S T O R A G E

INTRODUCTION

Storage CRT's continue to display a waveform after the input signal ceases. The period of the image retention runs from a few seconds to several hours depending upon the CRT and the storage circuitry involved. The stored display may be erased to make way for storage of a later waveform. Storage CRT's may also be operated as conventional (non-storage) tubes.

Storage oscilloscopes allow easy, accurate evaluations of slowly changing phenomena that would appear only as slow moving dots. They are also needed for viewing rapidly changing, non-repetitive waveforms whose images would otherwise flash across the CRT to quickly be evaluated.

Thomas A Murphy

TYPES OF STORAGE

There are currently three (3) types of storage CRT's in use:

1) Bi-stable phosphor storage tube
2) Variable persistence tube (sometimes called half-tone storage)
3) Fast transfer tube

The fast transfer tube can provide operating modes similar to the simpler bi-stable and variable persistence tubes.

BI-STABLE

The bi-stable phosphor CRT utilizes a special phosphor with two stable states, i.e., written and unwritten.

The storage or written mode allows waveforms to be stored and displayed a minimum of several hours or until erased by the operator.

Bi-stable storage is often the easiest to operate and is usually the most inexpensive. Most bi-stable phosphor CRT's have a split-screen viewing area which allows each half to be used independently for storage displays. The split-screen feature provides many unique advantages. With this system, a reference waveform can be stored on one-half of the screen and the other half can be used to store the effect that calibration adjustments or the insertion of filters, etc., have on circuit operation. If desired, this technique can be used where the reference portion operates in the stored mode and the other half of the display, operating in the non-stored mode, monitors an external input.

VARIABLE PERSISTENCE

Variable persistence storage allows a continuous graduation between the bright written level and the dark reference.

The variable persistence mode also allows for the selection of the time a stored image will be retained. The storage persistence can be adjusted so the entire waveform can be viewed, yet the stored trace fades from view just as the new waveform is being plotted. With the same feature, an entire display can be saved for further analysis, if desired.

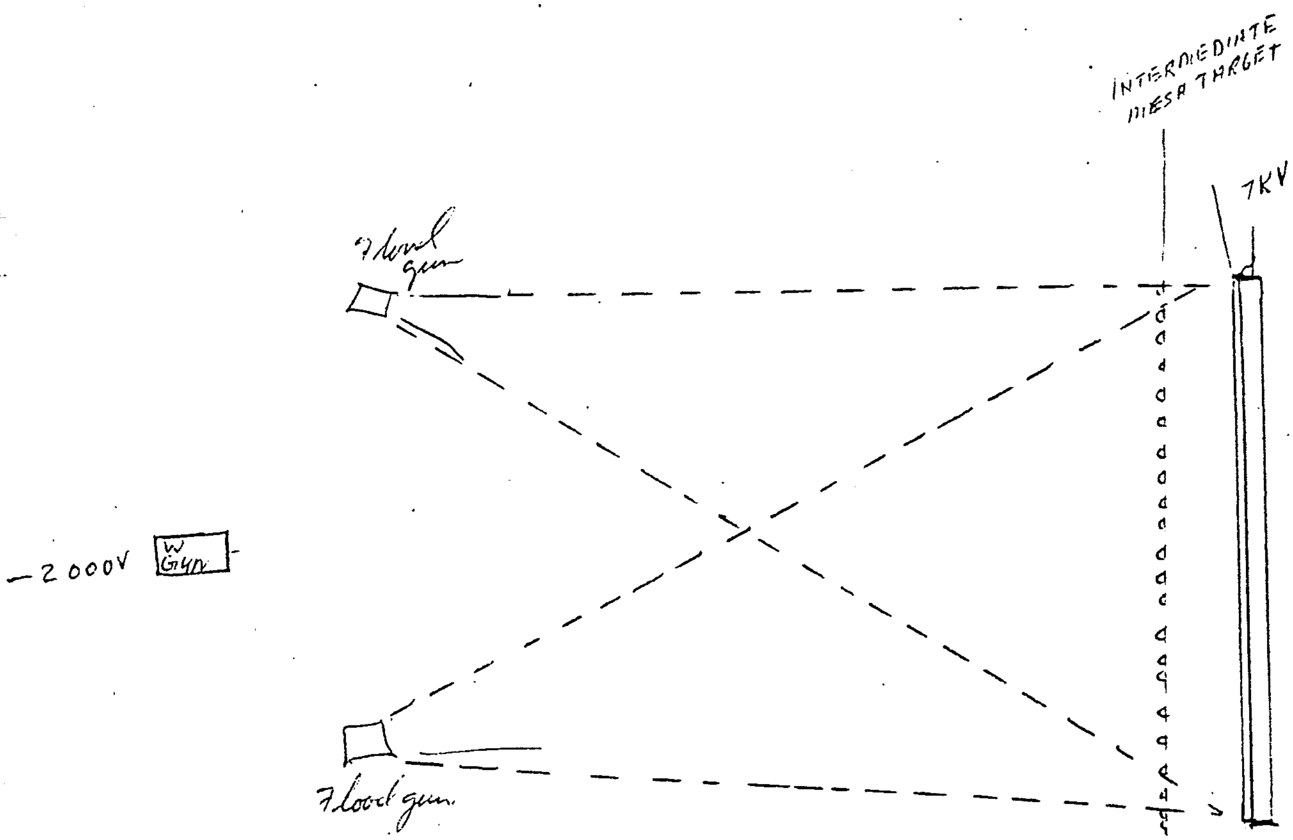
When measuring fast repetitive sweeps, the storage persistence can be set so multiple traces are displayed before the first trace fades from view. You can then view changes in signal response with changes in circuit conditions, time and adjustments. This method can also be used to provide display integration so that only the coincident portions of a repetitive signal are displayed. Any aberration or jitter not common to all repetitive traces will not be stored or displayed. Low repetition rate, fast risetime signals that are not discernible on conventional CRT's can be easily viewed.

VARIABLE PERSISTENCE (cont'd)

This type of storage provides the best display when storing displays with varying intensities such as delayed sweep or with Z-axis intensity modulation.

FAST TRANSFER STORAGE

Fast transfer storage uses a tube with a special intermediate mesh target. This target, which is optimized for speed, captures the waveform and transfers it to a slower, longer-storing electrode. The second target can be designed to offer bi-stable or variable persistence modes, in combination with the transfer mesh or by itself. Because of this combination of capabilities, unique multimode storage tubes are possible.



OSCILLOSCOPE STORAGE CONCEPTS

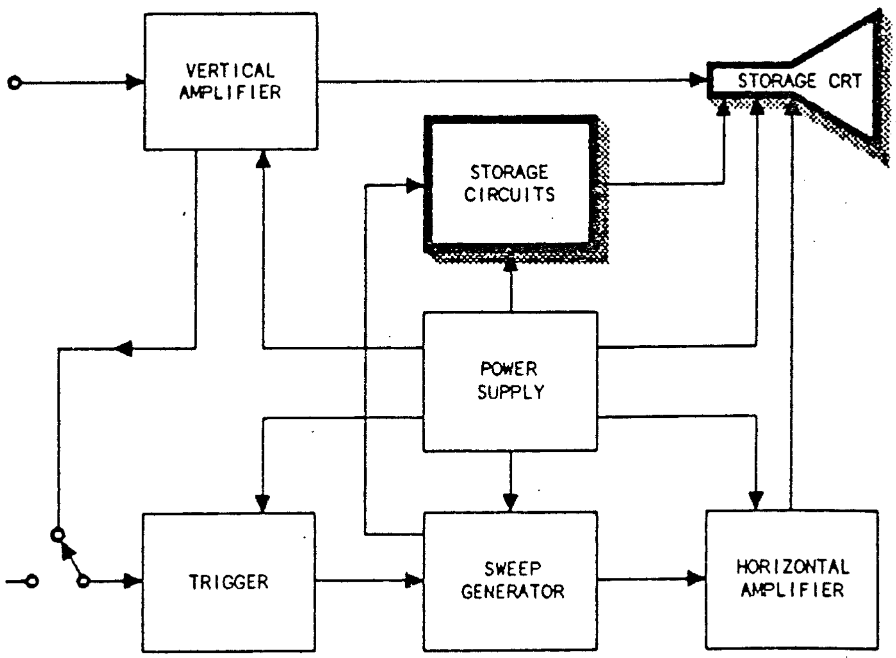
INTRODUCTION

An electrical event that occurs only once can be displayed on a conventional cathode-ray tube but the display is present only for a short period of time. This time may range from a few microseconds to several seconds. A storage cathode-ray tube allows a display to be retained for much longer periods of time (up to an hour or more).

The retention feature of a storage CRT is useful when displaying signals which occur only once or have low repetition rates. In the past many single-shot events required that the display be photographed. Storage offers a convenient alternative. Signals having low repetition rates often cause a flickering of the display which is distracting. Storage allows these signals to be displayed at a constant light level.

Storage cathode-ray tubes may be classified as either bistable or halftone tubes. The stored display on a bistable tube has one level of brightness. A halftone tube has the capacity of displaying a stored signal at different levels of brightness. The brightness of a halftone tube is dependent on beam current and the time the beam remains on a particular storage element. A bistable tube, as the name implies, will either store or not store an event. All stored events have the same brightness.

Storage cathode-ray tubes may also be classified as either direct-viewing or electrical-readout type tubes. An electrical-readout type tube has an electrical input and output. A direct-viewing type tube has an electrical input but a visual output.


VERTICAL AMPLIFIER
STORAGE CRT
STORAGE CIRCUITS
POWER SUPPLY
TRIGGER
SWEEP GENERATOR
HORIZONTAL AMPLIFIER

BASIC PRINCIPLES OF DIRECT-VIEWING STORAGE TUBES

storage target

bombarding energy

A storage target is a surface having the ability to store information when bombarded by an electron beam. One of the key questions in analyzing storage target behavior is how much bombarding energy a beam of electrons has as it arrives at the storage target surface. The bombarding energy of an electron on a target is directly related to the potential difference between the voltage of the target and the voltage of the electron's source (usually a thermionic cathode). Consider Fig. 2-1 which shows a cathode, two accelerators, a decelerator and a target. Electrons are emitted from the heated cathode at zero volts, accelerated to +1000 V, decelerated to +500 V, accelerated to +3000 V and then bombard a target whose voltage is +200 V. The electron potential at the target is +200 V, because the high-speed electrons in the +3000 V field must pass through a decelerating field immediately surrounding the target.

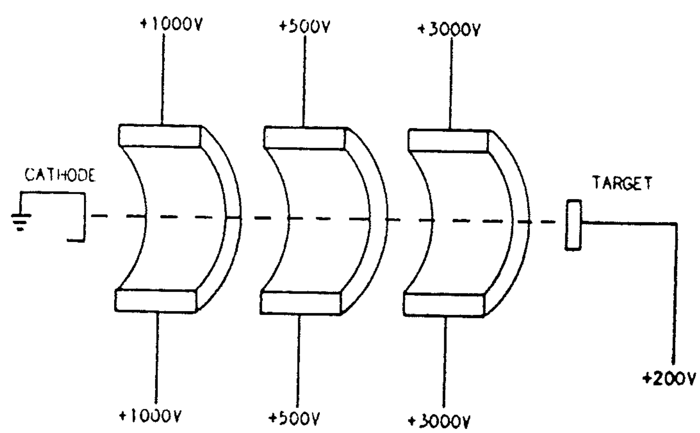


Fig. 2-1. Electron energy at the target is equal to target voltage - cathode voltage.

This idea is emphasized at the outset, because more complex situations involving this principle will be discussed later. Remember, it is not necessary to know the whole history of an electron along its entire path in order to know its bombarding energy. If the voltage of the emitting source and the target is known, the electron potential can only be equal to the voltage difference.

electron potential

ELECTRON POTENTIAL = TARGET VOLTAGE - CATHODE VOLTAGE

The above formula implies that an electron emitted from a cathode at zero volts would have zero potential on arriving at a target held at zero volts. The assumption has been made that electrons emitted from a hot cathode have no initial velocity. It has been found that electrons emitted from any source (thermionic cathode, photoemission, field emission, and secondary emission) have an energy of emission associated with them. Electrons emitted from a thermionic cathode will have a range of energies which can be measured by the retarding potential required to repel the electrons. A target with a voltage of -0.01 volts will repel only about 10% of the electrons emitted from a hot cathode at 850°C at zero volts. When the target voltage is -0.1 volts, about 66% of the electrons are repelled and when the target is at -1 volts, about 99% of the electrons are repelled.

stopping potential

The potential required to repel substantially all of the electrons from a particular cathode in a particular tube is often referred to as the stopping potential for that tube. The idea of stopping potential is useful later to explain why the region between complete collection and substantial repulsion of emitted electrons by a target is a rounded curve rather than a sharp cutoff.

secondary emission

Most storage tubes use the phenomenon of secondary electron emission to build up and store electrostatic charges on the surface of an insulated target. An understanding of this concept is imperative to the understanding of storage tubes.

When a target surface is bombarded by electrons, some of the energy of the bombarding or primary electrons separate other electrons known as secondary electrons from the surface of the target. The secondary-emission ratio

number of secondary electrons emitted depends on the number and velocity of the bombarding or primary electrons, the target composition, surface condition, and the angle of bombardment. The amount of secondary emission is usually expressed as the ratio of secondary-emission current (number of electrons per unit time) to the primary beam current and is termed the secondary-emission ratio or δ (delta).

$$\text{Secondary-Emission ratio, } \delta = \frac{\text{Secondary-Emission Current, } I_s}{\text{Primary Beam Current, } I_p}$$

An elementary but fundamental experiment with this effect is the determination of how the secondary-emission ratio changes when the bombarding primary electron beam energy is changed.

secondary-emission measurement

A typical experimental device for the measurement of the secondary-emission ratios of a variety of materials is shown in Fig. 2-2.

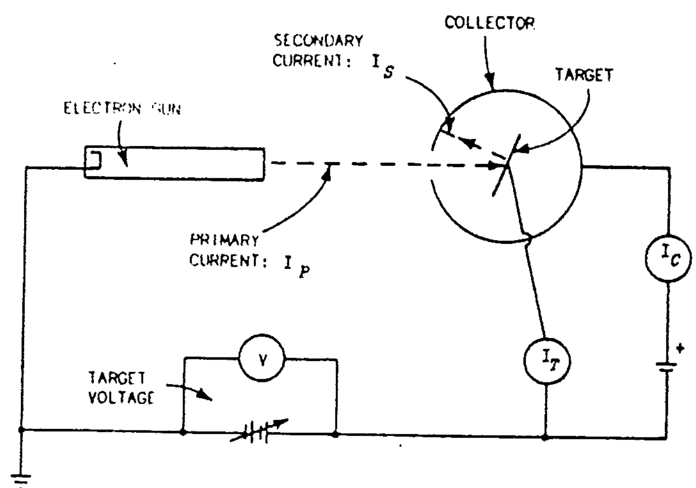


Fig. 2-2. Secondary-emission circuit for a conductive target.

The target voltage relative to the cathode determines the primary electron potential. The plot (Fig. 2-3) shows secondary-emission ratio (δ) vs target voltage.

In this experiment, a primary electron gun forms an electron beam which bombards a metal target plate in a vacuum. The target voltage is the independent variable for the curve to be plotted. A collector electrode surrounds the target, and it is held a few volts more positive than the target electrode by a voltage supply which is between the target and the collector. There will always be a strong enough field around the target electrode to insure collection of all the secondary electrons in this device.

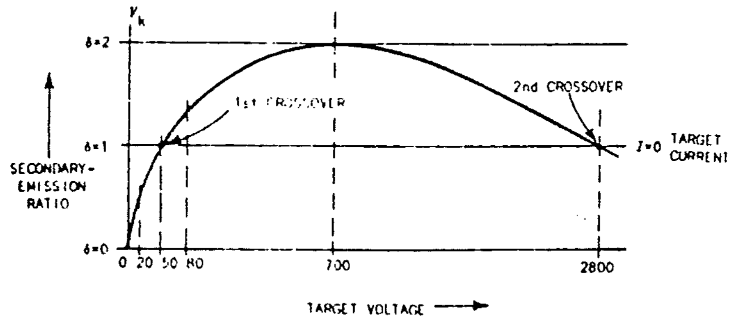


Fig. 2-3. Typical secondary-emission yield curve.

At some low positive target voltage, such as +20 volts, a primary beam current of 10 μA may cause a secondary current of perhaps 5 μA to flow from the target to the collector. The secondary-emission ratio would be 5 μA/10 μA, or 0.5. Notice that since the target is receiving 10 μA but is losing 5 μA of current by secondary emission, the net electron current collected by the target, and leaving the envelope through the target-lead wire, is only 5 μA.

At some higher target voltage, such as +50 volts, the bombarding energy is higher and the secondary current may rise to become equal to the primary-beam current. A 10 μA beam producing 10 μA of secondary-emission current from the target to the collector then results in a secondary-emission ratio of 1. Since the target is collecting 10 μA and losing 10 μA, the net flow of current in the target lead-wire is zero. Conditions where the secondary-emission ratio is unity will later be seen to have a special importance. Since the secondary-emission curve crosses the ordinate lines of $\delta = 1$ at such points, these points are often called crossover points, and the point just described, which is the lowest target voltage at which this crossover occurs, is usually referred to as the first crossover point.

first crossover

Fig. 2-3 shows that the direction and amount of flow of current in or out of the secondary-emission target surface, and in the lead-wire to the target, depends on the secondary-emission ratio. An additional scale of ordinates has been added on the right side of the figure to show net current through the target surface. The current scale is in units such that one unit equals the total primary-beam current.

When the secondary-emission ratio is one, there is no net flow of current to or from the target, and the current in the target lead-wire is labeled I = 0 in the figure. The current ordinate in Fig. 2-3 is given a positive direction for current flow into the collector, since the target surface is losing negative charge or gaining positive charge.

At some higher target voltage, such as +80 volts, the 10 μA of primary current may cause 13 μA of secondary current, resulting in a secondary-emission ratio of 1.3. The net flow of current at the target surface is now away from the target, since more current is emitted than is collected. An electron current of 3 μA now flows into the collector from the target lead-wire. At a higher target voltage, such as +700 volts, the secondary-emission ratio may reach a maximum, for example at $\delta = 2$. Above this voltage, the secondary-emission ratio decreases until, at perhaps +2800 volts, the secondary-emission ratio may again equal 1. This is another crossover point of special interest, and is commonly called the second crossover point. The drop in secondary emission which occurs above the maximum point is believed to be the result of deeper penetration of the more energetic primary electrons into the target material, before collision with the target atoms occurs. Large numbers of secondary electrons may be produced below the surface, but many are captured within the target before they reach the surface, and do not contribute to the current leaving the target.

second crossover

constant collector voltage effects

The preceding explanations have discussed the phenomena of secondary emission with the collector electrode always more positive than the target. Other electron-optical effects take place when the collector electrode voltage is held constant. These effects provide the basis for the study and understanding of bistable storage devices.

Fig. 2-4 differs from Fig. 2-2 in that the collector electrode is held at a fixed +200 V. This is the first of a series of changes to be considered in the step-by-step evolution of the understanding of a direct-viewing bistable storage tube.

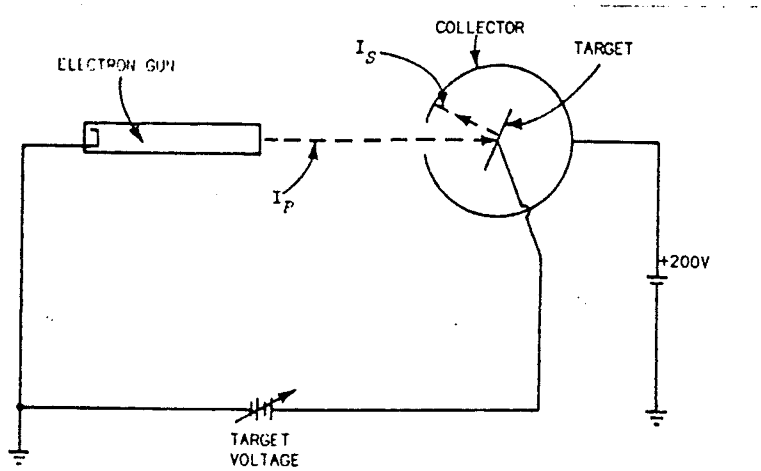


Fig. 2-4. Secondary-emission circuit modified to show effects of fixed collector voltage.

With the arrangement in Fig. 2-4, the secondary emission which occurs when the target is below +200 volts is collected as before, because the collector is more positive than the target. This emission and collection is shown on the curve of Fig. 2-5, just below the fixed collector voltage point.

When the target is well above the collector voltage, at +500 volts for example, secondary-emission electrons leave the target surface due to their energy of emission. The electrons are emitted into a retarding field caused by the lower collector voltage, which reflects most of them back to the target. Under these conditions, the net secondary-emission current is near zero, since essentially no secondary current reaches the collector. The target is receiving the primary beam current, and is acting simply as a collector of current. Current measurements from outside the envelope would show that the target current equals the primary beam current, $\delta = 0$, and the collector current is zero.

These are also the current conditions for a target material which is such a poor emitter of secondary electrons that no substantial emission current is collected. It can be seen that current measurements in this device cannot distinguish between the total return to the target of secondary electrons by the collector, and a true secondary-emission ratio of zero.

effective secondary emission

Another important effect occurs in the vicinity of zero volts, on the curve of Fig. 2-5. This effect results in a modified "effective" secondary-emission curve.

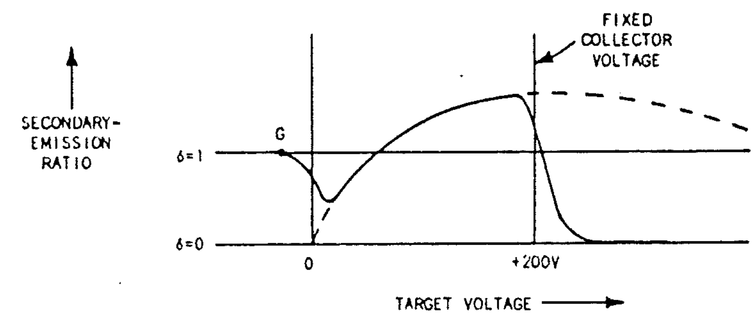


Fig. 2-5. Secondary-emission curve modified by fixed collector voltage.

At some point G which is substantially below zero volts (e.g., -5 V), the target is surrounded by a negative (repelling) field, which reflects all primary electrons to the collector. External current measurement shows that the collector current equals the primary current, and the target current is zero. These are the same current measurements which occur at the crossover points, where the secondary-emission ratio is one. At this voltage the target has an apparent or net effective secondary-emission ratio of one. The current measurements cannot distinguish between the total reflection of primary electrons, and the physical effect of a true secondary-emission ratio of unity.

As target voltage is increased, approaching zero volts from the negative side, it leaves the region of reflection of primary electrons and enters the region of actual target bombardment and true secondary emission.

The region around zero target volts is of particular interest since both halftone and bistable storage targets operate partially in this region.

apparatus effects

The results of these two "apparatus effects" is the net secondary-emission curve of Fig. 2-5. This is the important curve for bistable devices, and will be used often.

To summarize: The curve differs from the physical effect of secondary emission at both ends of the curve; near zero volts and near collector voltage. It differs for the same reason in each case; reflection of electrons by a more negative electrode. Reflection of primary electrons by the target occurs below zero volts; reflection of secondary electrons by the collector occurs above the collector voltage.

CHARGING AND BISTABILITY

floating target

At this point, another important change in the experimental tube will be discussed which will result in a device which is capable of simple storage effects. This effect will be accomplished by the use of a floating target instead of a target whose voltage is externally controlled.

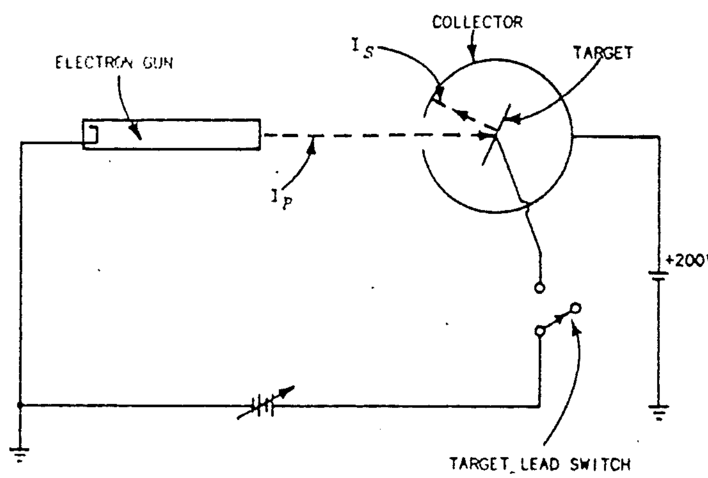


Fig. 3-1. Secondary-emission circuit modified to allow floating target.

floating target potential change

The device shown in Fig. 3-1 can be used to determine experimentally in which direction the potential on the floating target changes due to target charging, for any particular initial target voltage. With the switch closed, the target supply may be adjusted to any starting condition, and then the switch opened and the changing target voltage measured.

When the target is set at some low voltage such as +20 volts, a secondary-emission ratio of about 0.5 may typically result, as shown at point D in the curve of Fig. 3-2. For every unit of primary current collected by the target, 0.5 unit of secondary current flows back into the vacuum, so the net collection effect is 0.5 unit of electron current, which flows out of the envelope on the larget lead-in wire.

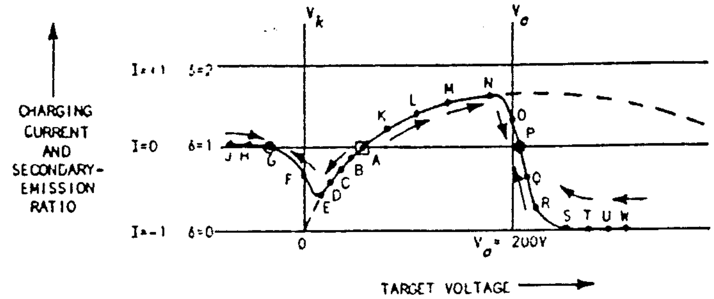


Fig. 3-2. Secondary-emission curve - fixed collector voltage.

If the switch in the target lead is now opened, the current in the target lead-in wire is interrupted, and the target starts to charge in a negative direction, due to the net collection of electrons. The target voltage then shifts downward from point D.

The curve of Fig. 3-2 is the result of opening the switch in the target circuit at many different target voltages, to determine its charge direction as a function of target voltage, as shown by the direction of the arrows. As the target charges more negative from point D, its voltage decreases sequentially to the voltage at points E, F, and G on the curve. The secondary-emission ratio changes as the target voltage changes, but it remains below one, between points A and G, so the direction of target charging remains negative, although the charging rate varies.

The rate of charging decreases as the target voltage closely approaches voltage G, since the secondary-emission ratio approaches 1. When the target reaches point G, the net charging rate becomes zero and there is no further drop in target voltage.

If the target circuit is opened when the target is between point G and J there is no net charging by secondary emission. Positive ion bombardment and conductivity across the insulating target support structure will cause the target to charge slowly in a positive direction, until point G is reached. The curve above point J shows that this effect results in a positive direction of charge, just as if the secondary-emission ratio were greater than one.

A target's voltage becomes stable when it arrives at point G. The charging effects balance to zero at this point, whether the target has been dropping in voltage from a higher voltage or charging positive from a lower voltage.

If a target at point G is temporarily disturbed from its rest position by a small voltage shift, in either direction, the net charging effect is no longer zero. A charge arises having a direction which restores the target to the voltage of point G. Since there is a restoring force on a target in the vicinity of point G, this point is a stable point as long as the primary electron beam is present to preserve this stability. A target at this point on the curve is referred to as being erased or unwritten. To "erase" a target in this device means to change the voltage to the lower stable point of the curve.

erase

lower stable point

The curve segment P-W has a net charging direction which is negative over the whole segment. When the target circuit is opened at the voltage of point W, for example, the target charges in a negative direction toward point P because $\delta<1$. As point P is approached, the charging ratio decreases because the secondary-emission ratio is approaching one, and the net target current is approaching zero. At point P, the target voltage stops dropping and becomes stable, the net charging rate is zero because $\delta = 1$. A target at this point on the curve is referred to as being "written." To "write" a target in this device means to change its voltage to the upper stable point on the curve.

write

upper stable point

The segment A-P of the curve lies entirely above a secondary-emission ratio of unity, so at every point on the segment, the net current is away from the target. This loss of negative charge drives the target more positive. When the switch is open, a target at point K increases in voltage until it reaches the voltage of point P, the rate of charge dropping to zero as it approaches.

When a target has charged to the voltage of point P, either from a higher or lower voltage, it has reached a voltage which is stable. A small disturbance of the target voltage will be corrected by restoring forces that return the voltage to point P, as long as the primary beam is present to preserve stability.

stable points

Notice that at the two stable points G and P, the curve of Fig. 3-2 crosses the line I = 0 with a negative slope. A stable point in a floating target voltage occurs wherever the curve of net charging current crosses I = 0 with a negative slope.

unstable point

At point A, the net charging current is also zero, but a small change in target charge from any "noise" source will send the target charging up or down to point P or G, depending on which way the voltage is first shifted by noise. Point A is a uniquely unstable point, and it should be noted that an unstable point in the voltage of a floating target occurs wherever the curve of net target charging current crosses I = 0 with a positive slope.

Since the target now has two stable points, G and P, at which its voltage will be held by restoring forces, (which point depends on its history before the switch in the target circuit was opened) we see that this device is an elementary bistable storage tube. This tube may be interrogated by measuring the target voltage. The measurement will tell whether the voltage supply was above or below the voltage of point A at the time that the switch was opened. The information is present in the form of a voltage at the target lead-wire, but there is no image displayed. This tube is an electrical readout tube (of one-bit capacity) as opposed to a direct-viewing storage tube. Bistable storage is frequently referred to as having "infinite" persistence, since the tube will retain its stored information indefinitely.

mechanical stability model

Stability is dependent on the presence of a restoring force. This fundamental idea can be made more familiar by comparison to a mechanical model. Fig. 3-3 shows a shaped surface with a small ball resting on it, under the influence of gravity. The ball will remain indefinitely in either of the stable positions G or P, if once placed in either of these positions. These sections of the model are comparable to the stability of the storage target just described, which will remain at either of its two stable voltages indefinitely.

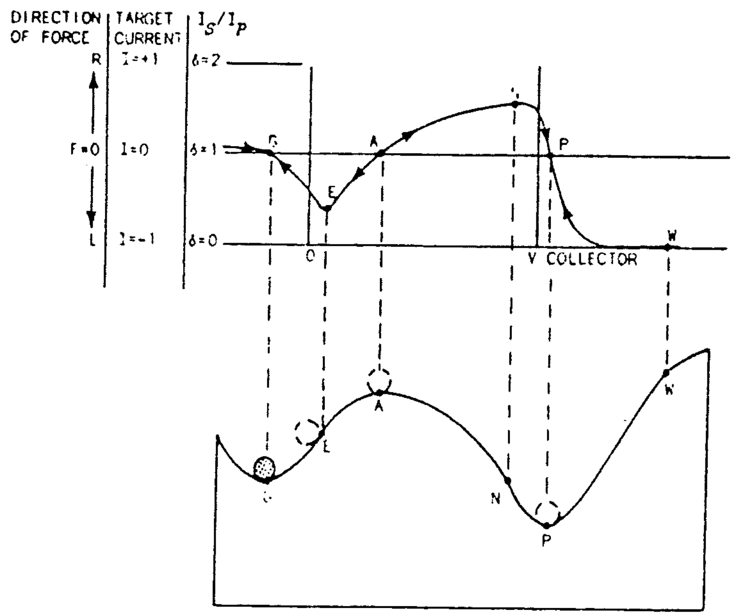


Fig. 3-3. Mechanical stability model and secondary-emission curve.

If the ball at point G is displaced to the right, to point E, it experiences a strong restoring force which returns it to point G; in fact, the surface at point E is the steepest slope on this portion of the model. This section of the model is comparable to a target at point E which is restored to stable point G, and has the highest negative charging rate on this part of the curve, at point E, where the effective secondary-emission ratio is low.

If the ball is placed at point A on the mechanical model it is unstable, and will drop to point G or P at the slightest disturbance, just as a target at point A on its curve is unstable and will shift to G or P at the slightest disturbance.

Notice that points E, N, and W on the target charging curve are points of highest charging rate, and correspond to points of maximum slope on the mechanical model. Points G, A, and P have zero charging rate on the charging curve and zero slope on the model.

The slope of the surface of the mechanical model is such that a graph of the forces on the ball at any point on the model's surface has the shape of the δ curve. The graph and the arrows on it show the amount of force on the ball, and the direction of force, which is to the left where the curve is below the line F = 0. An ordinate scale may be added on the left side of the graph showing this force. This one graph now shows effective secondary-emission ratio of a target, the amount and direction of target charging, the amount and direction of force on the ball, and the stable points for both the ball and the target.

It is possible to change the voltage of a target in either direction by shifting the cathode voltage of a single bombarding electron gun, to obtain a high-energy or low-energy beam at the target. Either a high or low secondary-emission ratio can be obtained, making the target charge up or down to the opposite stable point. In practical storage tubes, however, the cathode of a primary beam is generally not shifted in voltage, because the bias, focus, anode, and deflection voltages would all have to be shifted with it to maintain the beam size, location and current. It has been found much more practical to use two guns having their cathodes fixed at different voltages, and to keep most of the gun electrodes at fixed voltages.

target control with two guns

Accordingly, a step in the series of modifications of the previous simple devices, evolving toward the complete storage tube, can now be made. The next change will be to add a second electron gun, providing a second beam of primary electrons.

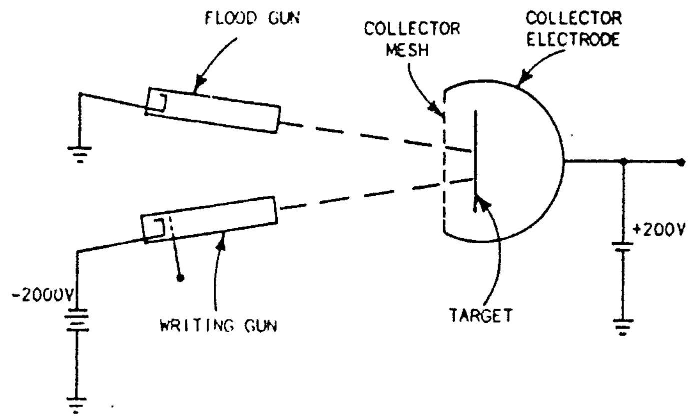


Fig. 3-4. Floating target control with two guns.

mesh

In the tube of Fig. 3-4, the entrance aperture in the collector has been enlarged to admit two electron beams. The resulting reduction of the strong collecting field in front of the target has been corrected by placing a mesh across the entrance aperture. The mesh maintains substantially the same field that would be there if a solid part of the collector occupied that position. A transparent high-transmission mesh is used for this purpose, to pass most of the primary electrons.

flood gun

writing gun

The upper gun will be called the flood gun and the lower gun the writing gun, in anticipation of later usage. For the present, the distinguishing feature of the flood gun is that it will flood the target at all times, not just intermittently as the writing gun does. Assume for the moment that the lower gun, the writing gun, has been biased to cut off, and is not bombarding the target. The tube cannot be written or erased by an external target voltage supply, because there is no connection to the floating target. This tube also cannot be written or erased with the single-gun effects of shifting cathode voltage, because we have fixed the cathode voltage instead of providing a variable voltage supply.

Since the flood-gun cathode is at zero volts, the target voltage in the charging-current curves may be read directly as the voltage difference from cathode to target. This is not the case for the writing gun, as the writing-gun cathode is fixed at -2000 volts relative to the flood-gun cathode.

writing

Writing is accomplished by gating on the writing beam with the writing-gun grid.

The combined effect of two beams hitting the same target surface is simply the sum of the individual effects that each beam would have alone. The secondary-emission ratio due to one beam is not known to be affected by the presence of a second beam having a different bombarding energy. (See Fig. 3-5.)

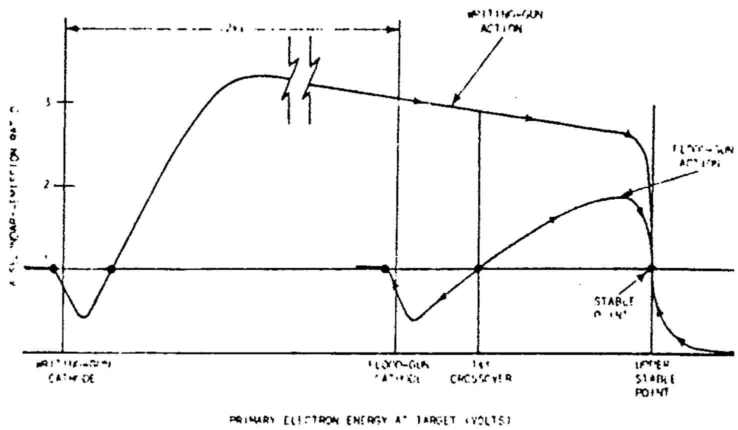


Fig. 3-5. Secondary emission.

When the target is at its lower stable point and the writing gun is gated on, electrons arrive at the target with a potential of about +2000 volts. The high secondary-emission ratio of the target for +2000 volts causes a high positive charging rate and the target voltage immediately starts to increase. As the target voltage leaves the lower stable point, restoring forces begin to oppose the writing effect of the writing gun, due to the stabilizing effect of the flood gun.

target charging

If the effect of the writing-gun current is greater than the effect of the flood-gun current, the target will charge up to the first crossover point and higher. After the target voltage exceeds the first crossover point for flood-gun emission, the flood gun is no longer opposing the writing effect, but is aiding it. It is only necessary for the writing gun to be gated on long enough to carry the target just past the first crossover. Flood currents alone will carry the target the rest of the way to the upper stable point. When the writing-gun beam is gated on for too short a period to carry the target past first crossover, the flood beam will return the target to the lower stable point after the writing beam is biased off, and storage will not occur.

During writing, the target shifts over the range from the lower stable point, slightly below zero volts, to the upper stable point, at about +200 volts. The writing-beam potential shifts from +2000 volts to +2200 volts because of the target voltage change.

This represents a little change in secondary-emission ratio for the writing beam, and, for any particular beam current, we may regard the writing beam as a nearly constant source of positive charge (via loss of secondaries) being delivered to the target, which overcomes the stabilizing current due to the flood gun.

erasing

The above explains how writing and storing are accomplished without shifting cathode voltages, by using two guns. Restoring the target to the lower stable point is carried out by pulsing the collector negative.

negative target charging

If it is assumed that the capacitance from the collector to the target is at least equal to the capacitance from the target to all other electrodes (which is a very conservative assumption in this tube), then half of the collector voltage change appears on the target. If the collector voltage is suddenly dropped by 150 volts, from +200 volts to the first crossover point at about +50 volts, two effects occur which tend to charge the target negative. One of these is the capacitive coupling of the collector signal to the target, which immediately drops the target voltage by 75 volts (in this example) to a new target voltage of +125 volts. The other effect is the negative charging of the target by primary collection. The collector cannot collect secondaries from the target when the collector is far more negative than the target, so, the secondaries are reflected back to the target, the effective secondary-emission ratio is below one, and the target collects flood-gun primaries and charges negative. This continues until the target reaches the lower stable point just below 0 volts.

The collector cannot now be suddenly returned to +200 volts without changing the target voltage, because the target would be pulled above the first crossover by capacitive coupling, and be written again by the flood beam. Instead, the collector may be returned to its voltage of +200, if desired, by a series of steps of voltage, each step small enough so that the target is not driven above first crossover, and each step followed by a delay long enough for the target to charge back down to the lower stable point from which it was displaced by capacitive coupling. A more practical method is to raise the collector voltage continuously, but at a rate slow enough that the negative-charging restoring forces on the target, near the lower stable point, are able to overcome the capacitively coupled positive charging effect enough to keep the target below first crossover and that the target doesn't charge positive to the upper stable point. A typical erase waveform that could be applied to the collector is shown in Fig. 3-6.

erase waveform

The recovery time needed for the collector voltage depends on the particular tube design and the flood current.

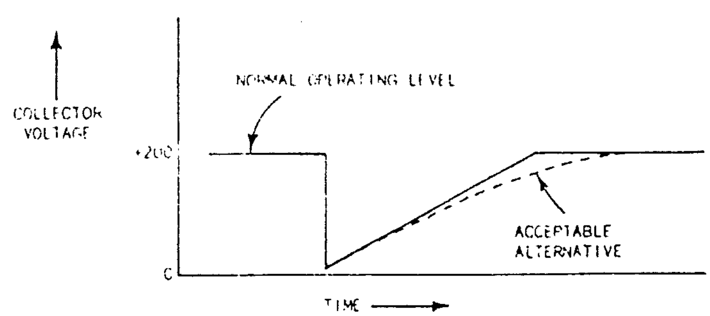


Fig. 3-6. Erase waveform for secondary-emission circuit.

It has been seen, in this section, that a floating target with no access to external supply voltages can be put in either stable position by control of the primary beam energy, or by control of the collector voltage. This is the first tube in the sequence which writes, stores, and erases a floating target with guns at fixed voltages.

BISTABILITY IN MULTIPLE TARGETS AND DIELECTRIC TARGETS

multiple targets

The next step in the structural evolution of a bistable storage tube (shown in Fig. 4-1) is to increase the number of targets within the tube.

In this tube, the flood-gun spot size has been very greatly enlarged to extend over all of the targets. This can be done with a relatively simple short gun, having no need for deflection plates. The writing gun still emits a focused, directed beam, and all of the writing beam current is directed toward one target at a time, such as target 3 in Fig. 4-1.

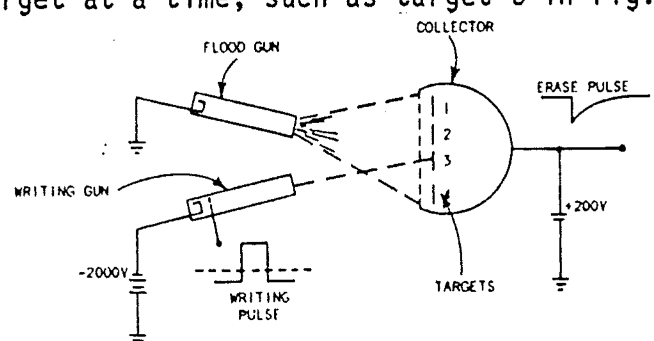


Fig. 4-1. Control of multiple targets with two guns.

Initially, the writing gun is biased off, the flood-gun cathode is grounded, the collector is fixed at +200 volts, and all targets are at their lower stable point. The restoring forces of bistability are present for all of the targets, and the flood gun is able to hold each target independently at either of its two stable points, once they are written or erased to those points.

When the writing beam is gated on and bombards target 3, for instance, this target charges positive and is written to its upper stable point. Target 3 is then held at its upper stable point, while the other targets remain held at their lower stable point by the flood gun.

When the erase pulse in Fig. 4-1 is applied to the collector, the written target is made to act as a net collector of current, and is driven to its lower stable point, as previously described. The unwritten targets 1, 2, and 4, are driven negative and then positive again back to the lower stable point, by capacitive coupling to the collector, as the erase pulse goes negative and positive.

When the erase pulse is applied to the collector, the written target's voltage drops (due to capacitive coupling) below first crossover and the target charges negative to its lower stable point (due to flood-gun bombardment). The erase pulse couples to the unwritten targets causing unwritten targets to descend with the erase pulse, to a voltage BELOW the lower stable point. At this time a strong negative field surrounds each unwritten target repelling flood-gun electrons. Unwritten targets then follow the erase pulse positive to the lower stable point. All targets at this time are at the lower stable point (erased).

dielectric sheet target

The next step in the structural evolution of a direct viewing storage tube is to substitute a single large dielectric target for the individual metal targets. Imagine increasing the number of rows and columns of metal targets indefinitely and at the same time decreasing the size of the targets and the space between them. When the targets become much smaller than the beam, we substitute a dielectric material for each target, as well as for the vacuum which insulates each target from its neighbors. The result is that the target array is replaced by a single dielectric sheet which is capable of having any area element of its surface written and held positive, or erased and held negative without effecting the adjacent area.

independent targets

In preceding tubes, each target was charged to the same potential over its whole surface, since the targets were conductors. With a dielectric target, each small area of the target may be charged to either stable point independently of its surrounding areas, as if the target surface consisted of very many small metal targets, which are incapable of current flow between targets.

The dielectric material may be a sheet of glass or mica, or other dielectric materials known to have a high secondary-emission ratio. These materials often have secondary-emission ratios which reach a maximum in the range of 2 to 5, and sometimes higher. With this change, the tube has evolved to the capability of writing, storing, and erasing a high resolution bistable two-dimensional charge-image. The next step will be to provide a visible image.

visible light image

When the preceding tube has a charge-image stored on its dielectric target, the written portions are being bombarded by flood electrons having much more energy than the few low-velocity electrons reaching the unwritten portions. This energy may be used to produce a visible light image by using a fluorescent material for the target dielectric.

phosphor dielectric

The target may consist of a phosphor layer coating a glass supporting plate, and the phosphor may be viewed through the glass plate from the side opposite the electron gun. Fig. 4-2 shows this tube.

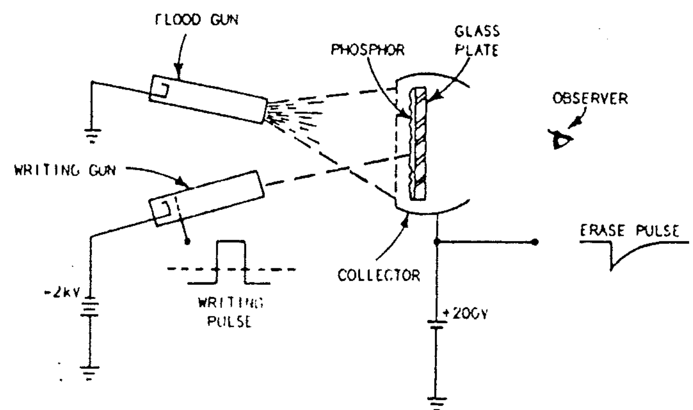


Fig. 4-2. Elementary direct-viewing bistable storage tube.

A large aperture has been placed in the rear of the collector so that the image may be viewed from that side.

The phosphor coating serves as a dielectric target, and has the same bistable storage properties exhibited in the previously described tube. Both the written and unwritten target areas are held at stable points which insure no net current flow to or from the target surface. Even though the arriving and secondary currents are equal, cancelling the transfer of charge to zero, there is a considerable net transfer of energy to the target. The flood electrons bombard the written areas of the target at the potential of the upper stable point. The secondary electrons leave the target with much lower energy. Some of the energy, which was largely dissipated as heat in preceding tubes, is now converted to visible light by the fluorescent phosphor target. In unwritten areas, the few flood electrons which reach the target (to maintain equilibrium with ion collection and leakage) arrive with too little energy to cause much target fluorescence or secondary emission.

target fluorescence

no gray scale or halftones

Since all the target areas are charged to either one of two possible stable potentials, the resulting light output in any element of target area is either of two intensities; full brightness or minimum brightness. There is no gray scale or halftones of brightness. This is characteristic of bistable storage tubes, and limits their usefulness to applications for which halftones are not essential, but 'infinite' persistence is desirable, such as in oscilloscopes.

early tube limitations

A tube of the type described was built and reported by A. Haeff in 1947. The tube is extremely interesting in comparison to the development of succeeding years. This early tube had the advantage of simple target construction, but suffered from low brightness due to the relatively low energy of phosphor bombardment. It also had a very limited stable range of collector voltage, as evidenced by the tendency of the written image to spread over unwritten areas or erase into written areas.

The brightness of the image formed by this tube may be increased, to a small extent, by raising the operating voltage of the collector. This increases the voltage of the target surface at the upper stable point, so that the more energetic primaries cause higher brightness of the written areas.

collector voltage critical

It has been found, however, that the collector voltage cannot be increased much before the image becomes badly degraded. The written areas expand into the unwritten areas as a result of motion of the boundary which separates the written and unwritten areas.

The opposite effect occurs when the collector voltage is low. Conductivity and other effects can lower the voltage in written areas near the boundary, and the boundary moves into the written areas.

When operating conditions permit the boundary to move in either direction, the image is ultimately erased, either by the entire viewing screen fading to a dark condition or by "fading positive" to a fully written bright viewing screen.

A storage system must include a provision for an operator to erase a stored presentation. Actuating the erase circuits drives all target elements below first crossover to be held at rest potential by flood-gun action. Erase circuits apply pulses to the backplate, flood gun or both.

backplate-erase pulse

Fig. 4-3 shows an erase-pulse shape for backplate application. The pulse capacitively couples to the entire screen area, to each individual target particle.

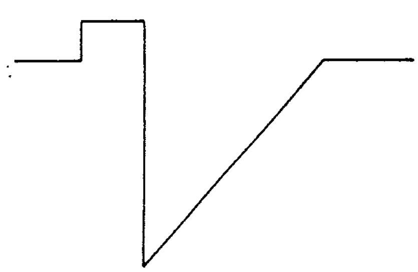


Fig. 4-3. Backplate erase pulse.

Erase-pulse geometry must write all targets, then drop all targets below first crossover and terminate by ascending to the quiescent level.

Screen make-up, of many small targets charged to different voltages, creates the necessity for a positive write step preceding negative erase excursion.

A storage-tube screen consists of myriad target elements charged to one of two voltage levels. This electrostatic environment prevents a simple pulse erasure. Applying a simple negative-pulse shape to the backplate results in one of two conditions: (1) No erasure or (2) partial erasure, sometimes called "railroad tracks."

Fig. 4-4 represents a CRT presentation illustrating the first, or no-erasure condition. A single dot appears in the CRT center. This dot, greatly enlarged, represents a single illuminated stored target element. The stored target element, charged to a second-crossover voltage, is surrounded by hundreds of target elements held below first-crossover voltage. A simple negative pulse applied to the backplate fails to erase. The pulse couples across to all targets equally. During the negative excursion, the nonstored areas set up a strong electrostatic field completely shielding the small stored area from flood-gun electrons. Each target element follows the erase pulse with fidelity, returning to its original voltage level. The pulse interrupts the display for a short time but fails to erase.

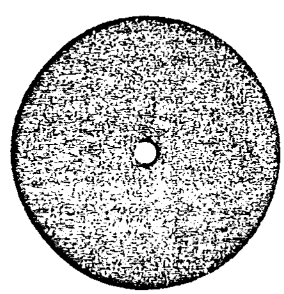


Fig. 4-4. Single-stored target (not drawn to scale).

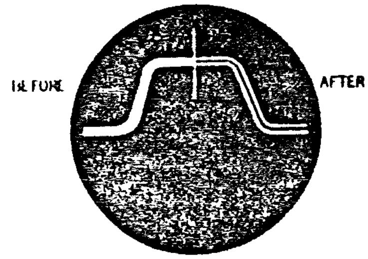


Fig. 4-5. Partial erasure.

Enlarging target area stored changes electrostatic environment to create the second or partial-erasure condition. Fig. 4-5 (before) shows one trace-width stored--a relatively large target area. The electrostatic field created in nonstored-target elements influences only adjacent stored-target elements. A simple erase pulse erases the trace center, but not the edges. Nonstored electrostatic fields shield edge-target elements forcing them to remain stored. With the passing of a simple erase pulse an illuminated trace outline remains. Fig. 4-5 (after) illustrates this "railroad track" presentation.

The more target areas stored, the higher the percentage of erasure. If all target elements are above second crossover, 100% erasure results from application of the simple erase pulse.

The complex erase waveform, shown in Fig. 4-6, causes all target elements to fade positive, or store, then erases the entire screen. Complex erase-waveform geometry must meet certain criteria:

1. Positive step amplitude must drive nonstored targets above first crossover.

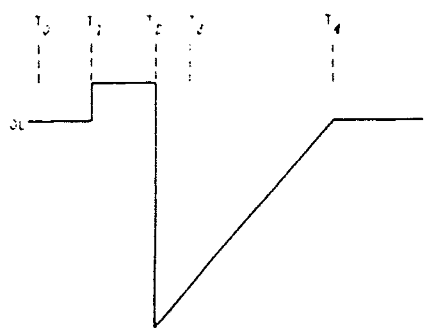


Fig. 4-6. Backplate erase waveform.

2. Positive step duration allows completion of the fade-positive action of previously nonstored targets.

3. The negative excursion should drive all targets below first crossover, but not below flood-gun cathode potential.

4. Ascending ramp slope must remain shallow enough for flood-gun action to hold all targets below first crossover.

Fig. 4-6 shows backplate voltage stepping positive at T_1, from a preset operating level (OL). Backplate voltage remains at the more positive level between T_1 and T_2, at which time the waveform assumes the shape of a simple erase waveform.

The complex backplate waveform superimposed on the nonstored- and stored-target waveforms appears in Fig. 4-7. Consider the nonstored-target waveform in Fig. 4-7(A).

T_0 - Target elements rest at a stable point below first crossover.

T_1 - Target voltage steps above first crossover as a result of the backplate stepping positive.

Since these target elements are now in an unstable portion of the charge curve above first crossover, they charge toward second crossover. Transition from one stable point to another takes time. The positive excursion must then last long enough for unstored-target elements to reach storage-target-backplate voltage, completing fade-positive at or before . . . .

T_2 - All targets are now stored. Refer to Fig. 4-7(B). All target elements descend to an equal voltage below first crossover.

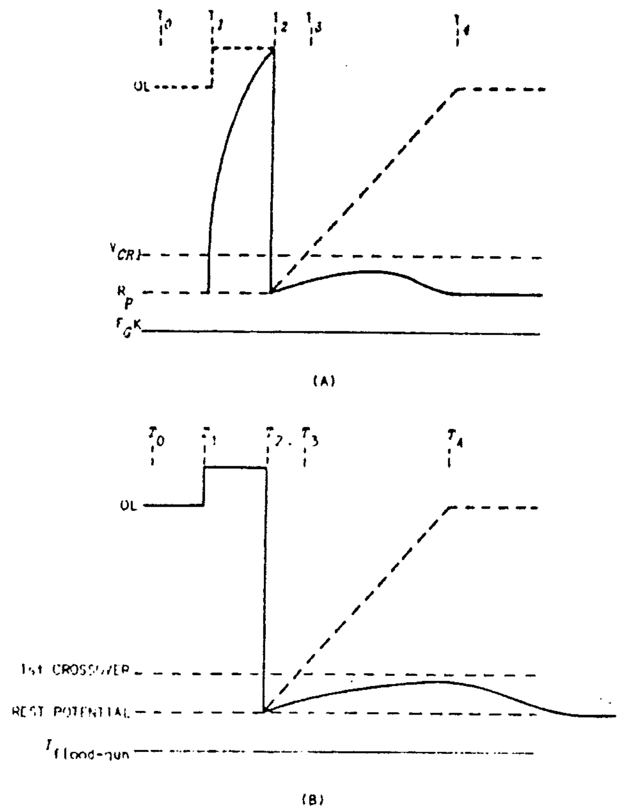


Fig. 4-7. Composite target element erasure.

T_3 - Flood-gun current contains target potential below first crossover during backplate-voltage ascension. The ramp slope remains within the device charging capability, holding target elements below first crossover.

T_4 - Erase waveform returns backplate to operating voltage level and target elements charge to a stable rest potential below first crossover.

The positive ramp need not be linear as illustrated. Ramps can, and usually do, follow an RC charge rate.

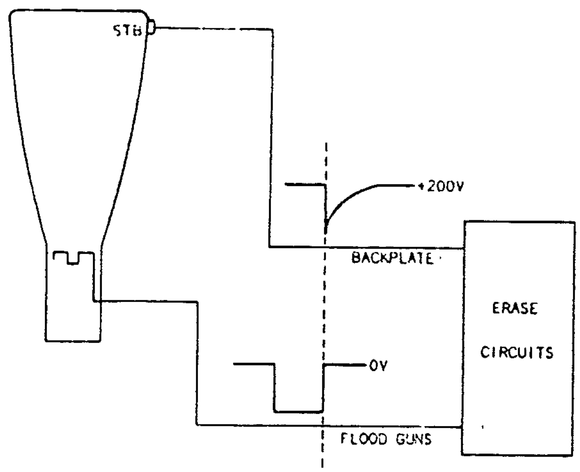


Fig. 4-8. Both flood gun and backplate erase pulsed.

Erase waveforms may be applied to either flood gun, backplate or both. Fig. 4-8 illustrates portions of the erase waveform applied to both flood gun and backplate. The negative pulse applied to the flood guns causes all target elements to fade positive, or write. Following the write pulse, the negative erase pulse appears at the backplate driving all targets below first crossover.

NOTE: This technique negates split-screen operation. Flood-gun cathodes are common to the entire screen: Applying "write" pulses to the flood-gun cathodes writes the entire screen area. Split-screen displays require separate backplates, individually pulsed, for erasure.

image retention buried charge

Occasionally an image remains or appears to return after an erase cycle. The retained image usually results from allowing a bright display to remain written for a long period. Written charges then penetrate deep into the target dielectric. Low-energy flood electrons fail to either fully write or fully erase the buried charge.

bright residual images

Target areas experiencing positive buried charges fade positive after an erase cycle, displaying the previously stored image. These are called bright residual images.

dark residual images

Target areas accumulating negative buried charges repel flood electrons, displaying dark images similar to trace shadowing.

An operator suspecting image retention initiates repetitive erasure. He accomplishes this by actuating the erase circuits in a fairly rapid series of five or more erasures. The buried charge, thus the residual image, appears to become more neutralized with each erasure.

When repetitive erasure fails to deplete the residual charge, write the entire viewing area, let the screen remain fully written for a few minutes, then erase. This should neutralize any residual image.

phosphor burns

Users sometimes confuse phosphor damage with retained images. Multiple erasure corrects for retained images but has no effect upon phosphor burns. Hence, keying the erase switch might aid determination of the type of display discrepancy.

TRANSMISSION STORAGE TUBES

"Current transmission" type storage devices store nonvisible images in a mesh dielectric, suspended to the rear of the phosphor viewing screen. The storage mesh then gates current to luminesce the viewing phosphor. Trnasmission tubes divide into two basic categories: bistable and halftone. Storage principles previously presented apply to both types.

Fig. 5-1 shows a target consisting of a dielectric sheet on which a charge image writes and stores. No visible target image results. In this figure the upper half of the target has been written positive and the lower half held negative. The target has been modified, however, by using a dielectric sheet which contains a great many small holes.

perforated dielectric target

Flood-gun emission approaching the holes in the written upper half of the target pass through a field having a potential not too different from the potential of the written surface of the target. Since this voltage may be two hundred volts positive, electrons pass through the holes at high velocity.

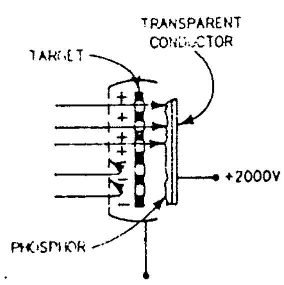


Fig. 5-1. "Grid control" of current through a perforated dielectric target.

Flood emission approaching the unwritten half of the target meets with a negative potential near the unwritten target surface. Most of this emission is reflected in front of the holes, since most of these electrons do not have sufficient energy to penetrate the retarding field.

phosphor viewing screen

The flood-gun current which passes through the target may be used to form a visible image by placing a phosphor layer in its path. A phosphor viewing screen has been deposited on a separate conductive electrode behind the perforated target. Electrons bombard this layer with a high velocity resulting from this electrode's potential. We may increase the phosphor voltage substantially, independent of the collector voltage, to obtain much higher brightness.

For example, the collector could be operated at +200 volts while the phosphor viewing screen is run at +2000 volts. After electrons pass the written area of the target, around +200 volts, they are accelerated to the much higher velocity of +2000 volts by the field between the target and the viewing screen and a visible image is formed on the viewing screen. This tube has the disadvantage of requiring a self-supporting dielectric target sheet, pierced with a great many apertures.

dielectric-coated mesh

This difficulty is overcome by supporting a dielectric coating on a metal mesh, as shown in Fig. 5-2. The dielectric-surface bistable charge mechanism is the same as described before, since the surface may charge independent of the mesh potential, because the surface of the dielectric is insulated from the mesh by the body of the dielectric.

mesh voltage usually operated at zero

In this structure, the field in the apertures is influenced by both the dielectric surface potential and the potential of the supporting mesh, which act together as a composite grid to control the passage of current through the target. The mesh is usually operated at zero volts, so that the field in the apertures of unwritten regions will remain cut off to flood current. Flood-gun emission easily passes through the field in the apertures at written areas, and is then accelerated to form the bright image on the viewing screen by a high potential on the aluminizing.

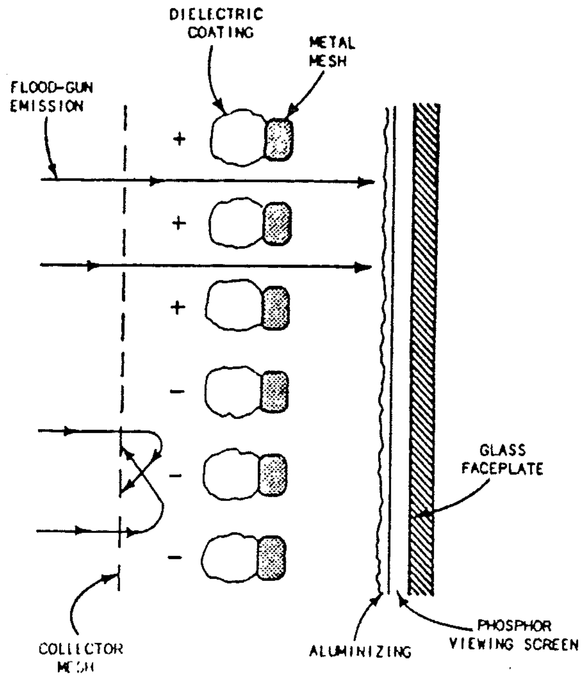


Fig. 5-2. Target with coated mesh.

This tube is the first tube in an evolutionary sequence which writes, stores, displays, and erases a bistable image and which uses a practically realizable storage target structure.

contacting collector mesh

During the development of the transmission-type bistable tube, it was discovered that improved operation resulted when the collector mesh contacts the surface of the dielectric (Fig. 5-3). In areas where the collector is touching the dielectric, conductivity to the collector and the shadowing of flood-gun bombardment by the collector, appear to act to some extent as barriers to migration of the boundary between written and unwritten areas. This extends the stable range of collector voltages over which the image does not become seriously degraded. The increase in stable range was quite an important development, since it had been marginal. The pitch and orientation of the collector mesh and the mesh which supports the dielectric are made dissimilar. Observation of a magnified portion of the image shows

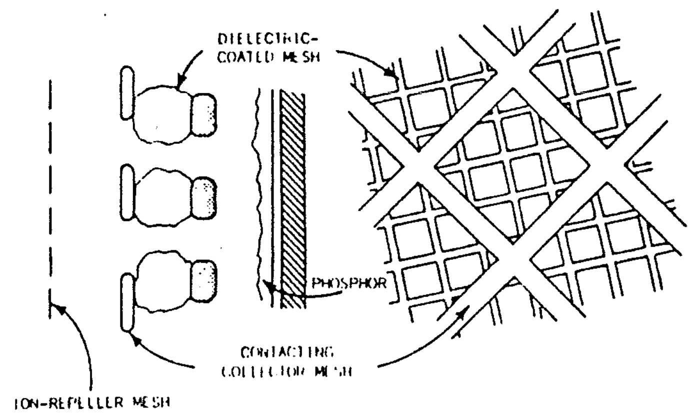


Fig. 5-3. Contacting collector mesh.

that all of the dielectric which is exposed to the flood gun through one square opening of the collector mesh, acts together in charging to either stable point. The tube of Fig. 5-3, the Haeff "transmission"-type bistable tube described here, typifies "second generation" storage tubes.

halftone

Halftone storage CRT's develop from the bistable transmission storage tube. Bistable tubes have two brightness levels, maximum and minimum. Halftone tubes on the other hand display images in several discernable brightness levels (gray scale halftones) from dark to maximum brightness.

Halftone and bistable transmission tubes exhibit similarities and differences. Consider first the similarities:

(1) A high-energy writing beam writes the targets positive by secondary emission.

(2) Structurally each uses a writing gun, flood guns, dielectric targets, ion repeller (?) and viewing screen.

(3) Collection of flood electrons erases the image.

(4) Flood-gun current produces the visible display.

Now the differences:

(1) The halftone tube's sensitivity to flood-beam collimation creates design problems.

(2) The long-persistence bistable tube has no halftones; while the halftone tube with its gray scale has limited viewing time.

(3) Theoretically the halftone tube has higher writing-rate possibilities.

(4) Halftone tubes have highest brightness, due to high-transmission target structure.

The secondary-emission curve, Fig. 5-4, shows bistable storage characteristics. Targets rest at one of two stable points. Flood-gun current drives targets below first crossover voltage to the lower stable point (L). Targets at this point repel flood electrons causing the effect of a unity secondary-emission ratio. Positive ions do charge target elements more positive but low-energy flood electrons then return these target elements to the lower stable point.

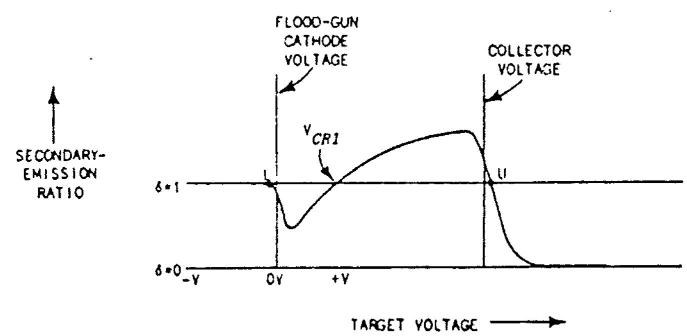


Fig. 5-4. Secondary-emission curve.

A voltage pulse or high-energy writing beam which raises a target above first crossover creates a write condition. Flood electrons strike target elements above first-crossover voltage with enough energy to cause secondary emission greater than 1. This charging action continues until target and collector potential are equal. Secondary-emission ratio now returns to unity at this, the second (upper), stable point.

bistable brightness

Fig. 5-5 shows that brightness varies little between first crossover and the upper stable point. One might expect halftones to exist in the region between first crossover and the lower stable point; however, flood-gun current drives target elements in this region toward the lower stable point.

Notice that 0% brightness occurs at target voltage more negative than the lower stable point. The background light at the lower stable point indicates that a minute quantity of flood electrons reach the phosphor viewing screen. Quantity and energy of flood electrons striking the phosphor determine brightness.

halftone transmission tubes

Halftone tubes are bistable devices operated with target voltages more negative than flood-gun potentials. The lower stable point represents maximum brightness. Cutoff, a few volts more negative, represents a dark screen or unwritten target.

or minimum?

The brightness curve, Fig. 5-5, indicates 0% brightness occurs at target voltages more negative than the lower stable point. Consider the 0% brightness point cutoff, the point of absolute secondary-emission ratio of 1.

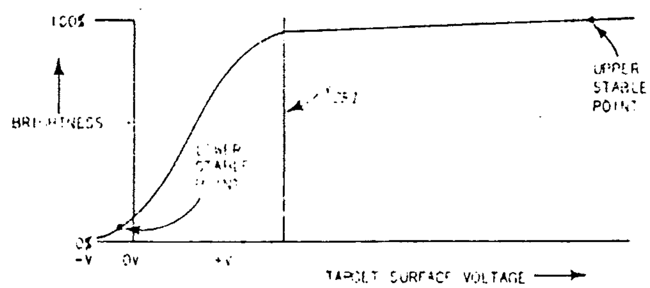


Fig. 5-5. Bistable brightness curve.

In Fig. 5-6 the secondary-emission curve extends to cutoff (point C). Flood electrons drive target elements to the lower stable point L. Target mesh elements, acting as a grid, setting at the lower stable point, allow a small quantity of flood electrons to reach the screen. Applying more negative voltages to the target grid reduces this current until, at point C, 100% repulsion or cutoff occurs.

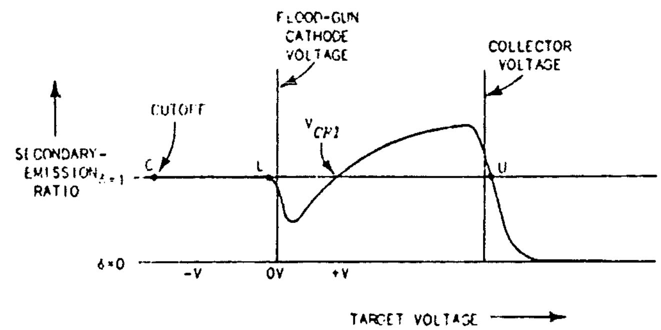


Fig. 5-6. Secondary-emission curve.

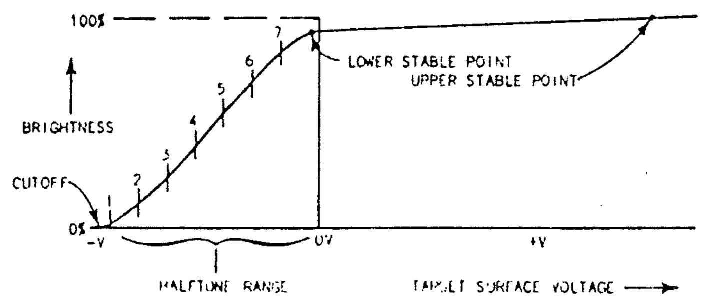


Fig. 5-7. Halftone storage brightness curve.

Operating between target voltages C and L, and returning the phosphor to a high positive voltage, allows halftone storage displays. One realizes several discernible brightness levels -- seven in Fig. 5-7. These tubes display a written image at any one of the brightness levels and brightness extends from 0% to just under 100%. (Assume, for now, that halftone tubes operate only between cutoff and the first-crossover target voltage.)

halftone construction

Halftone target construction lowers target grid cutoff. The basic secondary-emission curve serves to explain both bistable and halftone storage. This leads one to think both transmission tube types are alike -- not so! Haeff tubes store in bistable and halftone modes. These tubes produce a visible image in the bistable mode only. This is because halftone writing takes place below target grid cutoff. Therefore too few flood electrons reach the phosphor.

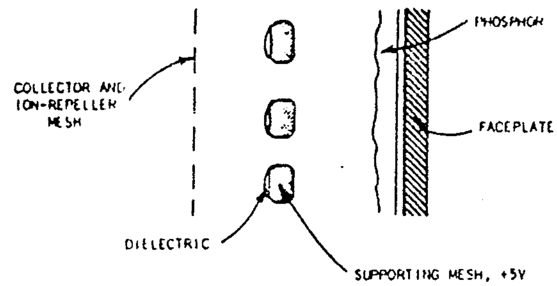


Fig. 5-8. Halftone construction.

Fig. 5-8 shows one type of halftone construction. The target dielectric is evaporated on the supporting mesh in a very thin dense layer. A thinner dielectric reduces mesh aperture shielding, resulting in more positive mesh aperture fields. Aperture fields increase even more, lowering transmission cutoff, by operating the supporting mesh at a positive voltage (shown at +5 V). Enough flood electrons now reach the phosphor to produce an image at maximum brightness, when the target grid elements rest at the lower stable point.

The collector need not contact the target surface and operating positive serves as an ion repeller. This simplifies halftone structure. Adjacent target elements charge to small voltage differences compared to bistable tubes. Flood emission creates no boundary migration, therefore a contacting collector becomes unnecessary.

halftone erasure

Applying a positive pulse causes the target to collect flood electrons, driving the target more negative. Assume the target rests at point L of Fig. 5-9. Further, point L is -3 V, C is -10 V, and V_{CR1} is +40 V. Now apply a +10-V pulse. The positive excursion elevates the target into an unstable region above flood-gun potential. Flood electrons charge the target negative, attempting to return it to the lower stable point. This charging action continues during the positive erase pulse interval. Terminating the pulse drops the target to point C. Since point C represents cutoff, the target rests at the nonstored or unwritten state and no electrons reach the phosphor. Erase pulses must be large enough in amplitude to cause target collection of electrons, yet not so great that any target element exceeds first-crossover

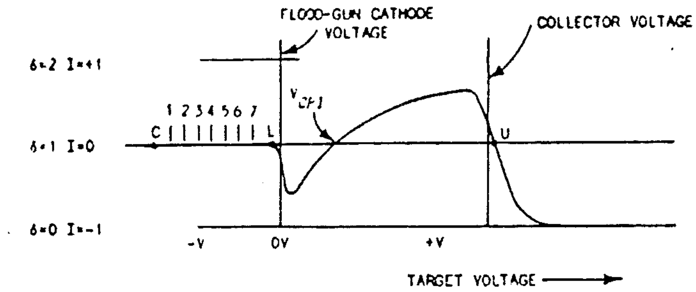


Fig. 5-9. Secondary-emission curve.

voltage. Positive pulse duration fixes the quantity of target charge which must equal L-to-C voltage (7 volts for conditions assumed above).

Halftone transmission tubes in use develop problems detrimental to a "clean" storage presentation. These effects are residual images, target elements charged to the upper stable point, and accumulation of positive ions in grid apertures. The complex erase pulse of Fig. 5-10 serves to eliminate these problem effects with each erasure.

One might consider Fig. 5-10 a combination of bistable and halftone erasure. The portion of the waveform occupying T_0 through T_3 is the bistable erasure; and that occurring from T_3 through T_4, the halftone portion.

> T_0 -- The mesh rests at quiescence, a few volts more positive than the lower stable point.

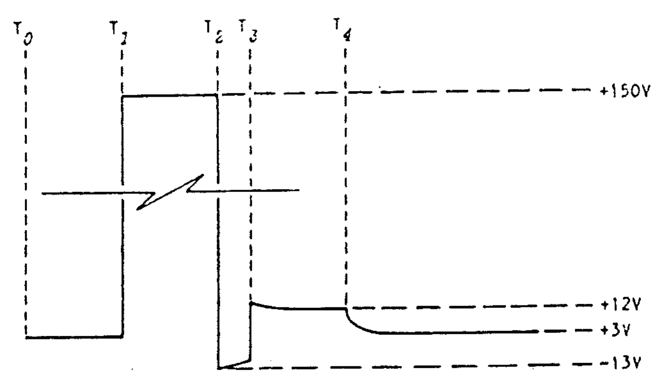


Fig. 5-10. Halftone erase cycle.

T_1 -- Actuating erase circuits applies a large positive excursion, driving target elements above first crossover. Target elements then charge toward the upper stable point. Writing-target elements bistably deplete buried target charge (residual image) and allow erasure of target elements inadvertently written to the upper stable point.

T_2 -- The negative pulse, lasting from T_2 to T_3, drives target elements below first crossover. Descending to a level below the lower crossover point, the pulse repels any positive ions occupying the aperture area.

T_3 -- This positive excursion elevates target elements into an unstable region below first crossover. Flood electrons accumulate on target elements so that at:

T_4 -- When the erase pulse returns the collector to quiescence, target elements drop below the lower stable point to cutoff. All target elements are erased.

Complex erasure waveforms such as the one explained, require as much as one-half second cycle time.

halftone writing

When the target is at cutoff the screen is dark. Arrival of a high-energy writing beam then charges target elements positive which in turn allows flood electrons to strike and luminesce the viewing screen. Electron quantity passing through the target mesh depends upon how far positive (toward the lower stable point) the target charges. Depending upon writing-beam density and dwell time, target elements charge to some increment between points C and L. Target areas charged to point 1 gate a small quantity of flood electrons for minimum image brightness. Point 7 represents maximum brightness.

Target areas charge toward the lower stable point becoming fully written after several minutes. Consider an area charged to increment 1 and another to 7: One dim and one very bright image appears on the screen. Positive ions charge target elements toward point L. Area 7 becomes fully written followed a few minutes later by area 1. Both images are now fully written. Unfortunately, the entire target area fades positive. Therefore, shortly after an area charged to increment 1 becomes fully written, the entire target area charges to point L. The overall screen area is now at maximum brightness displaying no intelligence. The target must be erased for waveform monitoring.

store

A technique called store increases viewing time. Positive ions, the cause of fade positive, result from the ionizing action of flood electrons. Reducing flood current then increases viewing time, accompanied by reduced brightness.

Actuating the store circuits applies (actually or effectively) a train of pulses to the flood-gun anode or cathode. These pulses turn the flood guns on and off. Pulse train duty cycle establishes average flood-gun cathode current, thereby setting viewing time and brightness: If viewing time increases by 10, brightness decreases by 10 since average flood current decreases by 10.

variable persistence

Another application of a pulse train develops the concept known as variable persistence. The technique partially erases the target area with a series of short-duration erase pulses. This maintains a good contrast ratio between written areas and background illumination, eventually erasing the entire target surface.

Applying short-duration fixed-amplitude erase pulses (usually to the flood guns) cause target elements to charge toward cutoff at the pulse rate. The viewer sees little if any flicker.

To him the image merely fades into the background. Varying the "fast" erase-pulse duty cycle changes the rate of erasure. A front panel control allows operator control of erasure, or call it duty cycle or variable persistence.

Variable persistence applies well to observations of repetitive signals superimposed on random signals (noise). Random signals write at lower halftones than repetitive. The random signals experience early erasure allowing one to view a "clean" repetitive signal.

STORAGE CONCEPTS

1. Flood-gun electrons are uniformly distributed over the stroage target area by ____________________.

2. In bistable storage, the STB voltage at which the trace on the CRT fades out is called _______________ threshold.

3. The STB of a bistable target can be increased until full written brightness level appears for all targets. This level is called ___________________.

4. The lowest bistable STB voltage which will cause a signal to be written is called the _________________ threshold.

5. The operating voltage range of a bistable STB is between the ________ ____________ and the __________ ___________ _____________.

6. Once a bistable target is carried above first crossover on the secondary emission curve by the writing beam, ___________ _________ electrons will cause the target to charge to the upper stable point.

7. The type of storage tube that stores a signal on a mesh dielectric and then gates current to luminesce the viewing phospher is a ______________ ______________ tube.

8. Bistable stroage has two levels of brightness, one level of background brightness at the lower stable point on the secondary emission curve, and a brighter level for targets written to the upper stable point. Halftone storage can display images in several discernable brightness levels, from dark to maximum brightness, by varying the target voltage between _________ __________ point and ______________ on the secondary emission curve.

9. The technique that partially erases the target area with a series of short duration erase pulses is called ___________ ___________. This technique allows one to better observe repetetive signals superimposed on noise.

10. Both bistable and halftone erase pulses first cause all target elements to charge to the _________________ stable point on the secondary emission curve.

STORAGE CONCEPTS

ANSWER KEY

1. Collimation systems
2. Retention threshold
3. Fade positive
4. Writing threshold
5. Writing threshold; upper writing limit
6. Flood guns
7. Transmission storage
8. Lower stable; cut-off
9. Variable persistance
10. Upper

Please do not write in lesson book.
Please return book with tape.

Thank you.

VIDEO

BASIC STORAGE CONCEPTS

INDEX

VIDEO

BASIC STORAGE CONCEPTS

Objectives

The objective of this video taped training course is to teach the viewer the basic concepts of Direct View Storage.

The program was designed around the "Test Out" concept. The viewer may take any part of the course, provided he has knowledge sufficient to successfully complete the pre-quizzes related to any portion of the package.

VIDEO

BASIC STORAGE CONCEPTS

Instructions

1. Read the <u>preview quiz</u> before viewing the video tape.
2. Answer only the questions you are sure of before viewing the video tape.
3. If you successfully answer all questions, viewing the tape is optional.
4. View the tape but DO NOT ATTEMPT to write answers to questions during viewing.
5. After viewing, answer as many questions as possible.
6. If unable to answer all questions correctly, review the tape until you can successfully complete the final quiz.

Basic Storage Concepts

(Video Tape Program)

Preview Quiz

(Tape #1)

Counter No.

Set #I FUNDAMENTAL STORAGE CONCEPTS.

1. Choose from below only those elements which make up the storage target of a direct-view storage CRT. 47

   (a) Flood-Gun Cathodes

   (b) Wall Bands

   (c) A Dielectric Surface

   (d) Flood-Gun Anode

   (e) A Conductive Backing Electrode

2. The chemical compound Magnesium Oxide (MgO) plays an important role in a direct-view storage CRT. Choose from below, it's correct function. 64

   (a) Reduces the light output from the display screen.

   (b) Accelerates flood-electrons toward the display screen.

   (c) Eliminates buried charges in the storage target.

   (d) Enhances the emission of secondary electrons from the storage target.

3. The Dielectric Surface Potential is brought about by the accumulation of ______________________________ on the target surface. Choose all possible correct answers. 78

   (a) Electrons

   (b) Gas Molecules

   (c) Positive Ions

   (d) Phosphor particles

Counter No.

4. The stopping potential (VStop) is one of many possible dielectric surface potentials. What is so unique about this concept? 109

(a) VStop prevents positive ions from landing on the storage target.

(b) VStop prevents writing gun electrons from landing on the storage target.

(c) VStop is a stable potential because flood electrons are reflected away from the storage target.

(d) VStop provides the background illumination from storage CRT.

5. What is the value of the stopping potential (VStop) with relation to the flood gun cathode? 144

(a) -1 volt

(b) -10 volts

(c) +1 volt

(d) +10 volts

(e) +140 volts

Basic Storage Concepts

(Video Tape Program)

Preview Quiz

(Tape #1)

Counter No.

Set #II BISTABLE STORAGE CONCEPTS.

1. What is the purpose of the flood electron guns in any direct view storage CRT? 225

   (a) The flood electron guns write the desired information onto the storage target.

   (b) The flood electron guns provide viewing electrons for the complete storage screen.

   (c) The flood electron guns erase the stored target.

   (d) The flood electron guns collimate the wall bands.

   (e) The flood electron guns maintain the desired MgO level in the target.

2. What is the purpose of the collimation or wall-band electrodes? 228 & 243

   (a) The wall-bands create electric fields which collimate the flood electrons for complete storage screen coverage.

   (b) The wall-bands create electric fields which focus writing electrons to a small spot diameter.

   (c) The wall-bands create electric fields to provide collection for all unwanted positive ions.

3. What is the voltage on the writing electron gun cathode with respect to the flood-gun cathode? 254

   (a) + 2000 volts

   (b) 0 volts

   (c) - 2000 volts

   (d) + 10 volts

   (e) - 10 volts

4. Name the electron gun that provides the highest energy electrons. 243-255

   (a) The flood gun

   (b) The collector gun

   (c) The writing gun

5. Choose the elements that make up the storage target in a bistable storage CRT. 270-290

   (a) The storage target backplate collector

   (b) MgO + phosphor

   (c) Flood guns

   (d) Collimation bands

   (e) Writing guns

6. Choose the stable potentials of the dielectric surface material. 144 and 292

   (a) VStop

   (b) L.S.P.

   (c) U.S.P.

   (d) First crossover

   (e) Vrest

Basic Storage Concepts

(Video Tape Program)

Preview Quiz

(Tape #1)

		Counter No.
Set #III	BISTABLE STORAGE -- UPPER AND LOWER STABLE POTENTIAL.	
1.	What is the lower stable potential if the S.T.B. collector is 0 volts?	378

(a) VStop

(b) First crossover

(c) VRest

(d) VSTB

(e) VFGK (flood gun cathode)

2\. What is the lower stable potential if the S.T.B. collector is connected to 140 V or the collector voltage to permit bistable storage? — 385 - 419

(a) VStop

(b) First crossover

(c) VRest

(d) VSTB

(c) VFGK

3\. What is the dielectric surface potential which determines the faceplate background glow? — 417 and 688

(a) VStop

(b) First crossover

(c) VRest

(d) VSTB

(e) VFGK

Counter No.

4. Choose the element below responsible for changing the storage targets' dielectric surface potential from VRest to an upper stable potential of +141 volts. 446

(a) Flood electron gun

(b) Writing electron gun

(c) Wall bands

5. What is the dielectric surface potential which establishes the brightness level of a stored target in a bistable CRT. 478-505

(a) VStop

(b) First crossover

(c) VRest

(d) U.S.P.

(e) VFGK

6. Make a drawing of the secondary electron emission curve and place the below list of labels on the curve. 515-690

(a) Dielectric surface potential

(b) S (secondary electron emission ratio) S · 0, 1 and 2

(c) The curve

(d) VStop

(e) VFGK

(f) VRest

(g) First crossover

(h) VSTB

(i) U.S.P.

(j) Target accumulates electrons

(k) Target loses electrons

Basic Storage Concepts

(Video Tape Program)

Preview Quiz

(Tape #1)

Counter No.

Set #IV BISTABLE STORAGE -- SECONDARY ELECTRON EMISSION CURVE

1. If the secondary electron emission ratio δ is greater than 1, the target surface will __________ electrons and the dielectric surface potential will change toward a more __________ potential. 663 - 790

(a) negative

(b) neutral

(c) lose

(d) positive

(e) accumulate

2. If the secondary electron emission ratio δ is less than 1, the target surface will __________ electrons and the dielectric surface potential will change toward a more __________ potential. 670 and 683-790

(a) negative

(b) neutral

(c) lose

(d) positive

(e) accumulate

3. If a target is at the rest potential and writing electrons land on it's surface, the target surface will __________ electrons and the dielectric surface potential will change toward a more __________ potential. 654-790

(a) negative

(b) neutral

(c) lose

3. (cont)

   (d) positive

   (e) accumulate

4. If a storage target is at the rest potential when writing electrons land, the target will change toward a more ____________ potential. If the writing gun is turned off before the target can cross the first crossover, the dielectric surface potential will become stable at the ____________. 793

   (a) first crossover (CR1)

   (b) stopping potential

   (c) rest potential

   (d) upper stable potential

   (e) negative

   (f) positive

5. If the same target (as in #4) were written above the first crossover, the dielectric surface potential will become stable at the ____________. 805

   (a) first crossover (CR1)

   (b) stopping potential

   (c) rest potential

   (d) upper stable potential

   (e) negative

   (f) positive

<u>Basic Storage Concepts</u>

(Video Tape Program)

Preview Quiz

(Tape #2)

Counter No.

Set #V BISTABLE STORAGE MODES OF OPERATION

1. The "NON-STORE" mode is set into operation by: 23

   (a) Disabling the flood gun cathodes

   (b) Connecting the S.T.B. to +140 volts

   (c) Pulsing the S.T.B. positive

   (d) Connecting the S.T.B. to +20 volts

   (e) Pulsing the S.T.B. positive, negative, then back to the operating level

   (f) Pulsing the S.T.B. negative

2. The "STORE" mode is set into operation by: 69

   (a) Disabling the flood gun cathodes

   (b) Connecting the S.T.B. to +140 volts

   (c) Pulsing the S.T.B. positive

   (d) Connecting the S.T.B. to +20 volts

   (e) Pulsing the S.T.B. positive, negative, then back to the operating level

   (f) Pulsing the S.T.B. negative

3. The "ERASE" mode is set into operation by: 126

   (a) Disabling the flood gun cathodes

   (b) Connecting the S.T.B. to +140 volts

   (c) Pulsing the S.T.B. positive

   (d) Connecting the S.T.B. to +20 volts

3. (cont)

   (e) Pulsing the S.T.B. positive, negative, then back to the operating level

   (f) Pulsing the S.T.B. negative

4. The "INTEGRATE" mode (repetitive sweeps) is set into operation by: 248

   (a) Disabling the flood gun cathodes

   (b) Connecting the S.T.B. to +140 volts

   (c) Pulsing the S.T.B. positive

   (d) Connecting the S.T.B. to +20 volts

   (e) Pulsing the S.T.B. positive, negative, then back to the operating level

   (f) Pulsing the S.T.B. negative

5. The "ENHANCE" mode (primarily intended for single sweep) is set into operation by: 325

   (a) Disabling the flood gun cathodes

   (b) Connecting the S.T.B. to +140 volts

   (c) Pulsing the S.T.B. positive

   (d) Connecting the S.T.B. to +20 volts

   (e) Pulsing the S.T.B. positive, negative, then back to the operating level

   (f) Pulsing the S.T.B. negative

6. Make a drawing of the bistable erase waveform and include the following information on your drawing: 126

   (a) Rest potential (VRest)

   (b) First crossover (CR1)

6. (cont)

   (c) Upper stable potential (U.S.P.)

   (d) Write positive step

   (e) Write negative step

   (f) S.T.B. operating level

   (g) Background brightness level

   (h) Stored brightness level

   (i) Targets carried positive by flood electrons

   (j) Targets carried positive by S.T.B.

   (k) Targets carried negative by flood electrons

Basic Storage Concepts

(Video Tape Program)

Preview Quiz

(Tape #3)

Counter Number

Set VI TRANSMISSION STORAGE CONCEPTS.

1. Select only those elements belonging to a Transmission Storage CRT. 174

   (a) Writing Gun

   (b) Flood Guns

   (c) Wall Bands

   (d) Phosphor Storage Target

   (e) Collector Mesh

   (f) Storage Target Mesh

   (g) STB Collector

   (h) Aluminized Screen

   (i) Any Phosphor P1-P35

   (j) Post Deflection Acceleration Electrode

2. Select the two elements most likely to provide a brighter stored image on a transmission phosphor screen. 139

   (a) Writing Gun

   (b) Flood Guns

   (c) Wall Bands

   (d) Phosphor Storage Target

   (e) Collector Mesh

   (f) Storage Target Mesh

   (g) STB Collector

   (h) Aluminized Screen

   (i) Any Phosphor P1-P35

   (j) Post Deflection Acceleration Electrode

Counter Number

3. Select the 3 Elements making up the Storage Mesh Target in a Transmission CRT — 230-244

(a) Phosphor Storage Target

(b) Collector Mesh

(c) Storage Mesh

(d) MgO Dielectric

(e) Transmission Aperture Holes

4. What is the term used for a Dielectric Surface Potential required to stop all Flood Electrons from transiting through an aperture hole in the Storage Mesh? — 245

(a) Stopping Potential (V Stop)

(b) Rest Potential (V Rest)

(c) Voltage Cutoff (Vco)

(d) Upper Stable Potential (U.S.P.)

(e) First Crossover Potential (Vcr1)

5. What is the term used for a Dielectric Surface Potential required to provide maxium transmission current through an aperture? Why? — 298-325

(a) Stopping Potential

(b) Rest Potential

(c) Voltage Cutoff

(d) Upper Stable Potential

(e) First Crossover Potential

6. Make a graph of the Aperture Transmission Current v.s. Dielectric Surface Potential; plot the curve and include the following: — 340-404

(a) Vco

(b) Halftone Brightness Gradient

(c) V Stop

(d) V Mesh

Counter Number

7. Make a graph of the Erase Waveform applied to the Transmission Storage Mesh Conductor. Also, superimpose over the Erase Wave form a graph of the following Dielectric Surface Potentials: 440-547

(a) Vco

(b) V Stop

(c) Changes between these potentials.

8. What may cause the stored image to fade positive? 549-569

(a) Collection of Electrons.

(b) Collection of Positive Ions.

(c) Collection of Negatvie Ions.

9. How can this fade positive phenomenon be minimized? 569-622

(a) By disconnecting the Wall Bands.

(b) By disconnecting the Flood Gun Cathodes.

(c) By disconnecting the Storage Target.

(d) By turning off the Oscilloscope.

(e) By biasing the Flood Gun Cathodes to cutoff.

10. How is storage persistence achieved in a Transmission Storage CRT? 670-706

(a) Pulsing the Storage Mesh with a negative pulse.

(b) Pulsing the Storage Mesh with a positive pulse.

(c) Flood Electron Guns disconnected from ground.

(d) Pulsing the Collector Mesh positive.

(e) Pulsing the Collector Mesh negative.

Counter Number

11. How is variable Storage Persistence achieved in a Transmission Storage CRT? 706

(a) Pulsing the Storage Mesh with a negative pulse.

(b) Pulsing the Storage Mesh with a positive pulse.

(c) Varying the pulse width of the negative pulse applied to the Storage Mesh.

(d) Varying the pulse width of the positive pulse applied to the Storage Mesh.

(e) Flood Electron Guns pulsed between conduction and cutoff.

Basic Storage Concepts

(Video Tape Program)

Preview Quiz

(Tape #4)

Counter No. 000

Set VII TRANSFER STORAGE

1. Select only those elements belonging to a transfer storage CRT. 100

   (a) Writing Gun

   (b) Flood Guns

   (c) STB Collector

   (d) Collector Mesh

   (e) Wall Bands

   (f) Phosphor Storage Target

   (g) Any Phosphor P1-P35

   (h) Fast Storage Mesh

   (i) Bistable Storage Mesh

   (j) Aluminized Screen

   (k) Post Deflection Acceleration Electrode

   (l) Collector Storage Mesh

2. Name the meshes contained within a transfer storage CRT. See above list 185-191

3. The "non-store" mode is obtained by: 234-255

   (a) connecting the flood gun cathode to +50 volts

   (b) connecting the flood gun cathode to 0 volts

   (c) biasing the collector mesh to -26 volts

   (d) biasing the FAST mesh to -26 volts

   (e) biasing the BISTABLE mesh to -26 volts

4. The "BISTABLE" mode is obtained by: 255-276

Counter No.

(a) connecting the flood gun cathode to +50 volts

(b) connecting the flood gun cathode to 0 volts

(c) biasing the collector mesh to +46 volts

(d) biasing the FAST mesh to +46 volts

(e) biasing the BISTABLE mesh to +46 volts

5. Make a drawing of the waveform used to achieve erasure while in the bistable mode. This waveform is applied to the ______ CRT element. See list (question 1). 276-289

6. The transmission mode ("variable persistence") is obtained by applying A - 9v level to the ________ ______ CRT electrode. While in this mode, storage persistence is obtained by applying ______ ______ to the _______ _______. Variable storage persistence is obtained by changing the _______ ______ _______. 290-298

7. Make a drawing of the waveform used to achieve erasure while in the transmission or variable persistence mode. This waveform is applied to the _________ ________. 300-320

8. Make a drawing of the waveforms used to achieve erasure while in the FAST transfer mode. Include the peak amplitude value for the transfer pulse and name the electrodes. 320-374

Counter No.

9. How does the multi-trace (multi-transfer) erase mode differ from the FAST transfer erase mode? 374-402

ANSWER:

10. The "SAVE" mode is obtained by: 403-411

(a) connecting the flood gun cathode to +50 volts

(b) connecting the flood gun cathode to 0 volts

(c) biasing the collector mesh to +46 volts

(d) biasing the FAST mesh to +46 volts

(e) biasing the BISTABLE mesh to +46 volts

11. How can the stored image be viewed while in the save mode? 411-417

(a) by pulsing the flood gun cathode negative from +50 volts

(b) by pulsing the flood gun cathode positive from +50 volts

(c) by pulsing the collector mesh positive from 0 volts

(d) by pulsing the FAST mesh negative from 0 volts

(e) by pulsing the BISTABLE mesh negative from 0 volts

12. The BISTABLE "INTERGRATE" mode is obtained by: 418-425

(a) connecting the flood gun cathode to +50 volts

(b) connecting the flood gun cathode to 0 volts

(c) pulsing the collector mesh positive

(d) pulsing the FAST mesh positive

(e) pulsing the BISTABLE mesh positive

13. Uneven aperture erasure is caused by a phenomenon called differential cutoff. How can the deterimental effects of differential cutoff be minimized? 425-455

14. Describe the concept of differential cutoff. 425-455

QUIZ KEY

Basic Storage Concepts

(Video Tape Program)

(Tape #1)

Counter No.

Set #I FUNDAMENTAL STORAGE CONCEPTS

1. Choose from below only those elements which make up the storage target of a direct-view storage CRT. 47

(c) A dielectric surface

(e) A conductive backing electrode

2. The chemical compound Magnesium Oxide (MgO) plays an important role in a direct-view storage CRT. Choose from below, it's correct function. 64

(d) Enhances the emission of secondary electrons from the storage target.

3. The Dielectric Surface Potential is brought about by the accumulation of (a) electrons and (c) positive ions on the target surface. Choose all possible correct answers. 78

4. The stopping potential (VStop) is one of many possible dielectric surface potentials. What is so unique about this concept? 109

(c) VStop is a stable potential because flood electrons are reflected away from the storage target.

5. What is the value of the stopping potential (VStop) with relation to the flood gun cathode? 144

(a) -1 volt

QUIZ KEY

Basic Storage Concepts

(Video Tape Program)

(Tape #1)

Counter No.

Set #II BISTABLE STORAGE CONCEPTS

1. What is the purpose of the flood electron guns in any direct view storage CRT? — 225

   (b) The flood electron guns provide viewing electrons for the complete storage screen.

2. What is the purpose of the collimation of wall-band electrodes? — 228 & 243

   (a) The wall-bands create electric fields which collimate the flood electrons for complete storage screen coverage.

3. What is the voltage on the writing electron gun cathode with respect to the flood-gun cathode? — 254

   (c) - 2000 volts

4. Name the electron gun that provides the highest energy electrons. — 243-255

   (c) The writing gun

5. Choose the elements that make up the storage target in a bistable storage CRT. — 270-290

   (a) The storage target backplate collector and
   (b) MgO + phosphor

6. Choose the stable potentials of the dielectric surface material — 144 and 2[illegible]2

   (a) VStop

   (b) L.S.P.

   (c) U.S.P.

QUIZ KEY

Basic Storage Concepts

(Video Tape Program)

(Tape #1)

Counter No.

Set #III BISTABLE STORAGE -- UPPER AND LOWER STABLE POTENTIAL

1. What is the lower stable potential if the S.T.B. collector is 0 volts? — 378

   (a) VStop

2. What is the lower stable potential if the S.T.B. collector is connected to 140 V or the collector voltage to permit bistable storage? — 385-419

   (c) VRest

3. What is the dielectric surface potential which determines the faceplate background glow? — 417 and 688

   (c) VRest

4. Choose the element below responsible for changing the storage targets' dielectric surface potential from VRest to an upper stable potential of +141 volts. — 446

   (b) Writing electron gun

5. What is the dielectric surface potential which establishes the brightness level of a stored target in a bistable CRT. — 478-505

   (d) U.S.P. (+141 volts on video tape)

QUIZ KEY

Basic Storage Concepts

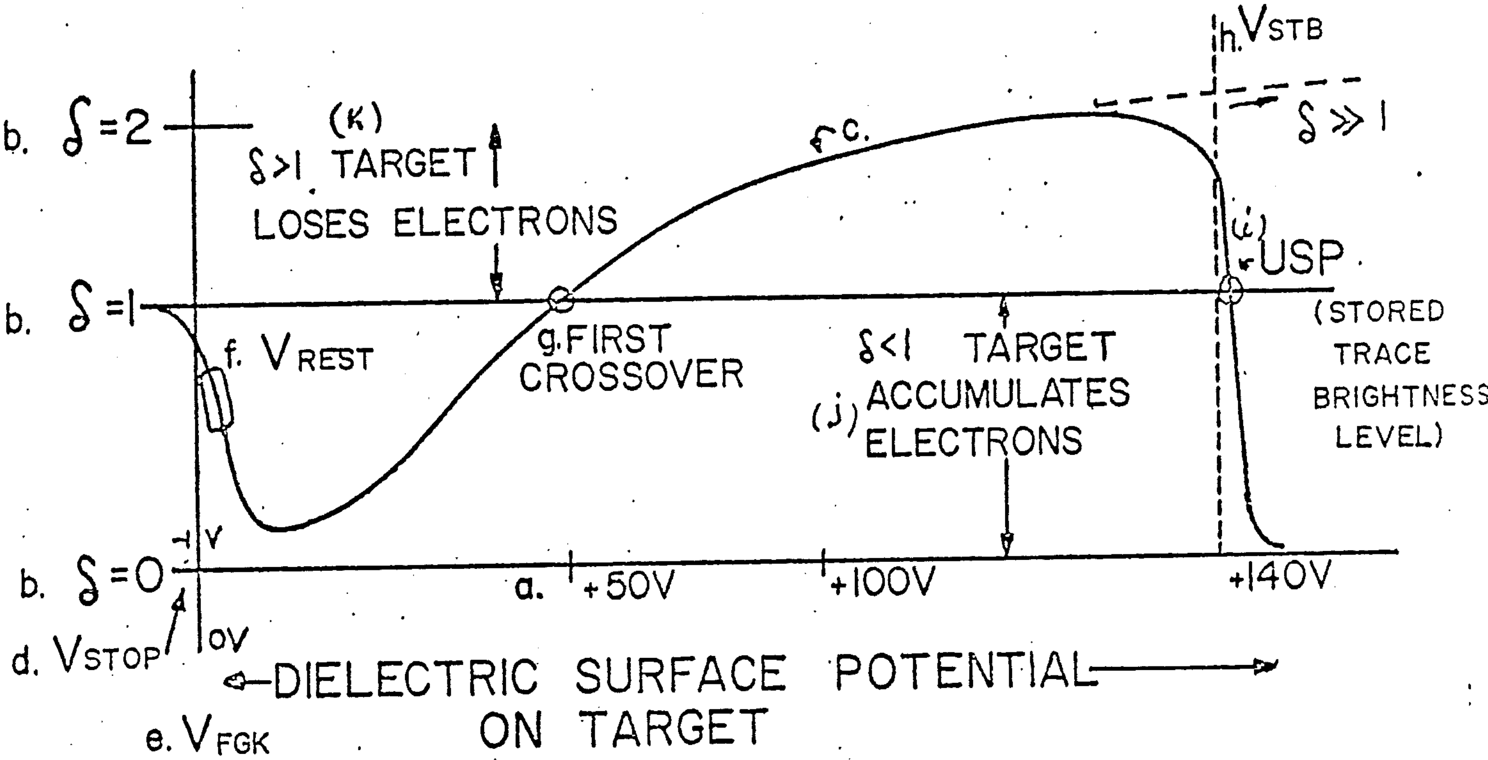
(Video Tape Program)

(Tape #1)

Counter No.

Set #III BISTABLE STORAGE -- UPPER AND LOWER STABLE POTENTIAL

6. Make a drawing of the secondary electron emission curve and place the below list of labels on the curve. 515-690



QUIZ KEY

Basic Storage Concepts

(Video Tape Program)

(Tape #1)

Counter No.

Set #IV BISTABLE STORAGE -- SECONDARY ELECTRON EMISSION CURVE

1. If the secondary electron emission ratio δ is greater than 1, the target surface will (c) lose electrons and the dielectric surface potential will change toward a more (d) positive potential. — 663-790

2. If the secondary electron emission ratio δ is less than 1, the target surface will (e) accumulate electrons and the dielectric surface potential will change toward a more (a) negative potential. — 670 and 683-790

3. If a target is at the rest potential and writing electrons land on it's surface, the target surface will (c) lose electrons and and the dielectric surface potential will change toward a more (d) positive potential. — 654 790

4. If a storage target is at the rest potential when writing electrons land, the target will change toward a more (f) positive potential. If the writing gun is turned off before the target can cross the first crossover, the dielectric surface potential will become stable at the (c) rest potential. — 793

5. If the same target (as in #4) were written above the first crossover, the dielectric surface potential will become stable at the (d) upper stable potential. — 805

QUIZ KEY

Basic Storage Concepts

(Video Tape Program)

(Tape #2)

Counter No.

Set #V BISTABLE STORAGE MODES OF OPERATION

1. The "NON-STORE" mode is set into operation by: 23

(d) Connecting the S.T.B. to +20 volts

Note: a student could answer (a) which would indicate that his reasoning is OK; however, this is not the practice used by engineering at Tek.

2. The "STORE" mode is set into operation by: 69

(e) Pulsing the S.T.B. positive, negative, then back to the operating level

(b) Connecting the S.T.B. to +140 volts

3. The "ERASE" mode is set into operation by: 126

(e) Pulsing the S.T.B. positive, negative, then back to the operating level

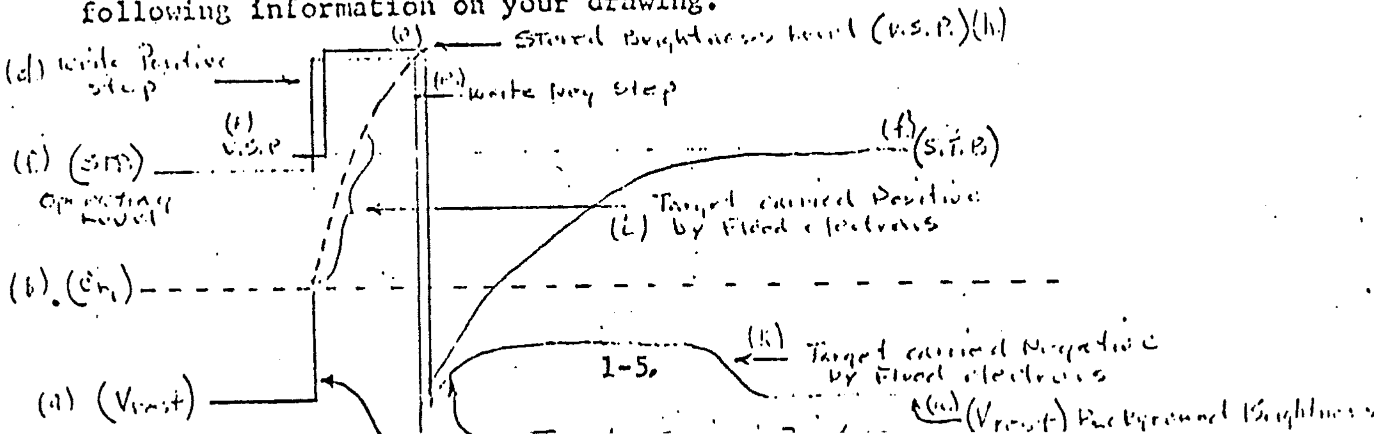
4. The "INTEGRATE" mode (repetitive sweeps) is set into operation by: 248

(a) Disabling the flood gun cathodes

5. The "ENHANCE" mode (primarily intended for single sweep) is set into operation by: 325

(c) Pulsing the S.T.B. positive

6. Make a drawing of the bistable erase waveform and include the following information on your drawing. 126



Basic Storage Concepts

Quiz Koy

(Tape #3)

Counter Number

Set VI TRANSMISSION STORAGE CONCEPTS.

1. Select only those elements belonging to a Transmission Storage CRT. 174

   (a) Writing Gun

   (b) Flood Guns

   (c) Wall Bands

   (e) Collector Mesh

   (f) St rage Target Mesh

   (h) Aluminized Screen

   (i) Any Phosphor P1-P35

   (j) Post Deflection Acceleration Electrode

2. Select the two elements most likely to provide a brighter stored image on a transmission phosphor screen. 139

   (h) Aluminized Screen

   (j) Post Deflection Acceleration Electrode

3. Select the 3 elements making up the Storage Mesh Target in a Transmission CRT. 230-244

   (c) Storage Mesh

   (d) MgO Dielectric

   (e) Transmission Aperture Holes.

4. What is the name for a Dielectric Surface Potential required to stop all Flood Electrons from transiting through an aperture in the Storage Mesh? 245

   (c) Voltage Cutoff

5. What is the name for a Dielectric Surface Potential required to provide maximum transmission current through an aperture? 298-325

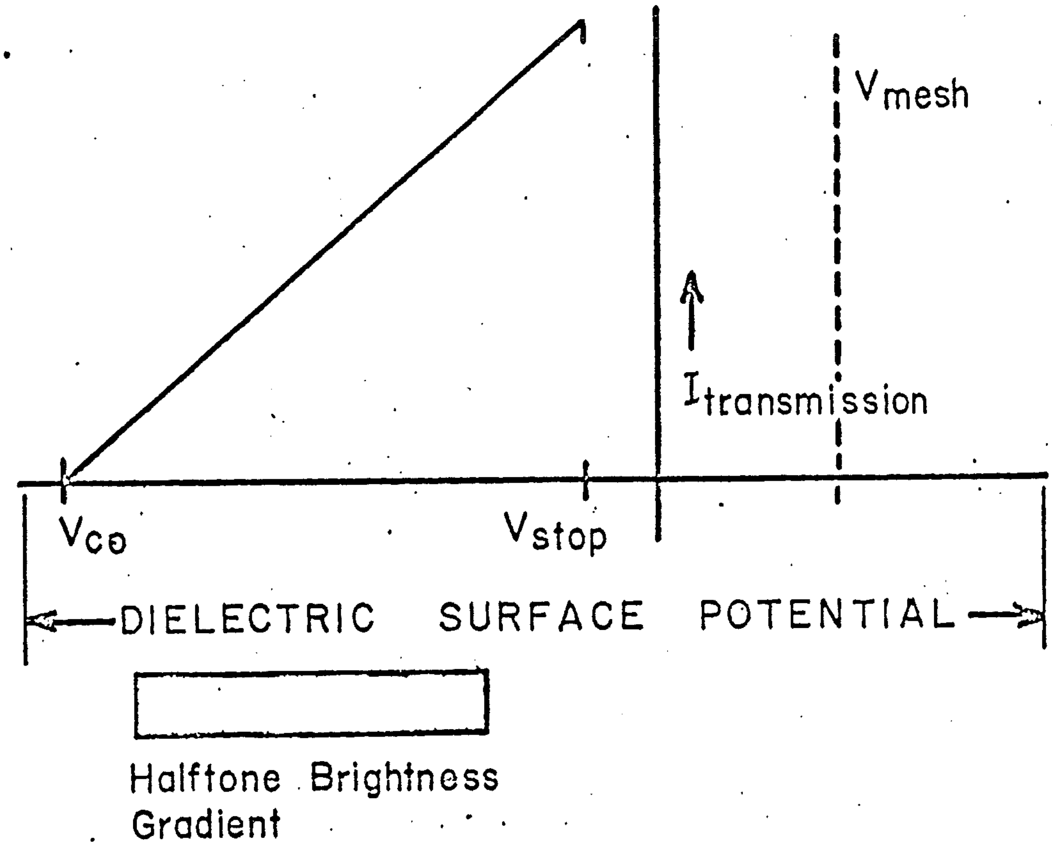
   (a) Stopping Potential

   Why? The Dielectric cannot charge more positive than the stopping potential because of the accumulation of Flood Electrons.

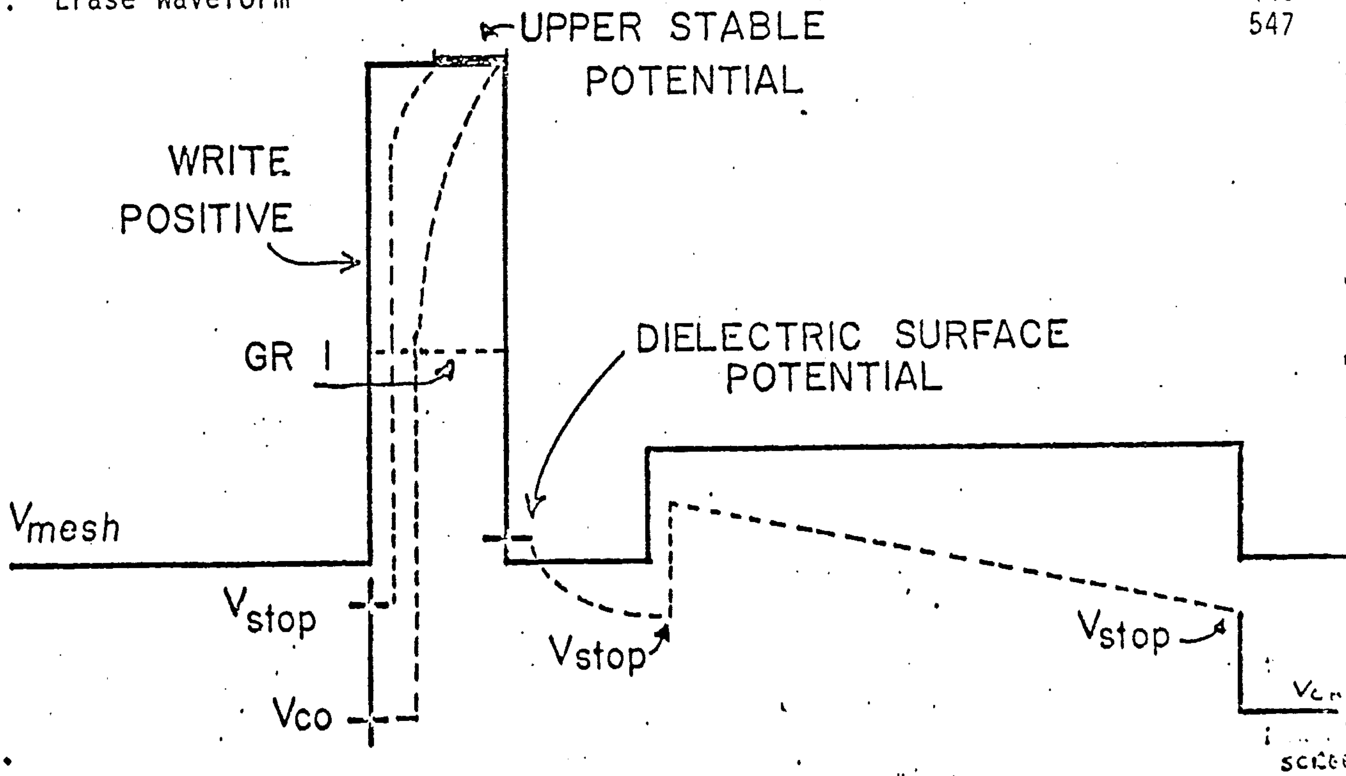
Counter Number

Transmission Storage Concepts (cont'd)

6. 340-404



7. Erase Waveform 440-547



Transmission Storage Concepts (cont'd)

		Counter Number
8.	What causes the stored image to fade positive? (b) Collection of positive ions.	549-569
9.	How can this fade positive phenomenon be minimized? (d) By turning off the oscilloscope (e) By biasing the Flood Gun Cathodes to cutoff.	569-622
10.	How is storage persistence achieved in a Transmission Storage CRT. (b) Pulsing the Storage Mesh with a positive pulse.	670-706
11.	How is variable persistence achieved in a Transmission Storage CRT. (d) Varying the pulse width of the positive pulse applied to the Storage Mesh.	706

Basic Storage Concepts

(Video Tape Program)

Quiz Key

(Tape #4)

Counter No. 000

Set VII TRANSFER STORAGE

1. Select only those elements belonging to a transfer storage CRT. 100

   (a) Writing Gun

   (b) Flood Guns

   (c) STB Collector

   (d) Collector Mesh

   (e) Wall Bands

   (g) Any Phosphor P1-P35

   (h) Fast Storage Mesh

   (i) BISTABLE storage mesh

   (j) Aluminized screen

   (k) Post deflection acceleration electrode

2. Name the meshes contained within a transfer storage CRT. See above list (question 1). 185-191

   (d) Collector mesh

   (h) Fast storage mesh

   (i) BISTABLE storage mesh

3. The "non-store" mode is obtained by: 234-255

   (a) connecting the flood gun cathode to +50 volts

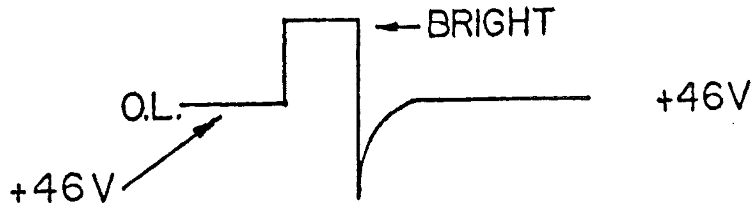
   (c) biasing the BISTABLE mesh to -26 volts

4. The "BISTABLE" mode is obtained by: 255-276

   (b) connecting the flood gun cathode to 0 volts

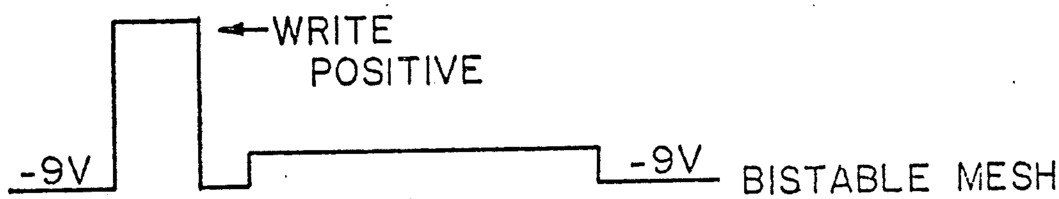
   (e) biasing the BISTABLE mesh to +46 volts

5. Make a drawing of the waveform used to achieve erasure while in the BISTABLE mode. This waveform is applied to the BISTABLE mesh CRT element. See list (question 1). 276-289

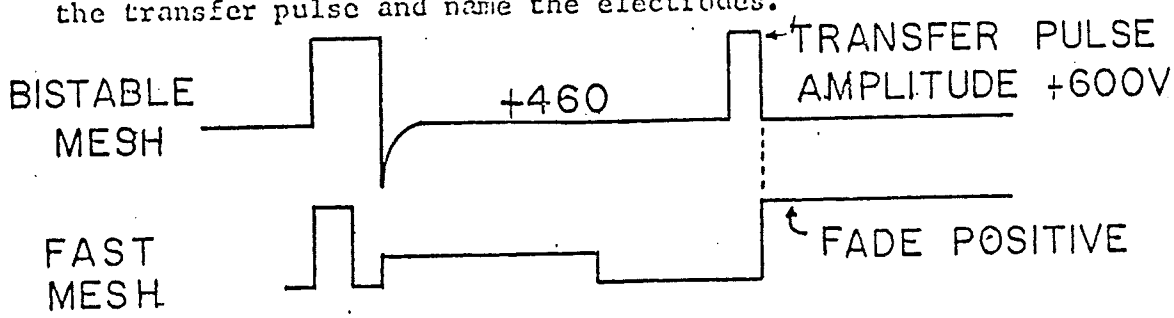


6. The transmission ("Variable-Persistence") mode is obtained by applying a -9 volt level to the BISTABLE mesh CRT electrode. While in this mode, storage persistence is obtained by applying positive pulses to the BISTABLE mesh. Variable storage persistence is obtained by changing the positive pulse width. HINT: Recall transmission storage concepts and use list (question 1). 290-298

7. Make a drawing of the waveform used to achieve erasure while in the transmission or variable persistence mode. This waveform is applied to the BISTABLE mesh. 300-320



8. Make a drawing of the waveforms used to achieve erasure while in the FAST transfer mode. Include the peak amplitude value for the transfer pulse and name the electrodes. 320-374



9. How does the multi-trace (multi-transfer) erase mode differ from the FAST transfer erase mode? 374-402

ANSWER: The BISTABLE erase waveform is not applied to the BISTABLE mesh prior to the transfer pulse.

10. The save mode is obtained by: 403-411

ANSWER: (a) connecting the flood gun cathode to +50 volts. This action eliminates the fade positive condition caused by the collection of positive ions.

11. How can the stored image be viewed while in the save mode? 411-417

ANSWER: (a) by pulsing the flood gun cathode negative from +50 volts. The fade positive condition will occur, but over a longer period of time.

12. The BISTABLE "INTEGRATE" mode is obtained by: 418-425

ANSWER: (a) connecting the flood gun cathode to +50 volts

13. Uneven aperture erasure is caused by a phenomenon called differential cutoff. How can the detrimental effects of differential cutoff be minimized?

ANSWER: The detrimental effects of the differential cutoff can be minimized by applying a positive pulse of ^{2}MSec duration to the appropriate storage mesh conductor. These pulses are referred to as pump pulses.

14. Describe the concept of differential cutoff.

ANSWER: The concept of differential cutoff can be easily understood by examining the transmission storage transmission current (IT) VS. Dielectric surface potential (DSP) curve. Each mesh aperture has a different cutoff voltage Vcd. Hence, the complete range of cutoff voltages is the differential cutoff.