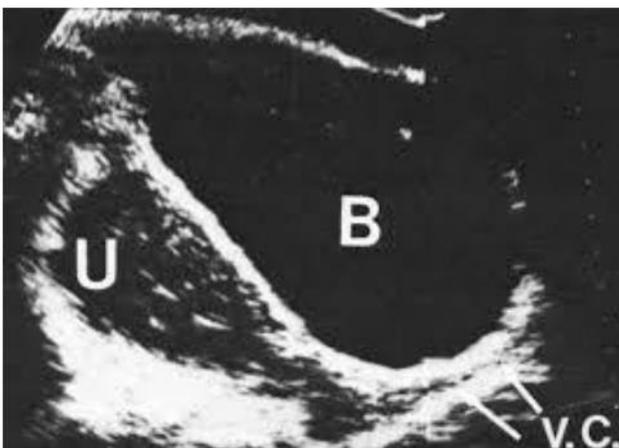
Original units used basically televisions with cathode ray tubes to create the image ( and cathode ray tubes used to be on the physics test!), but modern systems use flat screen computer monitors that allow for more lines of display, faster refresh rate and blacker blacks (LCD & OLED monitors).



Early ultrasound system displays were considered bi-stable. We've heard this before when talking about pixels - and it means black and white.

Gray scale displays can display multiple shades of gray as they relate to the echoes returned from the anatomy.

These images represent the non-gravid uterus. U=uterus, B=Bladder, VC = Vaginal canal.



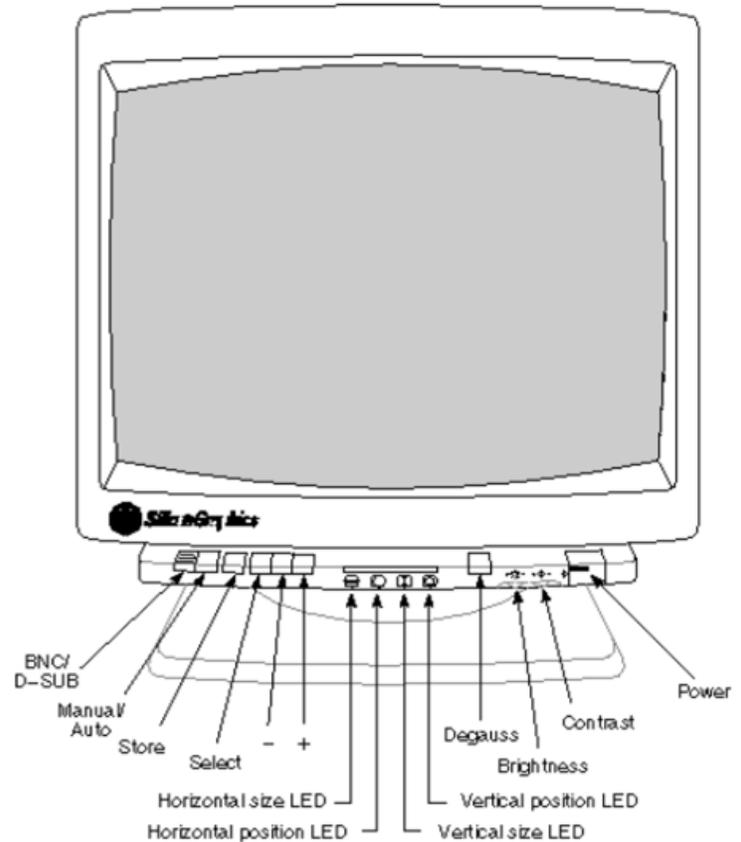
## 14.7.1 Monitor Controls

All monitors have their own controls to adjust contrast or brightness. They are typically found on the front or underside of the monitor.

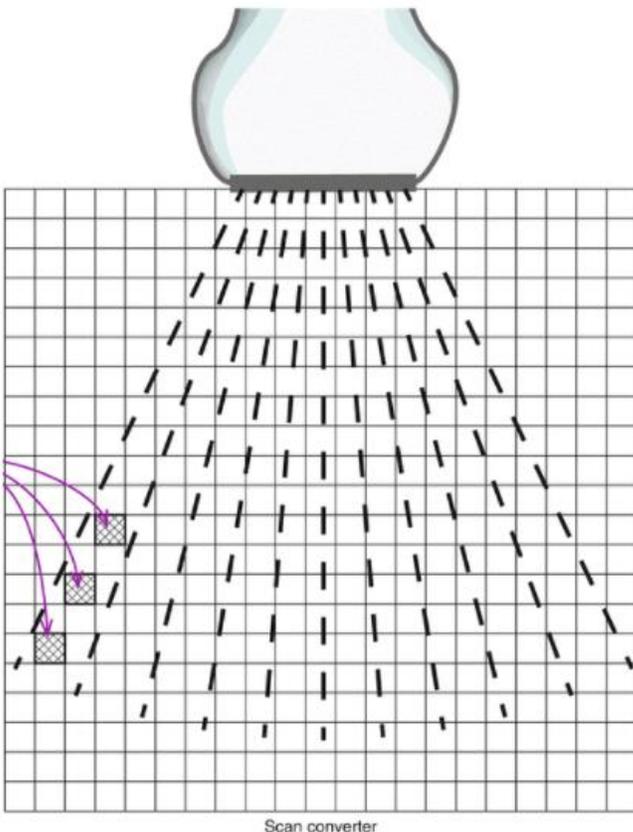
**Contrast** will determine how many grays are displayed on the monitor.

**Brightness** will determine how light or brilliant the grays look.

Do not confuse these controls with ultrasound system functions. These are independent of the system and can be found on any monitor.



## 14.7.2 Sending Data to the Display



During scanning, the image information from the transducer is more spoke like / vertical in orientation.

The scan converter must take that information and reorganize it so it can be displayed horizontally (in video format).

The scan converter translates the information from the spoke format to the horizontal video format.

## 14.7.3 Measurements & Colors

Displays include range marker dots. When the measurement tool is used, the computer operating the machine and the computer operating the CPU work together using the range marker dots and the calipers applied to the frozen image. It can then calculate the distance between the calipers and display it.



Modern systems also use LCD screens which are not only capable of displaying 256 shades of gray, but also able to display color as well. With many displays using over 700,000 LCD elements, these systems are considered 24-bit because they now use 8 bits per primary color of light: red, blue and green. Each crystal acts as a shutter, allowing only so much light through and can produce almost 17 million colors for each pixel in the display.

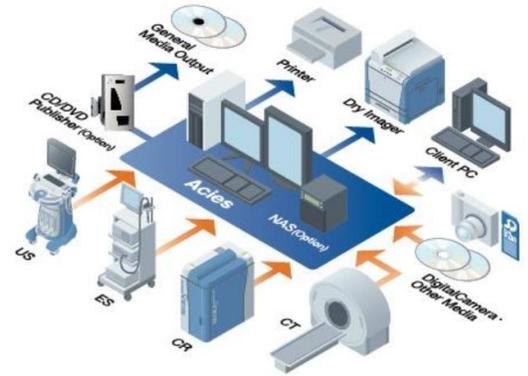


# Section 14.8 Storage

The last step of the process is to store the images taken for an exam. Storage can be digital or analog, so a digital to analog converter might still be necessary even if the monitor is digital.

The main types of output storage include:

- Internal hard drive
- USB
- DVD
- Paper
- PACS



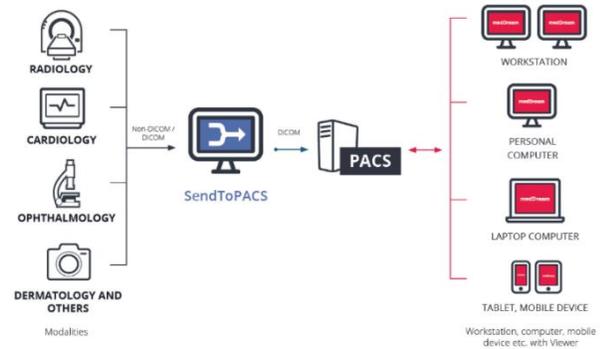
## 14.8.1 PACS & DICOM

→ **PACS stands for: Picture Archiving and Communication System**

PACS is a place for images and other medical information to be digitized and stored on a large computer network.

It has many advantages:

- Instant access to archives
- No degradation of data over time
- Promotes accessibility in remote sites



→ **DICOM stands for: Digital Imaging and Computers in Medicine**

DICOM images must follow rules that dictate medical imaging that is to be used on multiple systems. By following the rules, all devices will work with DICOM and this allows for better communication between systems.

**DICOM images are typically stored on a PACS system.**

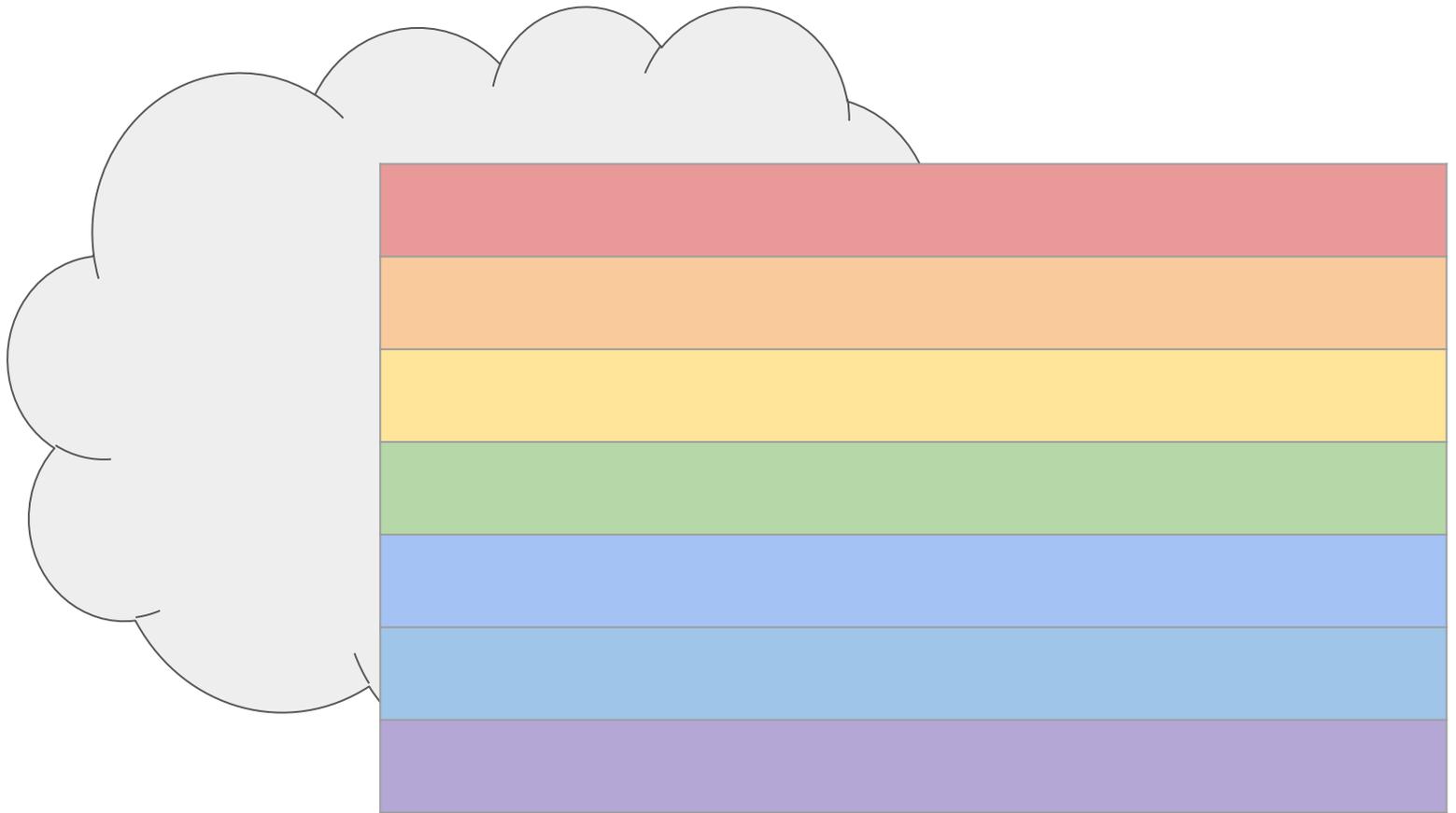
# Section 14.9 Activities ← [Link to Answers](#)

[PDF TO ANSWERS IF PREFERRED](#)

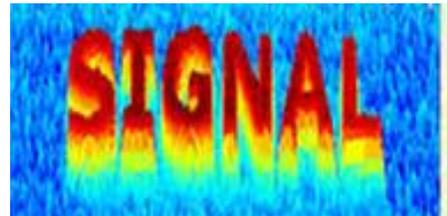
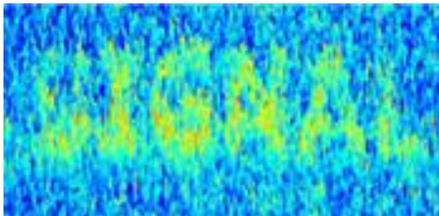
1. Match the machine component to the definition.

|          |                      |  |   |
|----------|----------------------|--|---|
| <b>A</b> | Transducer           |  | Presents the processed data as an image or spectral plot.   |
| <b>B</b> | Pulser / Beam Former |  | Maintains and organizes the proper timing of the pulser/ beam former's actions.                                     |
| <b>C</b> | Receiver             |  | Creates and controls the electrical patterns and strength of beam.  |
| <b>D</b> | Display              |  | Transforms the returning electrical signals through a 5 step process.   |
| <b>E</b> | Storage              |  | Transforms electrical energy into sound energy during transmission, changes back into electricity during reception. |
| <b>F</b> | Master Synchronizer  |  | Archival space for the ultrasound images.   |
| <b>G</b> | Scan Converter       |  | Gets the digital information ready for the display.   |

2. List the other names for the pulser voltage:



3. Sort the statements in relation to the SNR

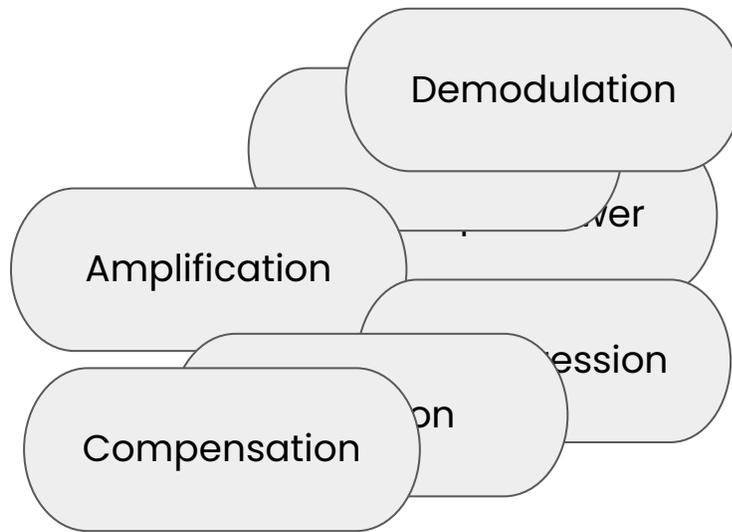


- Weak signal
- Strong signal
- Low Output Power
- High Output Power
- Low Quality Image

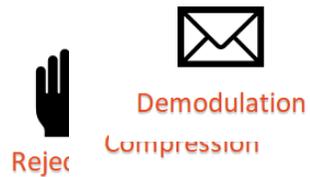
4. Sort the function/component as adjustable or not adjustable by the sonographer.

ADJUSTABLE

NOT ADJUSTABLE



5. Place the receiver functions in order:



First

Last

6. A rose by any other name...list the synonyms:



|               |  |
|---------------|--|
| Amplification |  |
| Compensation  |  |
| Compression   |  |
| Demodulation  |  |
| Rejection     |  |

7. Match the receiver function with its description:

|                        |   |
|------------------------|---|
| <b>A Amplification</b> | First rectifies the signal and then envelopes the signal to be used by the display. |
| <b>B Compensation</b>  | Reduces the amount of grays.  |
| <b>C Compression</b>   | Makes all the signals bigger  |
| <b>D Demodulation</b>  | Makes the picture uniformly bright to counteract attenuation                        |
| <b>E Rejection</b>     | Gets rid of low level echoes  |

8. Fill in the acronym:

A =  
L =  
A =  
R =  
A =

|  |
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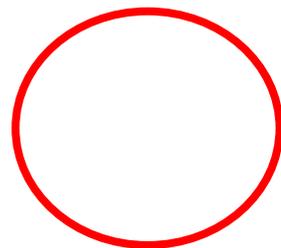
9. To improve this picture, what should be adjusted first? (move the red circle)



TGCs

Gain

Power



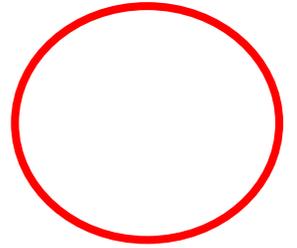
10. To improve this picture, what should be adjusted first?



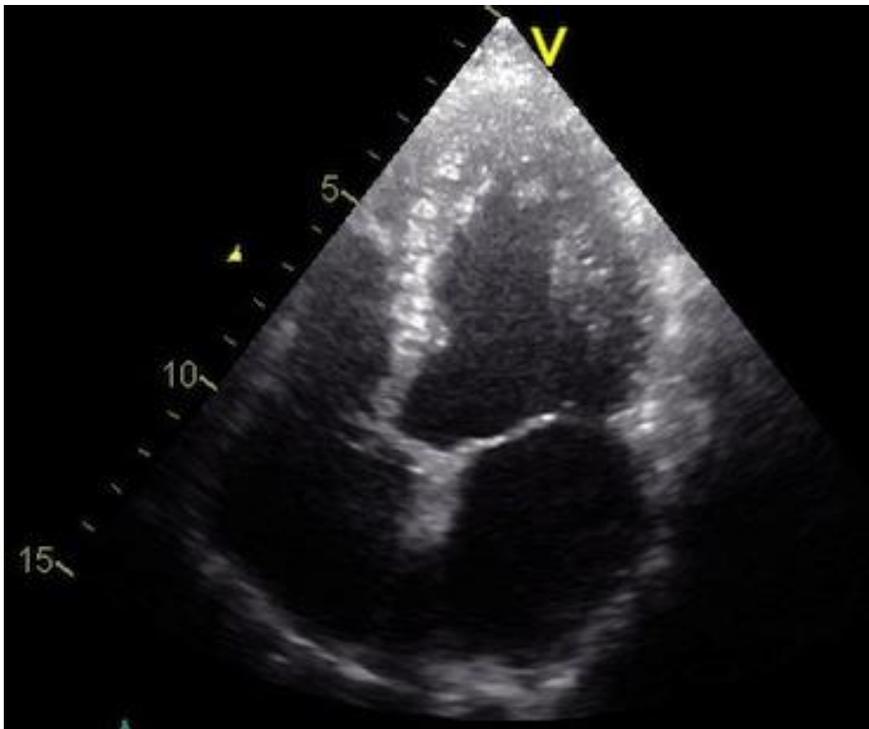
TGCs

Gain

Power



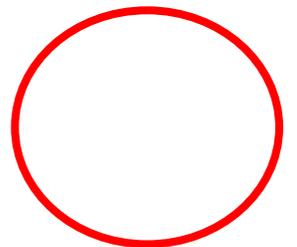
11. To improve this picture, what should be adjusted first?



TGCs

Gain

Power



12. Fill in the blank:

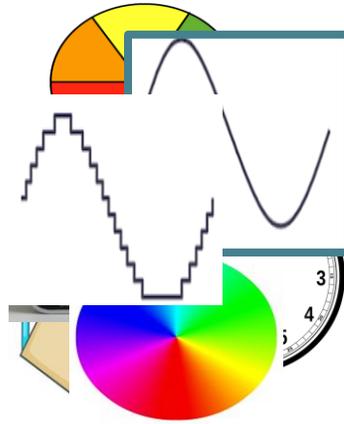
|   |  |
|---|--|
| When an image is black and white, it is known as a _____ image.   |  |
| The scan converter is also known as the _____.                    |  |
| When image data is being sent to the scan converter it is _____.  |  |
| When the image is displayed on the monitor it is _____.           |  |
| Early scan converters were _____.                                 |  |
| Modern scan converts are _____.                                   |  |
| The word _____ is derived from picture element.                   |  |
| The word _____ is derived from binary digit.                      |  |
| An increase in pixel density improves the _____ resolution.       |  |
| A bit can be on or off, black or white, this is considered _____. |  |

13. Sort the concepts of:

Analog

&

Digital



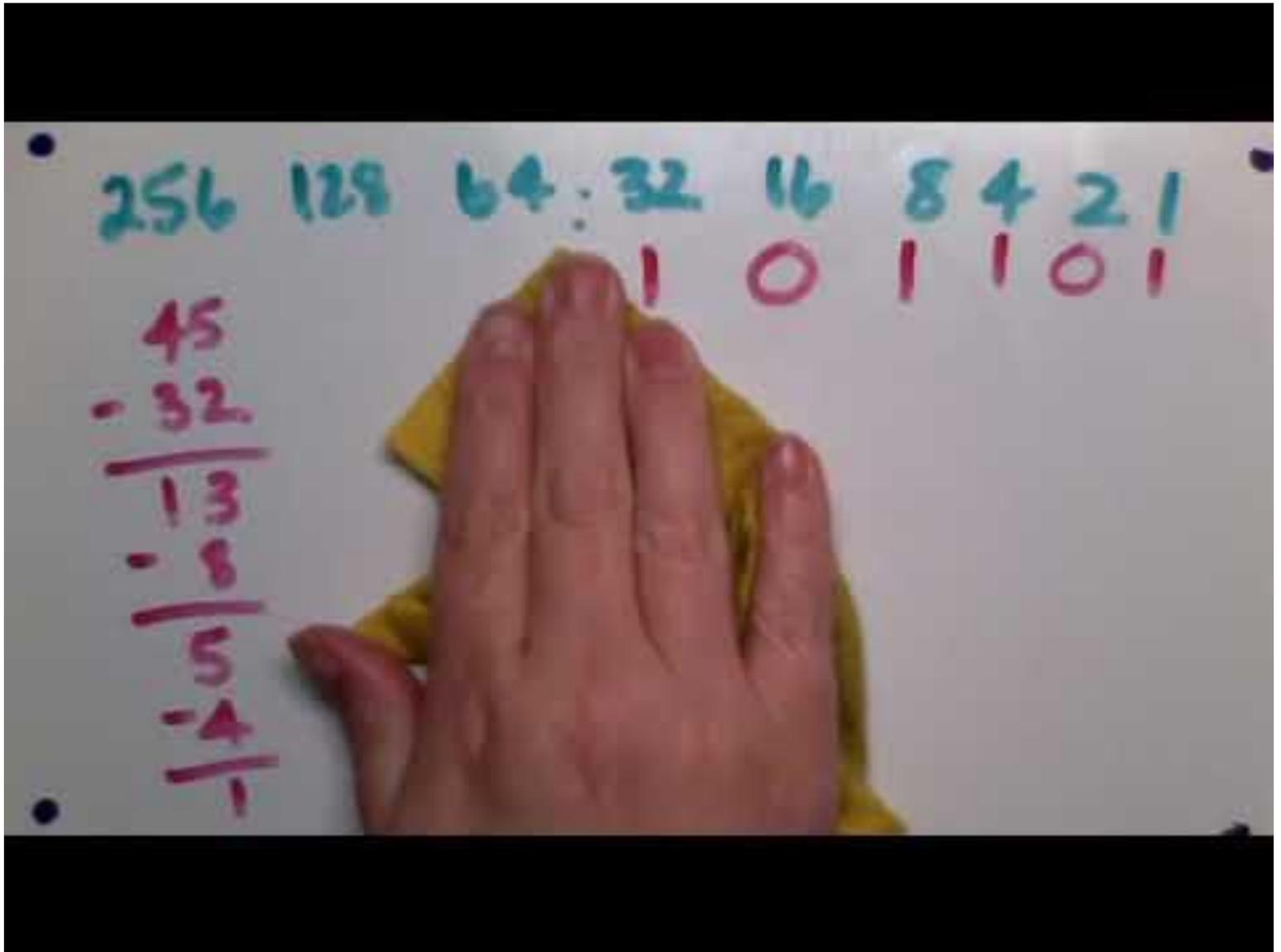
14. Calculate the exponents:

|       |       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|       |       |       |       |       |       |       |       |       |

15. Calculate the number of grays each memory could display:

| Memory       | Shades of Gray | Memory       | Shades of Gray |
|--------------|----------------|--------------|----------------|
| 8-bit memory |                | 4-bit memory |                |
| 7-bit memory |                | 3-bit memory |                |
| 6-bit memory |                | 2-bit memory |                |
| 5-bit memory |                | 1-bit memory |                |

For more information on binary numbers watch this video:



There are only 10 types of people in this world.  
Those that understand binary and those that don't.



16. Convert these binary numbers into decimal numbers:

| Decimal # | = | Binary   |          |          |          |          |          |          |          |          |
|-----------|---|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|           |   | 256      | 128      | 64       | 32       | 16       | 8        | 4        | 2        | 1        |
|           | = | <b>1</b> | <b>0</b> | <b>1</b> |
|           | = |          |          |          |          |          |          |          | <b>1</b> | <b>1</b> |
|           | = |          |          |          | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b> |
|           | = |          |          |          | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b> | <b>0</b> |
|           | = | <b>1</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> |
|           | = |          |          |          |          | <b>1</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> |
|           | = |          |          | <b>1</b> | <b>1</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>1</b> |

18. When making adjustments to a live image, this is considered:



19. When making adjustments to a frozen image, this is considered:



20. Fill in the acronyms:

**P**

**A**

**C**

**S**

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|  |
|  |
|  |

**D**

**I**

**CO**

**M**

|  |
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|  |

# Section 14.10 Nerd Check!

1. Know the path from start to finish to the ultrasound system.
2. What are key components of the beam former?
3. What type of transducers need a beam former?
4. What is the job of the master synchronizer?
5. What is the pulser?
6. When does the pulse operate?
7. What is the name of the power that the pulser puts out?
8. If the voltages are weak, what do the echoes look like?
9. If the voltages are strong, what do the echoes look like?
10. How is output power monitored?
11. Can output power be adjusted by the sonographer?
12. How does output power affect the echoes that are returning?
13. What is the signal to noise ratio?
14. How can a sonographer improve the SNR?
15. What is noise?
16. What are 5 consequences of using increased output power?
17. What does the beam former do during reception?
18. What does the beam former do during transmission?
19. What is T/R switch?
20. How does the T/R Switch fit into the pathway of the signal processing?
21. Where is the transducer in the signal pathway?
22. What is another name for the receiver?
23. What is the purpose of the receiver?
24. What are the order of the 5 functions of the receiver?
25. What is preamplification and amplification?
26. Why does preamplification need to occur?
27. Is amplification adjustable by the sonographer?
28. What knob affects amplification?
29. How does amplification interact with the echoes?
30. How does gain improve the SNR?
31. What risks for bioeffects does increase gain cause?
32. What unit is amplification measured in?
33. An increase in 3 dB is wave that is how much stronger?
34. An increase in 10 dB is wave that is how much stronger?

35. What does ALARA stand for?
36. What precautions should we take to make sure we're following ALARA?
37. If an image is too bright, in theory we should:
38. If an image is too dark, in theory we should:
39. If an image is not uniform in brightness, we should:
40. What does compensation do?
41. How many compensations occur?
42. What does compensation counteract?
43. Is compensation adjustable?
44. How would a sonographer change compensation?
45. Describe what the TGC panel looks like,
46. What is best practice with the TGCs?
47. What does the typical TGC placement look like, knowing attenuation is more prevalent in the far field?
48. What are the parts of a TGC slope?
49. What are other names for TGCs?
50. What unit is compensation expressed in?
51. What is compression?
52. How many compressions occur?
53. Can the sonographer adjust compression?
54. What knob would allow for changing compression?
55. What are other names for compression?
56. If compression is increased, what does the image look like?
57. If compression is decreased, what does the image look like?
58. What is the unit for compression?
59. What is another name for compression?
60. What is demodulation?
61. What is another name for demodulation?
62. What are the two steps of demodulation?
63. What happens during rectification?
64. What happens during smoothing?
65. What is another name for smoothing?
66. Can the sonographer adjust demodulation?
67. Why does demodulation occur?
68. What is rejection?
69. How many rejections are there?
70. What does rejection reduce in the image?
71. What are other names for rejection?

71. What is an ADC?
72. What is an ADC also known as?
73. Where is the ADC in the process?
74. What is an analog number?
75. What is an example of an analog number?
76. What is a digital number?
77. What is an example of a digital number?
78. How does the ADC represent the voltages going to the memory?
79. What does the summer do?
80. What is the scan converter also known as?
81. How do analog scan converters work?
82. What is the benefit of analog scan converters?
83. What are the pitfalls of an analog scan converter?
84. What are modern scan converters?
85. What are the benefits of a digital scan converter?
86. What is the image information represented in the scan converter?
87. What two resolution are affected by the scan converter?
88. What is the scan converters resolutions limited by?
89. What is a pixel?
90. How many shades of gray can a pixel display?
91. What is pixels per inch?
92. What happens when you increase pixels per inch?
93. How is pixel density related to spatial resolution?
94. What is a bit?
95. What does bistable mean for a pixel?
96. Decimal numbers are based on how many digits?
97. Binary numbers are based on how many digits?
98. What is 2 raised to powers 0 through 8?
99. How can we figure out how many shades of gray a system can create?
100. How does the number of gray shades affect contrast resolution?
101. How many bits of memory do most machines have and how many grays does that display?
102. How many grays can the human eye distinguish?
103. When does pre-processing occur?
104. When does post-processing occur?
105. If a system has a digital display, what component does it not need?
106. If a systems has an analog display, what component is after the scan converter?

107. What does CRT stand for?
108. How are modern displays made?
109. What does bistable means for a monitor?
110. What two setting can be changed on the monitor that will change the appearance of the image only on the monitor?
111. Scanlines come in \_\_\_\_\_, so the scan converter arranges them so the monitor can read them \_\_\_\_\_.
112. How can we make measurements on our images?
113. Name a few types of storage devices?
114. What does PACS stand for?
115. What are the advantages of PACS?
116. What does DICOM stand for?
117. What are the advantages of DICOM?