$3.00

APPLICATIONS OF OEI 3-D DISPLAY MODULES

2nd EDITION

OPTICAL ELECTRONICS INC.

'YOUR OPTICAL ELECTRONICS FUTURE'

P.O. BOX 11140 · TUCSON, ARIZONA 85734

602/624-8358
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This application book has been published to assist you in your understanding and use of our 3-D display products. OEI Applications Engineering is available to you to answer your questions and give you specific circuit information.

APPLICATIONS OF OEI

3-D DISPLAY MODULES

2nd edition

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INDEX BY SUBJECT

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USING THE 6100 SERIES GRAPHIC DISPLAY

INTRODUCTION. The 6100 series 3-D Graphic Display modules makes an excellent graphic display in a wide variety of systems. This application note describes various types of line images., their generation requirements and basic applications. The 6100 series provides image rotation and perspective depth cues to the image generated by the three input signals.

STRAIGHT LINE. The basic image is the straight line. This is generated by driving only one axis with a signal, grounding the other two. The signal required must produce constant beam velocity to maintain equal brilliance of all parts of the line. The sinusoidal signal cannot be used for this reason. The triangle signal is the only solution meeting this requirement, hence the triangle becomes the basic waveform for straight line generation.

OEI has published a collection of Application Tips describing circuits used to generate various line images. These are available on request. The 6100 series user can build a library of waveform requirements for various images. Figure 1 shows requirements for a straight line. Any source of triangle satisfies the needs.

DIAMOND. Figure 2 shows the requirements for a diamond shaped image. This is really a square tilted 45°. The two triangles required must be 90° out of phase with each other. They are applied to any two axes desired to get a flat, 2-dimensional image.

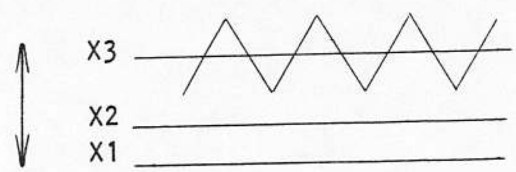


Figure 1. Creating the Straight Line Image.

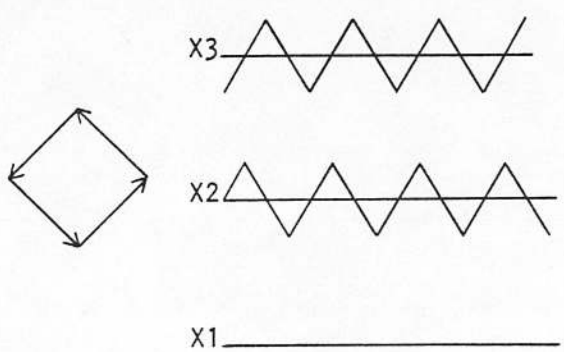


Figure 2. Requirements of the Diamond Image.

CIRCLE. The circle, and other circular images, uses sinusoidal shaped signals. In general, any non-straight line image requires sinusoidal signals (possible in combination with triangles). The sinusoids may be flattened or clipped, etc., to produce the correct signal shape.

The circle is the basic circular image just like the single straight line is the basic straight lined image.

requirements for the circle are shown in Figure 3. Two sinusoids, 90° apart, are ed. The third input to the 6100 series system is grounded. The two phase related gnals must be 90° for a perfect circle. If the phase gle is not 90°, an elliptical shape is created, ewed at an angle to the axes. An ellipse, igned with the axes, requires exactly 90° phase gle, but with unbalanced gains in the 6100 series required.

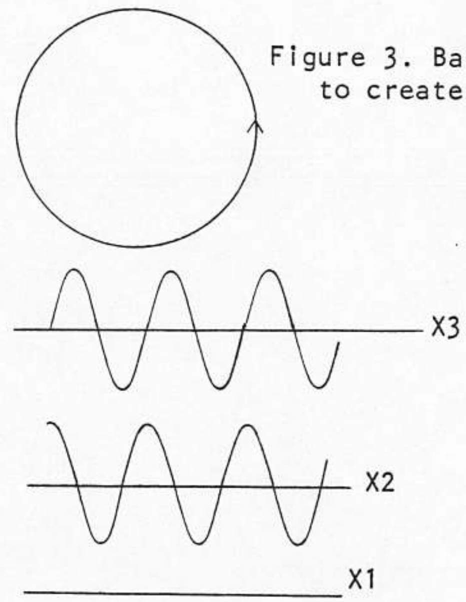


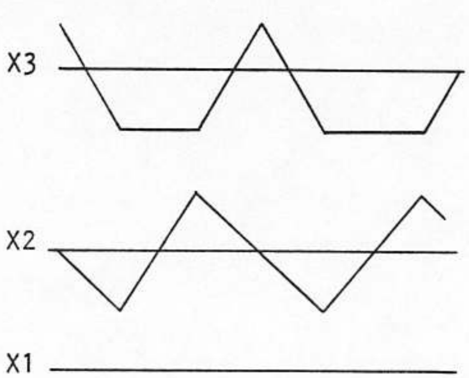
Figure 3. Basic needs to create a circle.

IANGLE. Returning to straight lined images, the iangle poses an interesting challenge to signal quirements. As shown in Figure 4, only two gnals are used, the third input to the 6100 ries is grounded. Both deflection waveforms are sically triangles, however they have been modified. e triangle creating the vertical motion is flattened the bottom peak. The triangle producing rizontal motion must be non-symmetrical with me (faster positive slope than negative slope). e arrows in the illustrated figures indicate the rection of "writing". An analysis of the CRT am strokes caused by the input signals shows e operation and image generation. The two triangles e related in phase as shown in Figure 4.

UARE. The square is much like the diamond in Figure 2 except that it is aligned with axes. The deflection signal requirements are the same as for the diamond except at the peaks are flattened, as shown in Figure 5, on the next page.

e generation of the triangles is identical to the diamond requirement - that is they st be 90° apart, in phase. The two signals are applied to the X2 and X3 axes.

Figure 4. Creating the triangle.



FLAT - 2-DIMENSIONAL IMAGES. In general, all 2-dimensional images are generated with only two deflection signals. All patterns, discussed so far, are flat images existing on a flat plane. By connecting the two signals to various inputs, three possible orientations of the flat image are available. At all times, the third input is grounded. By driving the third input - a solid image is developed. These are described below.

Ask for the Application Tips on Image Generation.

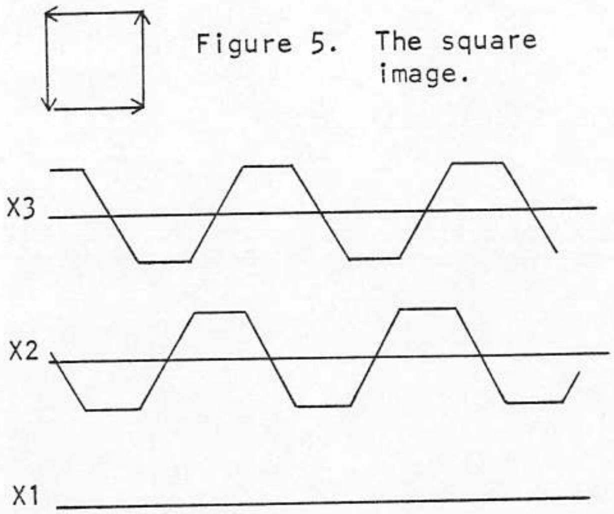


Figure 5. The square image.

SOLID - 3 DIMENSIONAL IMAGES. We have seen what two signals can do toward producing familiar geometric shapes on a flat plane. If a third signal is applied to the 6100 series, deflection perpendicular to the flat image plane will result.

If the third signal is completely unrelated to the original two, plane images are created. Referring to the Straight Line of Figure 1, an ordinary plane will result if the X1 input is driven. This is a flat image because X2 is not driven. If X1 input is driven with the signals of Figure 2, a diamond shaped pipe will be created. Adding X1 deflection to the circle image creates a standard, round pipe image. A triangular shaped pipe is created by adding X1 deflection in Figure 4. A square pipe is created using Figure 5. The length of the pipe is, of course, dependent upon the amplitude of the X1 input signal.

Patterns in and breaking up of the image will result if the X1 signal is related or near the frequencies of the X2 and X3 signals. A safe way to avoid difficulties such as this is to trigger the X1 signal with X2 or X3 and operate X1 100 or 300 times higher in frequency.

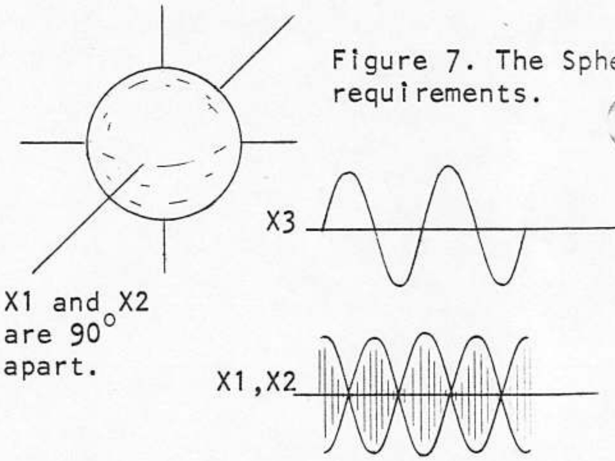


Figure 7. The Sphere requirements.

SOLID CUBE. The simplest 3-D or solid image to create is the cube. Three unrelated signals, as shown in Figure 6, are used from three independent triangular oscillators. What is created can be called a 3-D Lissajous pattern. Characteristics of the cube, such as solidity and line structure, is dependent on the frequencies of the three inputs.

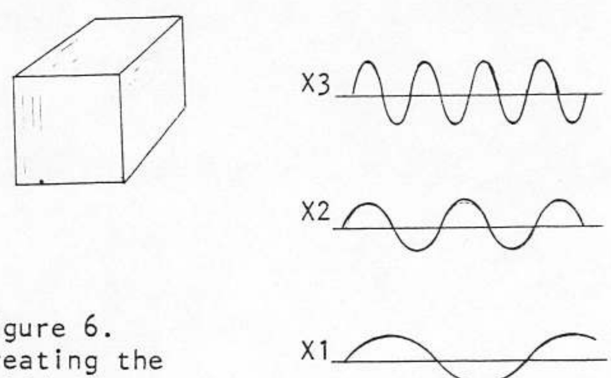


Figure 6. Creating the Solid Cube

SPHERE. Figure 7 shows what is necessary to make a solid spherical image. Being a circular type image, sinusoidal images are used. Actually a sine and cosine are applied to the X1 and X2 inputs of the 6100 series. This generates the circle found at the equator of the sphere. The amplitudes of the sine and cosine are simult eously modified by a third cosine signal that also deflects the X3, vertical, axis. This produces the spherical shape of the image.

Since changing the axes of the deflection signals will not change the image shape, it is not important which axes are used. There may be some line structure to the image, depending on the frequency relationships of the two basic signal frequencies. This line structure may be desired in a particular orientation.

ː GLASS. Figure 8, at the right, shows the ıirements for an hour glass figure. Similarly ᵋ sphere, a sine and cosine signal are ᵋd to the X1 and X2 inputs, producing the c, circular shape. A slower triangle is ı for X3 to develop a uniform vertical ection. That triangle is also used to fy the amplitude of the sine and cosine ıals.

ıriation of the hour glass is the cone. If triangle used in Figure 8 was unipolar, a ː shaped figure would result.

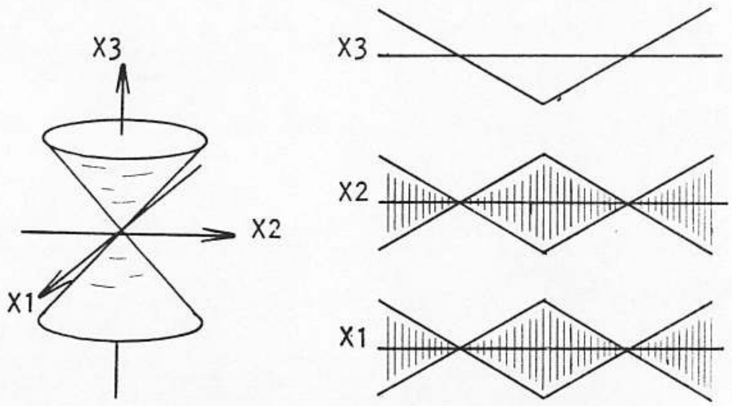


Figure 8. The Hour-Glass

PARABOLIC CYLINDER. Similarly to the cone image discussed above, assume that the bi-polar triangle were made a unipolar parabola by analog squaring techniques. If the parabola were used to modify the amplitude of the sine and cosine signals, and the unipolar triangle to deflect vertically, X3, a parabolic cylinder would result.

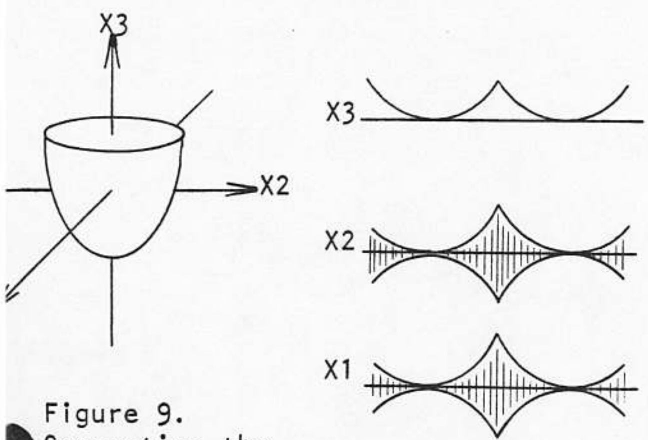


Figure 9. Generating the Parabolic Cylinder.

Analog circuit techniques have been used to generate the images shown in this Application Note. For Figures 5 through 10, below, standard OEI Modules can be used, as described in available Application Tips.

ːINED CUBE. Three clipped triangles are the basic requirements to create the edges or ine of a cube. As shown in Figure 10, two of the triangles are of the same frequency 90° out of phase. The third triangle is 2.5 times lower in frequency and phase related ːhown, to the other two signals. All triangles are clipped on their positive and negative ːs. The accuracy and flatness of the clipping is quite important for good image fidelity.

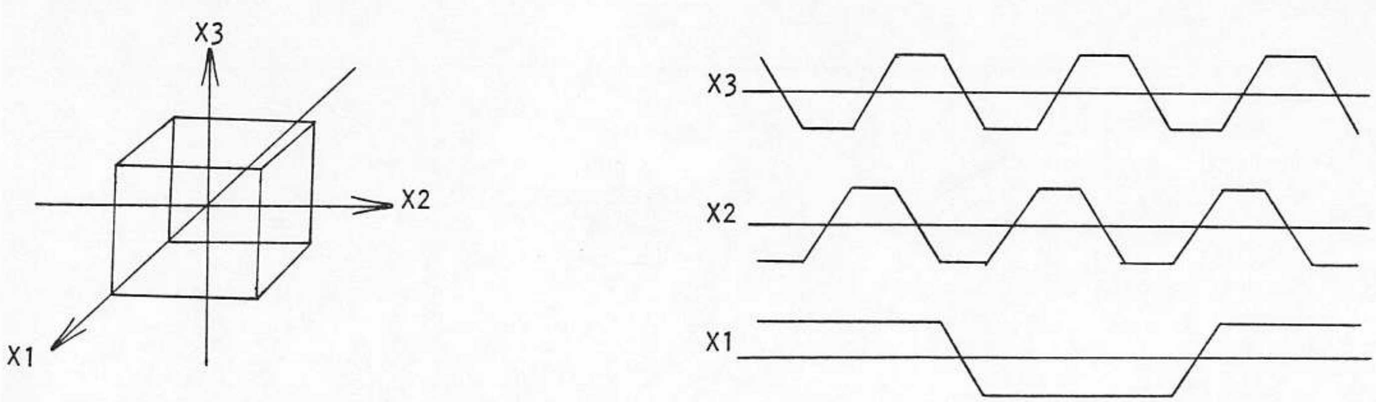


Figure 10. The Outline Cube Image.

GENERAL COMMENTS ON THE USE OF 3-D DISPLAYS

The OEI 6100 series of modules may be used to make over 150 different configurations of 3-D display systems. 3-D displays are used when it is desirable or necessary to show an image having three variables, a solid geometric image, a space scene or any three dimensional image. Two broad areas of application therefore exist for the 3-D display.

IMAGE SYNTHESIS. When it is desired to create a particular shaped image, signal generators are used in combination to produce the three deflection signals. The three generators are manipulated until the desired image is produced.

SIGNAL ANALYSIS. When three signals exist, the 3-D display is used to portray their relationship to each other.

Two basic and, in a sense, opposite applications exist for the 3-D display. Examples of Synthesis include design engineering, mathematics instruction and pattern and character generation. Analysis include testing, display of radar and sonar systems, Spectrum signature and analysis display, vectorcardiogram display.

Whether signals are made to fit the desired image, or the image represents existing signals, the 3-D display system requirements are determined by what amount of depth cues and image manipulation is desired.

Tech Tip 12030

THE PULFRICH FACTOR

In three-dimensional displays there is a phenomena, called the Pulfrich Stereophenomenon, that can produce a stereo effect in a single image with horizontal scanning.

Basically, there is a different time response of the human eye for different luminance levels. If a neutral density filter is placed before one eye, a significant time delay will cause a differential time delay between the two eye responses and a stereo depth impression will result. The horizontally moving point will appear closer for one horizontal direction and farther away for the opposite direction.

While the Pulfrich factor is not used in the OEI 3-D display system, it can be noticable if, for some reason, the observer receives unequal illumination in each eye.

There is also a color effect in the eye which produces a stereo effect. Diffraction in the eye itself causes different colors to be perceived differently. This produces a difference in apparent distance or depth, depending on color alone!

DISPLAYING HYPERDIMENSIONAL IMAGES

The OEI 6100 series of analog modules are used in various combinations to provide a real-time three dimensional image display on a CRT or other device. The display has three deflection inputs resulting in deflection along three orthogonal axes in the image. Thus one system of modules is used to display a three-dimensional image.

Using two of these "systems", as shown below, results in a display having five deflection inputs! *And the deflection axes are all mutually perpendicular to each other!!!* Obviously such an image cannot be displayed because we are in a three-dimensional space world. However, we can show any three of the five inputs at any given time by using the rotation controls to manipulate the five dimensional image.

To illustrate! Four deflection signals will be used to generate a four-dimensional "common" image called the tesseract - a four-dimensional cube having 32 edges! Figure 2 shows the waveform requirements.

A five-dimensional Lessajous pattern is made simply by driving the five inputs with five sinewave oscillators!

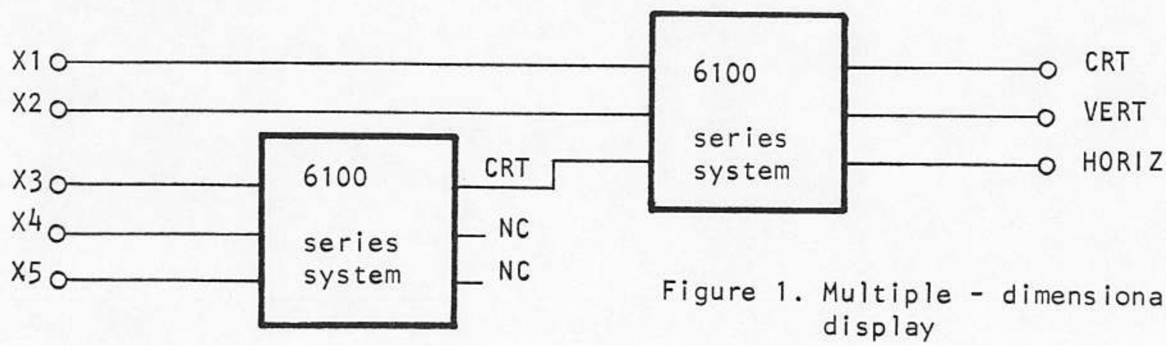


Figure 1. Multiple - dimensional display

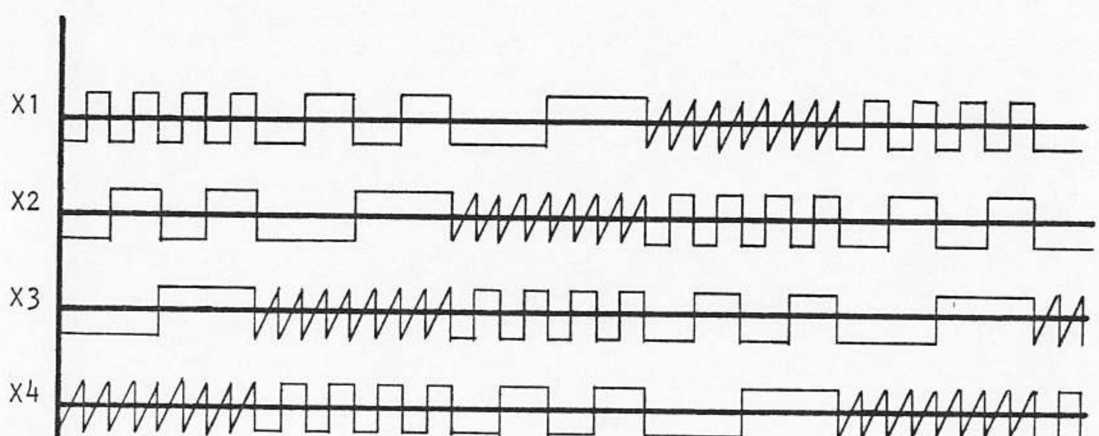


Figure 2. Tesseract deflection waveforms.

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RECORDING THREE DIMENSIONAL IMAGES

Three dimensional images, as portrayed by the 6100 series of 3-D display modules, may be recorded in several ways.

Still photography will capture the image but is not a satisfactory method because the viewer no longer has the ability to rotate, magnify or otherwise manipulate the image. Stereo still photography is better than monocular since one strong depth cue has been recorded. Motion photography with 8mm film is a better means since the image can be recorded under a wide variety of positions and other conditions.

Regardless of the type of film photography used, unless every conceivable image condition is recorded, the method of film storage leaves the future viewer limited in what he can see. It should also be pointed out that the CRT intensity levels and the dynamic range of film are generally not compatible. This results in loss of aerial perspective and over and under-exposed areas of film.

The arguments against photographic storage also apply to the use of storage type CRT displays. Any optical storage of the 3-D graphic image eliminates the possibility of further image manipulation or use of the 6100 display system.

This leaves storage of the image before the 6100 system which, of course, means recording of the electronic deflection signals. The recording of the three deflection signals permits the full use of the 6100 series modules to view the image differently with each playback. Tape speed can be varied to increase the frequency of slow data (biological waveforms for example) or reduce the frequency of high speed data (explosion, impact or failure data).

In addition to recording the three deflection signals, the rotation, magnification, focus, stereo, blanking and other information may be recorded for complete image storage. Another tape "trick" is to use an endless loop to repeat one cycle or one image for study and display purposes.

Tape recording of the 3-D graphic image is also preferred since it generates signals that are compatible with any 3-D system configuration and with other displays.

In addition to tape recording, any means of storage prior to the 6100 series of modules is desired over optical storage. Shift register, drum, core, RAM and other types of memories are well suited to digitally store the image information.

The OEI Model 6710 Buffer module contains digital-to-analog conversion plus recirculating shift register storage for 512 analog points. This type of storage is used merely to remove the burden of image refresh from the digital computer or system generating the image. The 6100 system is still capable of rotation, magnification, etc., regardless of the type of storage, as long as it's before the 6100 system inputs.

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3-D DISPLAY TRANSFER FUNCTION

When the 6100 series of 3-D display system is programmed by external sources (computer, programmer, etc.) it is required to know the transfer function of the various modules. The signal flow can be traced from the X1, X2 or X3 input to the vertical or horizontal output which involves 4 modules at the most.

The 6110A (6111A, 6112A or 6113A) channel amplifier handles the signal several times. At the input there is an impedance transformation and single ended input to differential conversion with a voltage gain of 2. In a complete system, the signal next passes through the magnifier module (6130, 6131, 6132 or 6133) which has a differential gain ranging from 0 to 1. The gain is governed by a 0 to +10V control voltage.

Rotation of the image is next with either the 6120 or 6124. The rotation function for one rotation about the X1 axis is:

$$V = X3\cos\theta - X2\sin\theta$$
$$H = X3\sin\theta + X2\cos\theta$$

For rotation about the X2 axis:

$$V = X3\cos\theta - X1\sin\theta$$
$$B = X3\sin\theta + X1\cos\theta$$

For rotation about the X3 axis:

$$H = X2\cos\theta - X1\sin\theta$$
$$B = X2\sin\theta + X1\cos\theta$$

For rotation about the X2 and X3 axes, two rotators are used to create the function:

$$V = X3\cos\phi - X1\sin\phi$$
$$H = X2\cos\alpha - (X3\sin\phi + X1\cos\phi)\sin\alpha$$
$$B = X2\sin\alpha + (X3\sin\phi + X1\cos\phi)\cos\alpha$$

This assumes that the ϕ rotation (rotation about X2 axis) occurs before the α rotation (X3 axis). If the α rotation is first, then:

$$V = X3\cos\phi - (X2\sin\alpha + X1\cos\alpha)\sin\phi$$
$$H = X2\cos\alpha - X1\sin\alpha$$
$$B = X3\sin\phi + (X2\sin\alpha + X1\cos\alpha)\cos\phi$$

For three rotators, ϕ(X2 axis) first, α(X3 axis) second and θ (X1 axis) third, the transfer functions are:

$$V = (X3\cos\phi - X1\sin\phi)\cos\theta - (X2\cos\alpha - X1\sin\alpha)\sin\theta$$
$$H = (X3\cos\phi - X1\sin\phi)\sin\theta + (X2\cos\alpha - X1\sin\alpha)\cos\theta$$
$$B = X2\sin\alpha + (X3\sin\phi + X1\cos\phi)\cos\alpha$$

Different algorithms may be obtained by changing the rotator connections (changing the rotation sequence).

For other rotation combinations, use the appropriate single axis equations for the first axis rotated. The resultant V, H, B are substituted for X3, X2, X1 respectively in the single axis equations for the second axis rotated. The resulting V, H, B are now used for X3, X2, X1 in the third axis equation.

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MAKING STEREO-PHOTOS USING A MONOCULAR THREE-DIMENSIONAL GRAPHIC DISPLAY

Although the OEI 6100 series is used with an oscilloscope to make an instrument that displays a three-dimensional MONOCULAR display, stereo photographs can be obtained with relative simplicity.

The stereo photo contains two different views of the same image. The two views differ only in parallactic information. Parallax is one of 12 recognized depth cues and is not normally supplied in the monocular image unless the image is being rotated.

Using a camera mounted on the oscilloscope, determine the proper exposure and eliminate the graticule marks. The camera/oscilloscope mount must have a provision to shift the film with respect to the image. If it does not, the horizontal position control must be used as follows:

A. Turn the image (5°) so that the point of view is the right side of the front. Shift the camera or set the horizontal position control so that this image is placed on the right side of the film. Take a piture.

B. After making the first exposure, shift the camera or set the horizontal position control so that the image will be placed on the left side of the film.

C. Rotate the image (5°) so that the point of view is the left side of front. Take a picture.

D. The developed film or print can be viewed as a stereogram. Use a viewer or place a piece of paper vertically between your eyes and the two images. Experimentation with the amount of rotation (parallactic information) and the spacing of the two images will result in perfect stereo pairs for viewing.

Model 6170, one of the 6100 series building blocks will create a true stereo image by implementing steps A, B and C in one image, requiring one exposure.

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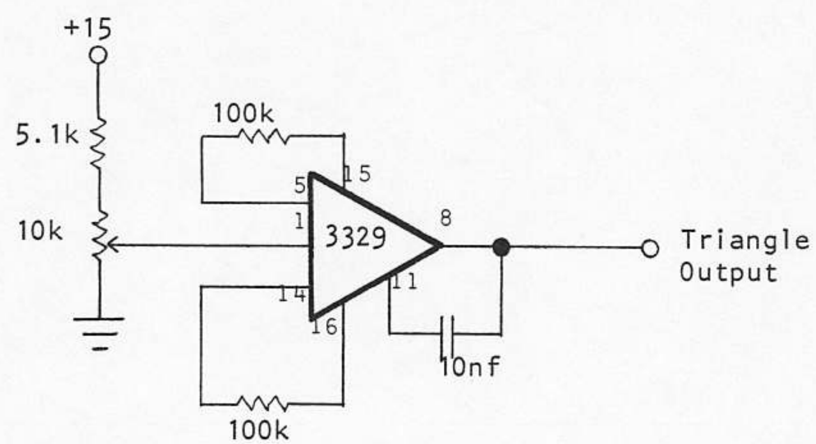
GENERATING A STRAIGHT LINE IMAGE

Creating a straight line image with 3-D Graphic Display Equipment requires a triangular deflection signal. This is the basic straight line image and the triangular beam stroke is necessary to create constant intensity of the line.

This basic image is, also, the simplest to generate. A Model 3329 Voltage-to-Frequency Transducer is used to generate the triangle. Frequency of operation is determined by the external components and the 3329 input voltage, set by the potentiometer. See the 3329 manual for details. The potentiometer is desirable to vary the frequency to avoid "beat" patterns in some more-complex images.



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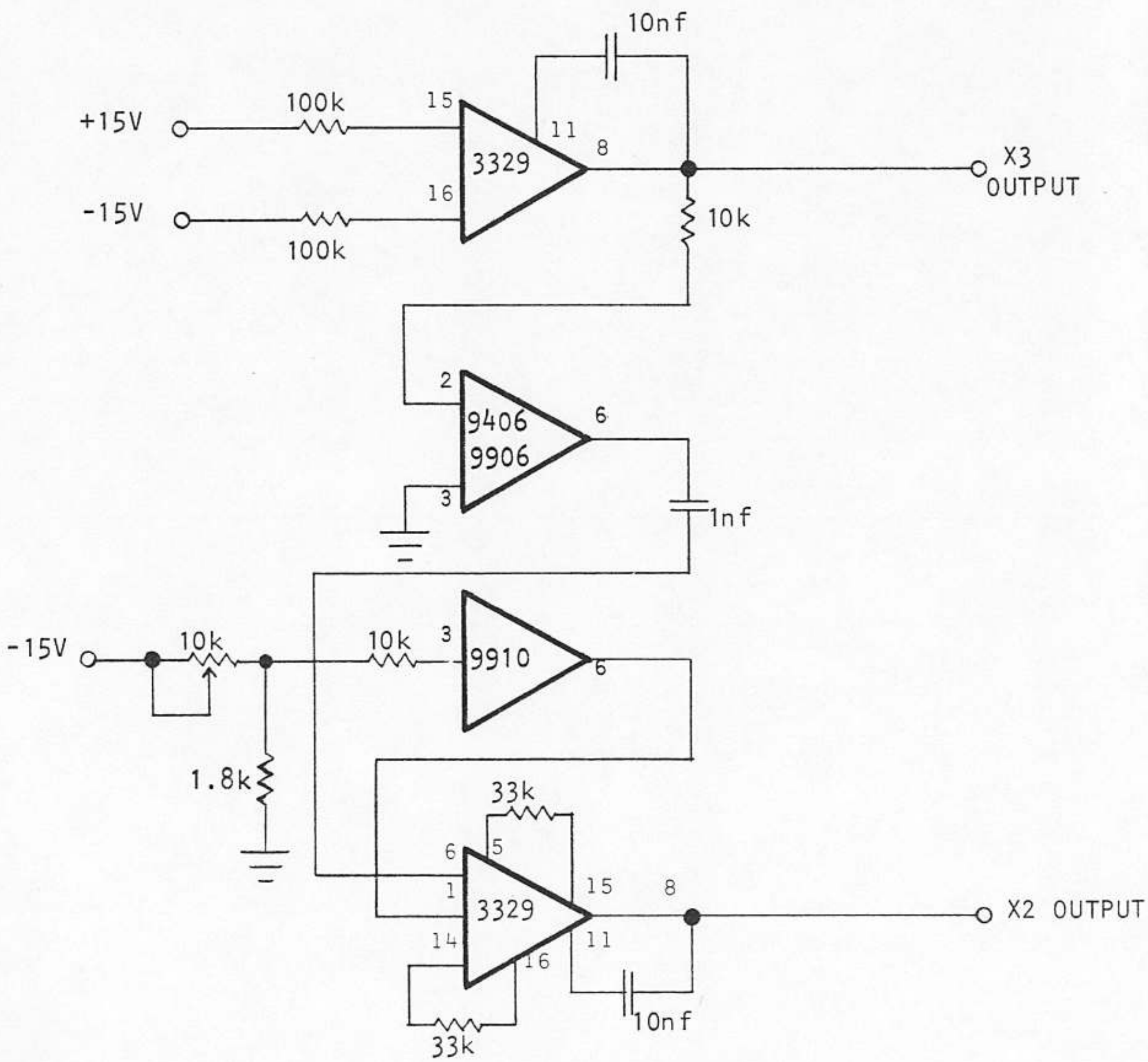
CREATING A DIAMOND IMAGE

The diamond shaped image is a straight-lined image, thus requiring triangle deflection waveforms. The main challenge is the generation of two triangles, 90° apart in phase.

The OEI Model 3329 Voltage-to-Frequency Transducer is used to produce the triangle waveforms. This module, basically a voltage controlled oscillator, is capable of being synchronized by an external signal.

One 3329 is used as a fixed frequency triangle oscillator. Its zero crossings are detected by a Model 9906 Operational Amplifier. The zero crossing information is differentiated to produce pulses. The pulses and a variable DC voltage are summed by a Model 9910 to drive the second 3329. The second triangle begins when the first triangle crosses zero, hence a stable, 90° phase shift.



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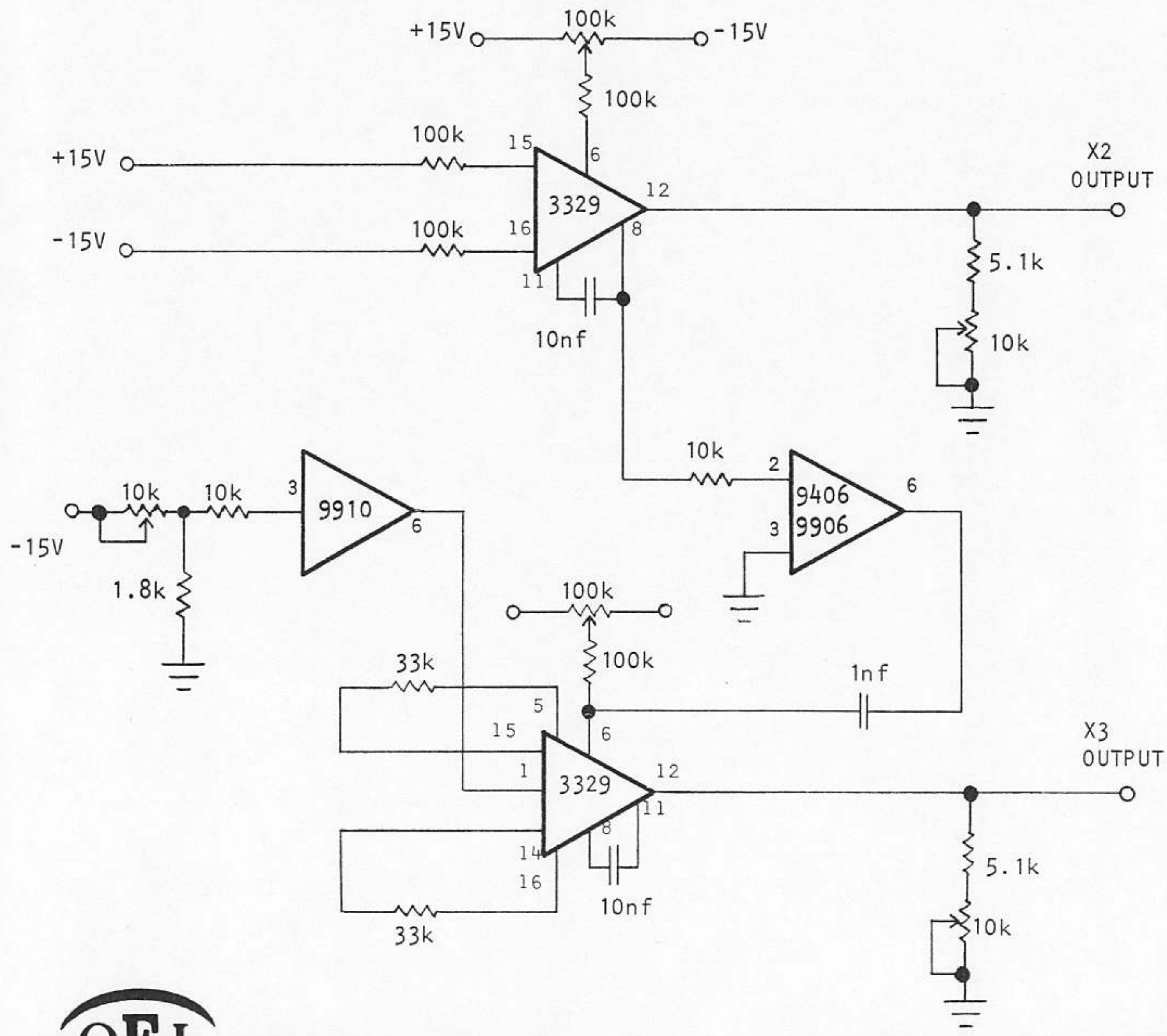
CREATING A CIRCLE IMAGE

Producing circles with 3-D Graphic Display equipment, or any XY display medium, requires two sinusoidal shaped deflection signals 90° apart in phase.

The circle is the basic circular or non-straight-lined image. All requirements call for sinusoids in one form or another, mixed, possibly with triangles. Being the basic circular image, the circle is the simplest to generate.

Two Model 3329 Voltage-to-Frequency Transducers are used to create the sine and cosine deflection signals. The first 3329 operates at a fixed frequency. Its triangle output is used to drive a zero crossing detector. The zero crossing information is differentiated and summed with a variable DC voltage to drive the second 3329. Sine wave symmetry and shaping are made adjustable on both 3329s to produce the best circle shape.



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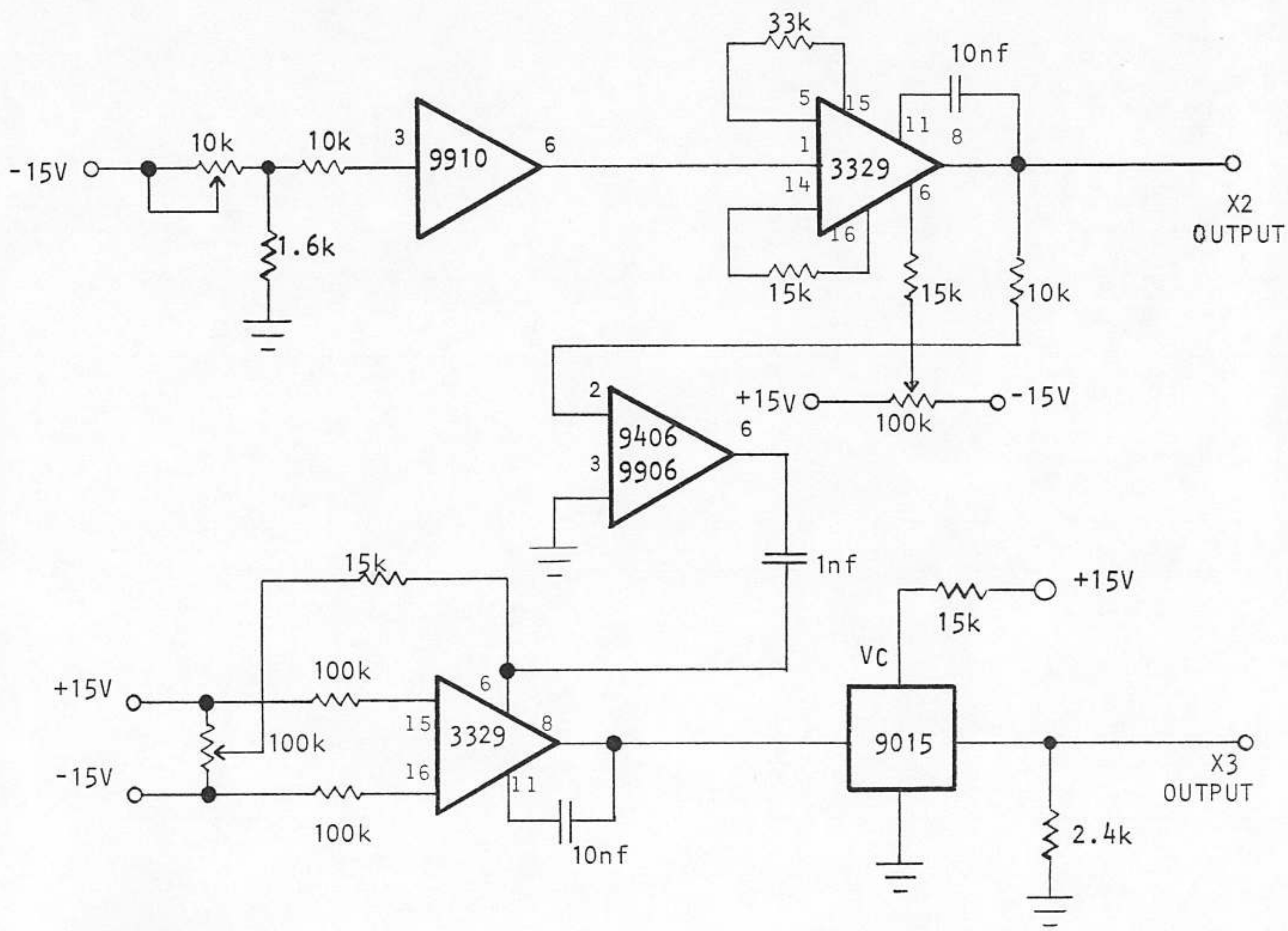
GENERATING A TRIANGLE IMAGE

Producing triangle images requires two modified triangles. The triangles are basically 90° out of phase, but both have different shapes.

The versatile OEI Model 3329 Voltage-to-Frequency Transducer may be used to produce non-symmetrical triangles (sawtooth waveform). See the 3329 manual for frequency of operation and waveform information.

The first 3329 operates as a standard triangle generator having a positive slope of twice the negative slope. A Model 9910 is used to vary the frequency of oscillation for synchronizing the second 3329 which operates at a fixed frequency. A Model 9906 acts as a zero crossing detector which drives an integrator. This triggers the second 3329 to start a triangle when the first crosses zero, thus producing a 90° phase angle.

A Model 9015 produces a clipping action on the second triangle to produce the required waveform. A hard clipping action and precisely adjusted symmetry (time-wise) are important for good image fidelity.



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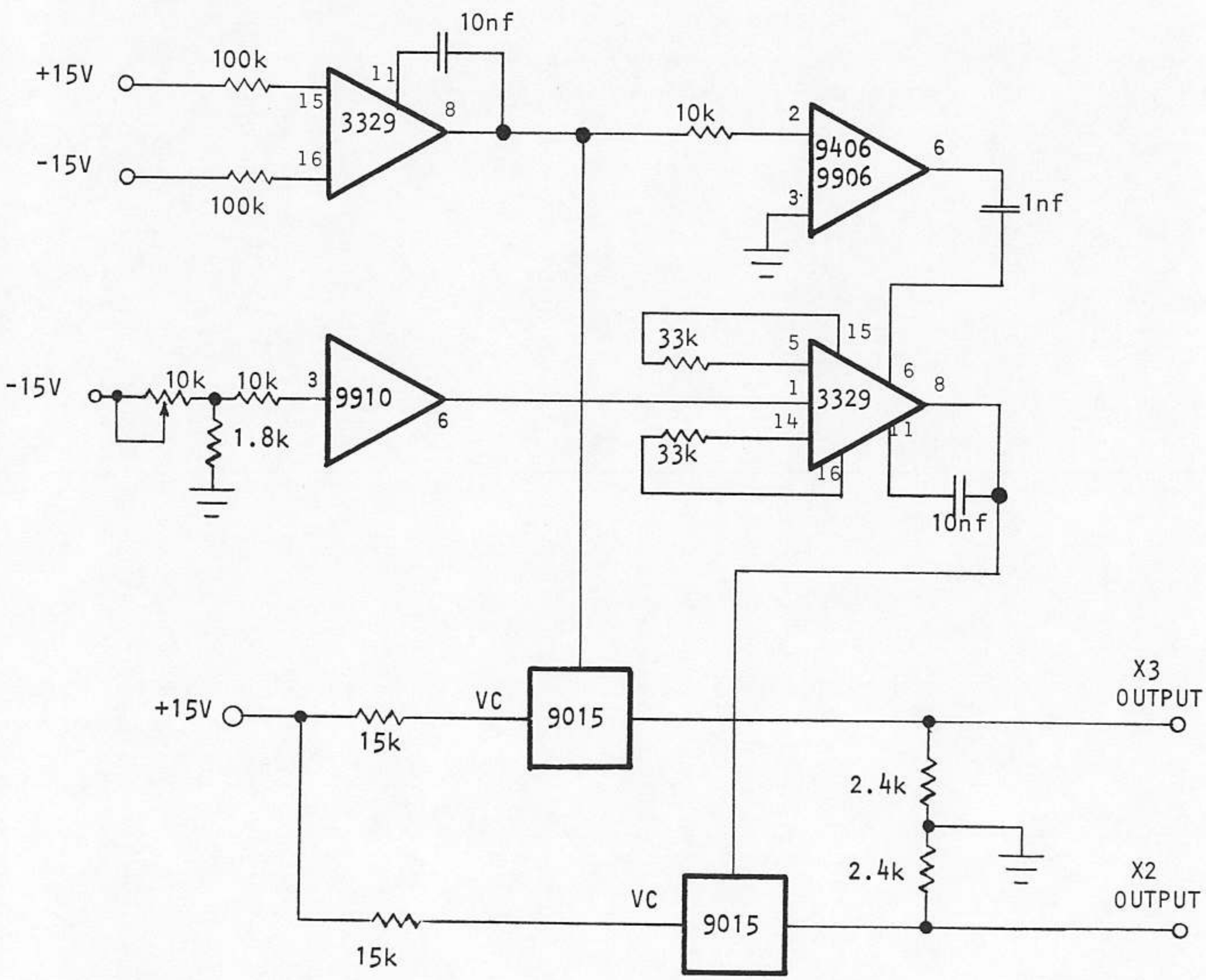
GENERATING A SQUARE IMAGE

The square image appears quite similar to the diamond but has modified signal requirements. Generating the square requires two triangles, 90° apart in phase, with precise amplitude limiting.

Generating the two triangles requires the OEI Model 3329 Voltage-to-Frequency Transducers. The first 3329 operates on a fixed frequency, triangle basis. Its output drives both a Model 9015 clipper and a 9906 acting as a zero crossing detector. The 9906 drives a differentiator network providing a trigger pulse to the second 3329. A Model 9910 is used to provide a variable DC input to the 3329. The second 3329 drives a 9015 module that clips the positive and negative portion of the triangle.

The amplitude limiting action on the triangles must be accurate and "hard" to produce good image fidelity.



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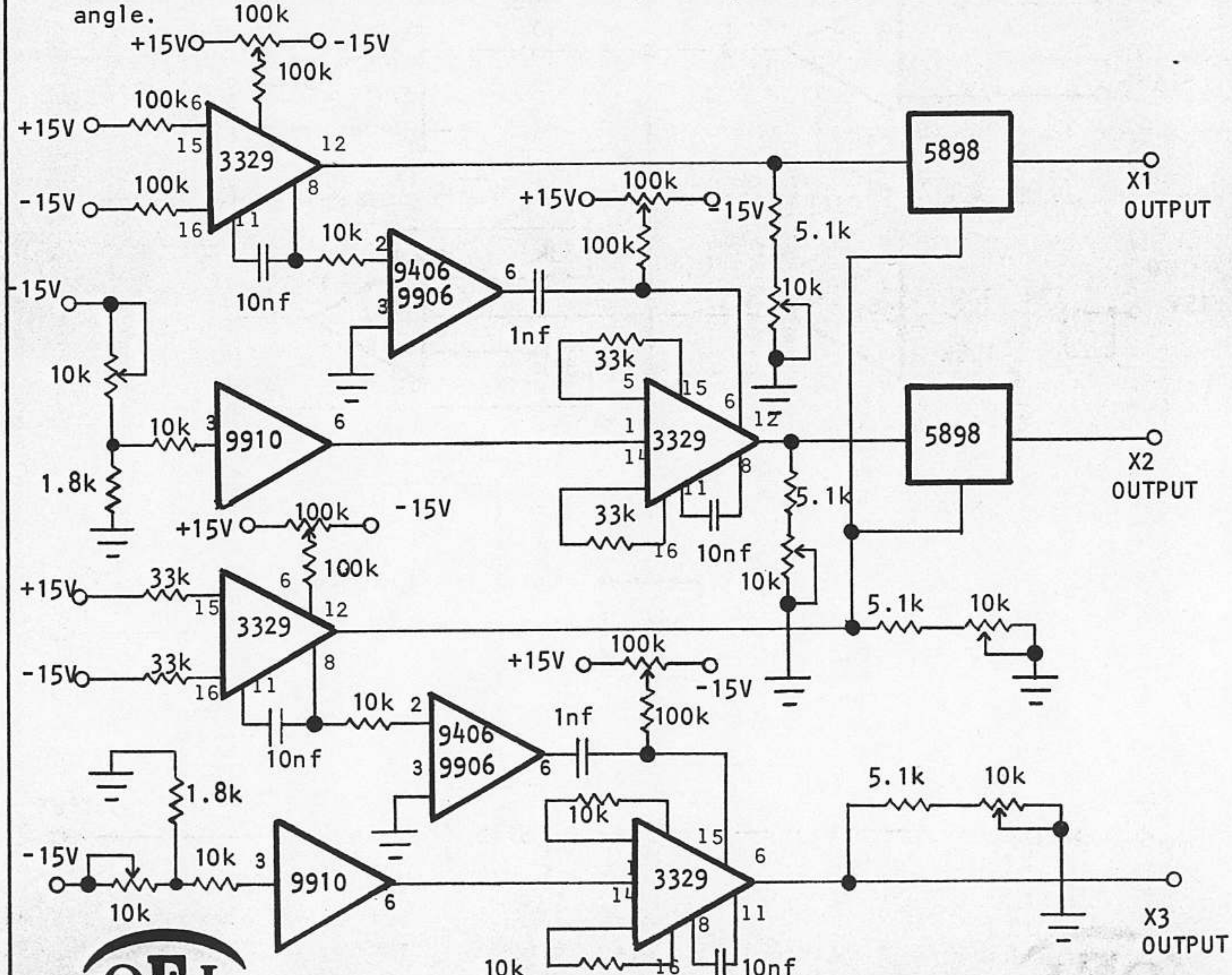
CREATING A SPHERE IMAGE

Producing a sphere image with 3-D Graphic Display Equipment requires three related sinusoid type signals. The three signals are of two basic frequencies.

Four Model 3329 Voltage-to-Frequency Transducers produce two sets of sine and cosine deflection signals. Two analog multipliers are used to obtain the required three deflection signals.

Model 3329s' are used in pairs with Models 9910 and 9906 to generate two sets of sine and cosine signals. The 3329' have sine shape and time-symmetry adjustments as optional to minimize image distortion. The Analog multipliers must be properly set up for a best accuracy performance. See the Model 5898 manuals for procedure on input offset voltage correction. Output DC voltage offset and scale factor levels are not as important in this case.

The 3329s' are used in a master oscillator - slave oscillator combination. The 9910 and 9906 produce the synchronization of the two oscillators. The slave 3329 begins its integration cycle (maximum sinusoidal amplitude point) when the master oscillator crosses zero, thus producing a fixed 90° phase angle.



PRODUCING A HOUR GLASS IMAGE

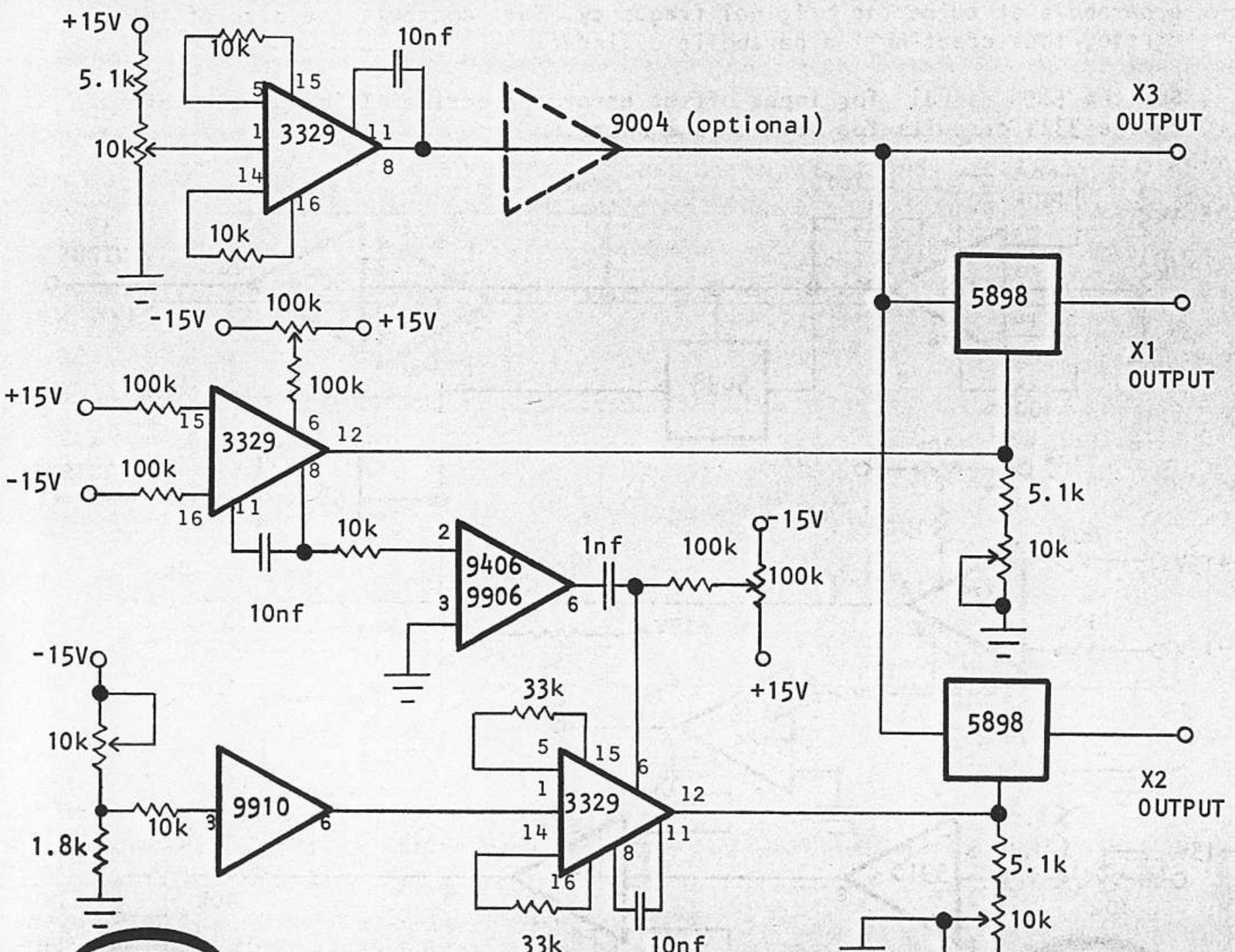
Generating the hour-glass image with 3-D Graphic Display equipment requires three related deflection signals. A modification of the hour glass, the cone, is discussed.

The hour glass is circular in nature, hence sine and cosine signals are generated. Their amplitude is modified with analog multipliers by a slow triangle that provides the vertical sweep.

The OEI Model 3329 is used to create all three signals. One 3329 is a master-fixed frequency sinusoidal oscillator. A Model 9813 and 9000 are used to slave a second 3329 exactly 90° in phase apart from the first 3329.

A third 3329 is used in a triangle mode to produce the vertical deflection and multiplier drive signals. Two Model 5898 analog multipliers are used to alter the amplitude of the sine and cosine deflection signals.

A Model 9004 absolute value module is used if a cone image is desired. The "folded" triangle is now used for vertical deflection.



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MAKING A PARABOLIC CYLINDER IMAGE

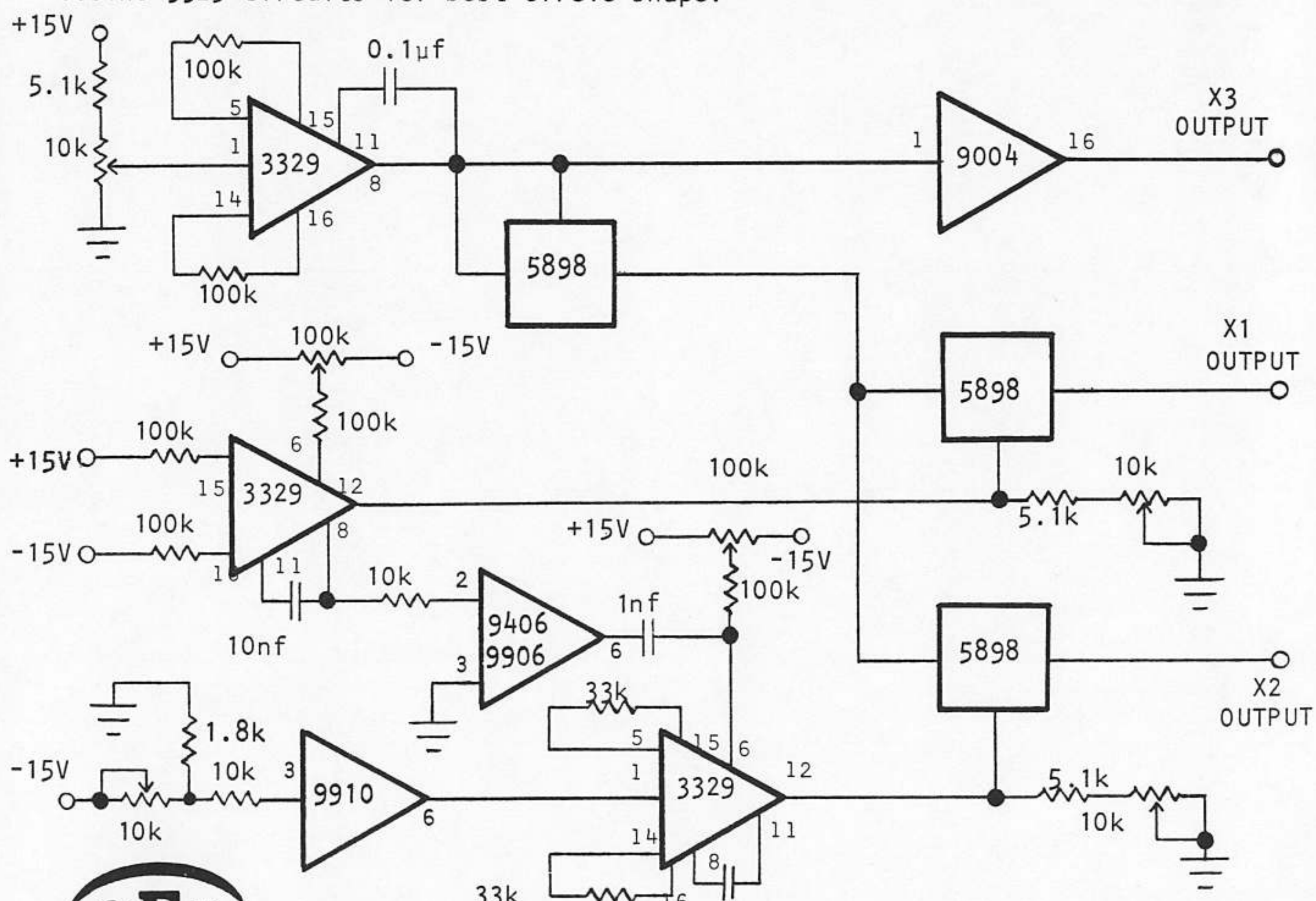
Making a parabolic cylinder image on 3-D Graphic Display Equipment requires three deflection signals. Two signals are sine and cosine in nature to create the cylindrical shape. A third, slower deflection signal is a unipolar triangle, which is also squared to alter the sine and cosine amplitudes.

The versatile OEI Model 3329 Voltage-to-Frequency Transducer is used in a fixed frequency sinusoidal mode. A Model 9906 and 9910 produce proper synchronizing of a second 3329, 90° in phase apart from the first oscillator. This produces a circle, the size of which is governed by two Analog Multipliers OEI Model 5898.

A third 3329 creates a low, fixed frequency triangle that passes through a 9004 absolute value module. This converts the bipolar triangle into a unipolar triangle at twice the original frequency. This is the vertical deflection signal.

The bipolar triangle is also squared by another 5898. The squared triangle is a parabola at twice the original frequency. This controls the size of the circle, thus creating the parabolic cylinder.

See the 5898 manual for input offset error correction. Trim the sine and cosine 3329 circuits for best circle shape.



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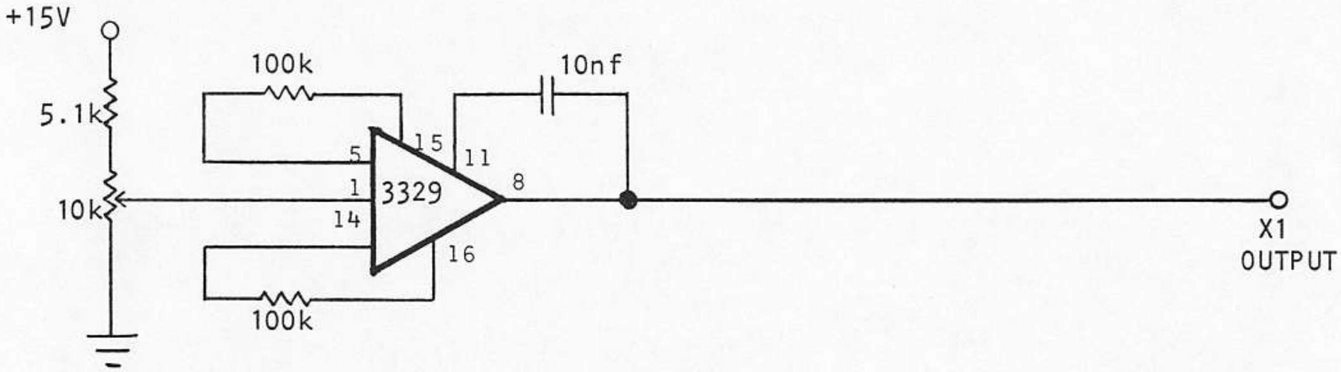
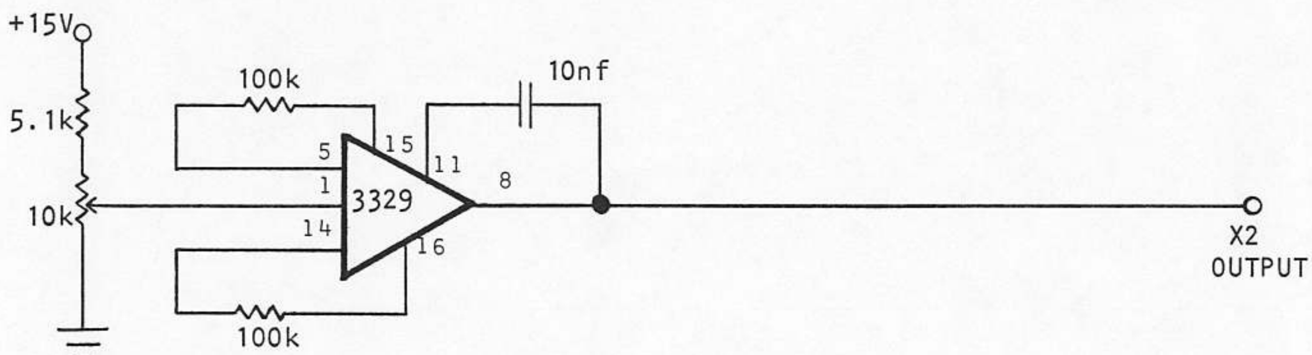
CREATING A SOLID CUBE IMAGE

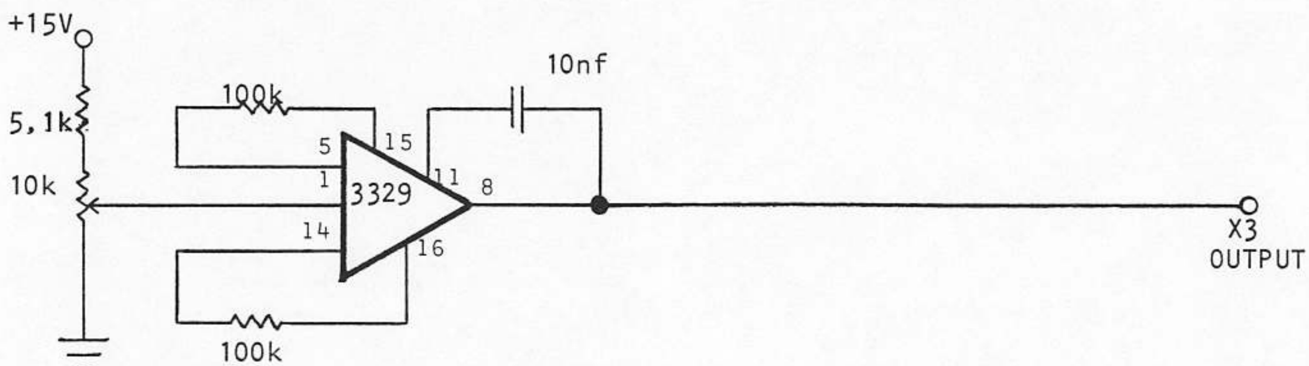
One of the simplest solid 3-D images to create, the solid cube requires three unrelated deflection signals.

The solid cube image on the 3-D Graphic Display Equipment requires three independent triangles, at different frequencies.

Three Model 3329s' are used in identical, independent circuits. The frequency of each is adjustable to produce fine or coarse lined images.







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MAKING AN OUTLINED CUBE IMAGE

Generating an outlined cube image (edges of a cube) on 3-D Graphic Display Equipment requires three related modified triangular deflection waveforms.

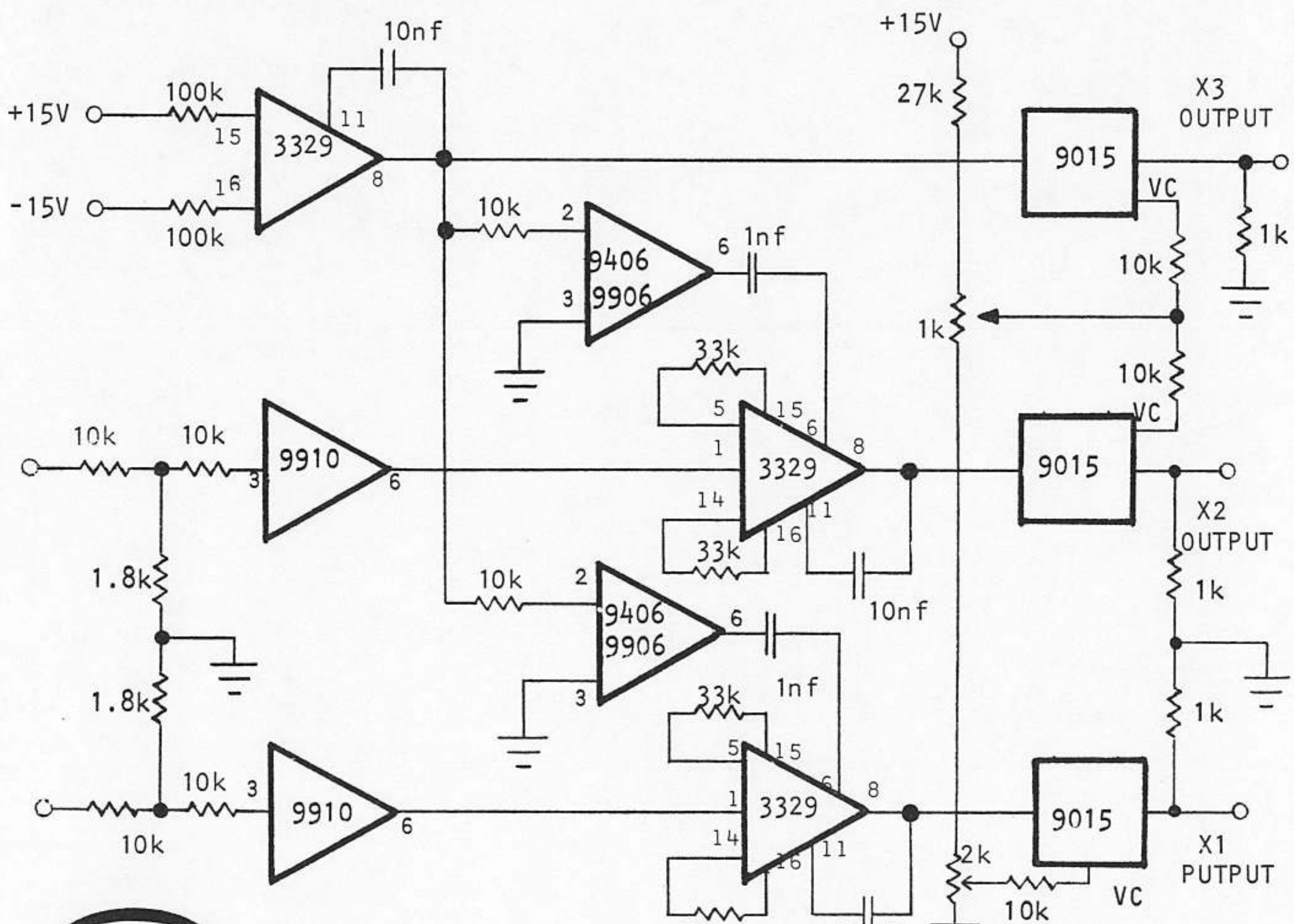
Two Model 3329 Voltage-to-Frequency Transducers are used in a master-slave oscillator circuit. The first produces a fixed frequency triangle. A Model 9906 and 9910 are used to sense the zero crossings and synchronize the second 3329.

When the first 3329 crosses zero, the slave 3329 begins its triangle, hence a 90° fixed phase relation between the two.

A second set of 9910 and 9906 is used to trigger a third slave 3329 operating at 40% of the master frequency.

The three triangles drive three Model 9015 Precision Limiters that precisely clip the positive and negative portions of the triangles.

These signals produce some repeat tracing which may tend to brighten some segments of the cube outline. Generally, this can be eliminated by blanking, but the added complexity limits the practicality of doing it.



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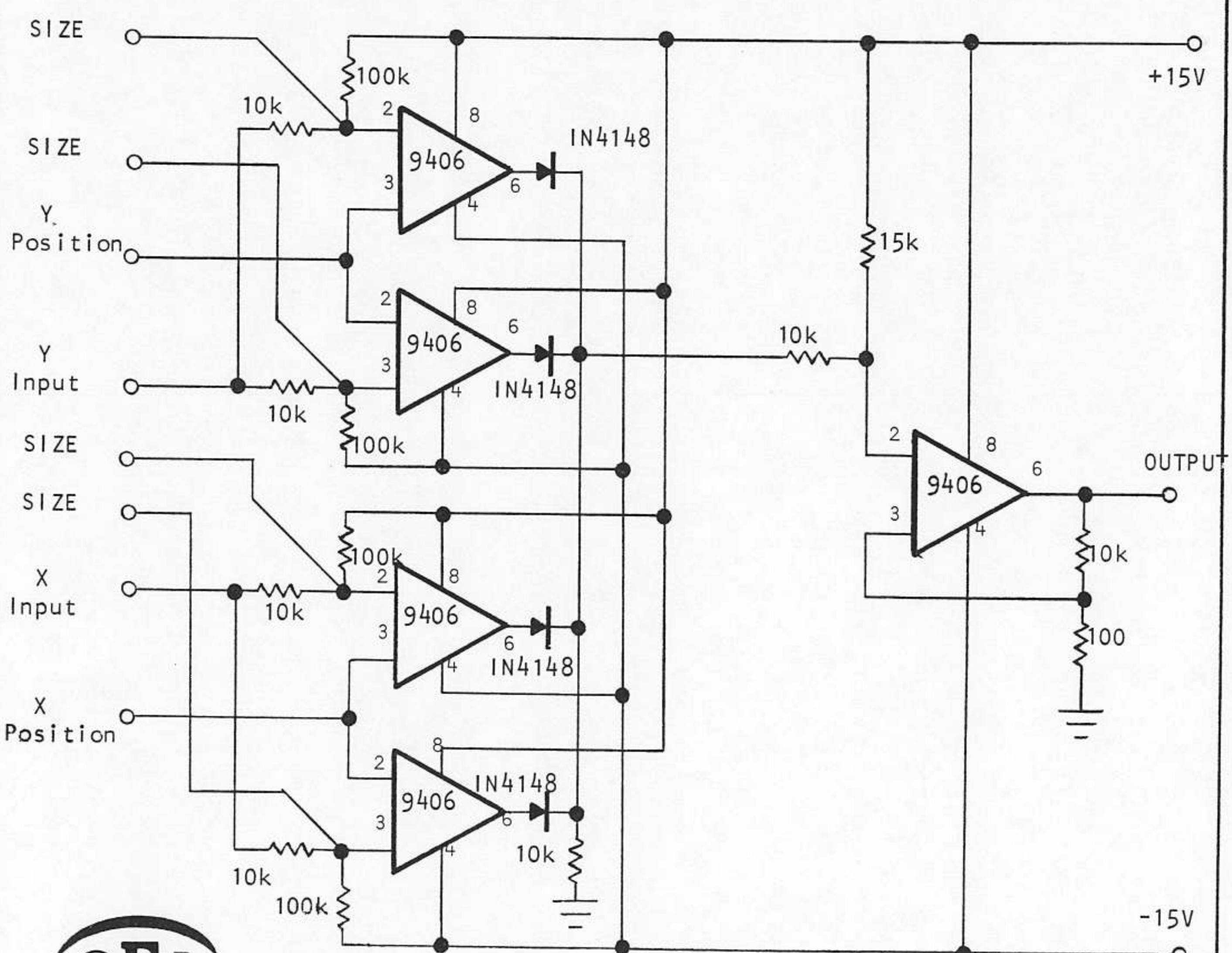
GENERATING A POPULATION DISPLAY

The creation of a display that visually maps out the coordinate area and shows the location of the existance of population (or coincidence) is easily done with high speed operational amplifiers and a comparator, shown below.

The four operational amplifiers are OEI Model 9406 and are used in two identical sets of dual comparators. One set is used for vertical, the other for horizontal (or X and Y). Their outputs are ORed together and drive a comparator with hysteresis.

The size of the population location (coincidence) is determined by external resistors - one at each dual comparator. Connecting a resistor to the two terminals marked "size" will reduce the coincidence size. A short circuit will reduce the size to zero.

The height of the output is fixed and merely indicates the existence of a coincidence (population). Connections to the 6100 series 3-D Graphic Display System is indicated.



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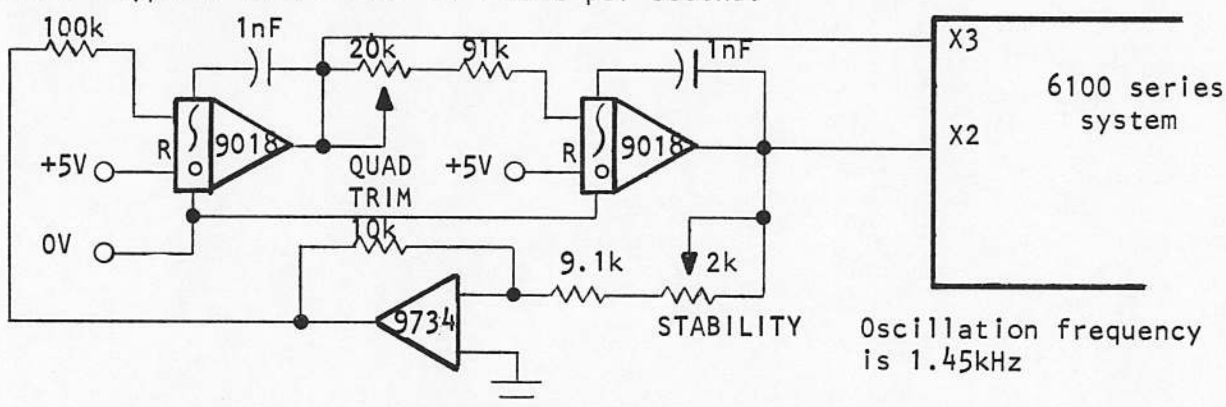
GENERATING PERFECT CIRCLES

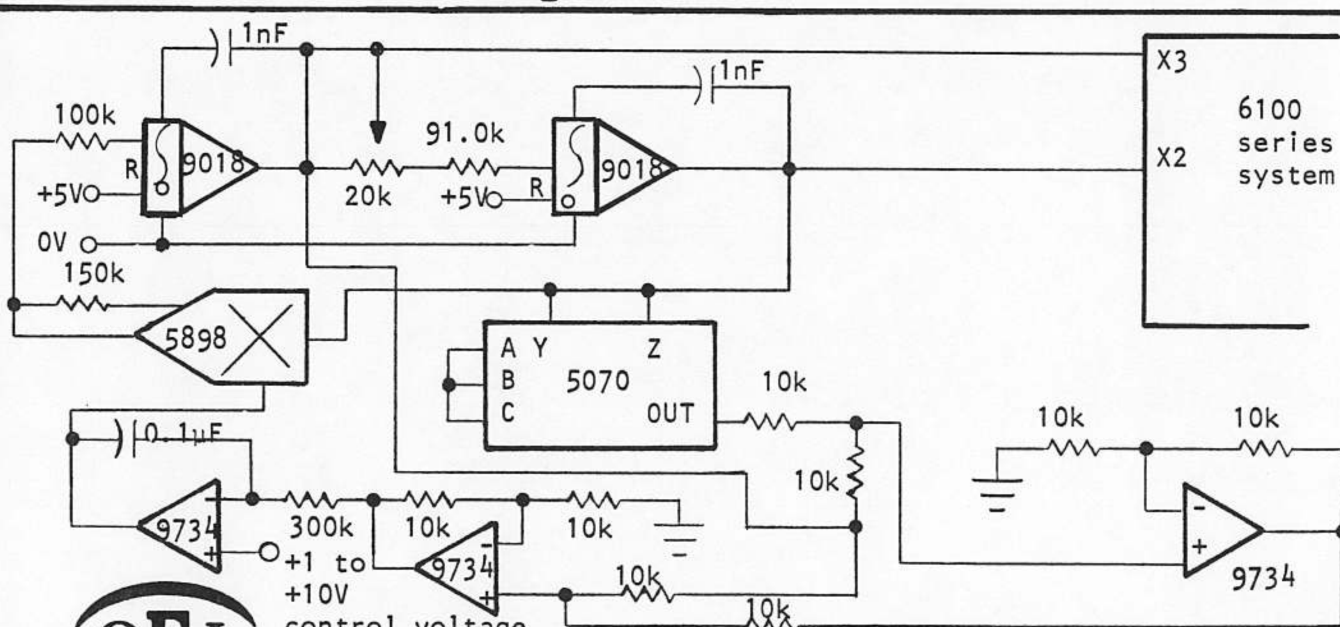
By using the rotation modules, 6120 or 6124, in a 6100 series system, one can rotate a point, located away from the origin, about the origin to obtain a circle. This will not produce the best circle for display purposes. The circuit shown at the bottom of this page is called a quadrature oscillator and will produce "perfect" circles to better than 0.1% accuracy.

The circuit below will generate a ±11 volt quadrature signal. The circuit uses two Model 9018 three mode integrator modules that have an internal ±11 volt bound circuit. Frequency is determined by the RC time constant of the 9018's. Quadrature error may be trimmed as shown below.

The size of the circles may be controlled by using the magnifier module, Model 6130, 6131, 6132 or 6133. A more complex method is also shown below using a Model 5070 and two 9734 op amps. This circuit provides a control voltage input which determines the amplitude of the loop oscillation and, thus, circle size. This method maintains the high accuracy of the simple circuit.

In both circuits, raising the "0" inputs to +5 volts will stop the circuit and hold the point stationary. The point will drift due to the memory decay of the 9018. Typical drift rate is 1 volt per second.





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3D DISPLAYS OF A TWO-DIMENSIONAL VECTOR GENERATOR

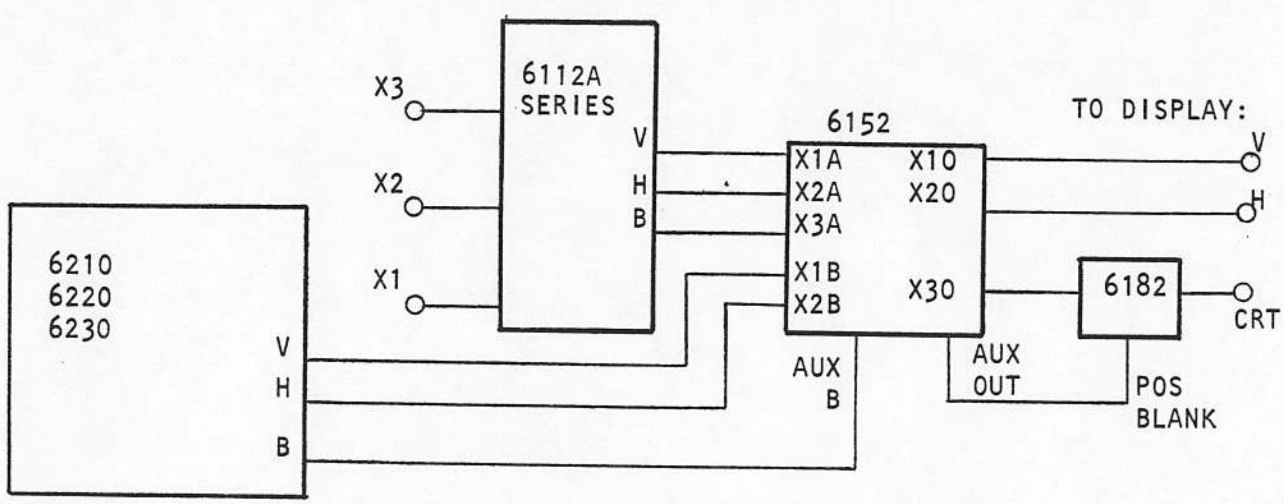
Models 6210, 6220 and 6230 form a two dimensional vector generator that can be used with the 6100 series 3-D Display system. Vector generators are devices that accept both analog and digital information concerning the position of the start point and end point and how fast to draw a line between the points. They are used with computers to present graphic and alphanumeric information on CRT displays.

The output of a two dimensional vector generator is a vertical deflection voltage, horizontal deflection voltage and a CRT blanking voltage. The CRT is normally cut-off and is only unblanked during the vector generation.

The use of a two dimensional vector generator is shown below with the 6100 series system. A Model 6152 multiplexer module allows the vector generator image to be superimposed with another image. The second image may come from any other source including the 6240 series of background static display generators.

Because of the maximum writing rate of the 6210 series, the 3-D display modules should be the 6112A or 6113A family. The 6111A family may be used if the writing rate is restricted to 3 volts/μsecond maximum. If the writing rate were limited to 0.3 volts/μsecond, the 6110A family could be used but the image would be limited to simple line structures.

The circuit below provides complete rotational capability of the graphics input but the vector generator image will remain fixed. If it is desired to rotate, use the 6152 at the 6100 inputs (see the 6152 manual for details). The vector generator blanking information must still bypass the 6100 system as shown below.



See the 6210, 6220, 6230 manuals for Vector Generator configuration.

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DISPLAYING THREE DIMENSIONAL VECTOR GENERATOR IMAGES

The OEI Models 6210, 6220 and 6230 Vector Generators can be connected so that a true three-dimensional image can be created. Of course, there must be three sets of coordinates for start and end point position along the vertical, horizontal and longitudinal axes. The computer supplies this information to the vector generator modules via digital-to-analog converters.

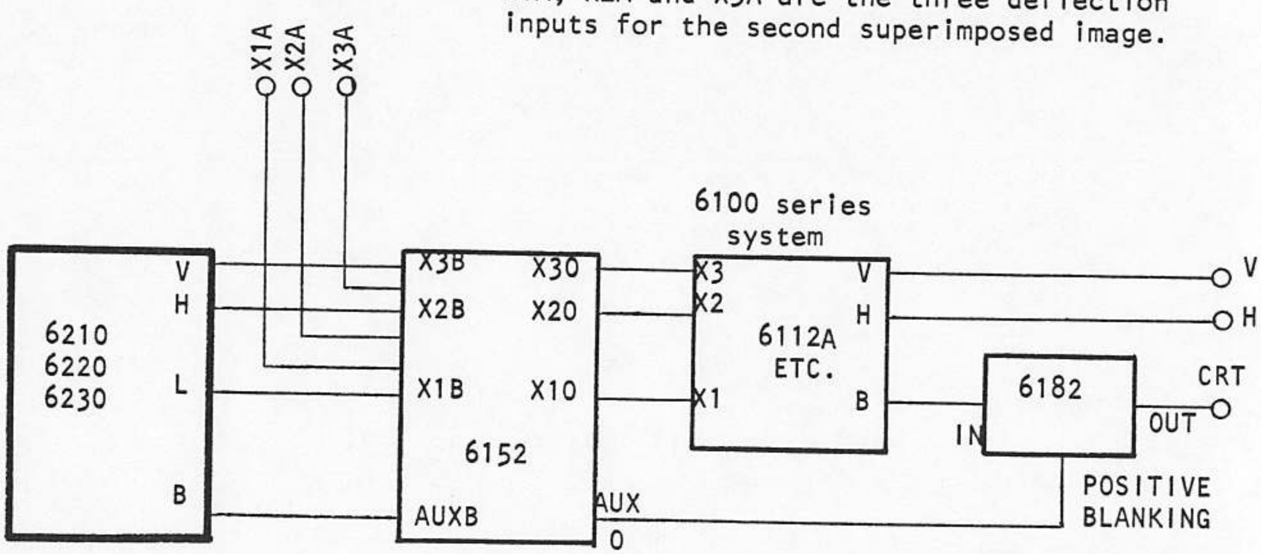
The outputs of the vector generator represent vertical axis, horizontal axis and longitudinal axis deflection voltages. Also, a CRT unblanking output is provided.

The 6100 series of 3-D display modules are used as shown below to display the three dimensional output of the vector generator. The use of a Model 6152 image multiplexer module is shown to superimpose the generated image with another graphic image. The fourth channel of the 6152 is used to connect the CRT unblanking output of the vector generator to a Model 6182 blanking generator.

The vector generator normally has the CRT display cut-off and only unblanks the CRT during vector generation. The 6152 uses time sharing to superimpose the vector generated and analog graphic images. The CRT unblanking voltage is only applied to the 6182 during the time that the vector generators are connected to the display system. In this way, the vector generator has absolutly no effect on the other image.

The computer can control the 6152 so that one complete vector generated image is presented before the 6152 switches to the other image.

X1A, X2A and X3A are the three deflection inputs for the second superimposed image.



NOTE: The AUX-A input of the 6152 is not connected.

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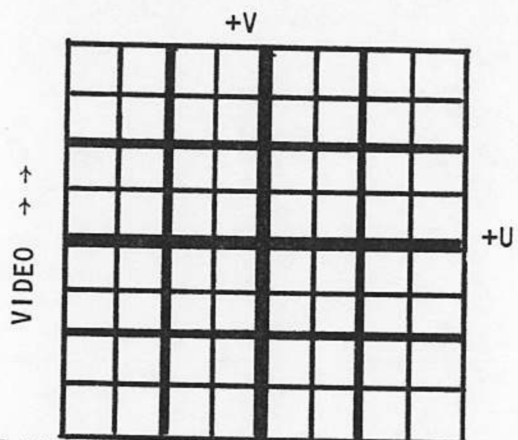
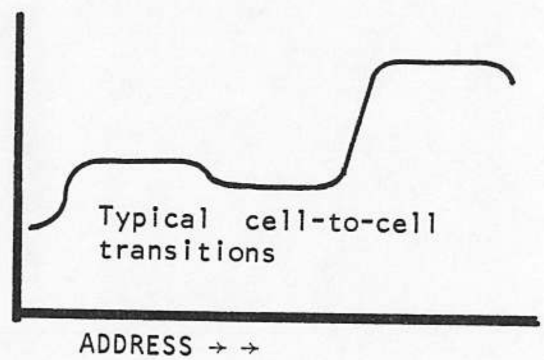
USING THE TWO-DIMENSIONAL BACKGROUND GENERATOR

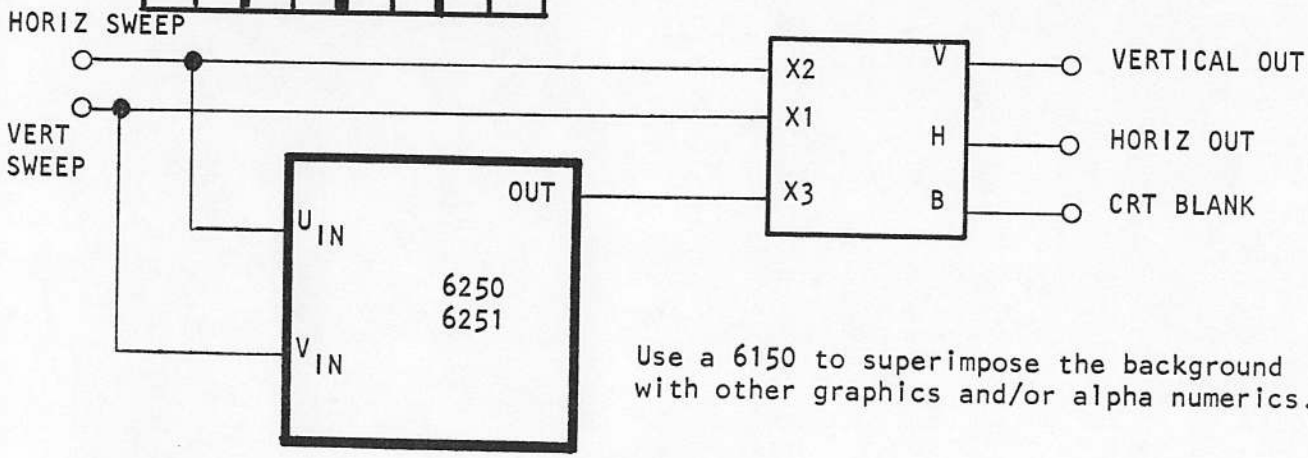
The OEI Models 6250 and 6251 are used to make a two dimensional background generator. This is a "Read Mostly Memory" programmed with resistors and addressed by analog inputs. The 6250/6251 memory is organized in "cells" arranged 2x2, 4x4, 8x8, etc. This is illustrated below. The address voltages select the quadrant by address polarity and the actual memory cell by actual voltage level.

The transition from one cell to the next is smooth and is typically 25% of the cell size as shown below. The cell contents are programmed by potentiometers if adjustability is desired or with fixed resistors if a permanent pattern is desired.

The output of the background generator is an analog voltage between -10V and +10V, determined by the addressed cell content. Normally the vertical and horizontal address inputs (called U and V) are driven from raster generator deflection waveforms. The raster generator produces a flat plane when viewed with an XY display or with our 6100 series 3-D Display Modules. The background generator output can be used to modulate the XY display intensity or it can be used as the third deflection input to the 6100 system as shown below. The two dimensional generator can be used to create a plane with hills and valleys representing geographical terrain or other physical contours.







Use a 6150 to superimpose the background with other graphics and/or alpha numerics.

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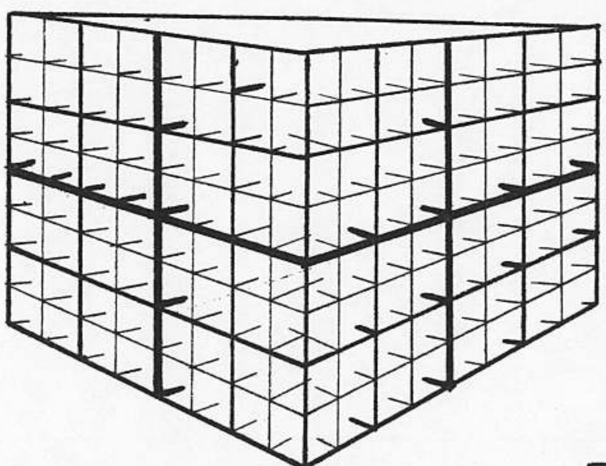
USING THE THREE-DIMENSIONAL BACKGROUND GENERATOR

The OEI Models 6260 and 6261 combine to form a read mostly memory having three address inputs and one output. External fixed resistors or potentiometers are used to program the memory. The three address inputs locate a particular memory "cell".

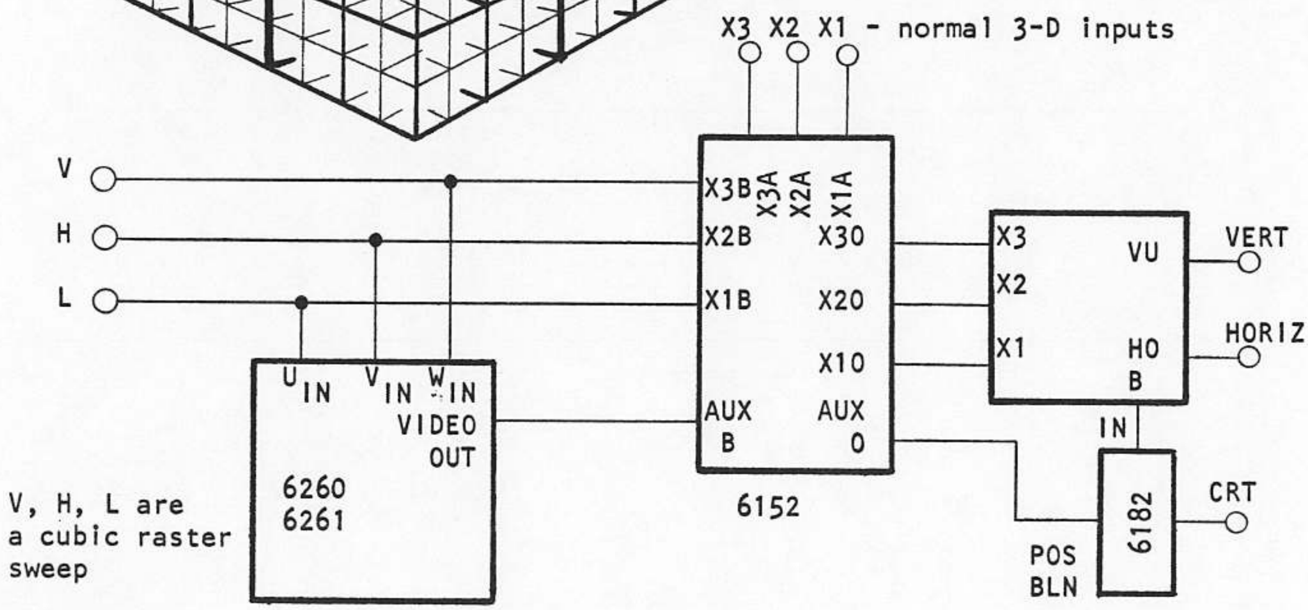
The Memory cells are arranged in octants of a cube, meaning the smallest memory has eight cells. The next larger memory subdivides each primary octant into octants, hence it has 64 cells, then 512 cells, etc.

The 6260-6261 background generator is called that because its' output is designed for use as a static 3-D display image used as a background or reference superimposed on real time graphics and/or alpha numerics.

The three dimensional background generator address inputs are the three deflection inputs forming a solid raster. The memory output is the video information which is connected directly to our Model 6180 blanking module via the 6150 multiplexer. The solid raster produces an area which is intensity controlled by the memory video output. A "scene" type display results.



Cubic memory cell organization



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APPLICATIONS FOR THE ONE-DIMENSIONAL BACKGROUND GENERATOR

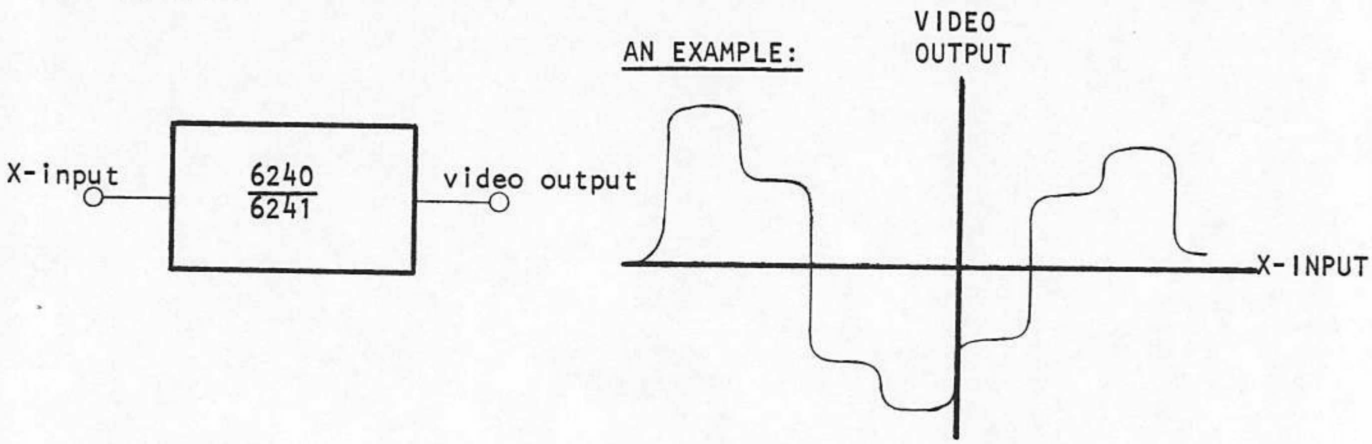
The Models 6240 and 6241 one-dimensional background generators are analog memories having a single analog address input. The 6240 is the control module containing four memory cells. The 6241 is the expansion module used to increase the entire generator in size to 16, 64, 256, etc., memory cells.

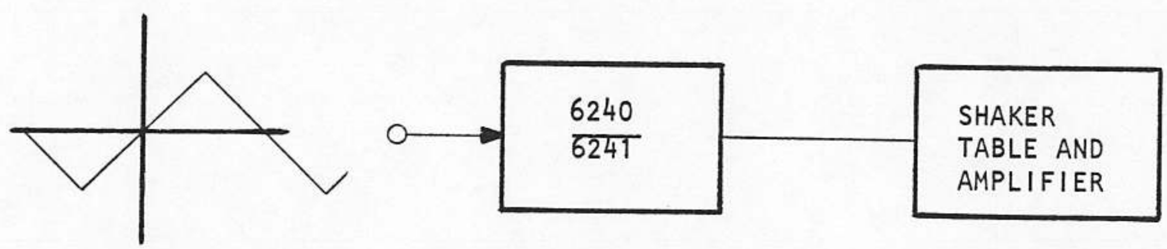
Each cell is programmed by a resistance, either fixed, a variable potentiometer or a voltage controlled resistance. In the one-dimensional design, the cells are arranged linearly with the address input as shown below.

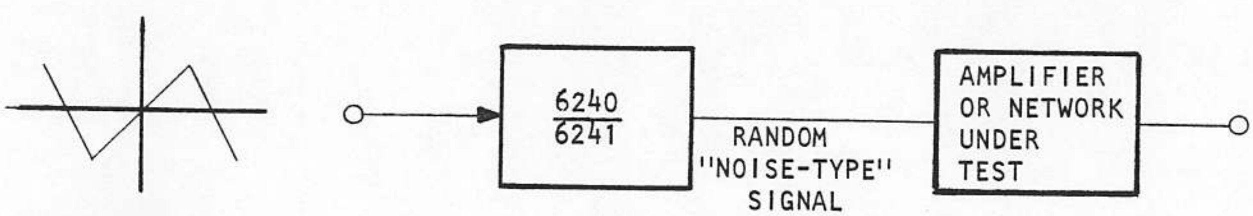
The function illustrated shows the arbitrary transfer function capability of the one-dimensional background generator. The prime application of the 6240/6241 is to generate fixed patterns in spatial deflection or intensity in a 3-dimensional image produced by a 6100 series system.

Whenever an arbitrary or complex function is required, the 6240/6241 can be used. In non-display applications such as vibration testing, analog circuit testing, sound synthesis and general waveform synthesis, the 6240/6241 are quite useful as low cost function generators. Brief examples are shown below of several applications.

AN EXAMPLE:







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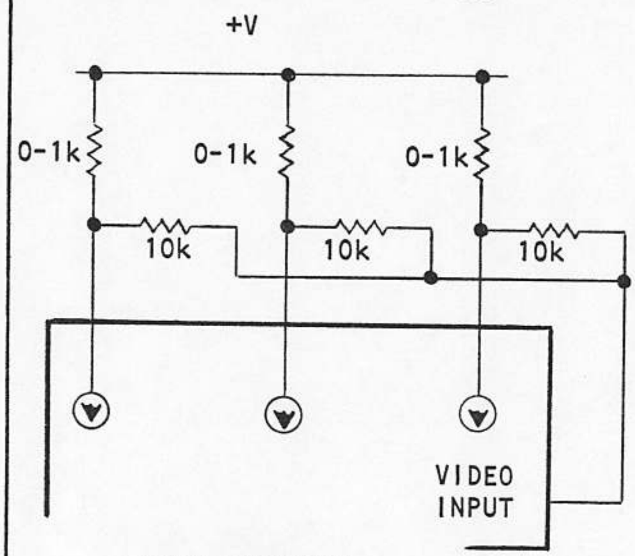
VOLTAGE PROGRAMMING THE BACKGROUND GENERATORS

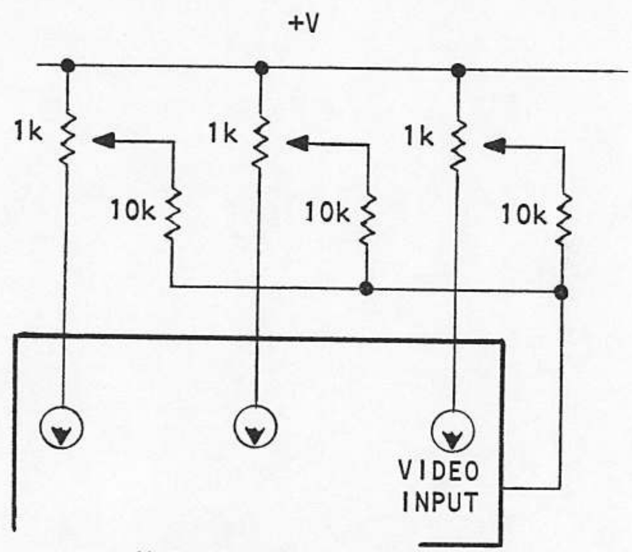
The OEI Models 6240 and 6241 one dimensional, 6250 and 6251 two dimensional and 6260 and 6261 three dimensional generators are analog memories. They are classified as read mostly memories since they are intended to produce static display backgrounds. The memories use a resistance to determine the contents of a memory cell.

The determining resistance is external to the memory module and one resistance is required for each memory cell. The output of the memory module is shown, detailing the external resistance configuration. Either a potentiometer or a fixed resistor may be used for "fixed" programs.

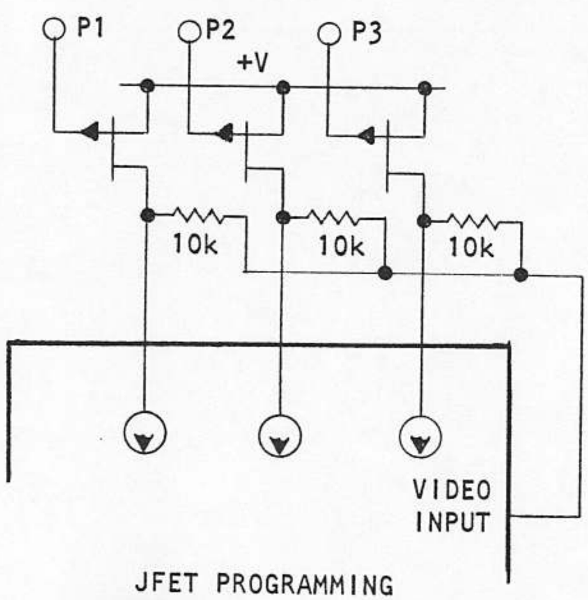
If a voltage variable resistance were used at each memory cell, then a voltage programming capability would result. A circuit using FET's as resistance elements is shown below. The full scale resistance of the FET must be 1000 ohms maximum, hence a high I_{DSS} or low R_{DS} FET is required.



FIXED RESISTOR
PROGRAMMING

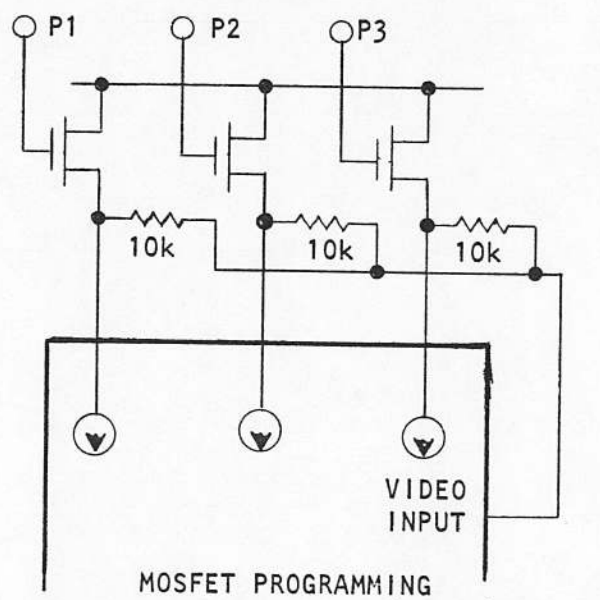


VARIABLE RESISTOR
PROGRAMMING



JFET PROGRAMMING

+V<"P"<(+V+V_G)



MOSFET PROGRAMMING

(+V-V_G)<"P"<+V

V_G is gate voltage for R_{DS} of 1000 ohms.

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SYNCHORONIZING THE 6150 AND 6170 FOR VECTOR AND BACKGROUND IMAGES

The Model 6150 image multiplexer module switches from one set of inputs (or one image) to the other. The amount of time spent on each image depends on the clock frequency and the setting of the relative intensity adjustment. When one or both of the images are generated by a vector generator or background generator or other cyclic generation, it is desirable to present an integral number of images before the 6150 switches to the other image.

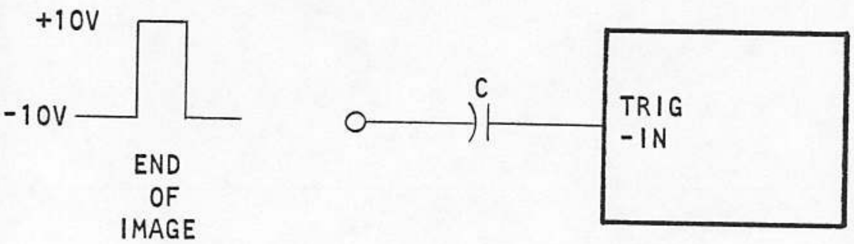
The same comments apply to the 6170 stereo generator which switches from the left-handed to the right-handed image.

To ensure that one or more complete images are "written" before the 6150 or 6170 switches requires synchronized operation of the 6150 and 6170 with the image generation circuit. If the image is from the 6210 series vector generators or the 6240 series background generators, an "end-of-image" signal must be made available to trigger the 6150 and/or 6170.

If the display system includes only the 6150 or 6170, then the trigger signal may be used directly. If both modules are used in the system, then the 6170 must switch and write complete binocular images before the 6150 switches images. Shown below are the signals and connections necessary to synchronize the 6150 (6151, 6152 or 6153) and 6170 for best image fidelity.

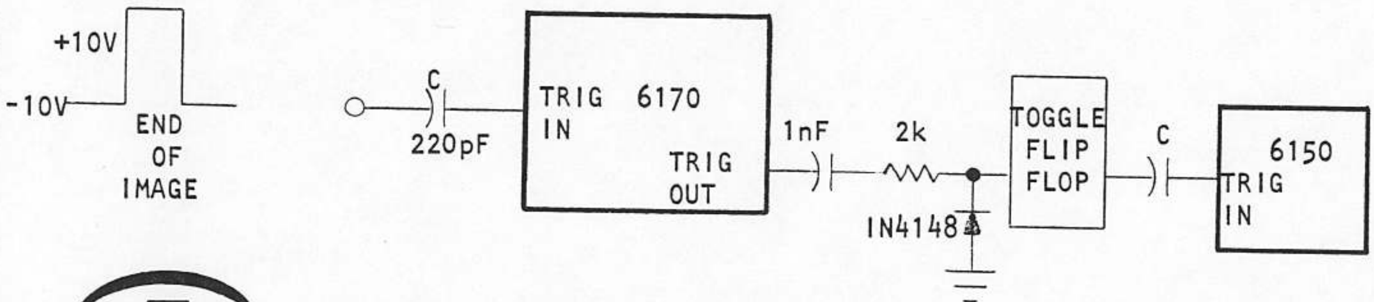
The free running clock frequency of the 6150 and 6170 should be set a little below the minimum frequency of switching. If the switching interval will be random, eliminate the coupling capacitor, C.

SYSTEMS WITH
6150 or 6170:



MODEL	C:
6150	470pF
6151	150pF
6152	50pF
6153	15pF
6170	220pF

SYSTEMS WITH
6150 AND 6170:



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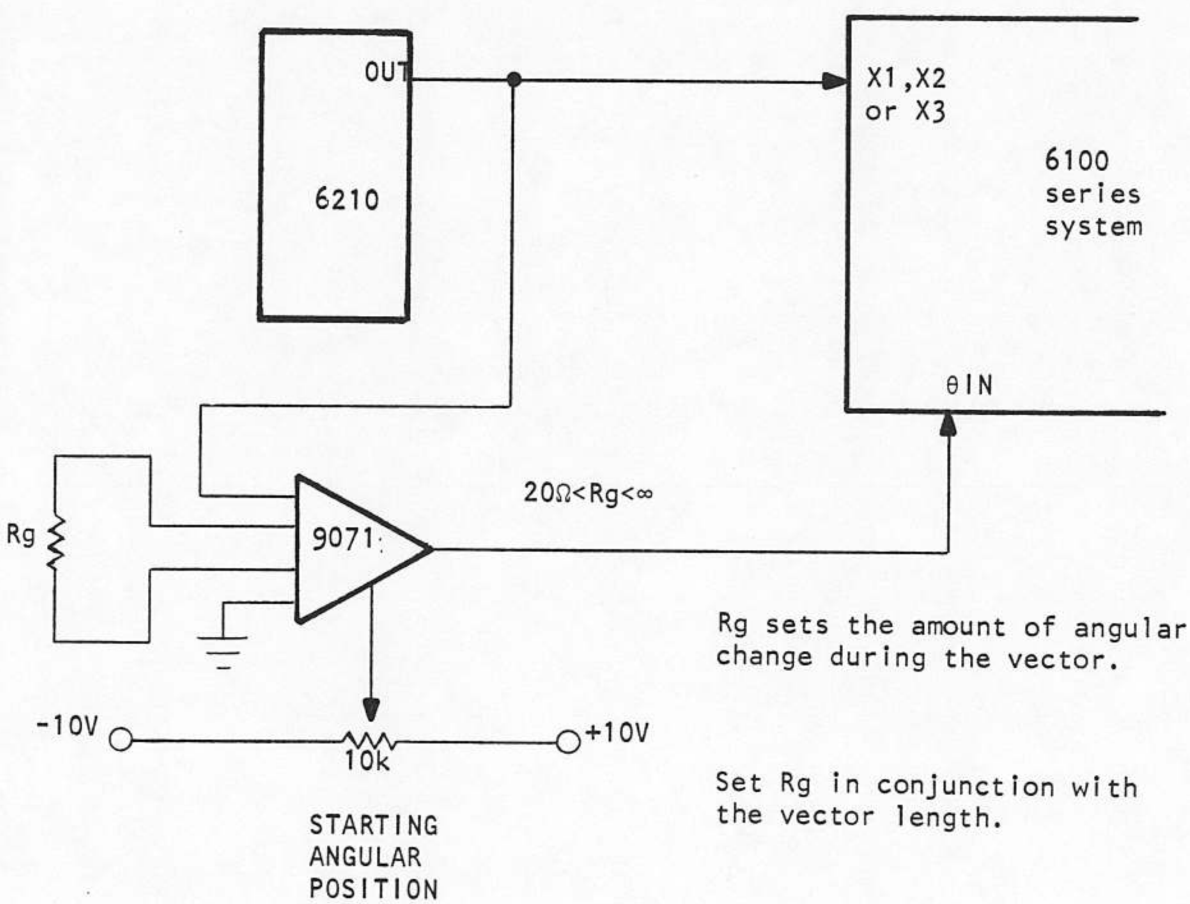
DRAWING CURVED LINES

Conographics might be defined as drawing curved lines and surfaces by rotating straight line vectors. Using a single Model 6210 Vector Generator Module and the 6100 series system with 6120 or 6124 rotators, curved lines and surfaces may be generated.

An instrumentation amplifier is used to amplify and offset the vector voltage that is generated by the 6210. This is then used to control the rotation angle of the rotation modules in the 6100 series system. The higher the gain of the amplifier, the greater the angle through which the vector is rotated. Offset voltage of the amplifier determines the starting angular position. The offset voltage can even be programmed by an external voltage.

Consult the 6210 operating manual for required digital and analog operating voltages.

The 6120 or 6124 manual will describe the rotation function.



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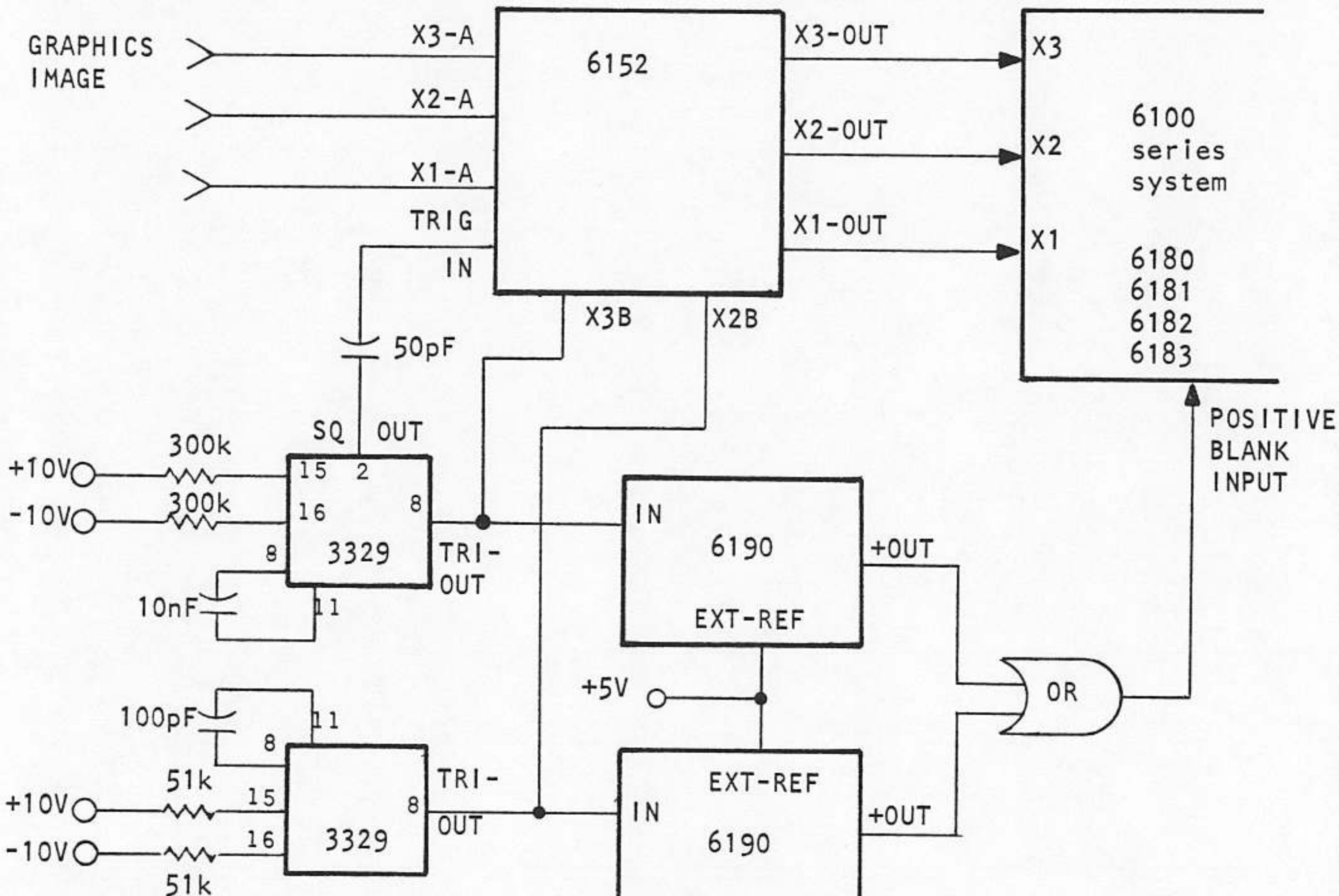
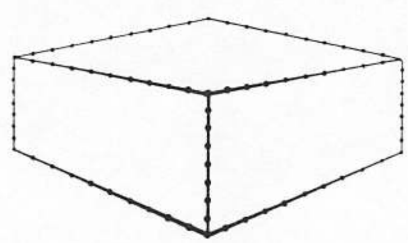
CREATING A FULL GRATICULE

Model 6190 Reticle Generator creates an image as illustrated below. In some applications, the fact that there is no reticle line to refer to when there is no image existing could be bothersome. The circuit shown below produces a full graticule in two dimensions which is always visible and which is superimposed with the graphics image and follows the image with rotation.

The principle is simply that a raster is generated and used to drive (address) the two 6190 modules. The raster is invisible (blanked out) except for the graticule lines. A Model 6152 image multiplexer module performs the superimposition. If the graphics image is a raster type, the two 6190 modules may be driven by the image raster, otherwise a raster must be generated as shown.



Example of a standard 6190 reticle application:



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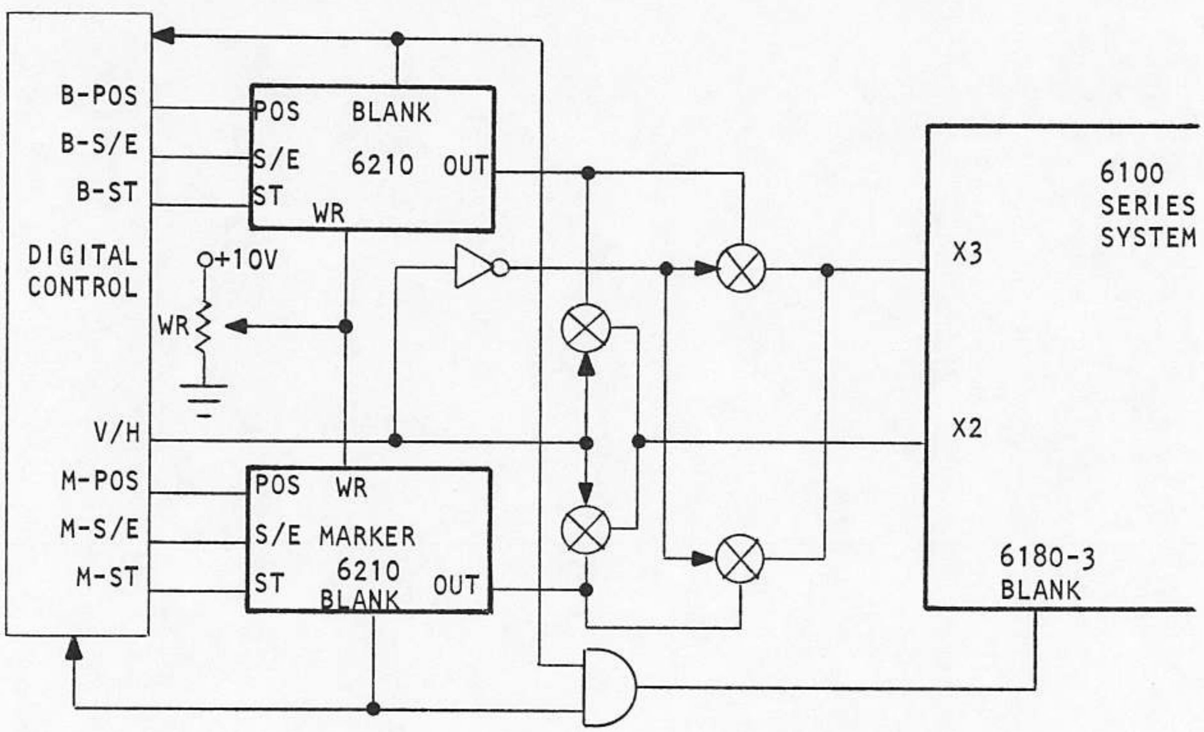
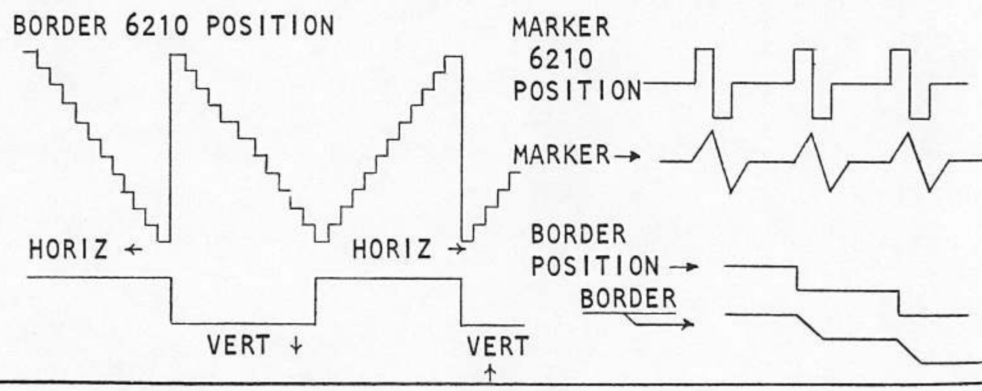
DRAWING A TWO-AXIS CALIBRATION GRID

Two Model 6210 vector generator modules can be used to draw a two-dimensional image without the calculator modules (6220, 6230) as long as the vectors are vertical and horizontal and not diagonal. The border type image shown is generated with a relatively simple digital control circuit (not shown). The basic waveforms required to operate the 6210 modules are shown.

One 6210 draws the border while the other 6210 draws the short markers. A basic concept involved is that one single axis generator is drawing both the vertical and horizontal border, while the other single axis generator is drawing both vertical and horizontal markers. This is possible by switching the outputs of the border and marker generators between X2 and X3 inputs of the 6100 series system.

The calibration grid is normally multiplexed with an image of interest. The required waveforms include the border staircase. The number of steps in the staircase determines the number of markers in the calibration grid.





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APPLYING THE 6100 SERIES TO SPECTRUM ANALYSIS

INTRODUCTION. The 6100 series 3-D Graphic Display modules with a suitable XY display or oscilloscope, makes a complete 3-D display. The three deflection inputs can be connected to a sweep generator, spectrum analyzer or spectrum signature equipment so that signal amplitude (Fourier amplitude) is displayed vertically on a horizontal plane. The plane represents signal frequency versus time. The plane is tiltable and rotatable for various views of the image.

BASIC SYSTEM. The basic spectrum analysis system has a frequency sweeping signal source and detector or sweeping receiver. This provides the frequency and amplitude information. Time may be generated by a time base in the sweep instrument or other source that might be related to the signal being displayed. The time base may be triggered by modulation of an incoming signal in the spectrum signature case.

Figure 1 shows a basic system and the connections to the 6100 series. The broken lines to the time base indicate that the time base may be triggered on the sweep generator or on the network under test (if it has some time varying function).

Figure 2 shows the basic type of image obtained from the system and shown on the 3-D Graphic Display. The image may be rotated about any or all axes.

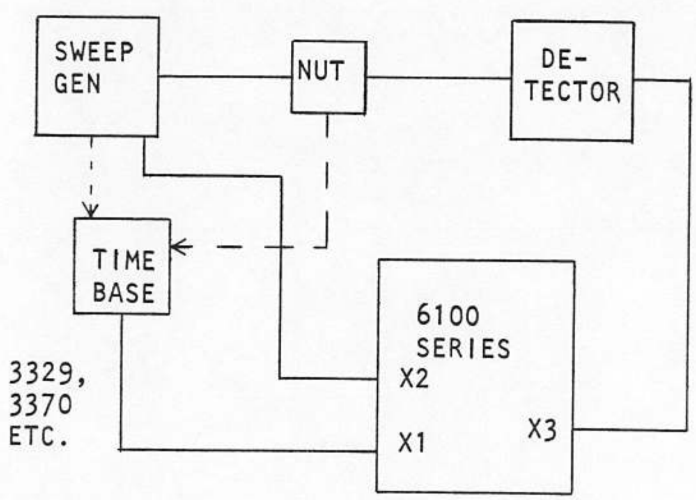
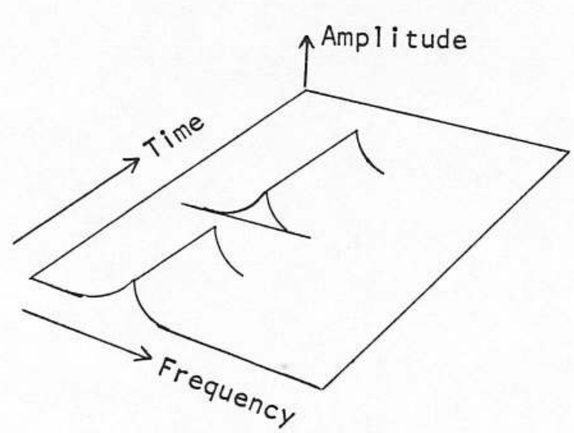


Figure 1. Basic Analysis System Configuration

Figure 2. Typical Image



MEASUREMENT OF A STEADY STATE NETWORK. Consider the case of an active or passive frequency filter. Whether it is low pass, high pass, band pass or notch type, it may be displayed as shown in Figures 3 and 4.

Note that the time base generator is triggered on the sweep generator. This is to eliminate the possibility of creating a "beat" between the sweep signal and the time base, disrupting the raster. Set the time base for 100, or so, sweep cycles. This will produce a fine lined raster which is pleasant to look at.

Phase shift can become visible if there is an excessive sweep rate. The detector that senses the NUT output and produces a porportional DC output, may produce phase shift at high sweep rates due to its' filtering.

From the Human factors standpoint, a sweep rate less than 30Hz will definitely cause fatigue or visible flicker. Sweep rates over 60Hz are suggested. If the signal frequency is near or below 1kHz, a multiple pole, active filter should be used to reduce ripple at least 40dB but produce no visible phase shift at the sweep rate.

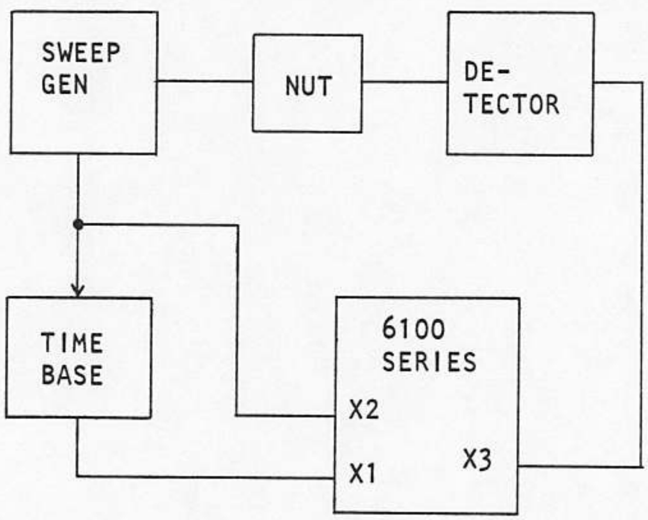
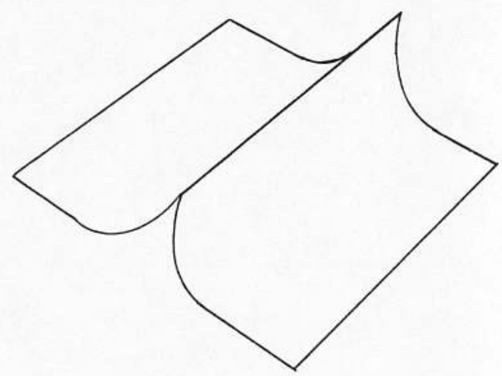


Figure 3. Analysis System for Steady State Active or Passive Networks.

Figure 4. Typical Image Example showing Frequency Response of the NUT.



FREQUENCY RESPONSE OF A TIME VARYING NETWORK. If a network, active or passive, has some time varying function, it can be three-dimensionally displayed as shown in Figures 5 and 6.

Note the similarity of this to the steady-state circuit of Figure 3. The one difference is that the time base is triggered by the Network-Under-Test. This signal is obtained either directly from the NUT, if available, or from the detector.

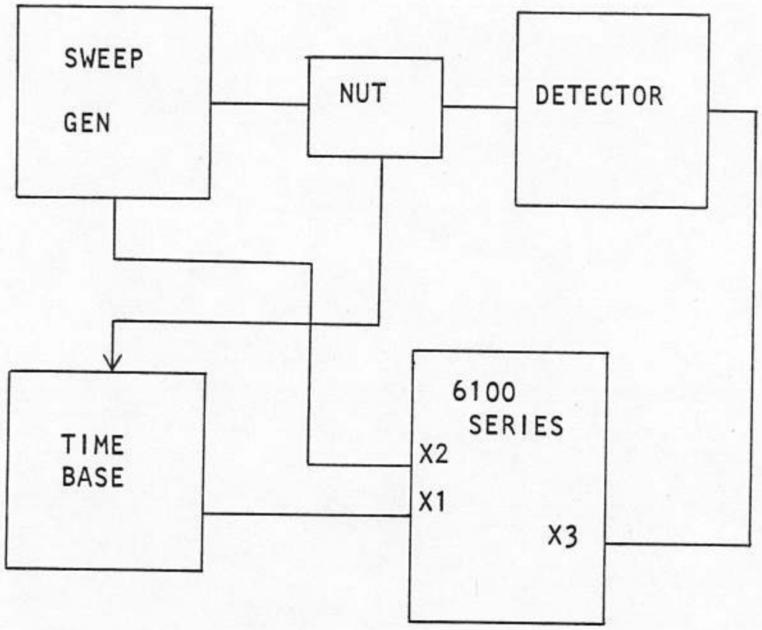
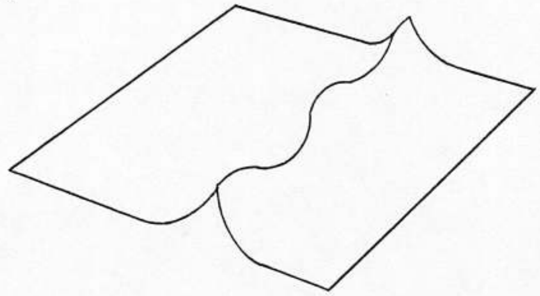


Figure 5. Analysis System for Time Varying Active or Passive Networks.

Figure 6. Typical Image showing Amplitude variation illustrating Time Varying Network characteristic.



SPECTRUM ANALYSIS - SPECTRUM SIGNATURE. The 6100 series provides a startling presentation of the output of a frequency swept receiver. Figure 7 shows the basic system makeup for three-dimensionally displaying the spectrum of received signals.

The system uses detected modulation of an input signal to trigger the time base. By placing the time base in the auto-trigger mode, a time base will always be present - free running in the case of no modulation for triggering.

The sweep generator may or may not be triggered by the time base. It is best if it is simply because of the stable raster produced. A free running sweep generator may tend to produce "beat" patterns in the raster.

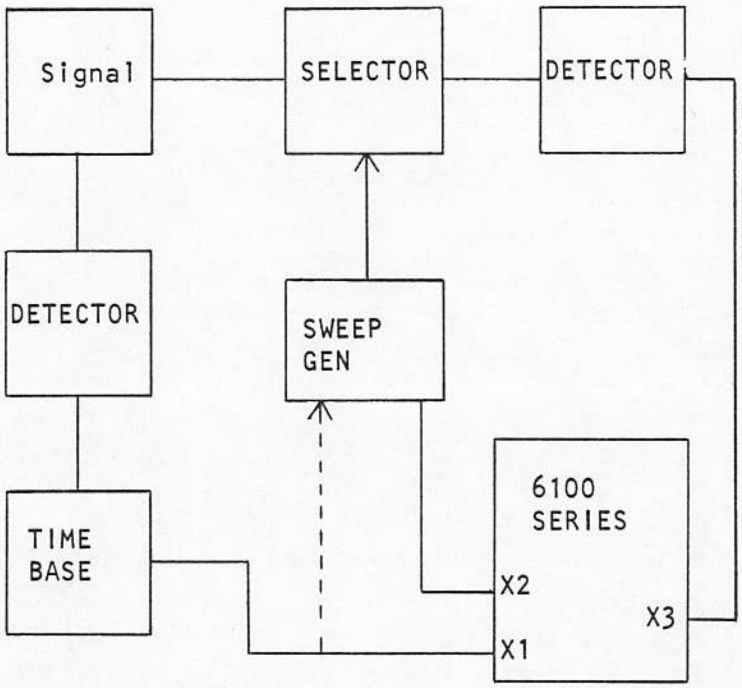
The sweep generator sweeps the receiver frequency to scan the incoming signal spectrum. A wide sweep range (an octave or more) is used for spectrum analysis (panoramic receiving). If a signal of interest is detected, the sweep width may be reduced (1/3 - 1/2 octave, etc.) for spectrum signature display. Modulation, such as PCM, PWM, etc., is clearly visible on the 3-D display as shown in Figure 8a.

SUGGESTED CIRCUITS. Figures 9 and 10 show suggested circuits for the sweep and detector portions of the systems discussed. OEI Application Tip numbers 10207, 10208, 10209 and 10210 cover the following circuits in detail. They also describe a swept filter circuit useful in low frequency spectrum signature and analysis.

Figure 9 shows a sweep generator using two Model 3329 voltage-to-frequency transducers and a 9910 buffer. A1 generates the actual sweep voltage that drives A2 - producing a swept frequency sine wave output. A3 provides a low output impedance for driving the NUT.

The detector circuit of Figure 10 uses a Model 9004 Absolute Value Module, A1, followed by an inverting active filter, A2. The multiplier feedback filter reduces ripple from the sweep generator output, yet keeps phase shift low due to the sweep rate.

Figure 7. Panoramic Receiver.



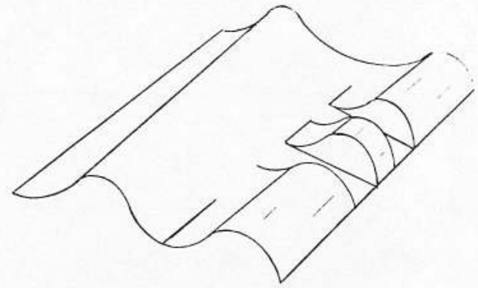


Figure 8a. Spectrum Analysis

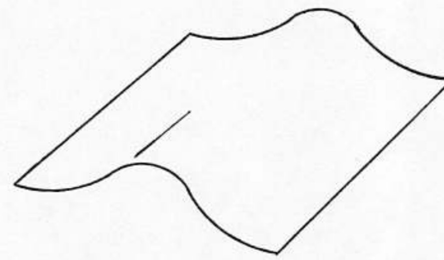


Figure 8b. Spectrum Signature

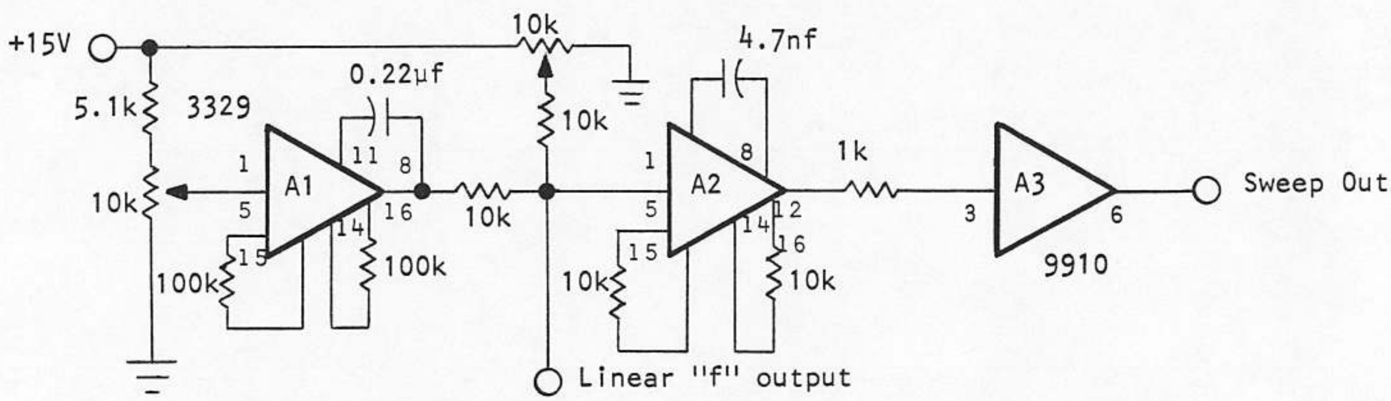


Figure 9. A Sweep Generator using standard OEI Modules

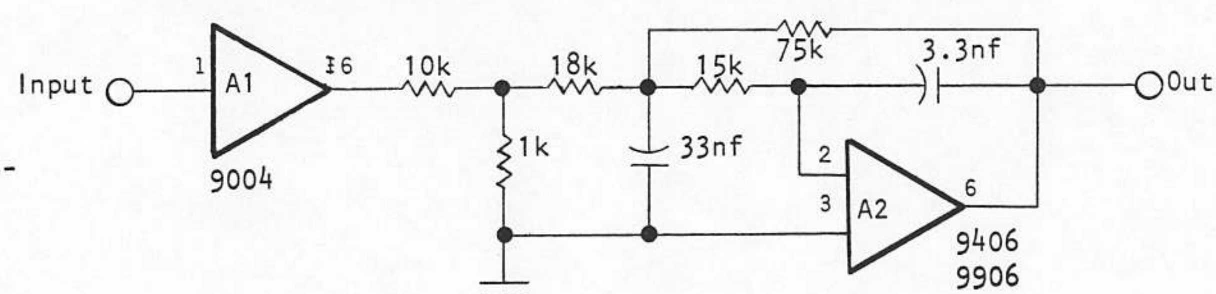


Figure 10. A Detector Circuit.

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USING THE 6100 SERIES AS AN INTERACTIVE DISPLAY

The 6100 series 3-D Graphic Display modules may be used in an interactive system, to write new information into a memory, generate functions, etc. Each of the three axes are written independently to create any desired 3-D image. The equipment needed is a suitable read-write memory and a light pen.

The memory portion may be a shift register with a "data stream selector" as shown in Figure 1. Figure 2 illustrates the light pen circuitry.

In operation, the light pen has an output only when the oscilloscope beam is in front of it. If the scope vertical input is connected to the output of the light pen circuit, the scope trace may be positioned by the light pen. Normal oscilloscope beam location is off to one side of the screen. The light pen will "bring" the beam to the other side as it is moved.

The X1, X2 and X3 inputs may be controlled by the light pen, one at a time. Each axis must be parallel to the oscilloscope CRT face when "writing".

The time base or sweep of the oscilloscope must be triggered by the memory clock. This is illustrated below.

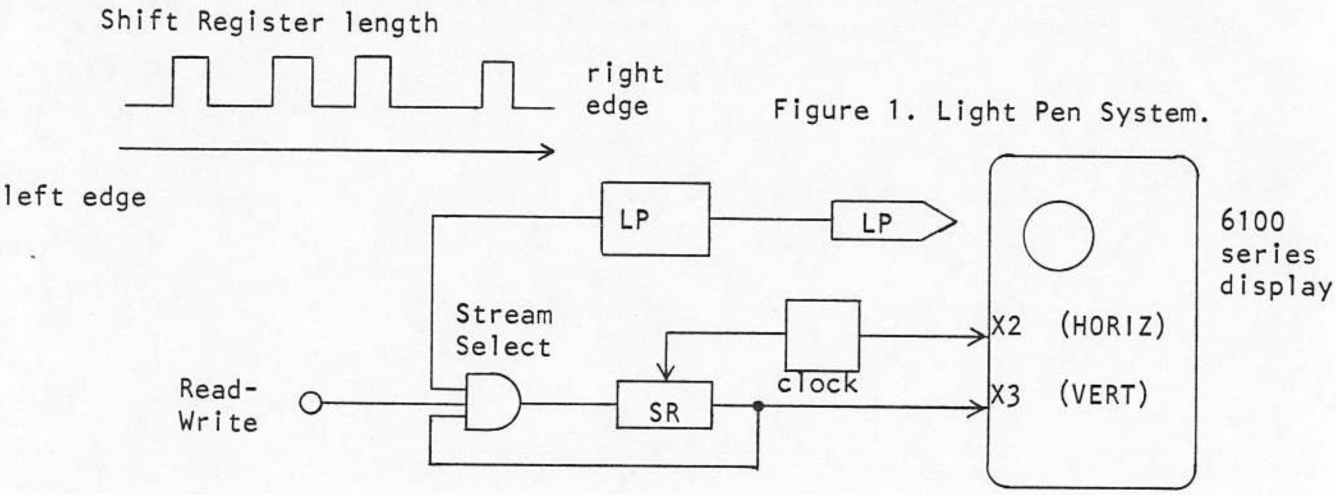

Figure 1. Light Pen System.

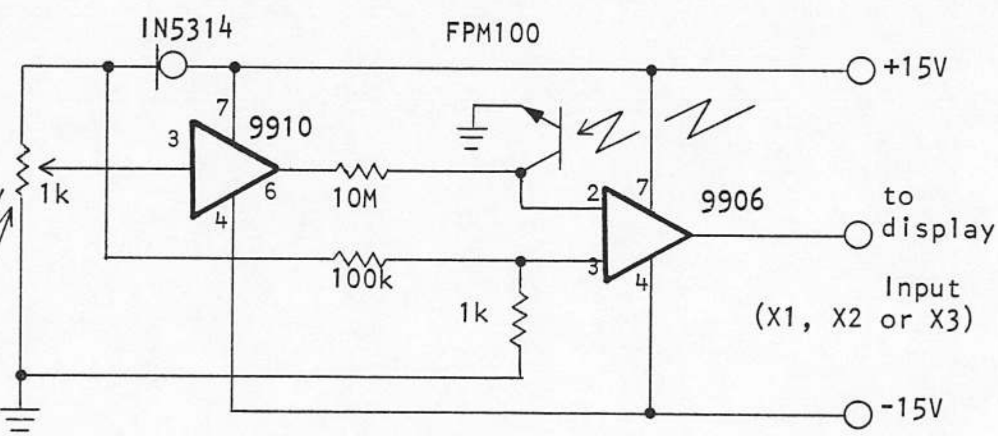

Figure 2. Actual Light Pen Circuitry

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THE 6100 SERIES USED IN MEASUREMENT DISPLAYS

INTRODUCTION. The 6100 series 3-D Graphic Display modules are an important display component for measurement systems. While the information is displayed visually in 3-D form, 200% more information is visible in one image than on conventional XY displays.

Whether the display is of system transfer functions, device parameters or populations, three times the information is available in the image. Standard XY displays put the information on one plane. The 3-D Graphic Display system places the information on three planes. Figure 1 shows three deflection axes found in the 3-D Graphic Display. The system has three deflection inputs causing movement along the axes.

As can be seen, any two deflection inputs describe one plane, but all three deflection inputs describe three planes. Three dependent parameters are usually displayed on the three axes, and the functional relationship between any two of them can be displayed by rotating the image. A viewing angle skewed to all three axes permits the viewing of all three sets of functions. In production or test measurements, the 3-D image becomes easily recognizable as being correct or abnormal.

Described in this Application Note are typical examples of the types of measurement applications using the 3-D Graphic Display equipment.

SYSTEM CHARACTERISTICS. The application described shows three transfer functions of a single system. Since the three signals are all related to each other, they all are of the same frequency and the image produced is a single line.

The one-variable image is always a straight line. Orientation of the line is noted by the position of the rotation controls. The aerial perspective depth cue becomes the key cue in this image. Rotation is secondary in determining the exact position of the line display. Stereo is quite helpful in this case.

Repeated use quickly permits distinction between "normal" line images and the "abnormal" line patterns.

Referring to Figure 1, the X2-X3 plane contains the overall system transfer function. This is observable by placing X1 in a position perpendicular to the observer (X2-X3 plane flat to the observer). The X1-X2 plane shows the transfer function between the system input and some intermediate point. The X1-X3 plane contains the transfer function between that intermediate point and the output.

The intermediate point may be any point inside an analog system....After

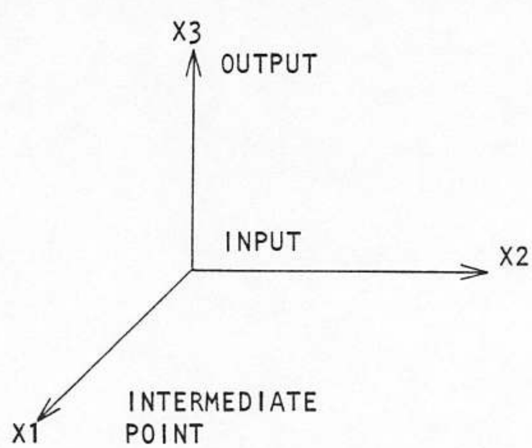


Figure 1. Basic Display

the log conversion and before the anti-log conversion....After input buffering and scaling and before the line driver, etc.

POPULATION DISPLAY. There are many population maps and models made mechanically by hand. There is some equipment available that will automatically produce mechanical models. The 6100 series 3-D Graphic Display modules will display a population map as shown in Figure 2. OEI Application Tip 12027 describes how to use standard OEI Modules to construct a simple system to produce this type of display. It is available on request.

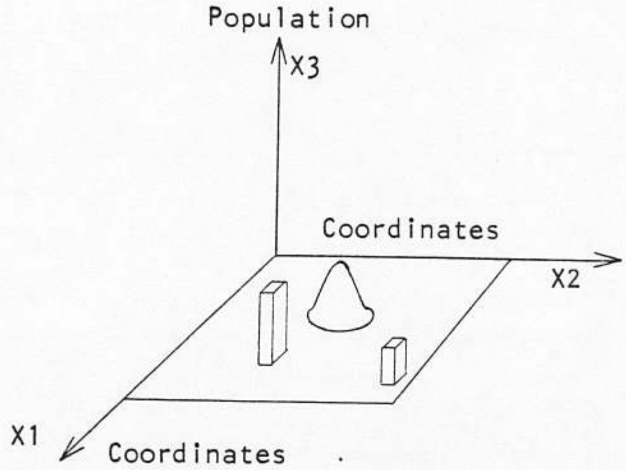


Figure 2. A Population Display image.

The display consists of the amount of population or existence of population displayed vertically on the X3 axis. The location of the population is displayed on the X1-X2 plane. The X1 and X2 deflection signals are normally sawtooth or staircase coordinate signals that drive comparators (sense amplifier).

If simple existence of population is important, the comparator outputs are simply ORed together and used to drive the X3 axis. If population count is displayed, a pulse count or multi-channel analyzer is required and the analog information is then displayed on the X3 axis.

The population display can show the 3-D presentation of a spectrum analyzer (coordinates are time and frequency), 3-D correlation (coordinates are time and time delay), nuclear population, photographic analyzer, etc.

The population Display is a plane-image since there are two variables. This is shown in Figure 2.....the two variables being the two coordinate sweep signals.

DEVICE PARAMETERS-TRANSISTOR PROPERTIES. The 3-D Graphic Display may present three parameters of a transistor. Conventionally, collector current is displayed versus collector-emitter voltage for a family of base current drives.

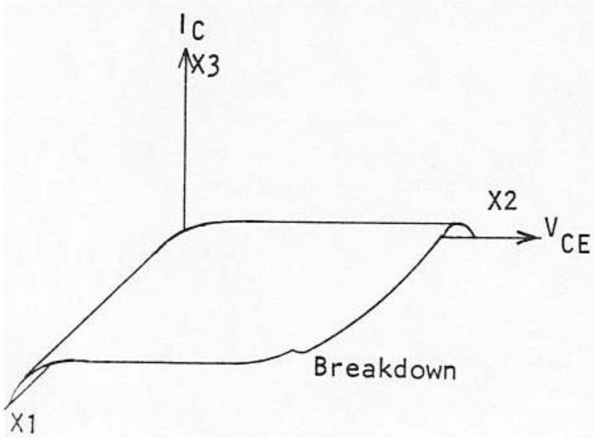


Figure 3. A display of Transistor characteristics.

Figure 3 shows the type of display when collector current versus collector-emitter voltage versus base current is shown. The image is a plane-image type because there are two variables. Base current and collector-emitter voltage are both swept at different rates (usually base current is swept slower than collector-emitter voltage).

Other combinations may be displayed, such as I_c vs. V_{cE} vs. V_{BE}; V_{BE} vs. V_{cE} vs. I_B; I_B vs. I_c vs. V_{cE}; where the first parameter listed is the measurement dependent on the other two parameters.

Their independent characteristics of the transistor under test may be viewed. The Conventional I_c vs. V_{cE} for various base currents, I_c vs. I_B and the driven parameters I_B vs. V_{cE}. All three sets can be seen simultaneously by viewing from a skewed angle.

DEVICE PARAMETERS-FET PROPERTIES. The Field Effect Transistor can be advantageously observed in the same manner as the bipolar transistor discussed above. Groups of parameters observed could be I_D vs. V_{GS} vs. V_{DS} or V_{GS} vs. I_D vs. V_{GS} or I_D vs. R_S vs. V_{GS}, etc.

Figure 4 shows the nature of the plane-image FET parameter display. The two driven axes are V_{GS} and V_{DS} with I_D being the measured dependent parameter.

OPERATIONAL AMPLIFIER PARAMETERS. The versatile operational amplifier has many sets of parameters. One particularly useful combination of characteristics to be three dimensionally viewed is the output voltage versus input differential voltage versus power supply voltage. This presents the open loop gain versus power supply voltage, output voltage swing versus power supply voltage and input offset voltage versus power supply voltage (power supply rejection).

Other combinations to be displayed are open loop gain (or closed loop gain) versus phase versus frequency, output current versus R_L versus power supply voltage, Input Offset Current versus Input Common Mode Voltage versus Power Supply Voltage, Common Mode Rejection versus Common Mode Voltage versus Frequency, etc.

The operational amplifier characteristic shown in Figure 5 is a plane-image because there are two driven variables; Power Supply Voltage and Differential Input Voltage. The Output Voltage is the dependent measured variable.

The operational amplifier is given as an example of a complex "component". An analog multiplier may be displayed with the two inputs as the two driven parameters on axes X1 and X2. The output is the dependent parameter viewed on X3 axis. This produces a twisted plane centered about the origin (zero product point).

Other Analog functional blocks such as dividers, squarers, square rooters, log amplifiers, sense amplifiers, etc. may be similarly observed. Any three parameters that are measureable and can be instrumented can be three dimensionally presented. Three times the amount of information over the conventional XY display is presented in one visual image. Despite the added complexity of the display, subtle differences from "norm" can be easily detected.

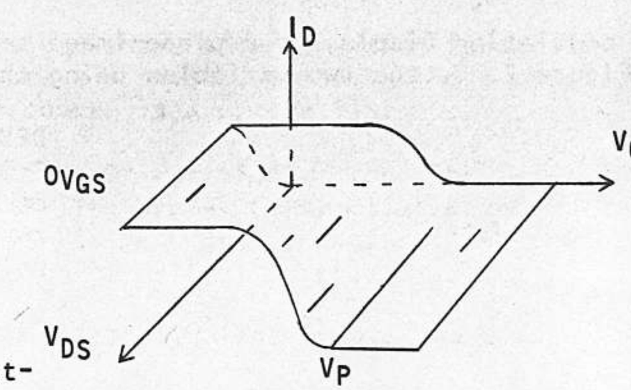


Figure 4. FET characteristics

DIGITAL GATE PARAMETERS. Figure 6 shows the input-output transfer function of the digital gate versus power dissipation. This is a particularly used presentation if the gate under test is a low power type.

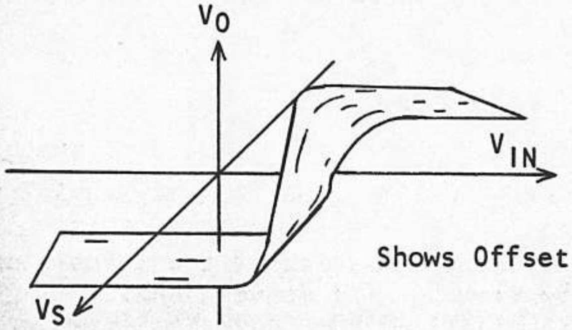


Figure 5. Operational Amplifier Parameters

Other gate parameters to be observed might be output versus input versus supply voltage, output versus load (fan out) versus supply voltage, output versus one input versus the second input etc.

SUMMARY. Any set of three parameters that can be sensed of any device or system can be displayed, to a definite advantage, with the 3-D Graphic Display equipment.

The three deflection axes portray three times the information in a single image than a conventional flat, two dimensional image. Both images are equally easy to view but the 3-D system increases the information content and reduces performance decision time and improves testing efficiency.

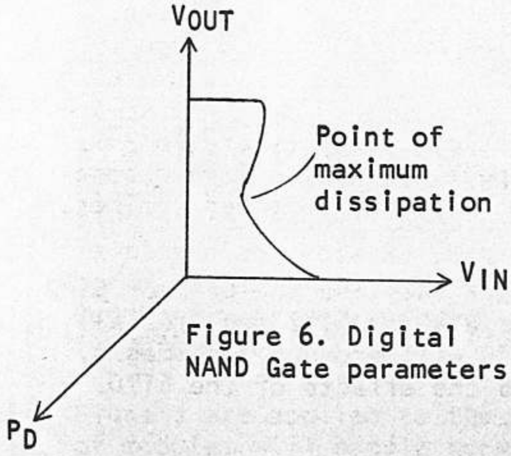
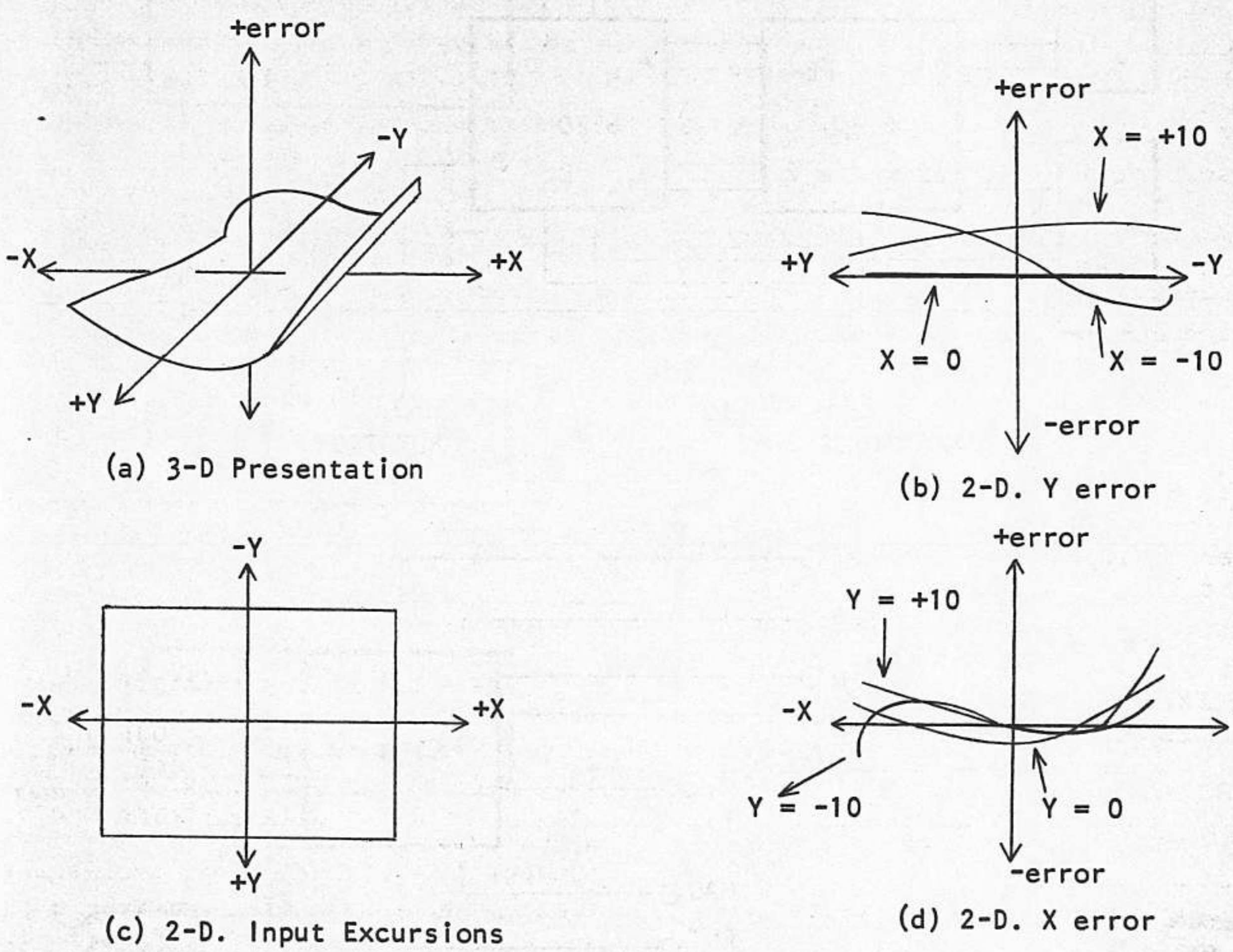


Figure 6. Digital NAND Gate parameters

Despite the 3-D nature of the image, by rotation, any two axes may be observed. Figure 7 illustrates this.

Figure 7a shows a typical 3-D presentation of four quadrant analog multiplier error. Figure 7b shows the same information with the X axes aligned in the sagital axis position, that is perpendicular to the viewer. Figure 7c shows the image with the error axis of Figure 3a aligned perpendicular to the viewer. Figure 7d shows the same information with the Y axis aligned perpendicular to the viewer.



(a) 3-D Presentation

(b) 2-D. Y error

(c) 2-D. Input Excursions

(d) 2-D. X error

Figure 7. Four Quadrant Analog Multiplier Error - various views.

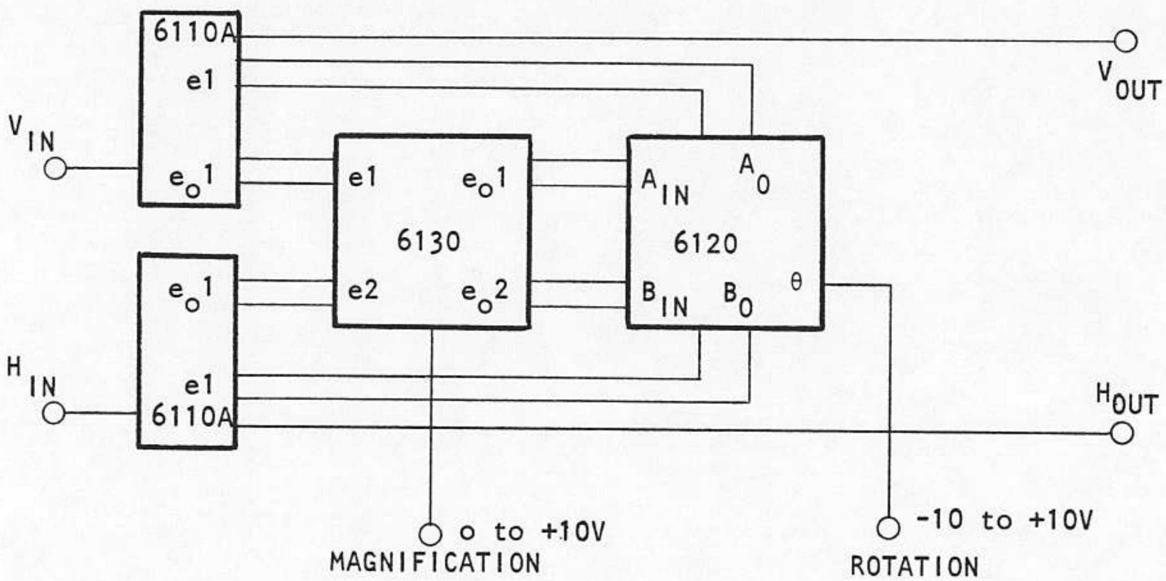
TWO-DIMENSIONAL DISPLAY APPLICATIONS FOR THREE-DIMENSIONAL DISPLAY MODULES

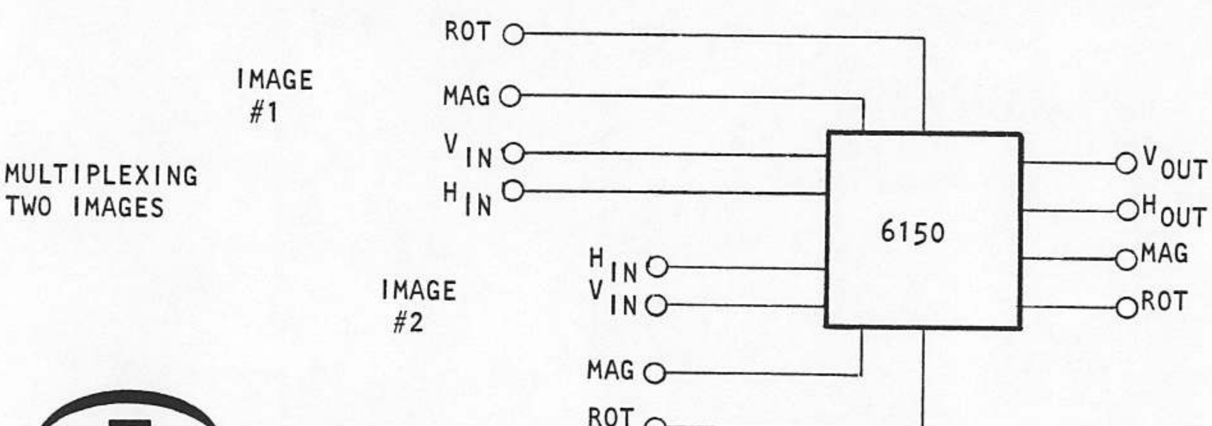
The 6100 series of 3-D graphic display modules can be used, as illustrated below, in two dimensional situations to provide rotation, magnification, and other display functions.

Basically, instead of using three channel amplifiers, two are required. Since rotation can only take place in one plane, only one rotator module can be used. The magnifier module can be used to voltage program the size of the displayed image. The image multiplexer and axis generator modules may be used to superimpose axes on the graphics or to add alphanumerics.

Connections to the modules are the same in 2-D applications, as they are in 3-D applications. One exception to this is that the perspective input of the channel amplifier module is left dis-connected. All other connections, component values, etc. are the same.

Two modules are not recommended for use in 2-D systems. They are the 6140 or 6142 Focal field module and the 6170 Stereo generator. The 6140 or 6142 requires all three deflection signals of 3-D applications. The 6170 will produce two images, but there will be a lack of depth cues which will void the effects of the 6170.





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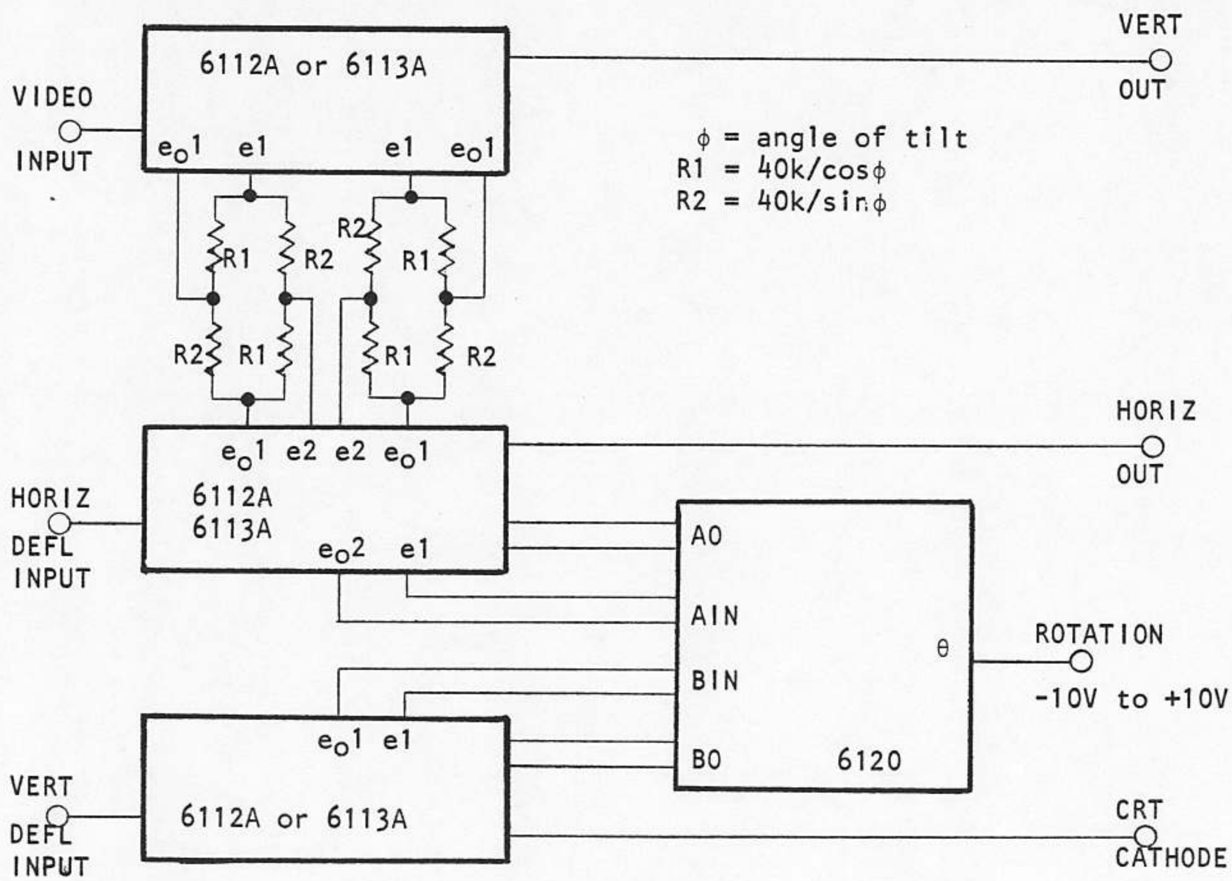
DISPLAYING GRAY-SCALE INFORMATION ISOMETRICALLY

In video systems, the video information is in the form of numerous shades of gray. In commercial television, there are about 8 shades of gray visible between black and white. This is generally acceptable for TV type scenes, alphanumeric and graphic displays. When the video system is used for spectrographic and photographic analysis, a large number of gray levels need to be distinguished. Since video information can be displayed on an oscilloscope and measured, an infinite video resolution is possible but awkward. The oscilloscope loses positional information and greatly complicates analysis and coordination of video information with raster position. A computer can be used but this is expensive.

Shown below is a method using the 6100 series of 3-D modules to display the raster as a flat plane with video as hills and valleys. This isometric image can be rotated and tilted for various viewing angles. The infinite resolution of the 6100 series allows the viewer to resolve hundreds of gray levels. If the image is tilted and rotated such that the raster is parallel to the viewing screen, a normal video picture is seen because of the behávior of the aerial perspective. Geometric perspective must be reduced to zero to eliminate positional distortion in this case.

Signals are applied to the 6100 system as shown. The 6112A series (500kHz family) of modules will handle normal TV raster signals but will limit video bandwidth. The 6113A series (5MHz family) should be used for full video bandwidth performance.



CANCELING OFFSET ERRORS IN THE 6100-SERIES SYSTEM

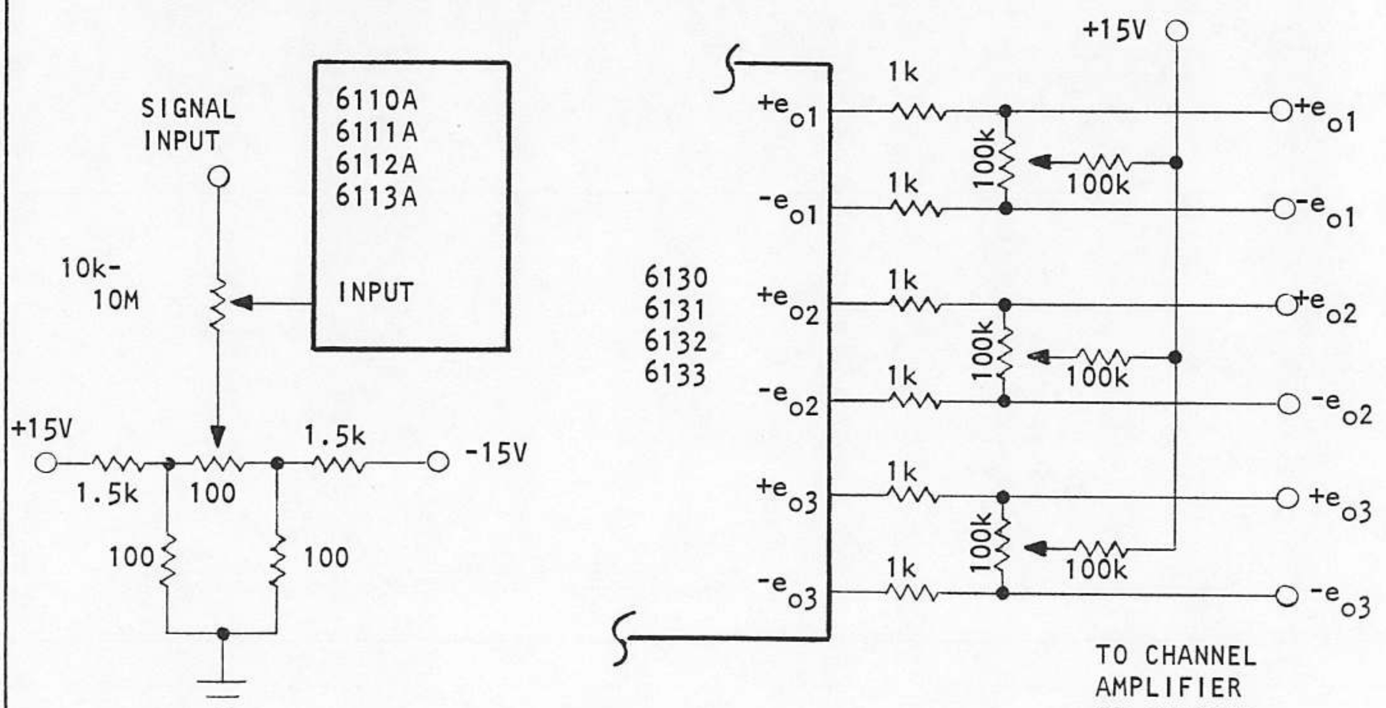
Offset voltages produce various undesirable effects in the 3-D display system, however they are easily eliminated. When an offset voltage (DC error voltage) exists at the output of the system, after rotation, the error causes a shift of the image away from the center of the CRT. This error is readily corrected with the position adjustments for the vertical and horizontal at the CRT display.

If an offset voltage exists in one of the deflection input signals, the image will rotate about a center away from the center of the image, in some cases, producing an annoying "bounce". Offset voltage produced at the signal source can be eliminated at the channel amplifier as shown below.

If the amount of offset varies with magnification, the offset errors are in the 6100 series modules. This offset can be corrected at the output of the magnifier module as shown.

To set up the various adjustments, connect the rotator angle input to a 1kHz, ±10V sine wave. The input corresponding to the axis of rotation should be connected to another signal source to produce a straight line. The other two inputs are grounded. With the fast rotation, adjust the pots, corresponding to the grounded inputs for a minimum amount of motion of the straight line. Then adjust the input offset at the channel amplifier and repeat both adjustments until the line has no motion for all magnification levels. When an input signal is then added, any "bounce" to the image will be due to an offset voltage in the image deflection signal (this offset may be part of the actual signal!).

With these adjustments, the effects of all offset errors can be eliminated for a precision display requirement.



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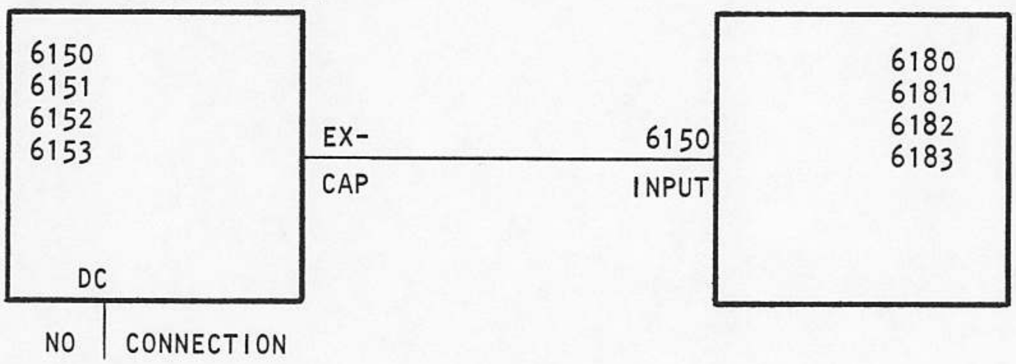
IMPROVING THE BLANKING IN THE MULTIPLEXED IMAGE MODE

Using the Model 6150 (6151,6152,6153) to superimpose two images is often desirable. When the 6150 "DC" pin is left open, there is an equal time sharing between the two images. Switching transients are automatically blanked by using the Model 6180 blanking generator module connected normally as shown.

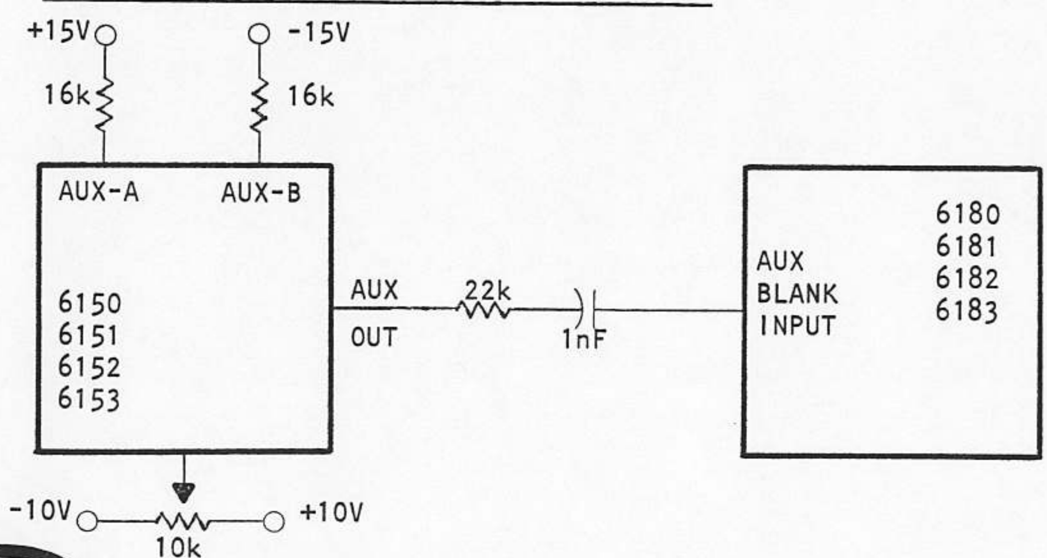
When a potentiometer is connected to the "DC" pin of the 6150, the duty cycle is changed from 50-50. This is useful in adjusting the relative intensity of the two images. When this feature is used, the connection from the 6150 to the 6180 must be changed as shown.

The 6180 receives a signal from the 6150 as to the switching times of the 6150. The 6180 produces a blanking pulse that turns off the display for a period of time necessary to blank all switching transients. For the variable duty cycle mode, the fourth, auxillary, channel of the 6150 is used to generate a switching waveform that can be differentiated and used to drive an auxillary input on the 6180. The RC time constant shown is a function of the 6150 clock frequency only and not on the model of module used (6151,6152,6153,6181,6182,6183).

"NORMAL" CONNECTION.



"VARIABLE RELATIVE INTENSITY" CONNECTION.



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USING THE 6100 SERIES 3-D SYSTEM WITH HEWLETT-PACKARD 1310A/1311A DISPLAYS

The OEI 6100 series of 3-D display modules performs all of the required signal processing from the three deflection inputs to the vertical, horizontal and blanking outputs. What they do not perform is the display function. A suitable CRT display should have a dark faced CRT, free of any reticule lines.

Electrically, the display must have identical vertical and horizontal deflection amplifiers having 10 volt full scale input level horizontally and (10V/H) volts full scale vertically, where V is the vertical dimension of the CRT and H is the horizontal dimension. This difference in input full scale sensitivity actually insures equal deflection sensitivity! It is important that there is the same inches/volt deflection factor for both vertical and horizontal.

Not only must deflection sensitivities be matched but frequency response of the vertical and horizontal amplifiers must match. Real response is not as important as the matching and relative phase shift is the key parameter. A phase shift of less than 1° over the bandwidth of the 6100 series modules is a must for good image fidelity.

The CRT video input must be positive blanking (that is a positive intensity input reduces the CRT intensity). Complete CRT blanking voltage must not exceed +10 volts. The intensity circuit (called Z axis) must be DC coupled and have a bandwidth that is at least as wide as the vertical and horizontal bandwidths.

Other important parameters of a desirable display is that the deflection amplifiers will produce full screen diameter deflection at the -3dB frequency (in other words - they are not slew rate limited). The CRT brightness must be great enough for the ambient lighting conditions of the application. Phospor protection should be considered. CRT size and other human - factors type parameters are up to the user and the application requirements.

The Hewlett-Packard 1310A and 1311A displays fulfill all requirements for a CRT display. An aluminized P31 phosphor CRT is standard which has a dark face. Deflection sensitivity is changed to 10 volts F.S. horizontally by adding and changing a resistor in the display. (R_a=27.4k, R_b=3.01k in the display - see HP manual.) Vertical sensitivity is set at 7.33 volts F.S. for the 1310A (R_a=26.1k, R_b=4.12k) and at 7.73 volts F.S. for the 1311A (R_a=26.1k, R_b=3.92k). These resistors are placed on an internal circuit board which is illustrated in the manual from Hewlett-Packard.

The "Z axis" or CRT blanking is internally at +1 volt for full cutoff, hence the output of the X1 channel amplifier or 6180-1-2-3 module must be reduced. A potentiometer at this point is desirable to accommodate the various settings of the display intensity control.

Request a copy of Application Note 166, "1310A/1311A Application and Interfacing Hints" from Hewlett-packard.

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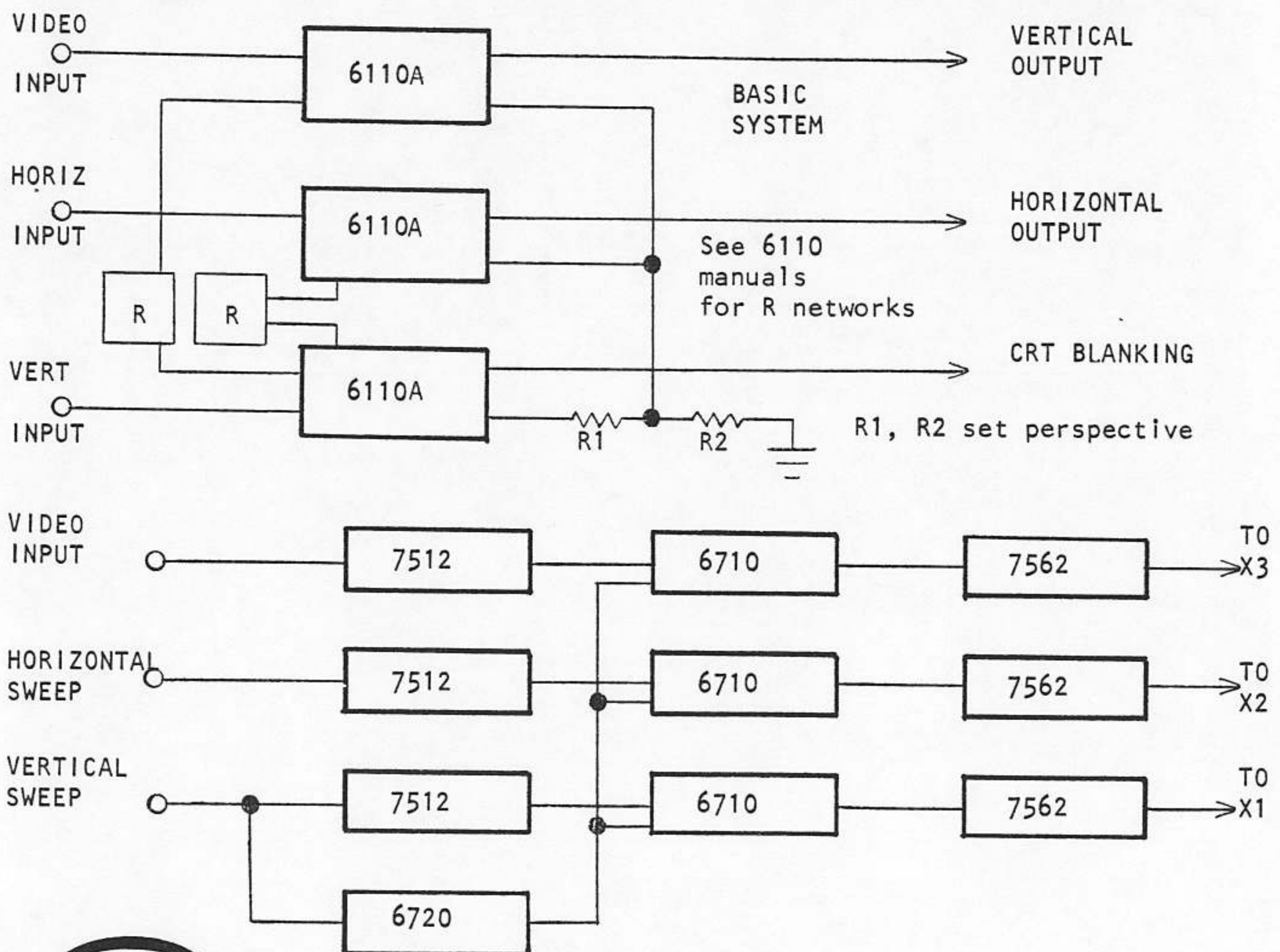
ISOMETRIC THERMOGRAPHY

The field of Thermography is similar to television in that an object is scanned to produce an image of the object. Differences to standard television include the exclusive use of long infrared wavelengths (typically 8 to 14 Microns), no ambient illumination and slow scanning.

Commercial thermographic equipment generally uses scan conversion equipment for display on conventional television equipment. The different shades of gray indicate different temperatures. Because the thermal sensitivity of medical thermographic equipment is usually less than 0.1°C and the gray scale is limited to 8 shades of gray, the dynamic range is quite restricted. In industrial equipment, a greater thermal range is convered but here the resolution of temperature is lost.

The circuit shown below uses the OEI 6100 series 3-D display modules to isometrically display the temperature. Because of the slow scanning rates involved, the 6110A series of lowest cost modules are used. The temperature represents the elevation of the V-H plane which represents vertical and horizontal position. Because of the slow scanning rates, some means of image storage must be used for a flicker free display. A storage scope may be used if no image manipulation is to take place (no rotation, magnification or focal field). If any manipulation is desired. the Model 6710 recirculating memories should be used.



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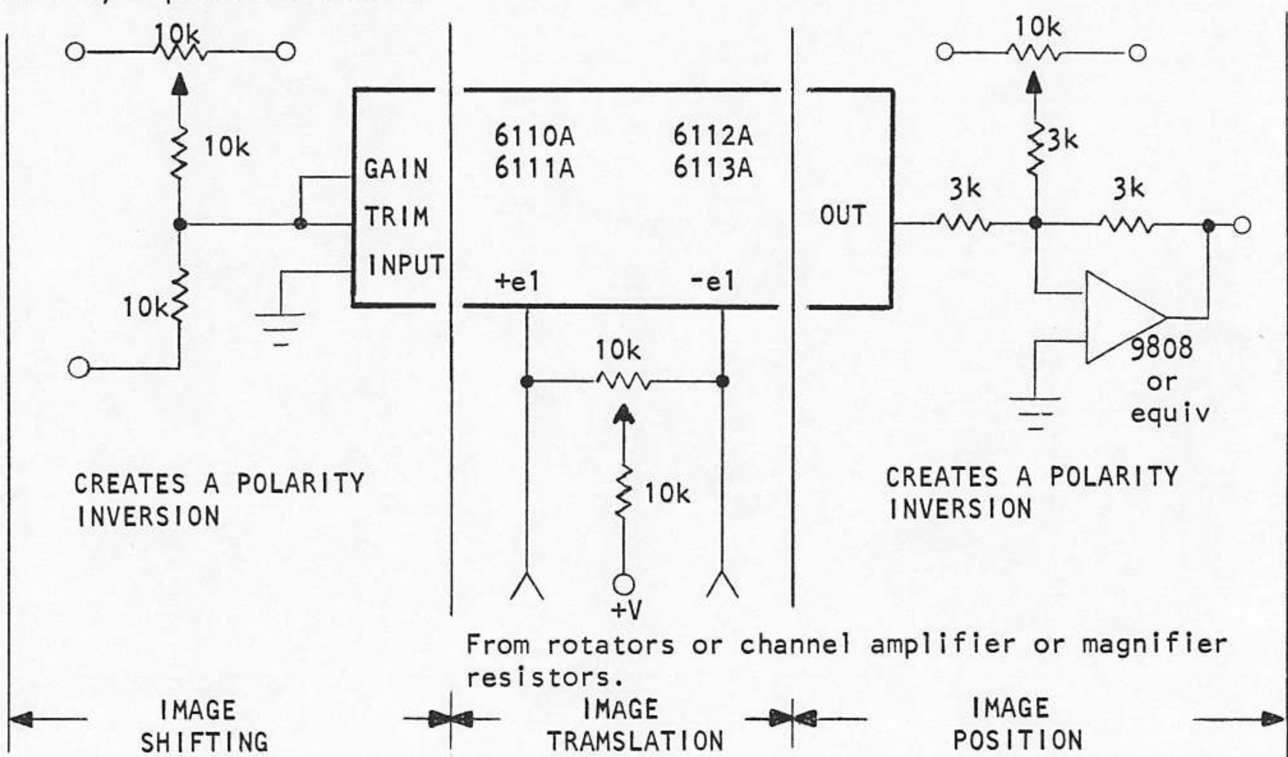
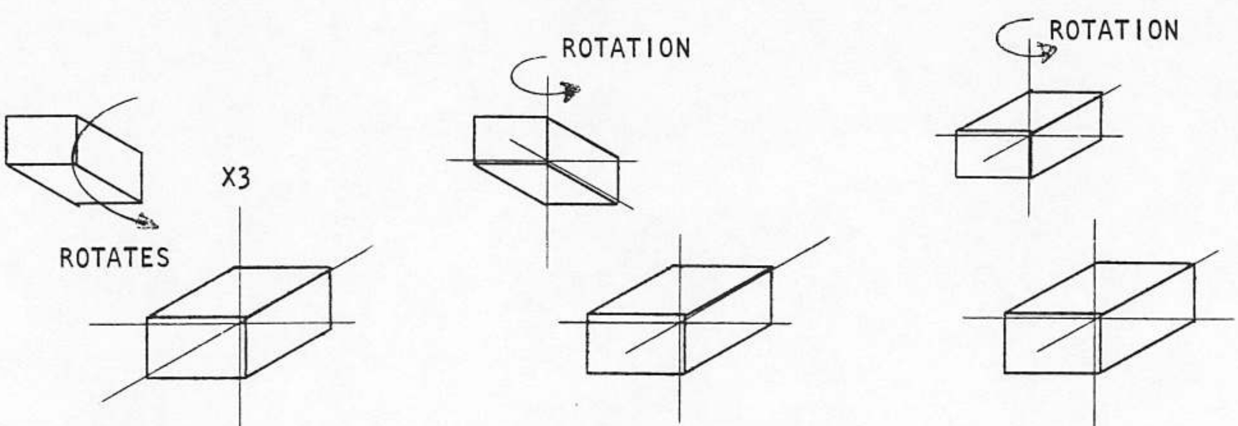
POSITIONING THE 3-D IMAGES

It is required, in some applications, to move the position of the image. With the 3-D system, there are six ways in which the image can be moved: (1) vertically, (2) horizontally, (3) longitudinally, (4) along X1 axis,(5) along X2 axis or (6) along X3 axis. Positional movement vertically or horizontally refers to movement on the face of the CRT. Longitudinal movement is the positional shift towards or away from the CRT face. Movement along the three deflection axes represents a DC shift of the input deflection waveforms.

There are two means of causing a vertical or horizontal positional shift. If the 6100 series vertical and horizontal output voltages are shifted with DC, the image has had a positional change. If the DC level has been changed at the channel amplifiers as shown below, the image has had a positional translation. This is graphically represented below.





Assuming an X2 and X3 positional change:

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DISPLAYING 3-D IMAGES ON TELEVISION

The outputs of the 6100 series system are intended to drive the vertical, horizontal and blanking inputs of a conventional CRT XY Display. The three outputs of the 6100 series system may drive the inputs of a Scan-Converter.

Scan converters are available from several manufacturers and convert analog XY inputs into a composite video output. The basic connections are shown below.

The Hughes Model MSC-1 requires an attenuation factor of 20 to drive the 1.0 volt peak-to-peak deflection inputs from the 6100 series outputs. The deflection bandwidth is compatible with the 6110A and 6111A series. The video input requires an attenuation factor of 40 from the CRT blanking output.

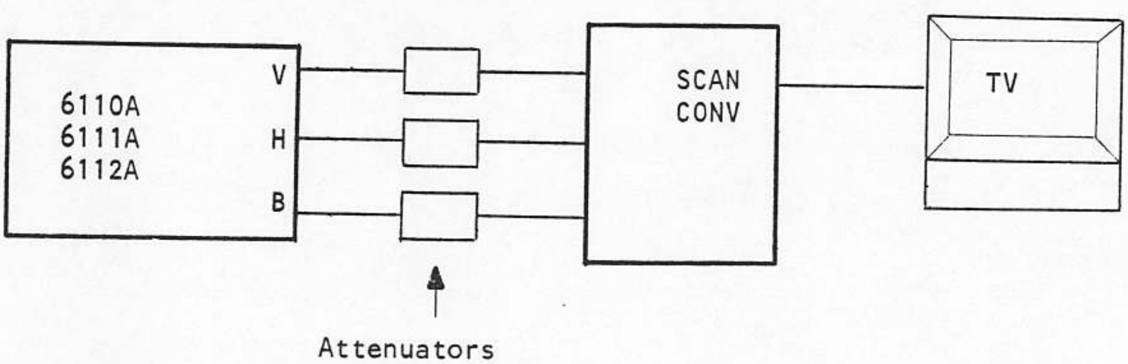
The Hughes Model 639 has the same requirements described above but offers greater flexibility. Both models require write and erase commands. Since these are storage devices, the erase time limits the number of different frames per second. The MSCI provides 3 frames per second while the 639 runs at 30 frames per second.

The Princeton Electronics Products Model PEP-400 is compatible with the 6110A, 6111A series and the 6112A up to 200kHz. The vertical and horizontal outputs must be attenuated by a factor of 13. The CRT blanking output requires an attenuation factor of 20. Two to four frames per second are possible. Write and erase commands are required.

Systems Research Laboratories Model 324 is compatible with the 6110A, 6111A series and the 6112A series up to 100kHz. The vertical and horizontal outputs must be attenuated by a factor of 13 to 50 and the CRT blanking output requires a 20X attenuation. 30 frames per second are possible. Write and erase commands are required.

The Tektronix Model 4503 Scan Converter may be used with the 6110A, 6111A or 6112A series. The vertical, horizontal and CRT blanking outputs require an attenuation factor of 20. 30 frames per second are obtainable.

In addition to the scan converters, television type hard copy recorders are available. The Alden Models 400 and 600, Gould Model HC610 and Tektronix Model 4602 are examples. A hard copy of the three-dimensional television image complete with gray-scale rendition is possible.



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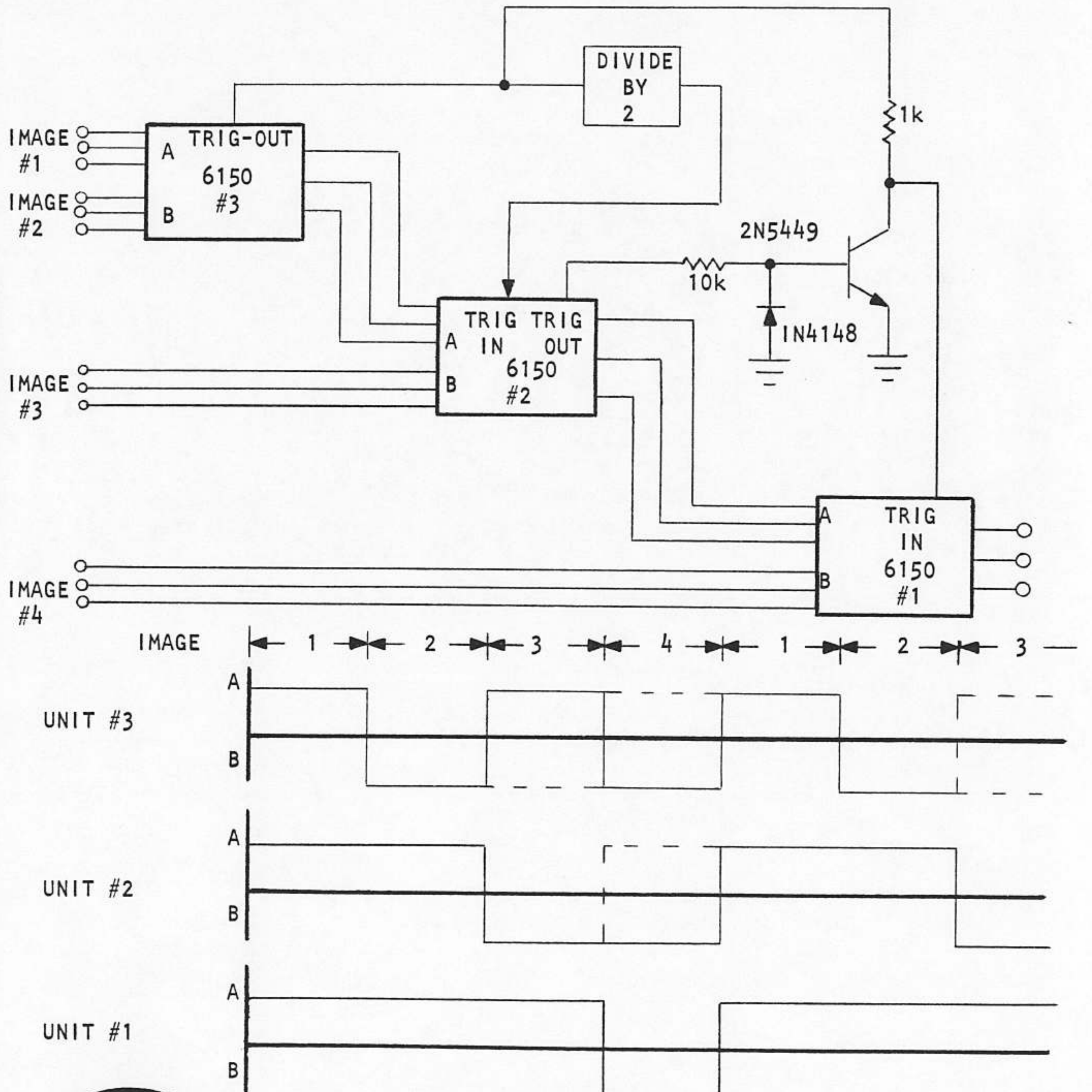
USING MULTIPLE 6150's FOR USE WITH THREE OR MORE MULTIPLEXED IMAGES

The Models 6150, 6151, 6152 and 6153 are image multiplexers used to superimpose two images. The 6150 can be used to switch from an image to the output of another 6150. This is illustrated below.

The main item of concern in this application is the switching times of the 6150's. In the example below, unit number 3 has the highest clock frequency and unit number 2 has exactly one-half the clock frequency of number 3. If more than three Model 6150 multiplexers are used, the timing is the same for units 1, 2 and 3. Unit number 3 would be slaved by number 4 in the same way as unit 2 is slaved by 3. The highest numbered 6150 can be slaved by an external sync signal.



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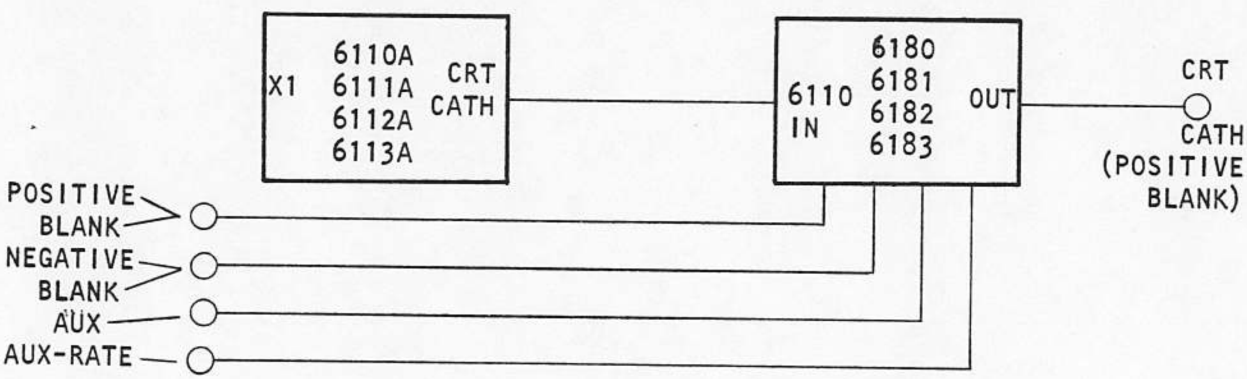
AUXILLARY CRT BLANKING WITH THE 6100 SERIES 3-D SYSTEM

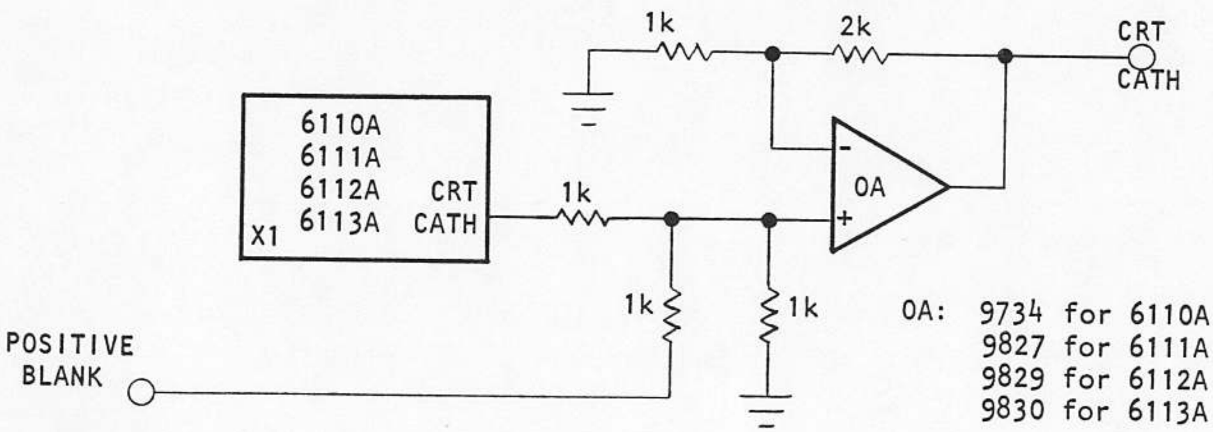
The OEI Model 6100 series of three-dimensional display generation modules accepts three deflection inputs and provides vertical and horizontal deflection and CRT blanking outputs to drive a conventional XY display. If auxillary blanking is to be added to the image, it should be done as shown below.

The 6100 series system generates an analog blanking voltage to provide aerial perspective. When 6150, 6160 or 6170 modules are used, blanking are added to eliminate switching transients in the image. The 6180 module generates the blanking information and provides auxillary blanking inputs.

Externally produced blanking pulses may be desirable: to eliminate image disturbances due to image generation circuits in the customer's equipment; to blank a storage CRT between slow data. External blanking information may come from vector generators or other computer generated graphics or alpha-numerics.

The circuit below using the 6180 provides 4 inputs. The "POSITIVE BLANK" produces blanking for positive inputs. "NEGATIVE BLANK" produces blanking with negative inputs. These two inputs have unity gain reflected to the 6180 output. The "AUX" input produces a full +10 volt blanking with positive or negative inputs of 30 millivolts or more. This input is used with TTL logic levels. The "AUX RATE" input is used with an external capacitor in series to differentiate switching transients or non-linear deflection voltages. Positive or negative slopes will produce blanking.





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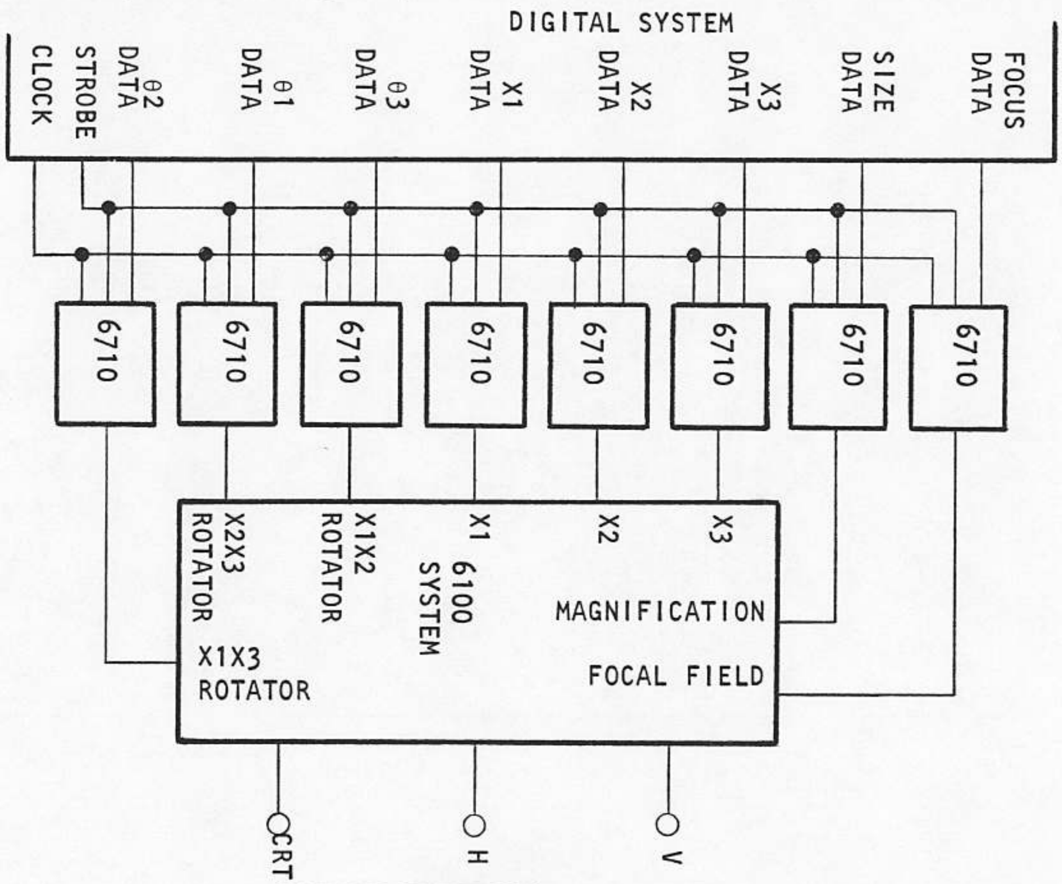
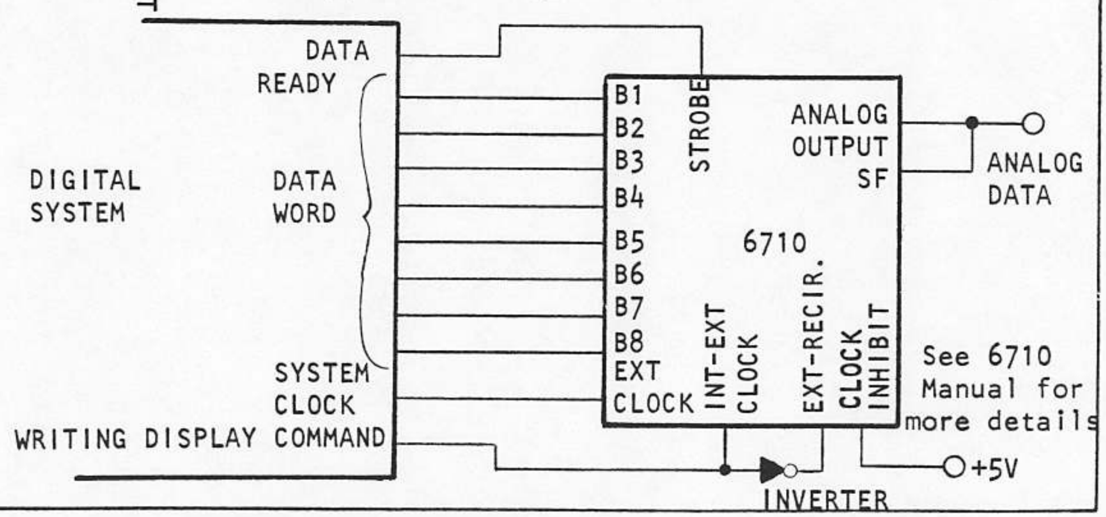
USING THE 6710 DIGITAL/ANALOG BUFFER INTERFACE

The OEI Model 6710 module is designed for use with the 6100 series 3-D display system. The 6710 contains a 512 word by 8 bit recirculating memory, internal clock and digital-to-analog converter. Information may be put into the 6710 at a rate different to the recirculating/output rate.

The 6710 is designed to store image deflection information or command information. The block diagram shows the maximum usage of the 6710 with the 6100 series system. A more detailed diagram below shows how the 6710 receives data from the digital system. The internal digital-to-analog converter is driven from the input of the shift register memory, hence there is no recirculation delay in the "write" mode from digital input to analog output.





See 6710 Manual for more details

54-

USING THE 6100 SERIES FOR VECTORCARDIOGRAPHY

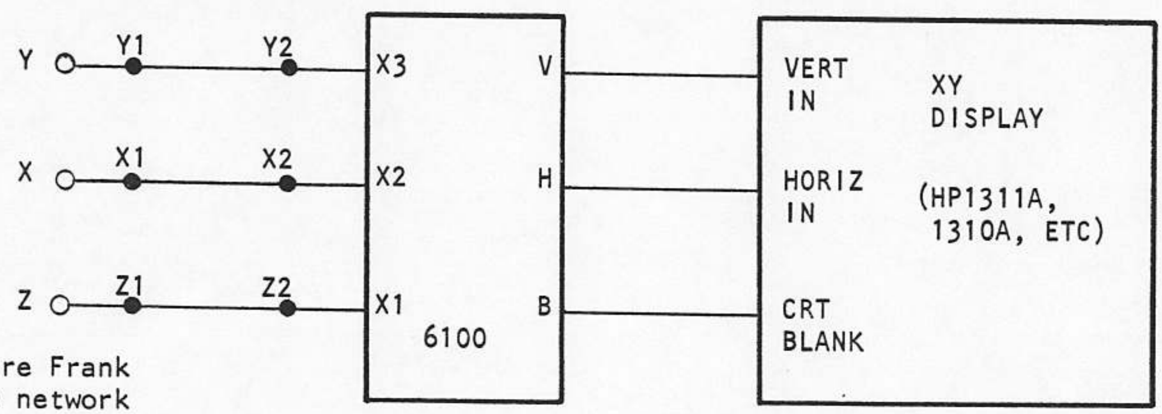
Vectorcardiography is the study of the electrical activity within the heart. Conventional vectorcardiograms are obtained by taking electrocardiograms along three orthogonal axes. Each ECG is displayed and photographed. A wire model (or other model method) is made if the 3-D VCG is to be studied.

The 6100 series 3-D Display Modules may be used to display the three ECG's in real time along three orthogonal axes. This method of display provides an accurate and realistic portrayal of the spatial VCG.

The 6100 series system has full scale input voltage requirements of 100mV to 10V, which necessitates the use of conventional ECG differential preamps.

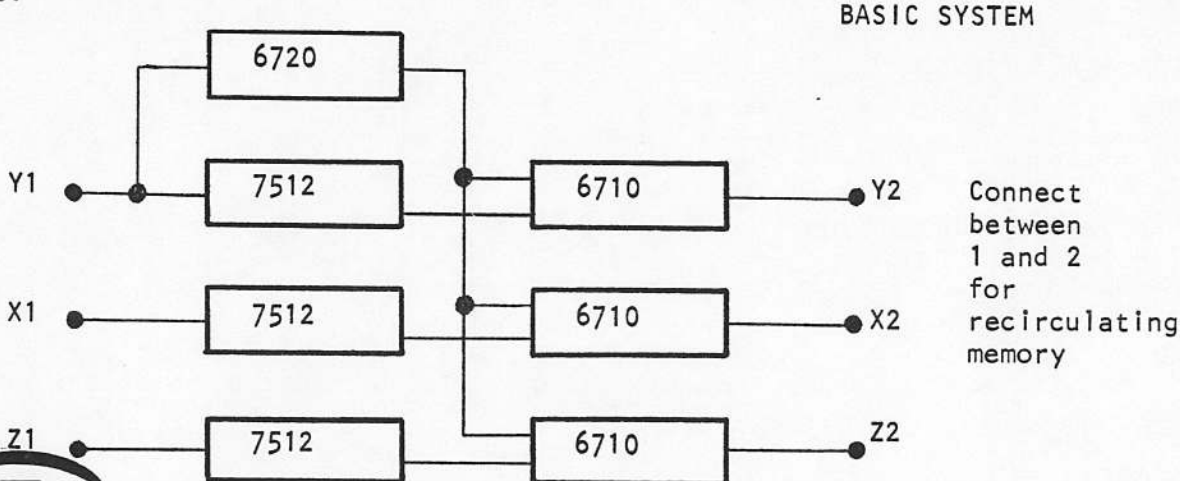
A storage type XY display can be used to show the VCG, however, no manipulation of the image is possible once the storage has taken place. To eliminate this problem, the use of the Model 6710 recirculating memory is recommended. A Model 6720 can be used to determine the VCG rate and establish a clock rate for the 6710 so that one complete VCG is placed in the 6710 memory. Readout of the VCG from the 6710 can take place at a much faster rate so that a steady VCG image is presented. No flicker will be present and all of the 6100 series system functions are usable such as rotation, magnification, stereo pair, focal field, etc.

A Model 6750 can be used to place the VCG on conventional magnetic tape cassettes for long term storage. An entire series of VCG's may be stored in a large recirculating memory, Model 6760 and 6770.



X, Y, Z are Frank Electrode network Outputs.

BASIC SYSTEM



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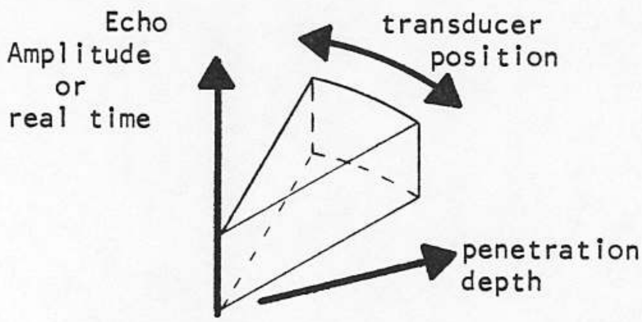
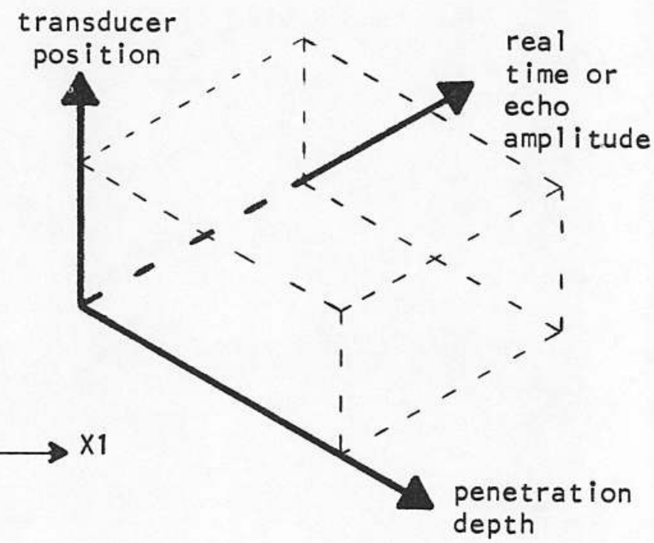
3-D ECHOCARDIOGRAPHY DISPLAY

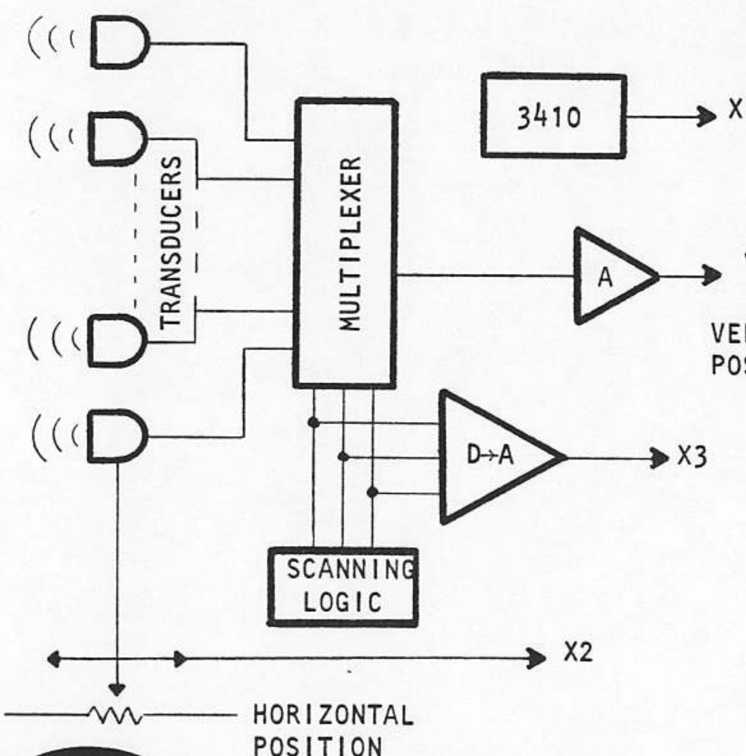
A major area of the application of ultrasonics in medicine is echocardiography. This is the "viewing" of the heart with ultrasonic energy from one or more transducers. Since the heart is a dynamic (time changing) organ, there are several modes of three dimensional display of the information.

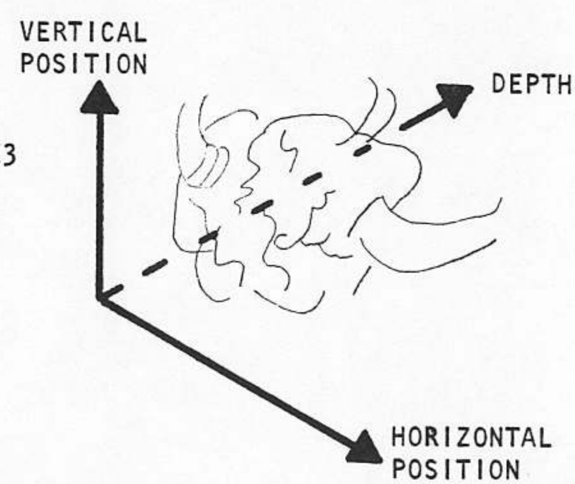
A single transducer must be scanned in a straight line (B-scan) or rocked (see Application Tip 12054) to physically scan the heart. Ideally, a raster scan would produce a total view of the heart but the rate of physical movement would be prohibitively fast for real time imaging. If a number of transducers are used in a linear array and physically scanned in one direction, a raster scan is accomplished. Outputs of the transducers are multiplexed and positioned on the display. The time delay of the reflected energy is converted into a voltage representing depth. A true 3-D scene representing the heart and its' surrounding is presented.

The simpler B-scan and rocking scan modes are shown below along with the more desirable raster scan display.









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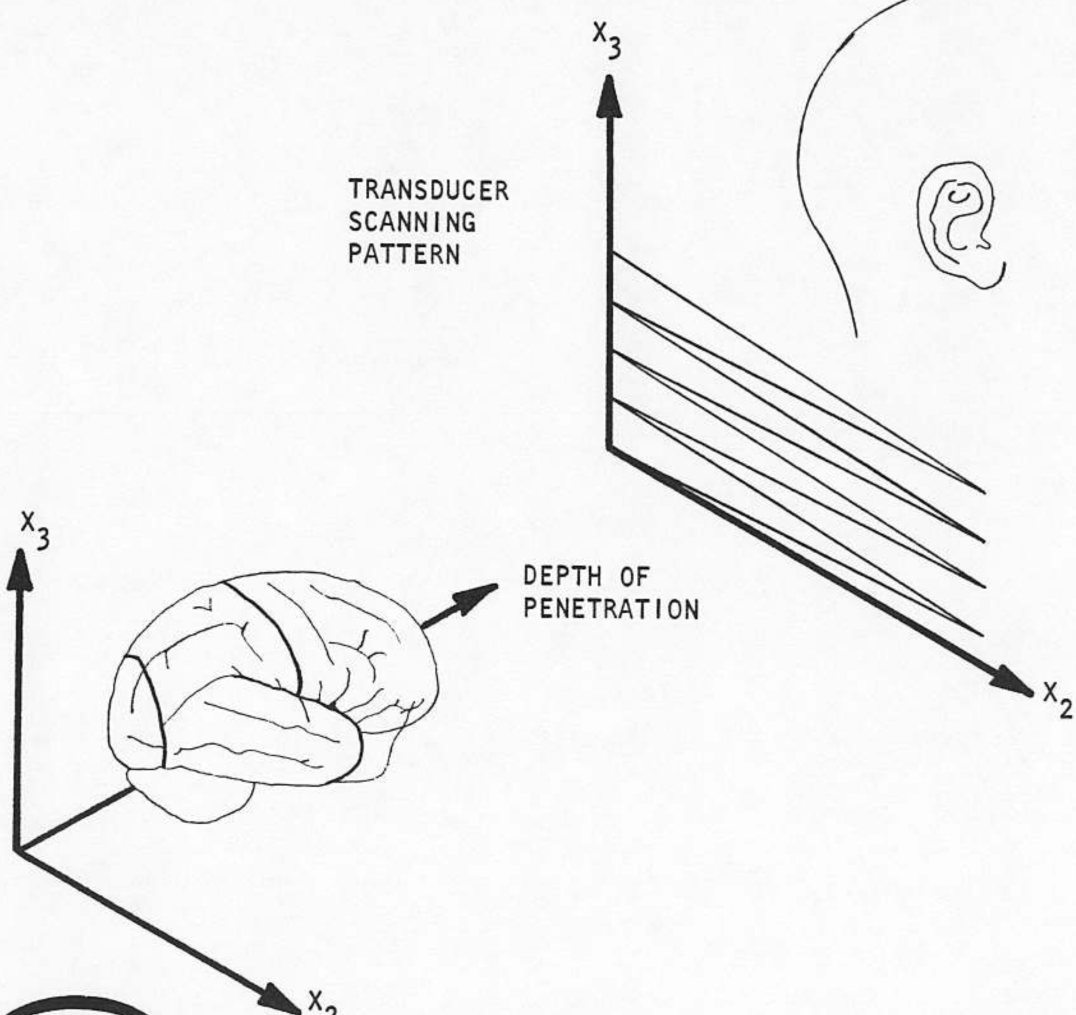
3-D SONOENCEPHALOGRAPHY DISPLAY

Sonoencephalography is the study of the brain using ultrasonics. Diagnostic ultrasound may be used to aid in determining the existence of lesions, hematomas, intracranial edema and tumors. The major area of application is in the determination of mid-line location or displacement.

Excessive accumulation of fluid or an increase of tissue mass cause mid-line displacement. The detection of a mid-line shift does not indicate the nature of the disease or injury, hence sonoencephalography is limited in usefulness to a diagnostic aid.

The display of the sonoencephalogram is quite similar to that of A-scan, (see Ap Tip 12053). Because there is no dynamic (time changing) nature that would warrant a 3-D A-scan display, a different scanning method may be employed to take advantage of the 3-D display advantages. Shown below is a C-scan (see Ap Tip 12056) 3-D display which illustrates a true 3-D scene of the cranial area.

The display is quantitative in nature allowing accurate ultrasonic depth of penetration data to be obtained. This not only allows accurate mid-line displacement measurements to be taken, but gives accurate positional information on other features.



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3-D ULTRASONIC A-SCAN DISPLAY

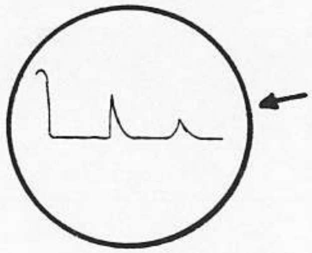
Ultrasonic scanning systems use an ultrasonic transducer that emits a short burst of energy, usually at a frequency between 20kHz and 20MHz. The ultrasonic kinetic energy is transmitted through a medium of gas, liquid or solid or a combination of the three. The velocity of propagation is dependent on the medium - fastest in a solid and slowest in a gas. A solid medium will transmit the energy with least attenuation, gas with the greatest attenuation.

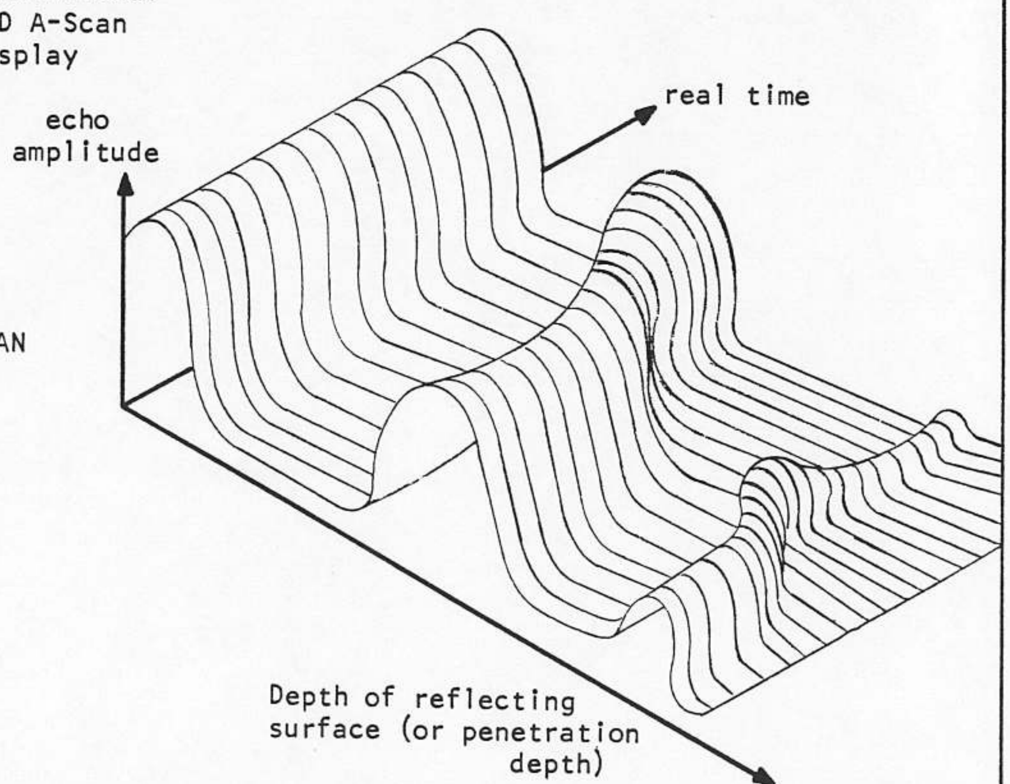
When the propagating energy strikes a surface, energy is partially reflected. The transducer acts as a receiver when it is not emitting. The reflections will arrive at the transducer at a time determined by the length of the return path, hence the time of return determines the depth.

Ultrasonics are used for industrial testing, flaw detection in materials, measuring physical properties and medical diagnosis.

The A-scan is a very common method of presenting the reflected energy as vertical deflection of a time base line on an oscilloscope. The echo strength is represented by vertical deflection and the depth of the reflecting surface is represented by horizontal position. This is conventionally displayed on an oscilloscope as shown below.

When the medium being scanned has a time changing characteristic, it is beneficial to add a real-time axis in a 3-D display as shown below. The 3-D display will illustrate the actual time-wise behavior of the medium characteristic or time variation of reflecting surface position. This is a 3-D presentation of Time-Motion scanning.





3-D DISPLAY OF A-SCAN

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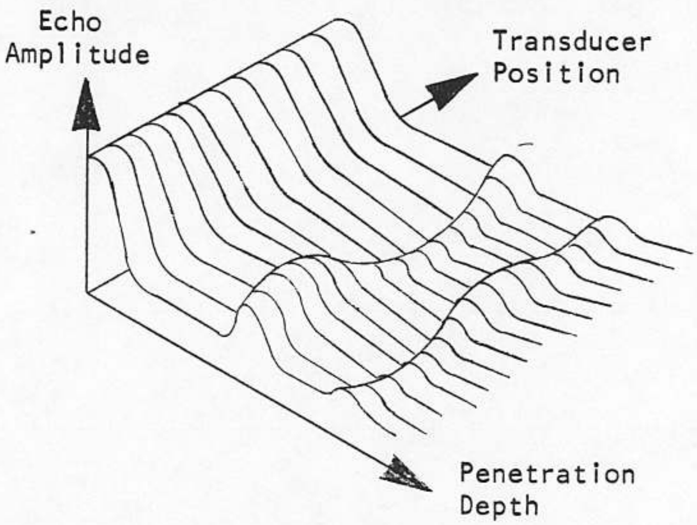
3-D ULTRASONIC B-SCAN DISPLAY

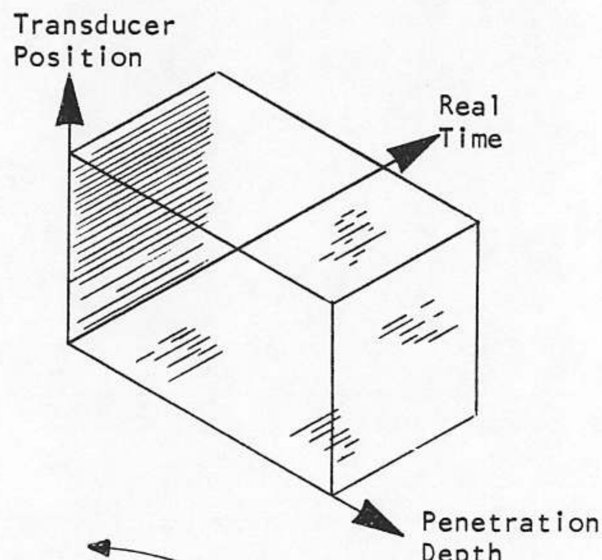
When an ultrasonic transducer is physically moved in a straight line path over the surface of the transmitting medium, three physical parameters to be displayed are presented. Conventional CRT displays show depth of echo as horizontal position, position of transducer as vertical displacement and amplitude of echo as intensity. Since intensity (or gray scale) presentation is very limited in dynamic range, the 2-D CRT display is basically qualitative in nature.

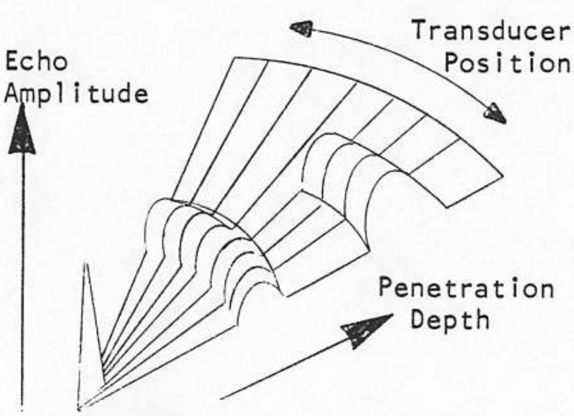
If the echo amplitude were presented as vertical deflection above a plane raster produced by penetration time and transducer position, then actual echo strength measurement can be made. This type of quantitative display conveys more useful information in most cases than conventional displays.

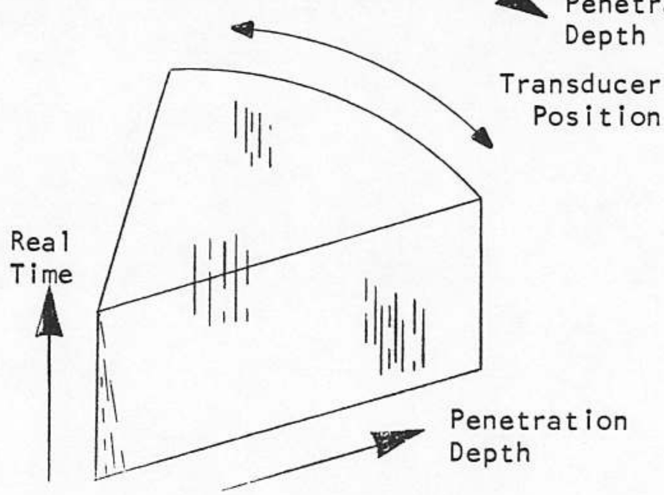
Another form of B-scan display has transducer position as vertical deflection, penetration depth as horizontal and real-time as longitudinal deflection. Echo strength is presented as intensity modulation. This is useful for time changing mediums such as the human body.

A variation of transducer movement is a rocking motion with the transducer held to a fixed point of contact with the transmission medium. This produces a wedge shaped display as illustrated below, and is called One-Point Sector Scanning.









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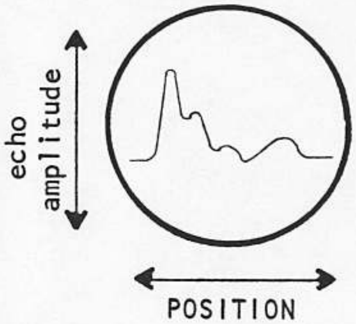
3-D ULTRASONIC THROUGH-TRANSMISSION SCANNING DISPLAY

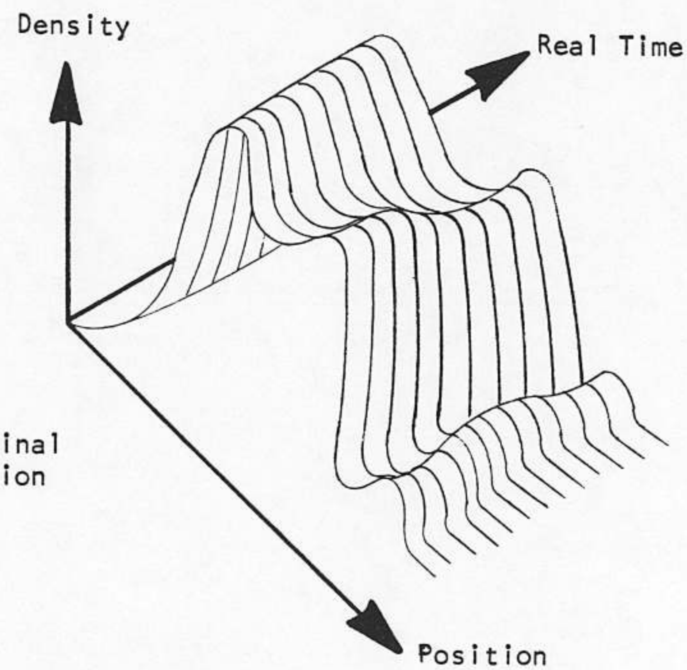
The density of a medium can be related to the attenuation of ultrasonic energy. If an ultrasonic transmitting transducer is placed directly opposite a receiving transducer, with some medium in between, the attenuation and density of the medium can be measured. The two transducers are physically moved in a synchronous manner. The receiver output is used as vertical deflection, physical position as horizontal deflection in conventional oscilloscopes. If the transducers are scanned in a 2-D raster, the receiver output is used as intensity modulation.

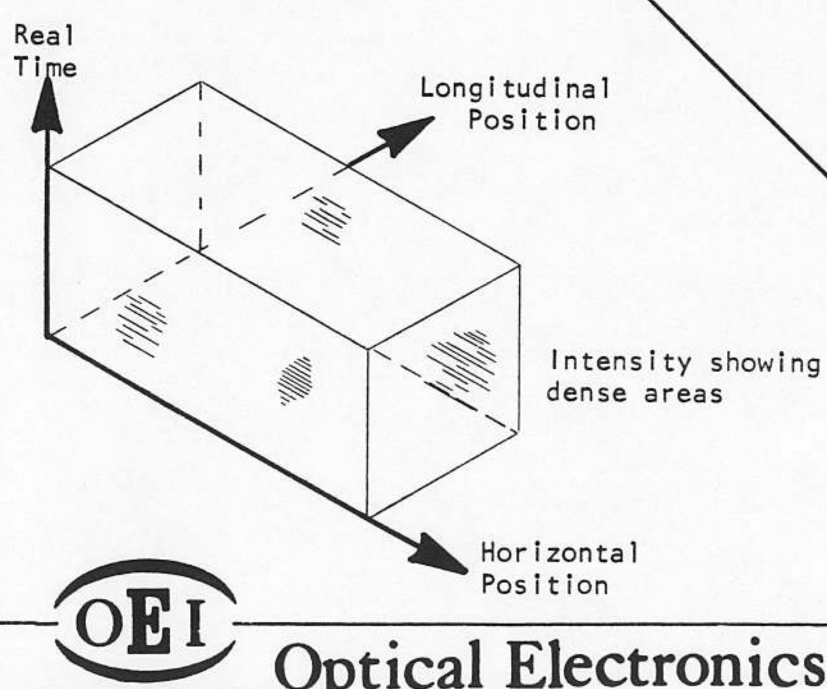
A 3-D display becomes useful with dynamic medium characteristics. If the transducers are moved in a linear manner, the display can show attenuation (density) versus position versus real time. If the transducers move in two perpendicular directions to make a raster scan, a 3-D presentation could be (a) density versus 2-D position or (b) real time versus 2-D position with density represented as intensity.

Applications of through-Transmission scanning range from contaminant location in industrial processes, flaw location in casting and molding operations to tissue density differences in medicine.

The 3-D display allows more meaningful presentation of ultrasonic scanning methods and permits the quantitative display of a two dimensional scanning system.







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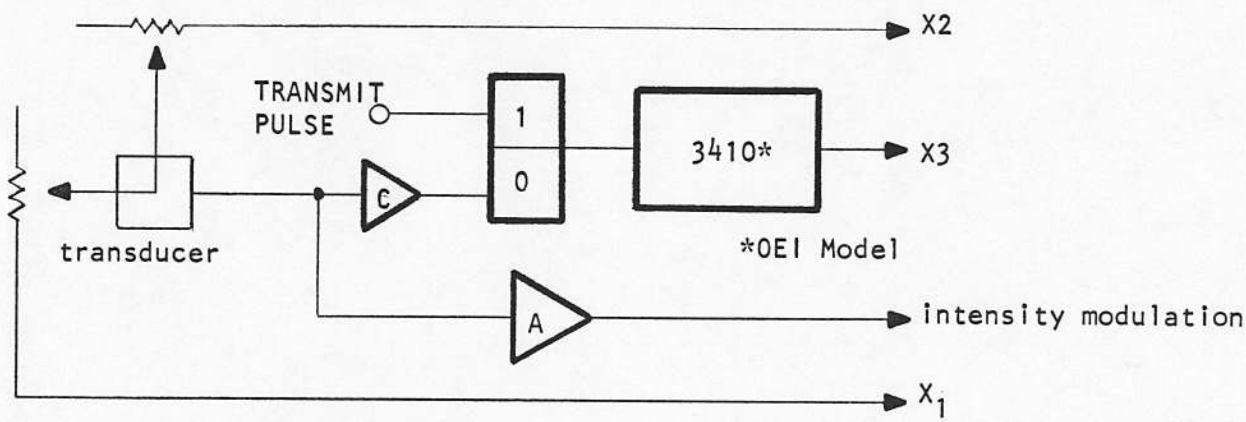
3-D ULTRASONIC SCANNING DISPLAY OF C-SCAN

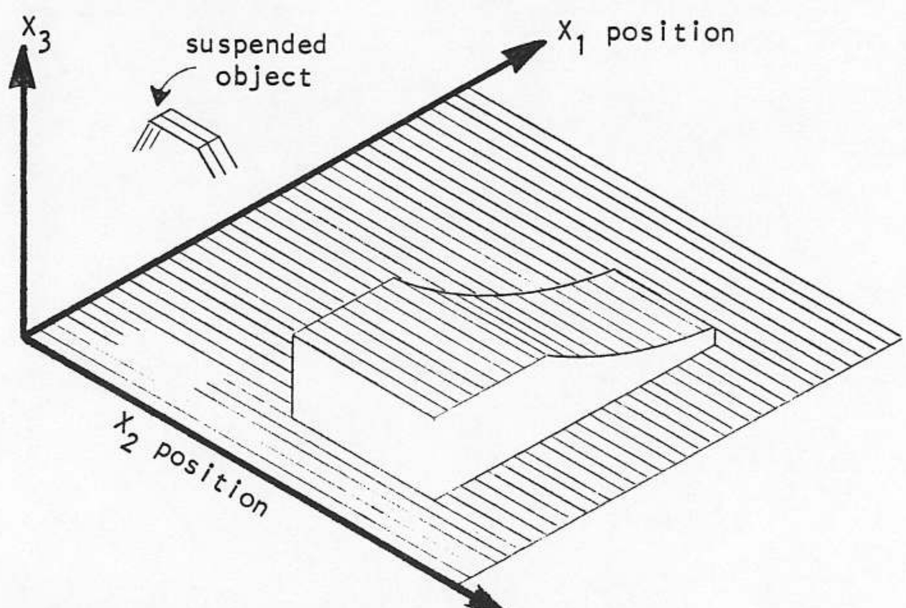
In an ultrasonic scanning system, when the single ultrasonic transducer is scanned in a raster configuration, the mode is referred to as C-scan. Two positional voltages may be obtained from the scanning mechanism and used as X_2 and X_1 (horizontal and longitudinal) deflection signals in the display.

The return echo amplitude may be used as the vertical (X_3) deflection, or as intensity on a flat 2-D raster. If the time-of-echo-return is converted into an analog voltage, then a voltage representing depth is made available. The "depth" voltage is used for vertical (X_3) deflection and echo amplitude used for intensity modulation.

The above arrangement will produce a true 3-D space scene of the ultrasonically scanned volume. The 6100 series system will permit rotation of the image without changing transducer placement. The system will also add geometric and aerial perspective, interposition and optionally focal field, magnification, binocular operation and superimposition of another graphic or alphanumeric image (for identification).



3410 is an OEI Module.
C is an analog comparator.
A is a video amplifier.



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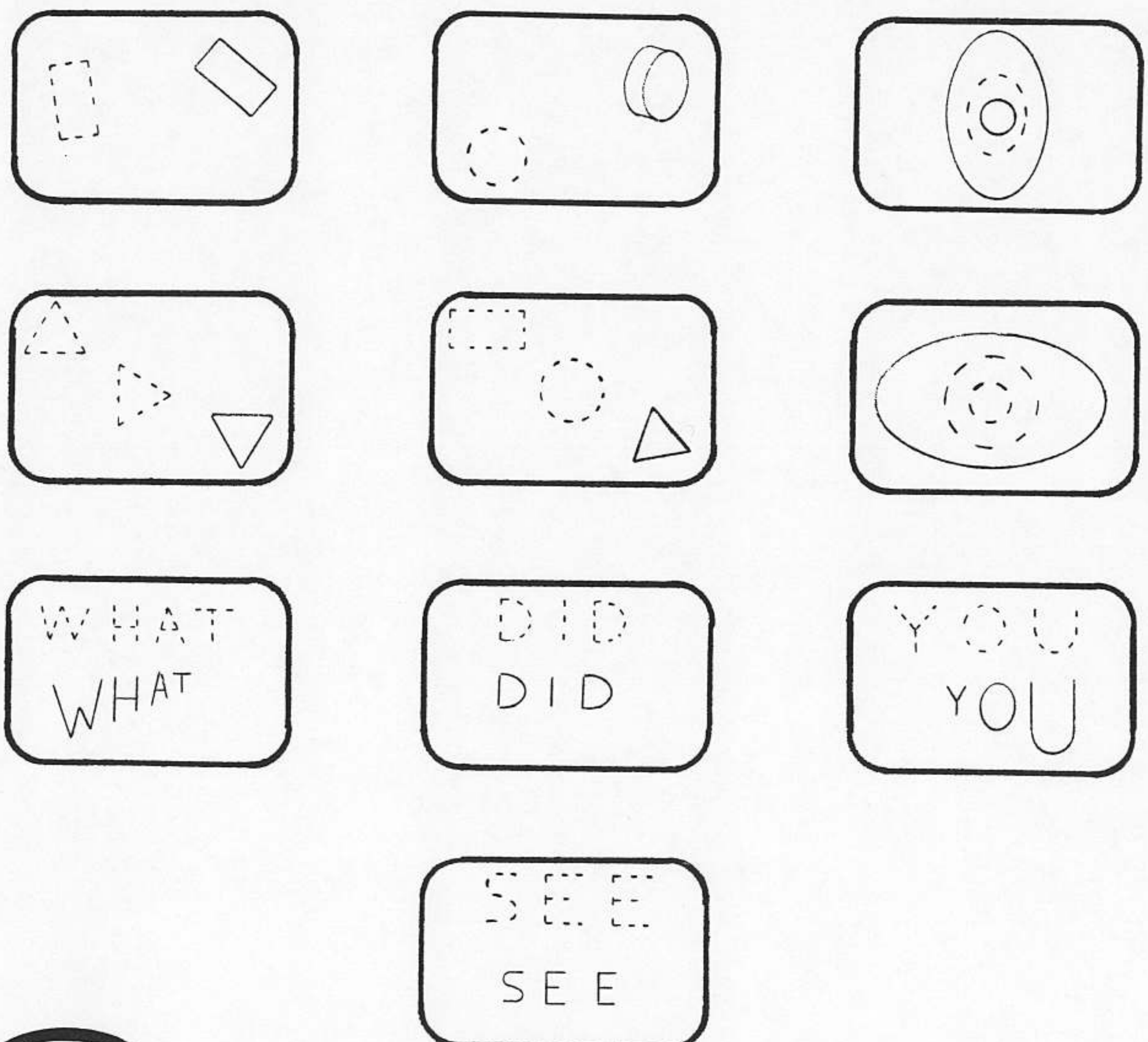
VISUAL PSYCHOLOGICAL STUDIES USING THE 6100 SERIES DISPLAY

The 6100 series 3-D display system may be used to portray an "infinite" number of geometrical shapes in different sizes and orientations. Standard rectangular and circular images can be generated by a number of methods (see Application Tips 12013, 12017-12027). The 6100 series system can perform single axis gain change (to convert a circle to an elipse, square to rectangle, etc.), magnification, rotation, superimposition and binocular image generation.

The image may be blanked during setup and unblanked for a predetermined length of time. For instance, a rectangle is positioned at left center, unblanked momentarily then blanked, rotated and shifted to the right and once again unblanked. Any number of manipulations are possible to present to the viewer, including alphanumerics. The interrogator questions the subject as to what he saw.

The 6100 series offers a fast and low cost alternative to a system controlled by a computer. It also allows depth cues to be added (see Ap Tip 12060) and rotation out of the plane of the CRT along the longitudinal axis. Monocular and binocular image perception studies are readily possible.



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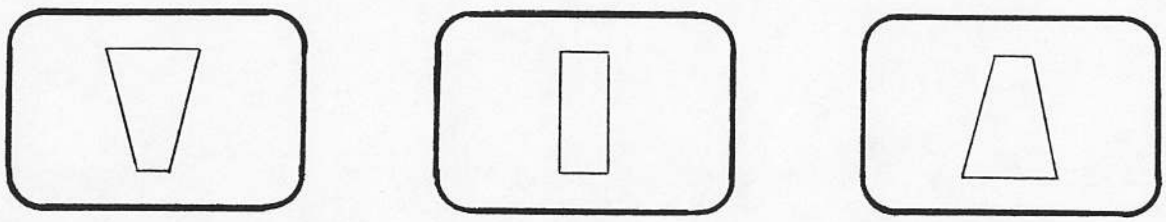
DEPTH PERCEPTION STUDIES

Several depth cues can be added to an electronically generated image by the 6100 series 3-D display system. Geometric and aerial perspective, movement parallax, interposition, depth of focus and stereo may be added to a large number of image shapes and sizes.

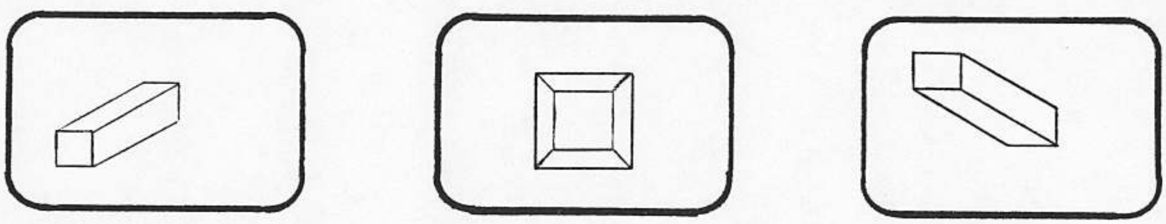
Studies can be performed on normal visioned, one-eyed and abnormal visioned subjects to determine their depth perception under controlled conditions of the depth cues present and missing and the strength of the depth cues presented.

Rotating the image away from the display plane along the longitudinal axis permits studies related to pilot perception of runway location from a flying aircraft. Some of the possible types of display are shown below.

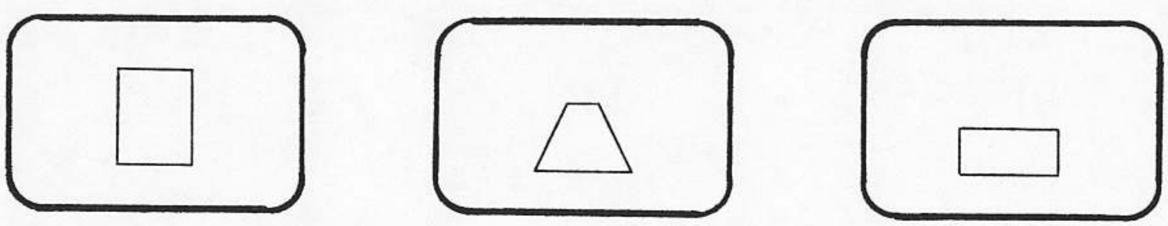
Images are unblanked momentarily after orientation is complete.



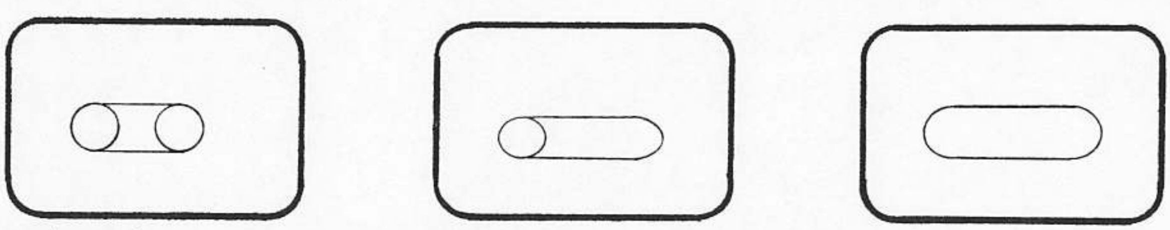
Is the plane pivoting top - front to back or is the plane swinging from the top?



Is the back end of this solid image larger than the front end?



Are these images all of the same plane or of two or three different planes?



Are these images of the same object under different depth cue conditions or different objects?

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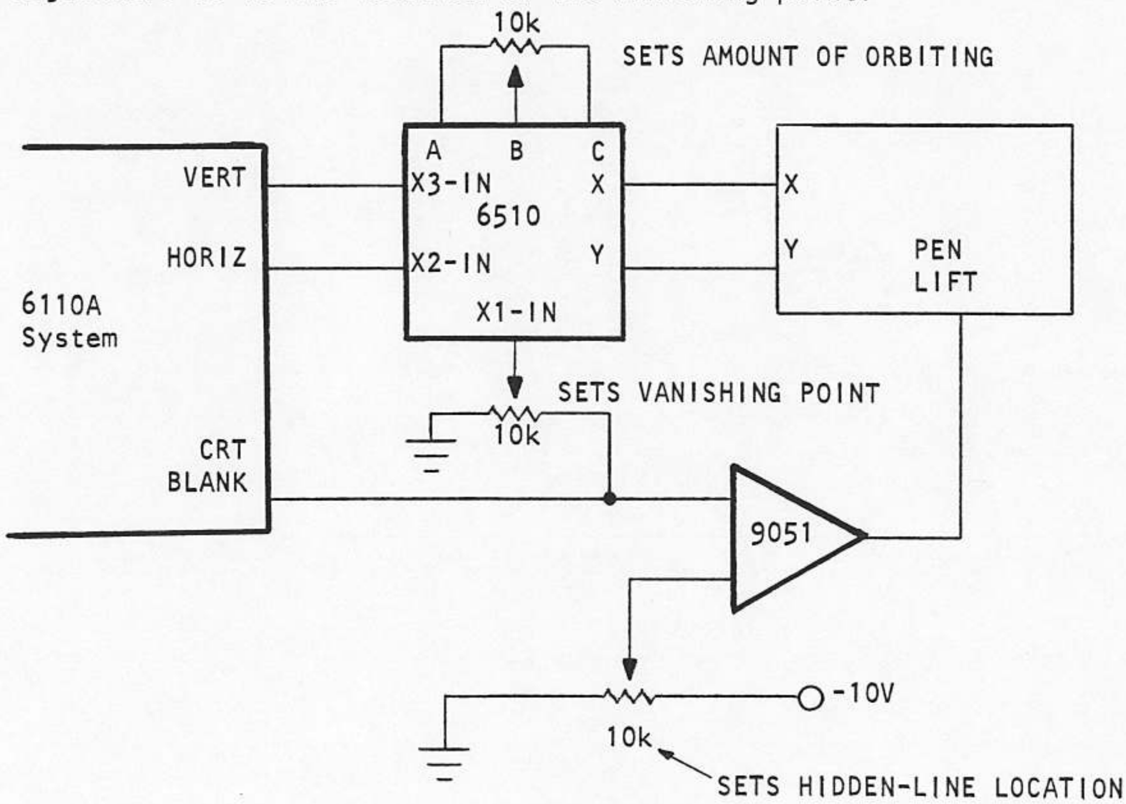
Phone (602) 624-8358
TWX (910) 952-1283

MAKING 3D PERSPECTIVE DRAWINGS

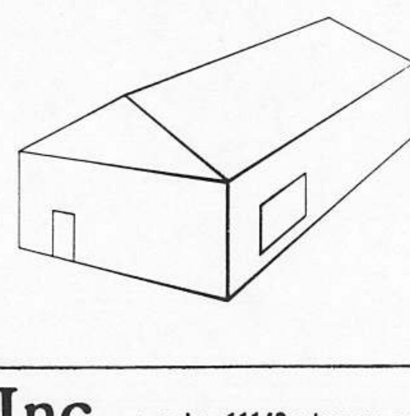
Three-dimensional perspective drawings may be easily made with the 6100 series system and an XY recorder. The speed with which the drawing can be made will depend upon the recorder used. The 6110A series of modules provide the geometric perspective, rotation, magnification, stereo pair generation and interposition. The Model 6510 orbiter module provides the aerial perspective.

The circuit is shown below. The 6110A system may be configured as desired for rotation, magnification, etc. The CRT output of the system is used to operate a comparator which controls the pen lift. This provides the hidden line depth cue (interposition). The comparator threshold must be adjusted for a given image for proper results.

The vertical and horizontal outputs of the 6110A system drive a 6510 which drives the XY recorder. The CRT output is used to control the 6510 to produce the magnitude of the orbiting of the recorder pen. This determines the amount of aerial perspective, which is illustrated below. The amount of perspective (pen orbiting) is adjustable as is the location of the vanishing point.



Example of a 3D perspective drawing on a XY recorder:



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THIS IS.......... OEI

Optical Electronics was incorporated in the State of Arizona in 1964 to research, design, develop and manufacture non-linear amplifiers and function modules. Logarithmic amplifiers were the only product offered for sale during 1964.

Continuing research resulted in our first three-dimensional display product offered in 1965. Called a Scenoscope, the product received the IR-100 award presented by *Industrial Research* magazine, for being one of the most important technical developments of the year.

Research and development of fast, wide band operational amplifiers is continuing at OEI. In 1965, the first truly fast wide band op amp was introduced and was the forerunner of the present product line. Today, OEI leads the state-of-the-art in this segment of the operational amplifier field.

A variety of non-linear analog function modules and voltage/frequency and analog/digital converter products have been added to the OEI catalog. Of particular emphasis is the very fast A→D and D→A converter line. These products were developed for use with the 3-D display products in conjunction with computers and other digital systems.

OEI is expanding the 3-D display line and adding various interface and memory products to facilitate the use of the 3-D system with existing and new computer systems.

The present op amp and function module product line is also being expanded and higher performance products are being added as technology permits.

OEI is your state-of-the-art leader in:

Fast, wide band operational amplifiers
Fast analog/digital converters
Three-dimensional displays

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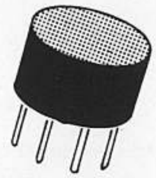
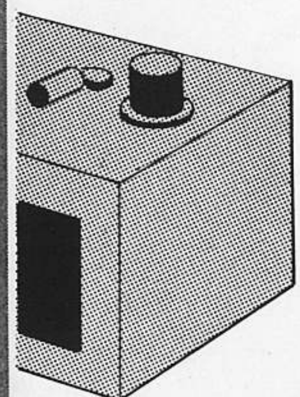
• Amplifiers

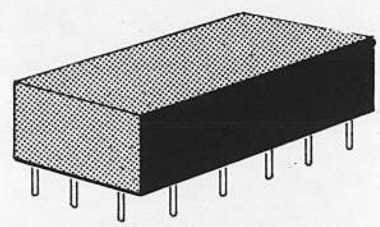


operational
logarithmic

• Function Modules

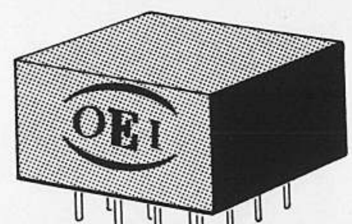


multipliers
dividers
squarers
square-rooters
peak sense & hold
sample & hold
voltage-frequency
frequency-voltage
analog-digital
digital-analog



• Three Dimensional Displays

vector generators



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