IMAGE PROCESSING

Experimental Television Center, 1986

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The following are excerpts from the Experimental Television Center (ETC) in Owego, N.Y., "Image Processing Manual." The manual was written in the early 1980's by Sherry Miller Hocking, in collaboration with Richard Brewster, and is an outgrowth of a prior "how-to" manual in 1976, cataloguing the video equipment at ETC.

The manual contains a review of fundamental video principles contained in waveforms, timing and synchronization. It acts as an educational and training vehicle for reference by visitors to the Center, but also includes descriptions of unique video art tools and how to use them. These depictions are accompanied with an underlying ideology : that informed exposure to the language and expressions of technological art tools will point toward their creative use in the video arts. — J.S.

SIGNALS: As a kinetic as well as an electronic form, video concerns itself with the time/space equation. Video image movement occurs within a predetermined space, and the process of change, by definition, is a temporal event occupying a specific length of time. Changes in the time frame or time base of the signals which define the image result in changes in the duration of images and in the locations of sections of images within the two-dimensional space of the image's display. On the level of electronics, the very construction of the video image, its generation as well as its display, is time dependent. The composition of the signal, then, defines the visual nature of the image as it exists in time; it dictates both the appearance of the single "still" image, which exists within a specific length of time, and its behavior through time.

On a primary level, the signal can be viewed as the art-making material; the creation of an electronic image is an architectural process and constructed in time. The signal refers to changes in energy levels and reveals a physical nature by forming and influencing images. Specific devices in an electronic image processing system perform specific functions or operations on signals, generating and altering the signals, or codes, and therefore the resulting images. In this way the hardware of the system can be viewed, in part, as a "carrier of aesthetic definitions." There are several general categories of signals specified by the processing system which include video, audio, control, and synchronizing or timing signals; as shall be seen, signals may perform functions within several categories. One signal, for example, can influence an image and also produce a sound. The term "signal," derived from the Latin *signum* meaning sign, refers in a general sense to the use of conventional symbols which refer to a verbal description of a concept or event. A signal then is a translation of the description of an event from one set of symbols to another set of codes. It is the representation of the event. The signal conveys information concerning the state of the event in any given instant through time. Video images are codes of information conveyed by signals. The specific video picture information conveyed by a signal is in the form of changes in voltage; changes in voltage dictate changes in the information being carried. Voltage changes can be categorized in terms of changes of strength, increased or decreased voltage, and changes of direction, alternating or direct current signals.

Electricity is usually defined as the orderly movement of electrons through a conductive material. When a voltage is applied to a conductor, a force field is established which causes electron movement and therefore electrical energy. The rate at which electrons move past a given point is a measure of current strength expressed in ampheres or amps. When a current of one amp flows through a conductor, 6 x 10 raised to the 18th power electrons are passing a given point each second. Electrons move only when an unbalanced electrical force or potential difference is present; voltage is a measure of the force causing electronic motion and is often described as electrical force or pressure. Ground is a reference point which has zero potential energy or zero volts. Because of the properties and dimensions of the conductive material, there is a resistance to the flow of electrons. Resistance is often likened to friction and is measured in ohms. It refers to the impedance of a current flow and results in the dissipation of power in the form of heat. Although the degree of resistance is dependent on the nature of the material, the resistance of any given material is constant.

Ohm's Law expresses the relationship between current, resistance, and voltage; it states that voltage equals current, measured in amps (I), multiplied by resistance, measured in ohms (R). Because the resistance of material does not change, voltage is proportional to current. Increases or decreases in voltage simultaneously produce proportional increases or decreases in current. A watt is a unit of electrical power produced when one volt causes a current of one amp to flow through a circuit.

Two of the effects of electrical current are heat and magnetism. The resistance of the conductive material to the flow of electrons produces heat; this is easily demonstrated by the warmth of an incandescent electric light bulb. An electrical current also induces a magnetic field; this can be seen in the deflection of a compass needle placed near a wire through which a direct and steady current is flowing. The force of the magnetic field is at right angles to the direction of current flow. Michael Faraday in 1822 demonstrated the reverse of this law by showing that an electrical current can be induced by a magnetic field. A flow of electrons can thus produce a magnetic field and is also produced by a magnetic field; a magnetic field can therefore be employed as a means of controlling the movement of a flow of electrons, a process basic to the functioning of the scan motions in a video camera or monitor and also the foundation of many scan processing devices.

Electrical signals have a **waveform** which conveys the time limits of the event, the strength of the event and the direction of change of the event relative to a base line or reference point. The electrical signal can be graphically displayed in a number of ways.

On a fundamental level the waveform of an electrical signal is displayed as an XY plot of voltage changing through time. By convention, the horizontal or X axis represents the time dimension and the vertical or Y axis represents the voltage or signal strength. An oscilloscope is a test instrument which visually displays any electrical signal as a change in voltage through time. A waveform monitor is a specialized oscilloscope which graphically portrays the composite video signal.

In discussing a black and white video signal, the range of the video or picture portion of the entire signal provides an indication of the relative brightness or darkness of the image represented by the signal. A higher voltage level measured on the Y axis indicates a whiter portion of the image while a lower level indicates a blacker portion of the image.

The concept of graphic representation of waveforms is crucial to the understanding of an image processing system. As we will see, the time dimension or time frame of the signal may be extremely brief as in the representation of a single line of the video image which occurs in 1/15,750th of a second; the time frame may also be relatively long as in the representation of a frame of video, a collection of 525 lines which occurs in 1/30th of a second. The basic XY format can also be extended to incorporate a third parameter represented along the Z axis which can be conceived of as a vector extending out into space. This notion is important to understanding the technique of colorization. Woody Vasulka developed a technique using this type of vector diagram to locate parameters of the time frame of a video image, employing the Rutt/Etra Scan Processor. This graphic representation defines the line rate, field rate and intensity information.

A waveform can be described in terms of its shape, the number of times it repeats per time unit, its strength, placement and direction.

A waveform may begin at any point but when it returns to the point past which it started, the waveform has completed one cycle. Cycle refers to the completion of one rise, fall and return of the signal. It is important to note that the waveform may pass through a number of times the particular voltage at which it began before one cycle is completed. For example, the **sine wave** begins at the point exactly half way through one cycle before ending at this value at the second cycle after beginning. The time it takes for one waveform to be completed is called the period of the waveform. The term periodic refers to a waveform wherein a regular, repeating pattern is observable as the voltage changes through time; **sine**, **square**, and **triangle** are all periodic waveforms with specific shapes. Sine, square, and triangle are the basic waveshapes which can be combined with each other to produce complex waveforms. As we will see, the sine wave is actually the fundamental form from which square and triangle are derived.

Noise refers to a signal which is not periodic but random in nature, with unpredictably varying signal strengths; it is often defined as extraneous information present in the signal which is determined to be undesirable either through the process of comparing the signal to a reference signal or by personal decision. Noise can be manifested either aurally or visually and can also be used as a control. Snow is an example of video noise; snow is a random organization of monochromatic blotches and is part of the vocabulary of image processing because it is used as an image element in composition in much the same way that audio noise is used in electronic music composition.

The number of times a waveform is repeated per unit of time is called the **frequency** of the waveform; frequency then implies the speed of the signal. The number of cycles the signal completes in one second is measured in cycles per second expressed in **Hertz or Hz.**

The **amplitude** of the signal refers to the maximum strength attained by the signal. It is measured by the height of the waveform expressed in volts. The signal may have both a positive and negative voltage dimension. The reference line of zero volts is called ground. The total voltage excursion of the signal, obtained by the addition of the maximum positive and maximum negative points reached by the signal, is referred to as peak to peak voltage and is abbreviated **Ppv**.

The term **gain** defines the total peak to peak voltage excursion of a given signal and indicates the relative strength of the signal. An increase in the gain of the signal causes an increase in the signal level and conversely, a decrease in the gain results in a decrease in the signal level; gain thus equates with the amount of amplification of the signal. It expresses the ratio of the amplitude of the input signal to the amplitude of the output signal.

The term **attenuate** means to reduce in force or intensity; with respect to an electrical signal; attenuation refers to the lowering of the amplitude of the signal with respect to ground. Instantaneous amplitude refers to the distance between a specific point in the waveform and the base line or ground and is expressed in **volts**.

The signal can be further defined by its positive and negative voltage dimension. An AC or alternating current refers to a signal which has both a positive and negative voltage dimension. An AC voltage rises to a maximum point and then falls through zero to a negative voltage level which is equal in amplitude to the maximum. A DC or direct current voltage does not change direction; the signal does not vary and is always either positive or negative. Polarity refers to the existence of two opposite changes, one positive and the other negative. When a signal is inverted, the polarity of the signal is reversed. Positive signals become negative and negative become positive. In the case of a black and white picture signal, all the black become white.

The term **bias** indicates the repositioning of the signal relative to ground; the absolute amplitude and frequency of the signal are unchanged. The term **phase** refers to the relative timing of one signal in relation to another signal. If one signal is "in phase" with another, they both possess identical timing and have begun at the same instant.

A waveform may also be frequency and amplitude modulated. In amplitude modulation, the amplitude of the signal, called the carrier waveform is determined by the amplitude of a second control signal called the modulating signal which is input to a function generator. In this case, the frequency of the output remains the same as the normal output. The amplitude of the modulated or output signal changes in proportion to the amplitude of the modulating or control signal. In frequency modulation, the amplitude of the output signal remains the same as the normal output signal but the frequency of the output signal is determined by the frequency of a second signal, the modulating signal, which is fed into the function generator. The change in frequency of the modulated signal is proportional to the amplitude of the modulating or control signal. **Modulation** refers to the process of changing some characteristic of a signal so that the changes are in step or synchronized with the values of a second signal as they both change through time.

In the process of **filtering**, certain predetermined information is masked off, allowing a specific portion of data to pass through unchanged while the remaining is eliminated. Most commonly, filters act on frequency ranges although they can also act on amplitude ranges. For example, a low pass filter cuts off high frequencies while passing low frequencies, while a high pass filter rejects low frequencies and passes high frequencies. The cut off frequency value can usually be controlled either by manual adjustment or with the technique of voltage control. A variable pass filter is actually a low and high pass filter working in series. The frequency range which passes is located between the cut off levels of the high pass and the low pass filter. The reverse process operates in a notch or band-reject filter. When the cut-off frequencies of both high and low pass filters connect in parallel overlap, the frequencies located between the two cut-off frequencies are rejected.

Signals can be further specified as **analog** or **digital** structures; the terms refer to ways of representing or computing changes which occur during an event. On a basic level, an analog signal is frequently explained as describing an event, a voltage for example, which continuously varies within its allowable range, ie. a thermometer. The measurement of the temperature is limited only by the resolution of the scale and how accurately the scale reading can be estimated. The position of the mercury relative to the scale markings must be estimated. Analog indicates that the signal as measured on a scale represents or is analogous to the information related by the signal. In a sense the scale represents the event. Analog devices use information which is constantly varying; within the allowable range, any value can be input or output. Conventional video cameras are analog systems; the video signal continuously varies and represents a pattern of lights and darks at which the camera points. A video monitor is also an analog device, but the representation flow is reversed in direction. The pattern of lights and darks, the image on the screen, represents a continually varying voltage, the video signal. A sine wave is also an example of an analog signal. The sinewave oscillator is an analog system which is specialized; it always produces a specific waveshape, the sine wave.

Digital signals are frequently explained as signals which describe information consisting of discrete levels or parts. Digital signals are concerned with stepped information; the change from one value to another in a waveform does not vary continuously but, with some qualification, occurs instantly. Digital devices are constructed from switches which have only two states; they are either on or off, open or closed. All of the various voltage levels in a digital waveform must be expressible by two numbers, one representing the off, closed or low state; and the other representing the on, open or high state. One point of an event or voltage can be represented as a series of open or closed switches; the number of open and closed switches is counted, and this information is translated to one value. A number of these values can thus be constructed which will eventually plot a complete waveform. A digital waveform then has a stepped, square-edged appearance; the **square wave** is a simple example of this type of signal.

Several number places may be required to express a complex digital signal. If we have a number with one place and each place can only be a zero or a one, then we can use this number to express one of two states; 0 and 1. If we have two places and each place can be either zero or one, then we can express four different states: 00, 01,10, 11. The number places are called bits, a contraction of binary digits. The large number of combinations mathematically possible using only two numbers and a given number of places allows for the expression of many signals. Many electronic image processing systems have both analog and digital components and are often described as hybrid systems. It is important to note that with analog signals the waveform or one characteristic of the waveform is manipulated. With digital signals, the information about the waveform is altered and then used to reconstruct the waveform.

A signal then conveys certain information about an event. It contains a number of variables, such as frequency, amplitude or placement which can be changed and controlled. Control over these variables is an issue central to electronic image processing. Whether achieved by manual or automatic means, control is exerted on a signal which defines an image and not the image itself. The achievement of control over the signals which define images is important to the use of electronic imaging as an art-making medium.

A **potentiometer** or **pot** offers manual control over voltage through the adjustment of a knob. A familiar example of a pot is the volume control on a television receiver. Turning the knob results in an increase or decrease of the amplitude or the audio signal and thus an increase or decrease in signal strength or loudness. A pot allows only a continuous type of change over a signal. It is not possible to move from one discrete setting of a pot to another without proceeding through all the intervening voltage levels. On a basic level, a pot provides a method of manual control over the signal; the rate of change can be altered but is limited by the speed at which the knob can be turned by hand and the process of change is always continuous. A pot has three connection points or terminals. Two of the terminals are connected to a material which resists signal flow. The position of the third terminal, called a wiper, is adjustable along this resistive material. By changing the position of the wiper by manual adjustment of the knob, the amount of resistance to current flow is changed and therefore the signal. Frequently pots are calibrated, often by a series of relative number settings; because the change is continuous, the resolution of the scale to some extent determines the accurate repeatability of the manual setting.

Control over signal parameters can also be achieved by exerting an automatic rather than manual control over the pots. The technique of voltage control in effect allows the pots to be adjusted by another voltage rather than by hand. The principle of voltage control is the control of one voltage, often called the signal voltage, by another voltage, the **control voltage**. If the control voltage frequency is within the range of human hearing the signal can function both as a control voltage and as an audible sound; this dual role for signals and the resulting relationship between image and sound is a technique used frequently in electronic imaging. By use of control voltages the problem of continuously varying changes is overcome; one can move between discrete values without having to proceed through intervening values.

Control voltages can be periodic or non-periodic waveforms. Because they are signals, control voltages themselves can be processed by techniques such as mixing or filtering or can be amplitude or frequency modulated before they are used as control signals. Control voltage signals can exert influences on audio signals, video signals or other control signals. They can be generated by voltage control modules, audio synthesis equipment, or computers.

SYNC: In video, the image is actually an electronic signal. This video signal has two basic parts: The section containing picture information, and the section containing sync information. Synchronization is derived from the Greek *syn* and *chronos*—to be together in time; the term implies that several processes are made to occur together in time at the same rate so that they are concurrent. For a coherent picture to be formed which is easily readable to the eye and brain, the scanning motions of both the image or signal generating device, for example a camera, and the image or signal display device, the monitor, must proceed in an orderly and repeatable manner. The scanning processes in both camera and monitor must begin and end at precisely the same time. The camera and monitor must be synchronized. As the camera begins scanning the objects in front of it, the monitor begins to scan the line which the camera is scanning. As the camera ends the scan line, the monitor must also end that line. When the camera reaches the bottom of the field, the monitor must be exactly in step. Without this synchronization, the camera image and the monitor image will have no relationship to each other. **Horizontal sync** maintains the horizontal lines in step; without horizontal sync the picture will break up into diagonal lines. Horizontal sync tells the camera and monitor when each horizontal line begins and ends. **Vertical sync** also keeps the picture stable; without this, the image will roll. Vertical sync tells the camera and monitor when each field begins and ends. Both together are essential to a stable rectangular shape. Sync then can be conceived of as an electronic grid which provides horizontal and vertical orientation to the image.

Each visible line forming the raster is drawn from left to right across the CRT. Before beginning the next line, the beam must return to the left, and this return must be invisible. During this horizontal retrace period, the beam is blanked out; this process and the time interval necessary to perform this function are called **horizontal blanking**. Horizontal blanking is a part of synchronization. At the end of each field the beam must return from the bottom to the top of the CRT before beginning to scan the next field. Again, this vertical retrace is not seen. This process and the interval are referred to as **vertical blanking.** Vertical blanking is also a part of synchronization.

Each of these blanking intervals includes information necessary to maintain proper timing relationships between camera and monitor so each begins scanning line and field at the same moment. The information which is contained in the blanking intervals is not picture information. The blanking intervals contain the timing signals which are called sync pulses. These sync pulses keep the images stable and accurate in terms of color.

Sync thus indicates a synchronization process. A number of sync pulses are required by an electronic image processing system. Normally these sync pulses are provided by a sync generator, a separate device external to the system which provides the same timing signals to each of the discrete devices within the system which need sync to operate. The single external sync generator provides identical sync signals to all of the cameras within the system.

One complete horizontal line includes both the visible picture information and also horizontal blanking. Within the period of horizontal blanking the horizontal sync pulse occurs. The horizontal sync pulses occur on each line during the horizontal blanking interval and before the picture information of that line is displayed. After the beam has scanned one line, the beam is blanked out in preparation for the next scan; it is during this interval that the horizontal sync pulses are inserted. They insure that the line just scanned by the camera can be accurately reproduced by the monitor and tell the monitor when each line is to be scanned. One complete horizontal line is scanned in 63. 5 microseconds, or .0000635 seconds. The visible picture portion of this line takes approximately 52.7 microseconds. The remaining time, 10.8 microseconds, is the horizontal blanking period. The blanking period consists of the front porch section which is approximately 1.27 microseconds, the horizontal sync pulse and the back porch section each of which are approximately 4.76 microseconds. The back porch is approximately 3.5 times as long as the front porch.

The vertical sync pulses occur within the blanking interval at the beginning of each field. The first 21 lines of each field consist only of timing information. They do not contain any picture information. They are collectively known as vertical blanking. The following 241.5 lines of the CRT are scanned, and then the beam has traced all of the picture lines. The period of time it takes for the beam to return to the top after each field is scanned is called vertical blanking, approximately 1330 microseconds long, much longer than horizontal blanking.

The first series of pulses to occur during the blanking interval are six equalization pulses. These are followed by the vertical sync pulse serrations, which are followed by another series of six equalization pulses. The duration of each set of pulses or three horizontal lines, is abbreviated 3H. The frequency of the equalization pulses is twice the horizontal frequency. These equalization pulses help to maintain the interlace between fields and also help to keep the oscillators which control the horizontal scanning in step during the time in which no lines are being scanned. The equalization pulses insure that the vertical deflection occurs at the same time as vertical sync. They also keep the horizontal deflection in step.

The vertical sync controls the field-by-field scanning process performed by the electron beam and also maintains the horizontal oscillator in step. The function of the vertical sync pulses is to indicate to the monitor when each field has ended so that the camera and monitor begin and end each field in direct relationship to each other. The vertical serration pulses help maintain proper horizontal frequency during the vertical interval. The frequency of the serration pulses is twice the horizontal frequency. The horizontal sync pulses which conclude the vertical blanking interval also help to keep the horizontal oscillator in step during retrace.

In order to achieve interlaced scanning, each field contains a half line of picture information. The line preceding the vertical interval of the odd field is one complete picture line. This line is the last line scanned in the even field. The vertical interval, occupying 21 H lines, then follows. The first picture line of the odd field which follows the vertical interval is one full picture line. 241.5 picture lines follow. The 21 lines of the vertical interval and the 241.5 lines of the picture information total the 262.5 lines needed for one field. The last 1/2 picture line of the odd field then immediately precedes the vertical interval for the even field.

The odd field, as noted, is preceded by one complete picture line, the last in the even field. The vertical interval for the odd field begins with six equalization pulses occupying 3H. Six serration pulses follow, also occupying 3H lines. After the next six equalization pulses, the horizontal sync pulses occur. The first of these occupies 1/2 line. It is here, in part that the off-set relationship occurs which provides for interlaced scanning. Eight to twelve horizontal sync pulses without picture information conclude the vertical interval. Following the 21st line of the vertical interval is the first picture line of the odd field, a complete horizontal line. The odd field scans 241 complete horizontal picture lines and ends with 1/2 picture lines.

The vertical blanking period under broadcast conditions contains two additional signals which are used for reference and testing. The first, called the **Vertical Interval Reference** or **VIR** signal, is added to line 19 of both fields to maintain the quality of the color transmitted. Certain color receivers are now made which use this signal to automatically adjust hue or color and saturation. The second signal, called the **Vertical Interval Test**, or **VIT** signal, is used as a test signal to evaluate the performance of equipment and appears on lines 17 and 18. Other information can be coded into the vertical blanking interval, including program subtitles for hearing impaired individuals. The captions, provided in 1980 by several of the networks and PBS, appear on the screen as text when used with user-purchased decoders. Other systems can provide data such as weather, sports and news reports.

Sync and drive pulses are the timing pulses which keep one or several cameras in step with each other and with the videotape recorder or monitor. In a single camera system, sync can be obtained from the internal sync generator built into the camera. The video and sync information together are then sent to the deck or the monitor. In a multiple camera system, the internal sync generator in each of the cameras cannot be used to send timing information to the rest of the system. All cameras must receive the same sync signals from a common source at the same time, from a sync generator external to all of the cameras. Video or picture signals from all the cameras are then mixed in the processing system and combined with sync information. This single composite signal, containing both picture and sync information, is sent to the deck to be recorded.

A black and white sync generator usually supplies horizontal and vertical drive pulses, composite blanking which includes both horizontal and vertical blanking, and composite sync which also includes horizontal and vertical components. The function of the sync pulses is to indicate to the camera or monitor when one line, in the case of horizontal sync, or one field in the case of vertical sync, will end and the next begin. The blanking pulses make sure that the retraces, both horizontal and vertical, are not visible. Drive pulses control the timing of the beam's scan.

The color sync generator supplies horizontal and vertical drive, composite sync and composite blanking and two additional signals variously called **burst** or **burst flag** and **subcarrier** or **3.58 MHz**. Color signals must carry all color information, including the hue, brightness and saturation of the colors, by the use of three primary colors: red, green, and blue. In addition, their structure must be such that they are compatible with black and white systems. A color signal must play on a black and white television with no interference. Color signals must therefore contain both **luminance** and **chrominance** information. Luminance conveys the variations of light intensity and is the part of the signal used by the black and white monitor. Chrominance conveys variations of hue, saturation, and brightness.

The subcarrier signal, with a frequency of approximately 3.58 MHz, carries information about color value. This frequency is produced by an oscillator in the sync generator, and is modulated or changed by the color information coming from the color camera to the colorizer in the image processing system. The ways in which the subcarrier is changed convey information about the color, its saturation and hue. For example, changes in the phase of the chrominance signal indicate changes in hue.

In order that changes in phase, for example, and the resulting changes in hue can be identified, a reference signal is required. The burst signal supplies 8 to 10 cycles of the 3.58 MHz subcarrier frequency without any color information. This serves as a reference point to establish the phase relationship of the subcarrier signal before it is modulated and starts to carry color information. The burst signal is located on the back porch of each horizontal blanking pulse. It is not present after the equalization or vertical pulses of the vertical interval. The average voltage of the color burst signal is equal to the voltage of the sync signal. Burst then helps to synchronize color.

The horizontal drive signal occurs at the rate of 15,750 Hz. Its duration is 1/10th of the time it takes from the beginning of one horizontal line to the beginning of the next, or about 63.6 microseconds. Vertical drive occurs at the rate of 60Hz and lasts for about 666 microseconds. Both pulses are sent to the cameras to control horizontal and vertical deflection circuitry, that which dictates the scanning processes.

Horizontal and vertical blanking pulses are pulses which make invisible the retrace lines which occur as a line or field is ended and the beam returns to begin the next trace. Vertical blanking lasts about 1330 microseconds and horizontal blanking about 1 microseconds. Composite blanking with the addition of the video signal is sent to the monitor to blank out the vertical and horizontal retraces. The camera usually is not supplied with vertical and horizontal blanking because the horizontal and vertical drive pulses can accomplish the same function. It is during the blanking intervals that horizontal and vertical sync occur. Horizontal blanking and horizontal drive control the direction and speed of each of the beam's horizontal traces and retraces. Vertical blanking and vertical drive control the change from one field to the next.

The sync signals tell the camera or monitor when the scan is to change. Horizontal sync controls the beginning and end of each horizontal line. Vertical sync controls the beginning and end of each field. It assists in keeping the monitor in step or in sync with the camera. In a multiple camera system it also keeps all cameras synchronized with each other. Some cameras use sync rather than drive signals to produce the deflection signals which control the beam's scanning processes.

Line frequency, or 15,750 Hz, is produced in the camera and monitor by crystals which oscillate or vibrate naturally at the speed of 31,500 Hz. This rate is then divided in half electronically to produce the required 15,750 Hz frequency.

The **field frequency** of 60 Hz can be derived by dividing the line frequency by the number of lines (525). These pulses can then be sent to the horizontal and vertical deflection circuits of camera and monitor to insure proper scanning.

Line and field time base stability refer to the precision at which the line and field frequencies operate. Exact operation is essential to the operation of the system as a whole and compatibility between output signals from different systems. The stability of the time base found in small-format recording can be corrected through the use of a time base corrector.

If the signal sent from the camera to the monitor includes picture information, horizontal sync, horizontal blanking, vertical sync, and vertical blanking, then the signal is called a composite black and white video signal. If the sync information is not included in the signal sent from the camera, this signal is called a non-composite video signal.

In a single camera system, the sync generator inside the camera may be used to generate the necessary sync information for recording and display. In this instance, the camera is usually referred to as being on internal sync, and the composite video signal is sent to the recorder or monitor. A single camera system may also be used with a sync generator which is external to the camera. In this case, the external sync generator generates the sync information which is then sent to the camera. The camera in this case is on external sync. Some cameras can operate on either internal or external sync. There is a switch on the camera for selecting the sync option. Many cameras only operate on internal sync. These cameras cannot be used in multiple camera systems. Whether internally or externally locked, signals are produced which drive the deflection systems of the camera and insert the waveform onto the video out signal which causes the monitor to be in sync with the camera.

In a multiple camera system, such as an image processing system, the sync information for all cameras must come from one common source. In a multiple camera system, each of the cameras is sending picture information which will eventually be combined and treated by a variety of image processing devices. Techniques such as mixing, switching, or keying can be employed. None of the cameras in the system is generating its own sync information. A common sync source is sending identical sync information to each of the cameras in the system. The camera then sends back to the system a composite video signal containing both picture and sync. If each of the cameras in the system were to generate its own sync, there would be no consistent timing information throughout the system. It would then be impossible to achieve a stable image. In an image processing system the sync generator which sends sync to all of the cameras is usually external to each of the other components in the system. One common source sends the same information to each of the cameras.

The monitor or deck receives a composite video signal from the system which includes: picture information, horizontal and vertical blanking, horizontal and vertical drive, and horizontal and vertical sync as well as the signals needed for color. The blanking, drive and sync information are used to control the deflection of the scanning beam, so that the image displayed is a stable and faithful representation of the camera images.

The sync generator then serves as a master clock which establishes the time frames for the signals which, when decoded, produce images. The sync generator insures that the scan and retrace processes for both horizontal and vertical in both camera and monitor occur at the same intervals with respect to video. The sync generator also provides blanking signals, both horizontal and vertical, which are added to the video waveforms. If the sync generator also supplies timing signals to drive the deflection systems of camera and monitor which then maintains the phase relationships between horizontal and vertical scanning, the 2:1 interlaced scanning is achieved. If 2:1 interlaced scanning is not present, the sync is termed "industrial" or random.

If the horizontal and vertical signals are not locked together in phase but are derived independently, then random interlace scanning results. In this type of scanning, the horizontal lines in each field are not in any fixed position and are not evenly spaced. Occasionally because of this lack of even horizontal positioning, horizontal lines may be traced on top of each other. This results in the loss of picture information contained in the superimposed lines and a degradation of the picture. This is called line pairing.

During the vertical sync period, it is necessary that horizontal information be supplied or the horizontal oscillator in the monitor may drift. The frequency corrections to that oscillator which are then needed following the vertical sync period may cause flagging at the top of the image. Flagging appears as a bend toward the left or right in the first several lines of the image.

VIDEO SYNTHESIZERS: A video synthesizer or "image processor" is a general term referring to an assemblage of individual video signal sources and processors, all of which are integrated into a single system. There are three general categories of devices: 1) **signal sources**—devices which output a signal used in the system to generate an image, a control signal or a sync signal. 2) **processors**—devices which perform some operation upon the signals, such as gain or phase changes, and are often used to mix inputs and put out combined or processed signals. 3) **controllers**—devices which generate signals which are themselves inputs to processing devices to control an aspect of the image. These devices can be analog or digital in nature.

A video source is any device which internally generates a signal that can be displayed, and includes cameras, decks, character generator or oscillator. A processor is a device which either changes the parameter of the incoming signal (e.g. gain, polarity, waveshape) or combines two or more signals and presents them to the output (e.g. mixing, switching, wiping). Video processors include keyers, VCAs, mixers, colorizers, sequencers, SEGs and frame buffers. These terms are not absolute but have meaning relative to one another. A signal can be routed through processors in a linear order.

Signals have direction: that is, they are originated, are passed through devices and eventually wind up at a device which transduces, or changes, the signal into a form of information that is directly meaningful to our senses. In the case of video, the electrical signal is changed into information by the video monitor which our eyes understand as light and ultimately pictures. The video image itself does not travel through the machine, rather it is an electronic signal which represents the image that travels. This signal originates in a video camera or some other type of signal generator such as an oscillator in an analog synthesizer.

The three main types of image processing signals are: 1) video signals—those which contain the complete information necessary for a monitor to construct an image 2) sync signals—those containing structural, rather than picture, information, which when combined with picture information allows it to be stable and rectangular. 3) control signals—those which contain information for the control of processes.

An image processing system is then a collection of devices the structure of which includes: 1) sync, 2) routing, 3) an output amplifier, 4) a method of monitoring, 5) a method of control.

Termination: A commonly used video connection scheme is the looped-through input, sometimes called a bridged input. This set-up facilitates ease in formulating multiple connections while maintaining the ability to "terminate" the video signal. Termination is required at the farthest input. This is usually done by connecting a terminator to the remaining bridged connector. Sometimes a switch is provided on a monitor input for termination, labelled "75 ohms" in one position and "high" in the other. The 75 ohm position is the terminating position.

Genlock: Sometimes it is desirable to take as an input to the image processing system a video signal from a pre-recorded videotape. Since the sync from the source is controlled from the point of origin (the VTR) it is necessary to "lock" the system sync to the sync from the source. A genlock is required for this operation. Genlock is also used for cameras which are not externally syncable. This includes most consumer cameras. The output of the camera goes to the genlock input of the SEG and the system will lock to the internal sync of that camera. A VTR cannot be used as a direct source once the genlock is occupied by the camera.

Three devices are used to check the signal coming from the output amp: The **waveform monitor**, **the vectorscope**, and the **color or black and white monitors**. These are also used to compare the signal at different points in the path.

The waveform monitor does no processing of the video signal. It allows us to examine the quality of the video signal by giving us a graphic representation of the voltage of the video signal with respect to time. The waveform monitor is really a special purpose oscilloscope. Vertical distance on the waveform display represents voltage, while horizontal represents time. There is a choice of "strobe" times so that one field or line of the video signal can be observed.

Normally, the waveform monitor is set to display two horizontal periods, or two lines of video. What is seen is actually an overlay of many different lines. Within this, you can see the luminance and black level of the signal as well as the stability of the sync. Other settings show the vertical scan period and an enlarged view of color burst.

A vectorscope shows the color portion of the video signal. It uses the convention of a color wheel to represent the signal. Chroma, or saturation, is indicated by how far the signal extends from the center. It should not exceed the outer circumference of the circle of noise which may appear in the recorded signal a few generations later. The hues are marked at specific points initialed M (magenta), R (red), G (green), Y (yellow), B (blue), and C (cyan). The vectorscope has a phase adjustment which places burst at 180 degrees. At this setting when color bars are patched to its input, the signal's six points will correspond to the marks.

There are several types of color monitors. There is also a bank of four black and white monitors, used as preview monitors. Their inputs are routed from four separate points on the matrix and are used to look at primary image sources, for example, cameras. They can also be used to look at the output of modules in various stages of a patch. They do not indicate the signal coming from the output amp.

Every module that you pass a color signal through will change the phase of that signal. Since the output amp is always the final destination, you can readjust the phase to compensate for hue changes.

When mixing a live camera or color genlock tape with the colorized image, consider the last module in the system where the two signals will be combined. Looking at the module's output through the output amp, adjust the phase control so that the "real"color is correct. Then adjust the hues of the colorized signal with the controls on the colorizer.

Some modules will generate noise at their outputs when a color signal is routed through their inputs. These include the clip inputs to keyers and the inputs to the frame buffer. The noise with the keyers may generate useful effects. Do not use a color signal as input to the buffer. A color kill is used with a separate input and output on the matrix. This strips the chroma and the original color signal still available from its point on the matrix. A monochromatic version to the signal is also available at the output of the matrix for routing into the buffer and key clips if desired.

A **sequencer** is a multi-input device which switches from one input to another automatically. The number of inputs and rates of switching vary with the device.

Keying is a process of graphically combining video signals. It originally was developed in the television industry for the purpose of electronically imitating a filmic technique known as matting. In this context, the most conventional use has been to take two camera images and juxtapose them in a way which creates the illusion of a single, continuous three-dimensional space. Thus keyers are often referred to in terms of placing one image "behind" an object in a second image or of "inserting" an image "Into" an area of another image. Using a keyer, you can create a shape in a first image, by defining the gray values that comprise that shape, and then remove all portions of the image within the boundary of that shape. Into that hole you can then insert the portions of a second image which spatially correspond as if the two images were to be superimposed. The development of a keyer as a three-input device, with voltage controllable parameters as well as its use in an image processing system necessitates a broader understanding of the functions of a keyer.

There are three channels in the luminance, or black and white, keyer: Two main channels, A and B, and a clip input. Each of the main channels is a VCA or voltage controlled amplifier, which sends the incoming signal to the same electronic switch. At any given moment, this switch chooses either signal A or B at its output. The rate of switching is fast, taking place several times within each horizontal line of each frame. The video signal that is going into the clip input controls this switch. A clip level determines a certain threshold point, and the clip input signal is compared to the threshold. It is the voltage levels of the signals that are being compared. When displayed on the raster, these voltage levels become the gray levels of the image. The comparison is being made at each point on each horizontal line. When the voltage of the clip input signal exceeds this threshold point, and the signal is therefore brighter than a predetermined gray level, channel A is presented at the output of the switch. When the voltage of the signal falls below the threshold, and is therefore darker than a certain gray level, channel B is seen. Moving the clip level control knob clockwise increases the threshold point. This allows more of B to be seen than A. Thus channels A and B will always be on opposite sides of the clip edge. A key reversal simply exchanges the positions of channel A and B relative to this threshold point.

The conventional use of a keyer as a matte device is a specific case in which one of the two signals going into the VCAs is also being used as an input to the clip channel. This technique is often referred to as **internal keying**. Some keyers are hardwired in a way which allows internal keying only. When a third signal, separate from either of the VCA input signals is patched to the clip input, this is called **external keying**.

Split-screens are a specific application of external keying. An externally-synced oscillator is used as the clip input signal to switch between the two main channels. A continuous change in the threshold point, or clip level, from low voltage to high voltage, or vice versa, is often called a **wipe**.

A **colorizer** takes as its input a black and white video signal, then adds color in a fashion according to the type of colorizer. Usually a colorizer unit contains other video processing as well, such as negative video, keying, mixing.

A chronology of the activities at the Experimental Television Center, Binghamton, New York, 1971-1978, founded by Ralph Hocking and currently under the direction of Ralph & Sherry Miller Hocking.

1972

NYSCA funding to the Center for construction of Paik/Abe Video Synthesizer. One system was designed and built at the Center by Shuya Abe and Nam June Paik for eventual placement at the TV Lab at WNET-TV in 1972. This system was used while still at the Center to produce a portion of Paik's "The Selling of New York,"included in the PBS series "Carousel," broadcast 1972 by WNET. A second system was built for the Artist in Residency program at the Center and used in '72 by artists such as Ernie Gehr, Hollis Frampton, Jackson MacLow and Nick Ray, and also included in an exhibition at the Everson Museum. A raster scan manipulation device was also constructed, the principles of which were defined by Paik's early TV experiments, such as Dancing Patterns.

1972-73

David Jones became technician at the Center. Artists participating in the Residency program included Taka Iimura, Doris Chase, and Michael Butler. Workshops in imaging were held regularly at the Center, and also at Global Village and at York University in Toronto. Oscillators were designed for use as signal inputs to the synthesizer. Initial research into the Jones gray level keyer and production of a black and white keyer. Modification of an existing SEG for direct sync interface with the Paik/Abe with provision for external wipe signal input.

1974-75

Workshops and performances based on image processing were conducted at The Kitchen, Anthology Film Archives and the Contemporary Art Museum in Montreal. NYSCA supported a series of travelling performances by Walter Wright on the video synthesizer. Over ten organizations throughout New York State and Canada took part. The workshop program at the Center continued. NYSCA provided funding for the development of the Jones Colorizer, a four channel voltage controllable colorizer with gray level keyers. The oscillator bank was completed and installed. The SAID (Spatial and Intensity Digitizer) was developed by Dr. Don McArthur (April 1975) as an outgrowth of research on b/w time base correction. Work was begun by David Jones, Don McArthur and Walter Wright on a project to explore computer-based imaging, and the interface of a computer with a video processing system. Artists-in-Residence included Neil Zusman and Gary Hill.

1975-76

The Residency Program included artists Nam June Paik, Phil Jones of Ithaca Video Projects, Ken Marsh and Ken Jacobs. The NEA in 1975 provided support for initial research into the computer-video processing project, which was expanded by Jones, McArthur, Wright, and Brewster to incorporate parallel research efforts by Woody and Steina Vasulka, and Jeffrey Schier. The LSI-11 computer was chosen as the standard. Jones developed hard and soft-edged keyers and a sequential switcher, which along with the Jones Colorizer was incorporated into the processing system. A commercially available SEG was modified to incorporate these keyers. A 64-point push button switching matrix was designed and built. We began to write a manual, developed initially to be used as a operator's guide to 1/2" reel-to-reel equipment, portapaks, editing equipment, and the like. The concept was later broadened to included step-by-step construction information on a Paik Raster Control Unit. By 1985, the information was expanded to include systems structure and theory of electronic signals and processing techniques. These manuals have been distributed to many individuals and organizations over the years. Cloud Music by David Watts, David Behrman, and Bob Diamond was presented at ETC.

1976-77

Artists such as Barbara Buckner, Aldo Tambellini, Nam June Paik, and the ADA continued to participate in the Residency Program. The computer project continued. The exhibition series, Video by Videomakers, was begun, introducing to this region video works by Beryl Korot and Barbara Buckner. The computer was installed as part of the system and made available to artists; software research began. For the second year, we conducted a series of workshops in school districts throughout the region, in collaboration with Binghamton's major arts center, the Robertson Center.

1977-78

NYSCA funding helped support the development by Jones and Richard Brewster of the Analog Control Box allowing the production of electronic sounds and also signals which controlled parameters of the video signal. The computer project proceeded, assisted by Paul Davis, then director of the student computer lab at the School for Advanced Technology at SUNY-Binghamton. Artists-in-Residence included Shalom Gorewitz, Sara Hornbacher, Hank C. Linhart, and Hank Rudolph. We conduct workshops for the City of Binghamton, Headstart, Tri Cities, 4H Program, and Center for Media Studies.

1978 TO PRESENT

Due to the historical nature of the exhibition, this listing only covers the early years. However, since 1978, the Center has continued their active programming based upon their mission as described.

R&D Program Concepts:

1. Modification of existing equipment: to expand its capabilities in order to bring out all possible controls to the artist.
2. Design and construction of image-processing equipment: to expand the Center's system; to make equipment and/or information available to individual artists.
3. Development of print information and educational strategies to teach artists and others the principles of image processing; to encourage artists to approach video as a directly mediated art practice; to encourage artists to use tools themselves in art-making ; to encourage artists to build or purchase equipment for their personal studios.
4. Design considerations: Flexibility; low cost; ease of use; greatest number of possibilities for image and sound generation, manipulation and control.