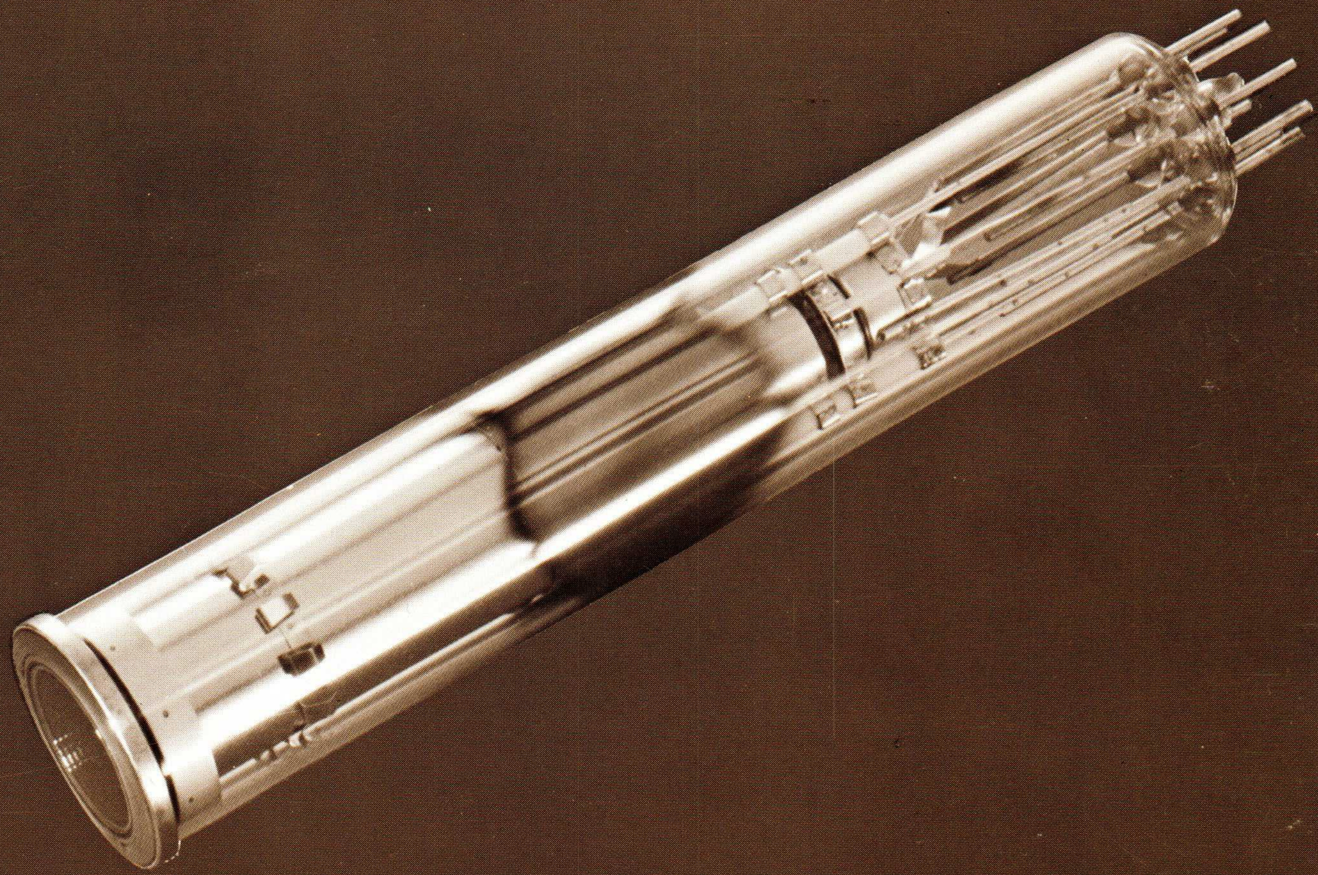
Bulletin CB-127

# TIVICON image tubes from Texas Instruments



# TIVICON IMAGE TUBES FROM TEXAS INSTRUMENTS

The Texas Instruments TIVICON* solid state image pickup tube uniquely combines semiconductor integrated circuit technique with electron tube technology. By combining a wafer of silicon containing 2.4 million photodiodes (620,000/$cm^2$) with a standard one-inch diameter vidicon electron optic structure, an image pickup tube is produced which has entirely new properties and provides many benefits to the television image tube industry. The spectral response of the TIVICON image tube is unmatched by any other image tube available currently.

The TIVICON image tube, when viewed externally, appears identical to a one-inch vidicon tube except for the metallic appearance of the silicon array behind the tube's faceplate. The electron optics used and voltages normally applied to a TIVICON image tube are those also applied to vidicon tube. The only electrical differences between a vidicon tube and TIVICON image tube are target voltage range and a higher signal current. These are discussed later. Figure 1 shows a cross section of an all-magnetic TIVICON image tube structure. Similarity of the characteristics and requirements of a TIVICON image tube and those of a vidicon tube can be noted. An actual 6.25-inch long TIVICON image tube is pictured in Figure 2, with a typical silicon diode array used in this tube shown separately.

The present TIVICON image tube form is a one-inch diameter vidicon-type using a planar silicon diode array of the type reported by Crowell, Gordon, et al.,[1,2] of Bell Telephone Laboratories as the light sensor rather than an evaporated photoconductive coating.

On the 0.875-inch diameter silicon slice, a 1000 X 750 array of the diodes is scanned in the standard 1/2 X 3/8 inch raster area. The diodes are approximately 5.0 $\mu$m in diameter on 12.5 $\mu$m centers. The tube utilizes magnetic focus and deflection of the electron beam. The substrate is typically 10 $\Omega$-cm, n-type silicon. The p-type islands are formed by diffusing boron through holes cut in the $SiO_2$ layer by a photolithographic process. A semi-insulating layer is applied for oxide discharging.

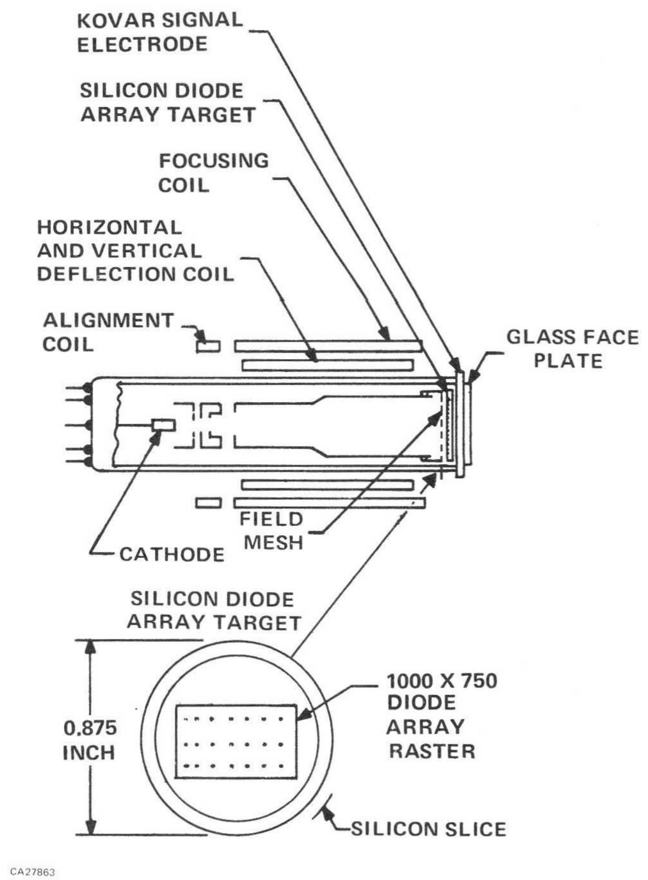



*FIGURE 1. Typical Physical Characteristics of a TIVICON Image Tube*

## TIVICON IMAGE TUBE OPERATION

To understand the operation of the device, visualize the electron beam scanning the diode array portion of the silicon slice. Since the substrate of the target is nominally 10 volts positive relative to cathode, the electron beam will deposit electrons at the diodes, charging them to cathode potential. The diodes will remain charged until the depletion layer capacitance, which is a measure of the diode charge-storing capability, is discharged by light-created minority carriers (holes) or by diode leakage. The holes generated at the light incident surface (as shown in Figure 3) are swept across the depletion region to the diode p-type region and contribute to the leakage current. Recharging of the diode by the electron beam creates the desired video signal at the video amplifier load resistor $R_L$. Since all the holes reaching a diode during a scan time contribute to the discharging of the diode, the signal is proportional to the integrated local photon flux.

For optimum performance of the array a semi-insultating film is deposited over the array during

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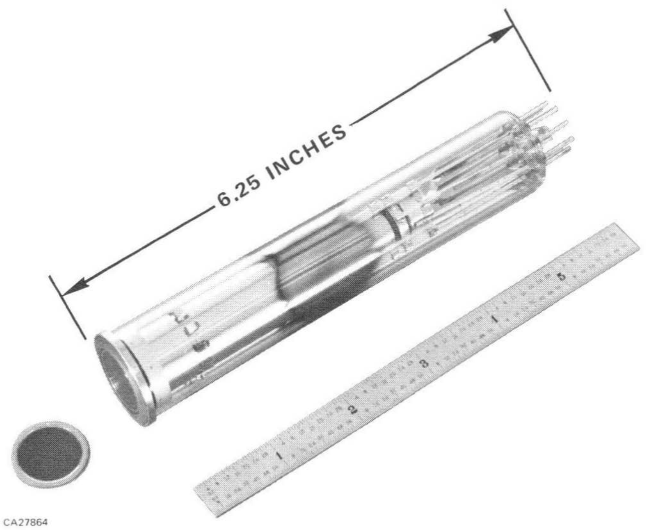


*FIGURE 2. 6.25-Inch TIVICON Image Tube with Silicon Diode Array Shown Separately*

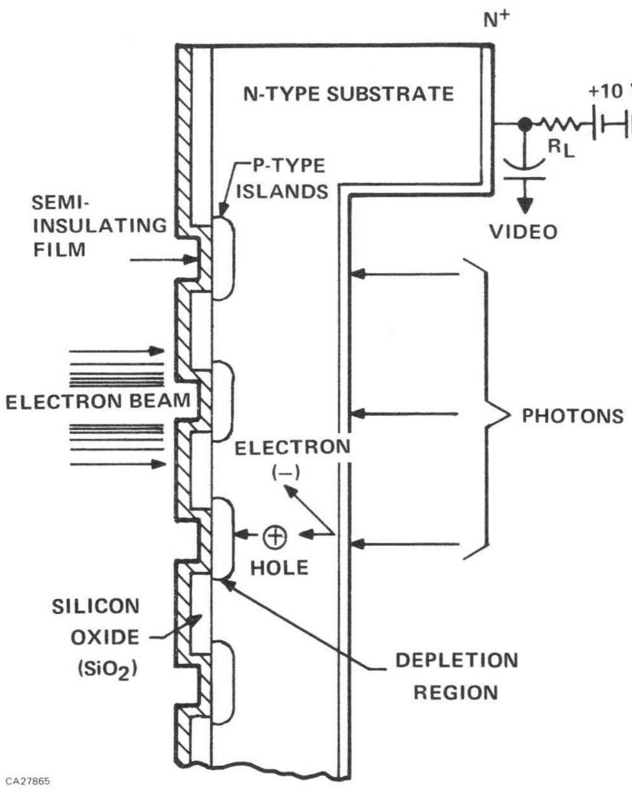


*FIGURE 3. Cross Section of Silicon Diode Array*

fabrication. Applying a semi-insulating film over the array will prevent the oxide from accumulating a charge; this charge-accumulation will hinder the electron beam's ability to interrogate the diodes and the electrons will, in fact, be repelled back toward the $G_4$ grid. The resistivity of the coating is chosen carefully to prevent a loss in resolution that may occur due to the shorting of adjacent diodes. In early tubes, metal islands were evaporated over the diodes to effectively remove the charge. The use of metal islands or other padded structures provided the advantage of a high temperature bake-out, but the disadvantage of a high defect count. The TIVICON image tube utilizes a "resistive sea" structure which is capable of high temperature bake out (250 to 400°C) but does not have the disadvantage of a high defect count.

## PERFORMANCE OF THE TIVICON IMAGE TUBE

The following paragraphs are a summary of performance values obtained from manufacturing lots of TIVICON image tubes. Due to normal manufacturing variances, ranges of values are often shown. If further clarification of performance testing procedures are needed, reference should be made to the TIVICON Image Tube Test Methods explained in the Test Procedures section.

**a. Sensitivity**

The spectral sensitivity of a TIVICON image tube is determined by the type of material used as the light sensing layer (target). Using silicon in the TIVICON image tube has resulted in the broadest spectral response curves ever obtained in an image tube which possesses both visible and IR response. Also, using silicon with its high absorption coefficient has enabled the TIVICON to have the greatest quantum efficiencies ever obtained for an image tube. Figure 4 shows the spectral responses of two different types of TIVICON image tubes which were made for visible (curve A) and IR response (curve B). (The equivalent quantum efficiency curves are shown in Figure 5.) Also shown in Figure 4 are the spectral responses of the Plumbicon* and vidicon tubes as reported in published data sheets and papers.[3,4] The spectral response of the TIVICON image tube is from 0.35 microns to 1.2 microns – offering sensitivity to numerous types of light sources as shown in Figures 6(a) and 6(b).

The relation between tube output current and input irradiance (the light transfer characteristic) is often expressed logarithimically as:

$$\log I = \log k + \alpha \log w$$

where

I is output current from the light sensitive target in amps

$\gamma$ is the power slope of the transfer characteristic of input irradiance w

w is the faceplate irradiance in watts/cm$^2$

k is the spectral sensitivity normalized for area

The TIVICON image tube $\gamma$ is 1.0. The vidicon tube $\gamma$ is 0.65, or higher, depending upon target voltage and light

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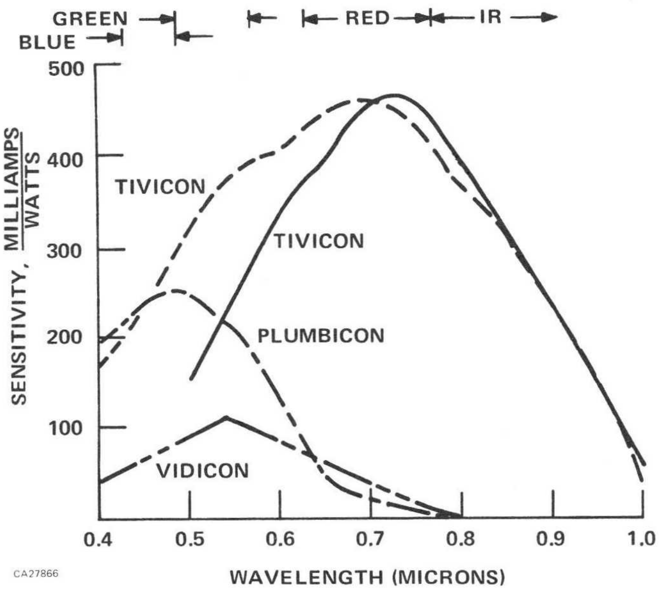



*FIGURE 4. Spectral Responses of Two Different Types of TIVICON Image Tubes, a VIDICON Tube, and a Plumbicon® Tube*

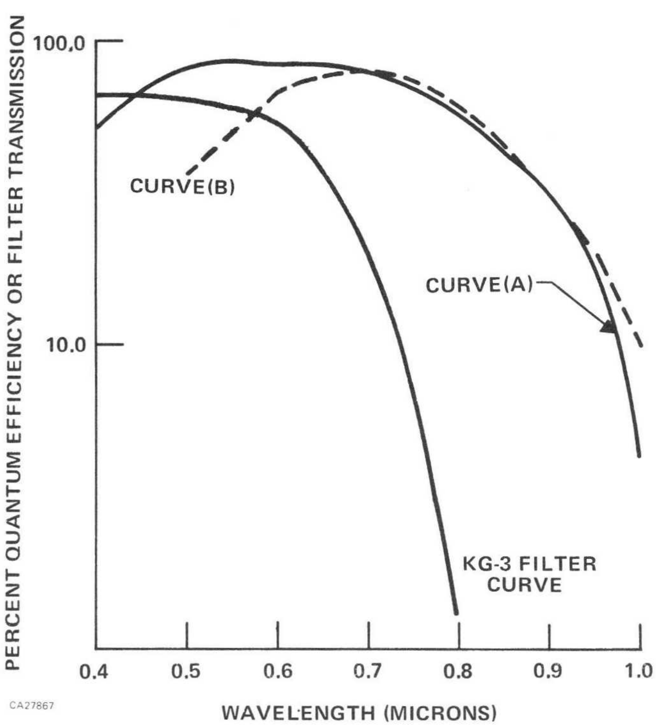



*FIGURE 5. Quantum Efficiency of Two Different Types of TIVICON Image Tubes*

level. Figure 7 shows a typical TIVICON image tube light transfer curve with a $3 \times 10^{-9}$ amperes current being generated by $6 \times 10^{-9}$ watts of peak optical power.

How these signal levels relate to what one might see using a high contrast resolution chart is shown in Figure 8.

In this illustration the limiting TV line resolution is plotted versus total signal level. The equivalent narrow band peak irradiance in microwatts per $cm^2$ and the equivalent unfiltered and filtered 2870°K illuminance levels are

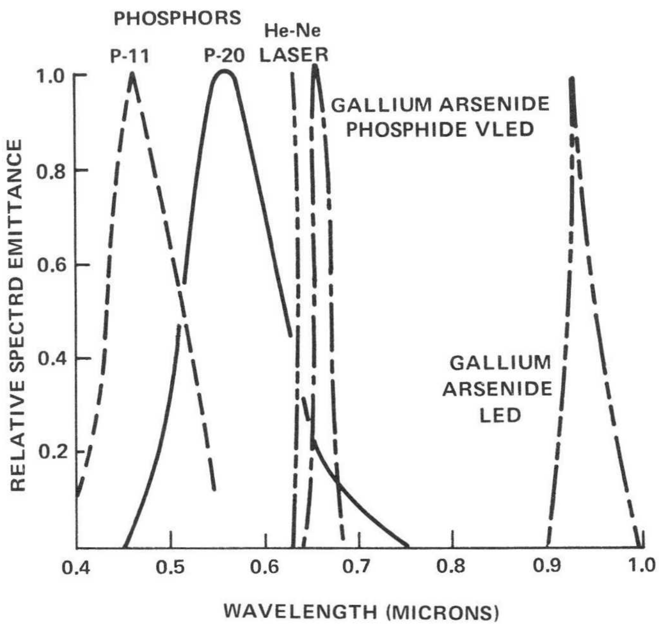



*FIGURE 6(a). Sensitivity of TIVICON Image Tube to Phosphor and Narrow Band Light Sources*

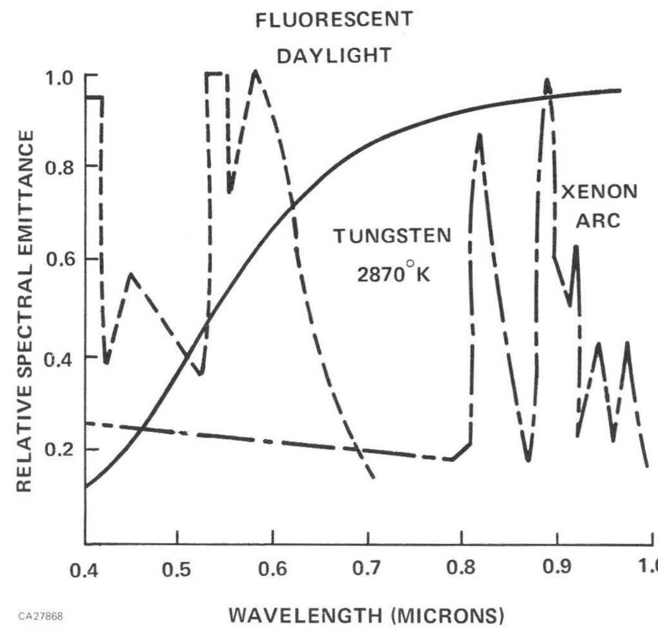



*FIGURE 6(b). Sensitivity of TIVICON Image Tube to Typical Illumination Sources*

indicated. The filtered scale was obtained by using a 5 millimeter thick Schott KG-3 visible pass filter. The transmission of this filter has been shown in Figure 5. The equivalent system peak signal to rms noise is also plotted The limiting noise parameter is the TV system preamplifier noise which was $9 \times 10^{-9}$ amperes rms equivalent input current.

**b. Resolution**

The resolution of the silicon-diode array is limited by several factors. These include:

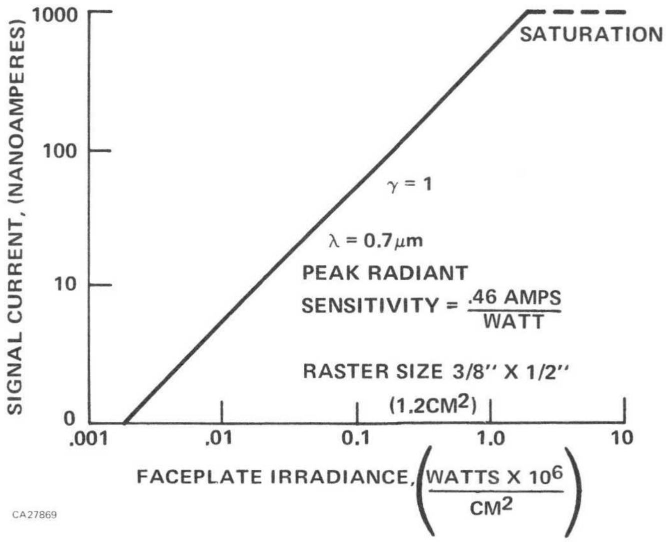



*FIGURE 7. Typical Light Transfer Curve of TIVICON Image Tube*

1. Target thickness
2. Diode-to-diode spacing
3. Resistive-sea resistivity

In the case of radiation in the far-blue visible spectrum, the carriers are generated near the surface of the target and the holes diffuse laterally as well as transversely. These factors, thereby, cause a loss in resolution. To obtain peak blue response, these factors dictate that the target be thin. Generally, a target thickness of about 12.5 microns is used for peak blue response of the array.

For some values of target thickness the discrete nature of the diode array places a hard upper limit on its resolution capability with the upper, usable limiting resolution and diode spacings determined by the number of diodes scanned. Moreover, the final diode spacings are also influenced by the existing photolithographic technology as well as diode geometry considerations from the standpoint of target capacitance (lag) and total array leakage.

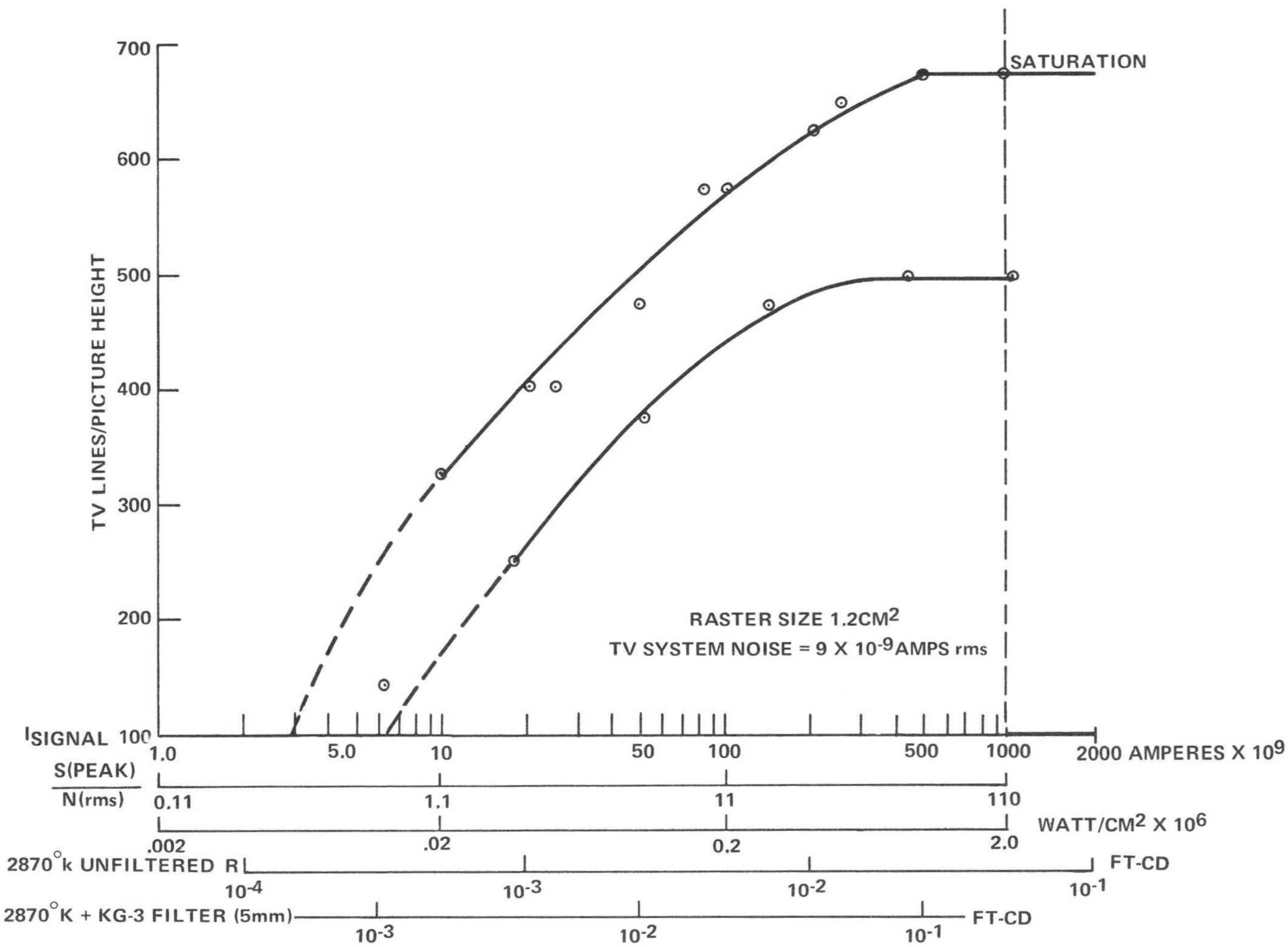



*FIGURE 8. Limiting Resolution versus Signal Current of TIVICON Image Tube*

Finally, the resistivity of the array coating must be carefully chosen. A resistive sea which is excessively conductive will cause a loss in resolution due to the shorting of adjacent diodes. On the other hand, if the resistance of the resistive sea is too high, excessive charge accumulation on the target will result.

For a 16-mm raster diagonal, the modulation value is typically 20% to 30% at 400 TV lines. Square wave modulation transfer function (MTF) curves for typical tubes are shown in Figure 9. It is possible to achieve higher modulation values than those shown, and indeed, many tubes will exhibit a modulation of 35% to 45% at 400 TV lines for a 16-mm diagonal scan. The higher modulation can be achieved by increasing the resistivity of the semi-insulating coating.

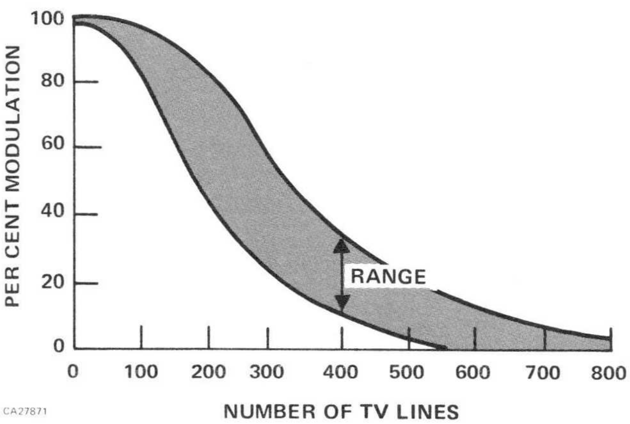



*FIGURE 9. Square Wave Modulation Transfer Curves for Typical TIVICON Image Tubes*

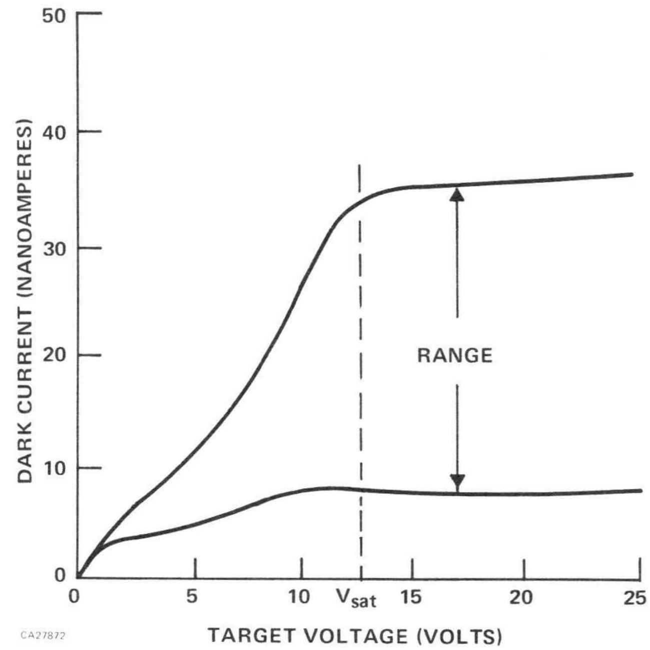



*FIGURE 10. Dark Current/Voltage Characteristics of TIVICON Image Tube*

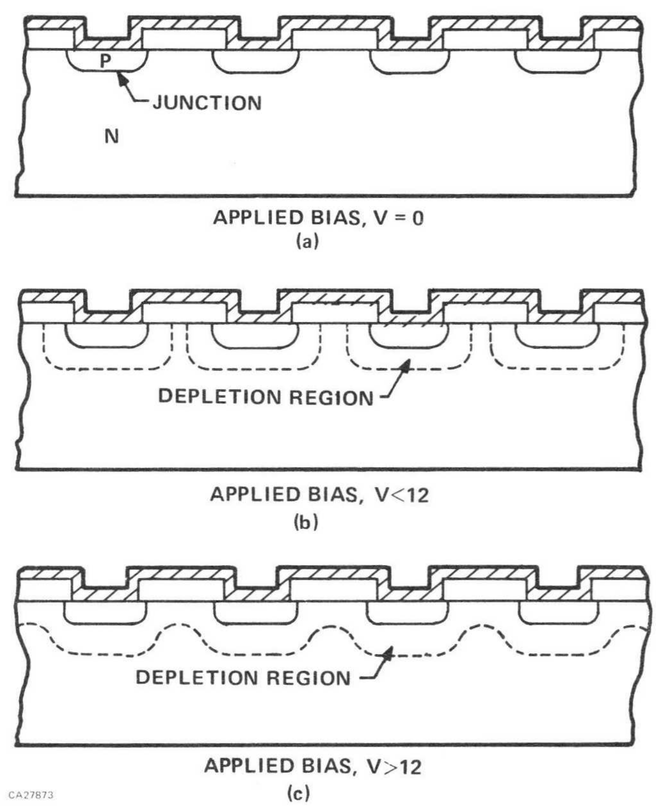



*FIGURE 11. Stages Illustrating Depletion of Junction Region at Various Bias Voltages*

## c. Diode Leakage

Dark current-voltage characteristics similar to those shown in Figure 10 are obtainable with the silicon-diode array for a 16-mm scan. The silicon surface is intially accumulated at the Si-$SiO_2$ interface due to the positive fixed charge in a thermally grown oxide. As the target voltage increases, the dark current increases as expected and a more rapid increase in leakage is evident as the field across the oxide compensates the positive fixed charge and the surface begins to deplete.

For the target in Figure 10 the silicon surface begins to deplete above 5 volts and a rapid rise in dark current, due to the generation centers at the interface, is observed. Above 12 volts (saturation voltage, $V_{sat}$), the surface is totally depleted and the dark current saturates. Figure 11 shows these stages of target depletion. The voltage at which the current saturates (approximately the flat-band voltage), as well as the saturated current level, is strongly process dependent. As is explained in detail in the following section, it is desirable to operate the target in the saturated region from a low lag standpoint. It is possible to operate in this region without defect blooming effects.

Dark leakage values of 15 nA, or less, are obtained for typical target voltages. With an optimization of the present fabrication process being employed, further leakage improvements can be made and a maximum saturated dark leakage value of less than 10 nA is expected.

## d. Lag

Lag is caused by the inability of the electron beam to completely recharge the target capacitance during a single scan after it has been discharged by light. With a silicon-diode array, an analysis of the sources contributing to lag becomes quite complex.

Of the factors contributing to the lag of a diode array, lag resulting from the energy distribution of the beam electrons (beam resistance lag) and lag resulting from the electron transport through the resistive sea appear to be most important. However, it should be mentioned that the effective use of the incident beam (array geometry) and target beam acceptance properties also play a part in lag considerations.

Both of the lag factors mentioned are a function of the effective diode capacitance. Therefore, a low capacitance is desirable with the lower limit of this capacitance determined by the ratio of the desired video current to the permitted voltage swing on the array.

Since the junction capacitance and the effective charge storage capacitance are dependent upon the reverse bias voltage, lag is a strong function of target voltage. A plot of tube lag versus array voltage is shown in Figure 12 for two different TIVICON image tubes and 3rd and 4th field at 60 fields per second. Lag can be virtually eliminated with an increase of target voltage. The acceptability of reducing the lag in the manner shown in Figure 12 depends upon the ability to control defect blooming.

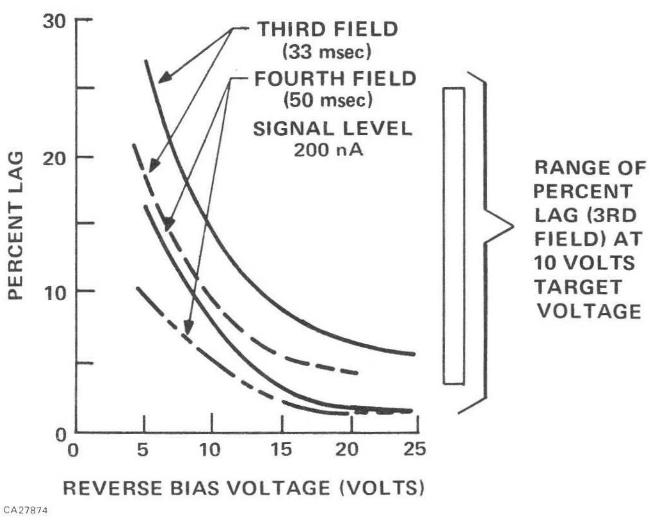



*FIGURE 12. Dependence of Lag on Target Voltage of Two Types of TIVICON Image Tubes*

Several different methods of silicon diode array fabrication have been tried in an effort to reduce lag, increase resolution, and, in other ways, improve its performance. Usually the methods employed have resulted in either a resistive-sea or padded-structure configuration. Texas Instruments, early in its development of silicon diode arrays, used padded structures but it soon found that array defects and defect blooming were undesired by-products. Consequently, Texas Instruments developed a high-temperature resistive-sea structure which provides many advantages compared to padded structures. The methods used by various other companies usually employ a padded structure, and consequently, increasing voltage to reduce lag also causes increased defect counts and an enlargement (blooming) of the already visible defect. Such competitive arrays do not achieve the ultimate lag reduction obtainable with the Texas Instruments array.

## e. Defects

The present Texas Instruments silicon-diode array processing techniques and clean-room facility yield targets with a low defect count. Typically on a 16-mm diagonal raster, there are no defects larger than 6 TV scan lines (525 scanline system) and there are fewer than 4 white and 4 black defects of 2 to 6 TV lines with no defects in the center 20%. Some TIVICON image tubes exhibit zero defects.* This is possible because of the use of a resistive sea rather than a complicated padded structure for the elimination of accumulated electron charge. Furthermore, a zero-defect level totally eliminates the problem of blooming discussed previously. Figures 13(a) and 13(b) show the control over defect blooming possible with the Texas Instruments array at 10 and 25 volts target voltage. The importance of low defect levels is, of course, obvious for applications involving TV video tracking techniques.

# TIVICON IMAGE TUBE RELIABILITY

The normal modes of image pick-up tube failure are accidental photoconductor or photoemitter light burn, electron beam raster burn due to sweep failures, thermionic cathode slump due to ion burn or other causes, and finally, vacuum leaks.

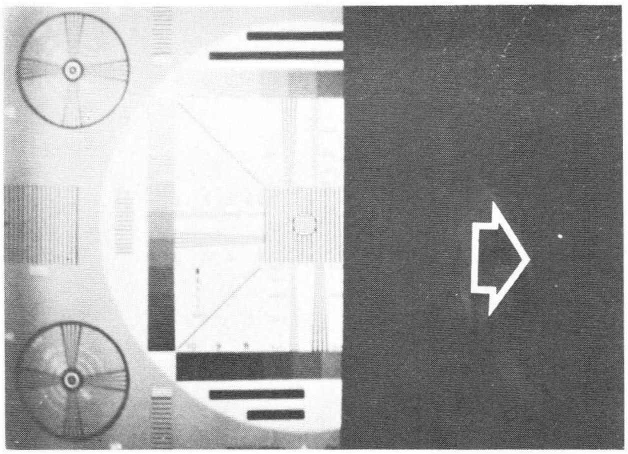
The TIVICON image tube does not demonstrate the light burning property seen in vidicon or Plumbicon image tubes and has more resistance to beam raster burn except raster burn caused by X-ray degradation of the target dark current.

It has been found[5] that the dark current of a silicon diode array target increases with operating time and that the degradation follows a $(V)^6$ dependence on mesh $(G_4)$ voltage. The apparent mechanism is the X-ray generation by return electrons from the target. The X-rays change the silicon target properties toward higher $I_{dark}$ values. Figure 14 shows the X-ray effect on the silicon target schematically.

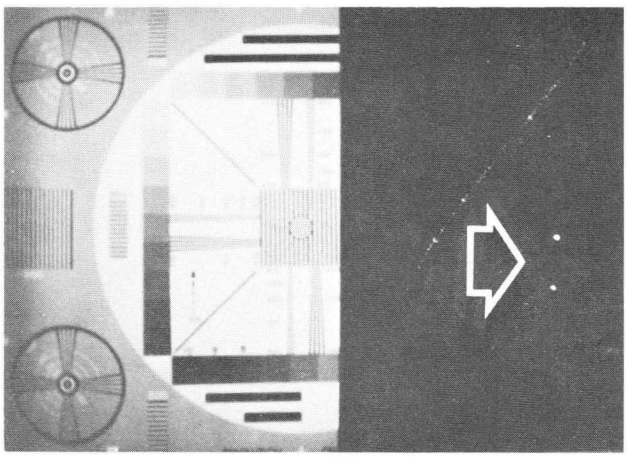
An obvious fix on the degradation is to reduce the $G_4$ mesh potential, thus reducing the rate of degradation. Typically, 300 to 450 volts of $G_4$ voltage will give the user at least 2,000 hours of operation with only a shift in black level depending upon the dynamic range of the TV system.

Texas Instruments does have available, on a limited basis only, TIVICON image tubes which will operate with

* Spots of 1 TV line or less (single diode size) are generally not objectionable to the viewer. These are not counted as defects unless they are clustered or the concentration is high and causes a smudged appearance.



A
TARGET POTENTIAL 10 VOLTS
DARK CURRENT 14 NANOAMPERES



B
TARGET POTENTIAL 25 VOLTS
DARK CURRENT 15 NANOAMPERES

CA27875

*FIGURE 13. Resistance of TIVICON Image Tube to Defect Blooming*

up to 650 volts on the $G_4$ mesh. If this particular advantage is needed for better scene uniformity or resolution, inquiries should be made to the Texas Instruments representative. Further announcements will be made concerning Texas Instruments solution to the X-ray degradation problem.

The remaining areas of failure, such as cathode slump, are expected to be greatly improved compared to regular vidicon tubes because of the high-temperature processing given the TIVICON image tube. The typical temperature range is 250°C to 350°C whereas a standard vidicon tube is currently processed at 125°C.

## TEST PROCEDURES

Meaningful comparison of the TIVICON data sheets with those of other image tubes requires knowledge of the test techniques used. The TIVICON image tube procedure is described in this section. No specifications are included because of their variation with the tube type.

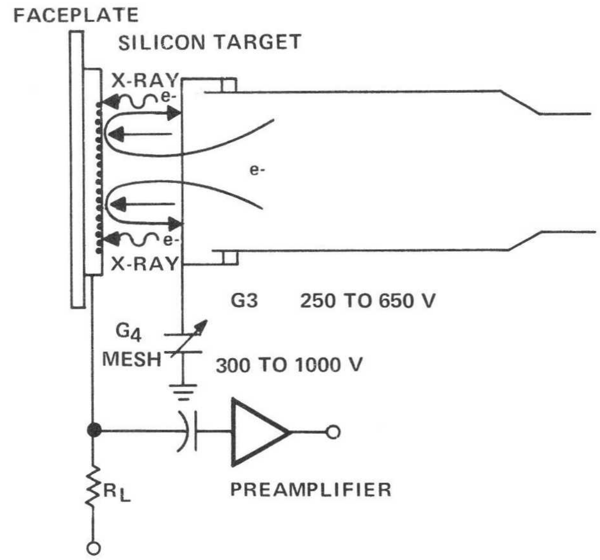



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*FIGURE 14. X-Ray Effect on the Silicon Target of the TIVICON Image Tube*

### The Test System

The test system is operated with a 525-line, 30 frame-per-second, 2:1 interlaced scan standard. Channel bandwidth is flat ± 0.5 db to 12 MHz. Rms equivalent input current is 9 nanoamperes or less. All necessary voltages, currents and fields are supplied to the tube by the system.

The system gain is adjusted to produce 0.7 volts of video with 500 nA of highlight current. The pedestal is set at approximately 0.1 volts to prevent "crushing" of blacks. No special video processing is used during test, such as aperture correction, gamma correction, or white clipping. However, the video is clamped and the monitor dc restored.

The system layout is shown in Figure 15.

### TIVICON Image Tube Set-Up

The TIVICON image tube is operated with a target potential of 10 volts, a 1/2 X 3/8 inch scanned area, and the beam set to discharge the saturation current. The horizontal scan is parallel to the plane through tube axis and the short index pin. For reference in recording spots the index pin is oriented to coincide with the right edge of the test chart *as displayed on the monitor*. A two-minute warmup is allowed for cathode temperature stabilization. The target requires no pre-test scanning. Scan-size adjustment and video setup is done with an 8 X 10-inch RETMA 1956 resolution chart transparency, back-illuminated by a variable color temperature incandescent source. Table 1 lists the typical setup potentials. The monitor contrast and brightness are set to display ten linear gray scale steps without blooming whites.

### The Tests

The tests are of three types: target background, static performance, and dynamic performance. They may be made in any order without effect on the results.

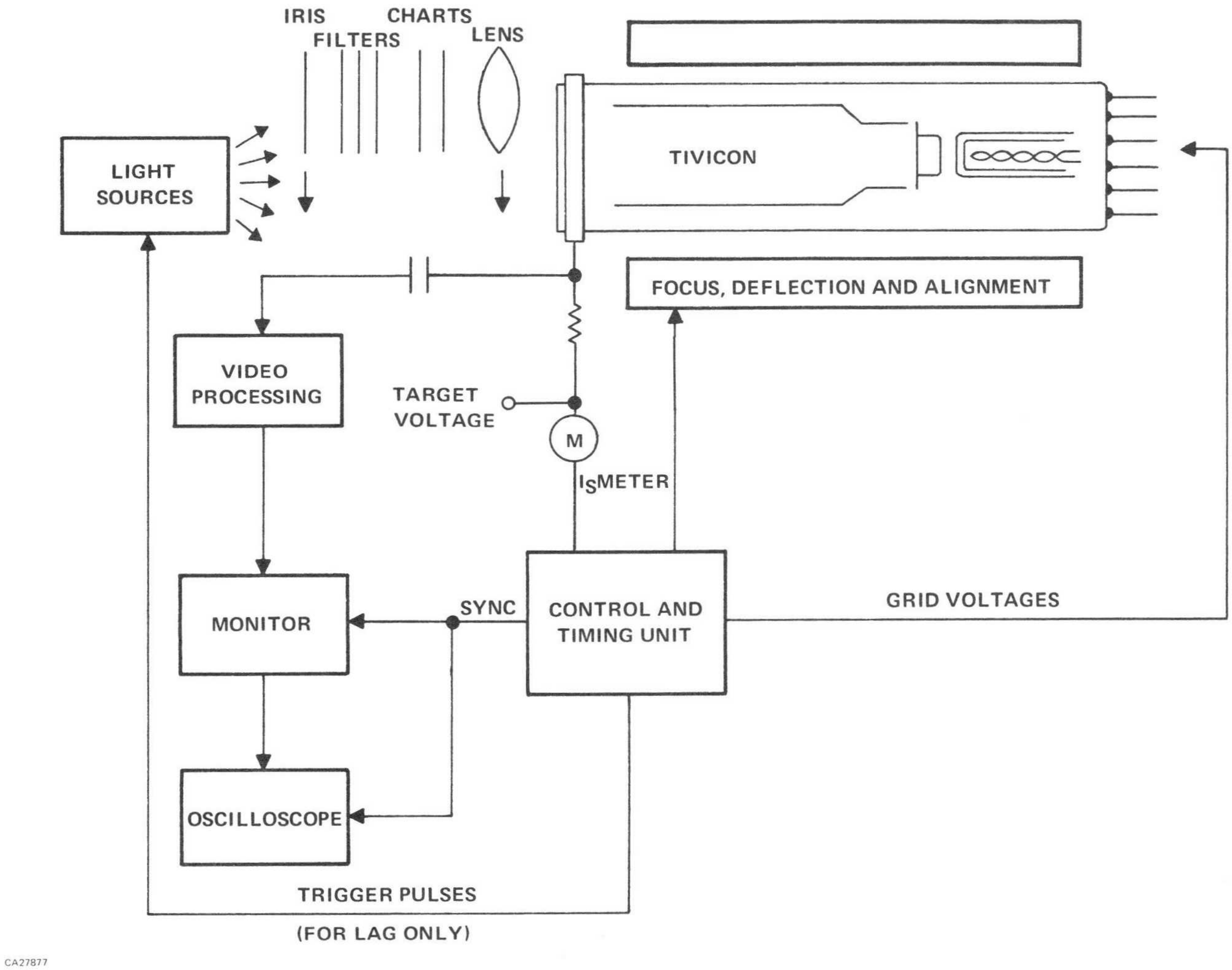


*FIGURE 15. Block Diagram of TIVICON Image Tube Test System*

**Table 1. Typical TIVICON Image Tube Operating Conditions**

| | | |
|---|---|---|
| Cathode | 0 | Volts (reference) |
| $G_1$ | 0 to –40 | Volts |
| $G_2$ | 300 | Volts |
| $G_3$ | 450 to 550 | Volts |
| $G_4$ | 650 | Volts |
| Target | 10 | Volts |
| Focus Field | 50 | Gauss |
| Alignment Fields | 0 to 4 | Gauss |
| Scan Size | .375 x .5 | Inches |
| Faceplate Temperature | 25 to 30 | °C |

**Target Background**

● Dark Current. With the target sealed off from light, the current which flows in the target lead is measured with an average-reading nanoammeter. (HP425A)

● Blemishes. White spots are counted with the target darkened and black spots are counted with uniform illumination on the target set to produce 200 nanoamperes of target current. The numbers, shades and sizes in TV scan line widths are recorded by zones (see Figure 16). Clusters are noted.

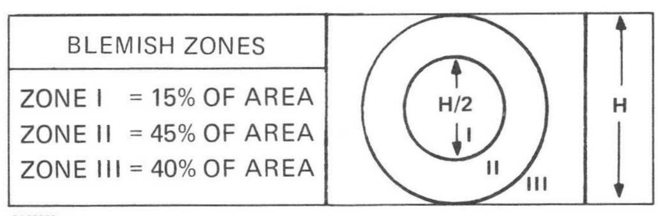


*FIGURE 16. Blemish Numbers, Shades, and Sizes in TV Scan Line Widths of Image Tube Recorded by Zones*

● Uniformity. The target is uniformly illuminated to produce a 200 nA signal. The oscilloscope is set to display one horizontal line halfway down the raster to be used as a reference. As the line selector is moved through the raster, deviations from the amplitude of a point in the center of the reference line are noted and expressed as a percentage of the difference between the illuminated and dark levels at that point. Both dark current and sensitivity variations and electron optics deficiencies are accounted for here.

● Distortion and Linearity. The camera is focused on a RETMA Linearity Chart ("ball chart") and its image is displayed on the monitor screen simultaneously with an electronically generated grating. With the center of the grating placed in the center ball the grating spacing and location is adjusted for best fit. Deviations of the grating intersections from the centers of the balls are noted and corrected for known system nonlinearities.

**Static Performance**

● Resolution. The limiting horizontal resolution is read from the monitor display using the RETMA 1956 resolution chart. The horizontal square-wave modulation is measured in the center of the raster using a multiburst chart. This chart consists of a reference black bar of width no less than 5% of the picture height followed by a white area of the same dimension followed by groups of black and white bars in spacings of 100 to 1000 TV lines per picture height. The amplitude of each burst is read from an oscilloscope display of a line in the center of the raster and expressed as a percent of the difference between the reference black and white levels. The curve must be corrected for known lens deficiencies. The charts must have contrast ratios of at least 100:1.

● Sensitivity. For spectral sensitivity, (radiant responsivity) a uniform monochromatic spot, approximately 20 percent of the picture height, is projected onto the target. The intensity is adjusted to give a signal in the 50- to 500-nanoampere range. The difference between the dark current and illuminated current is read from a properly calibrated oscilloscope display of a horizontal line through the spot. The intensity of the spot is measured and the sensitivity (amperes/watt) is calculated and corrected to a 1/2 X 3/8 inch area. From the sensitivity, the TIVICON tube's quantum efficiency may be calculated using the formula:

$$QE = 1.25 \times \frac{Sensitivity\ (Aw^{-1})}{Wavelength\ (\mu m)} \times 100\%$$

Luminous responsivity is measured in a similar fashion except that the source is a 2870°K unfiltered incandescent lamp. The light measuring device has a photopic response curve (Figure 17) which reads out in foot-candles. If filters are used for spectral shaping (e.g., infrared cutoff), it is noted whether the light level is measured in front of, or behind the filters. Luminous responsivity is presented in microamperes per lumen for a 1/2 X 3/8 inch area. Gamma information is obtained by varying the light level with neutral density filters, measuring the changes in signal current, and making a graphical calculation.

● Blooming. A uniform spot of light, approximately 1% of the picture height, is projected on the target. The apparent diameter of the spot is recorded as its intensity is increased to a level 1000 times the intensity required for saturation.

**Dynamic Performance**

● Lag. The camera is focused on a small, translucent white disc, back-illuminated by a strobe which fires during vertical retrace every fourth field. The video pulse generated in the center of the raster is displayed on an oscilloscope. The height of the first field pulse is set to some predetermined current level, typically 200 nanoamperes, and the height of the third field pulse is read out as illustrated in Figure 18. The lag is the ratio of the third field pulse height to the pulse height of the first field, expressed in percent. Complete decay curves are determined by lengthening the time between strobe flashes. The pulse height is plotted as a function of field.

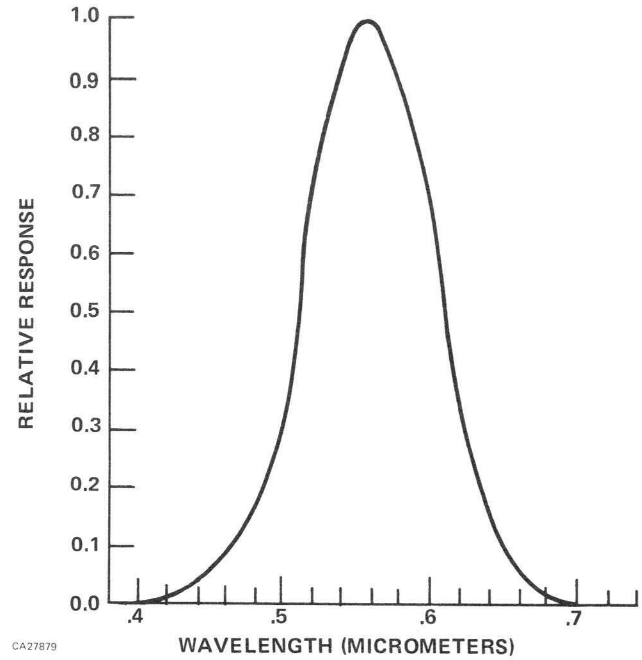


*FIGURE 17. Illuminance Meter Response Curve*

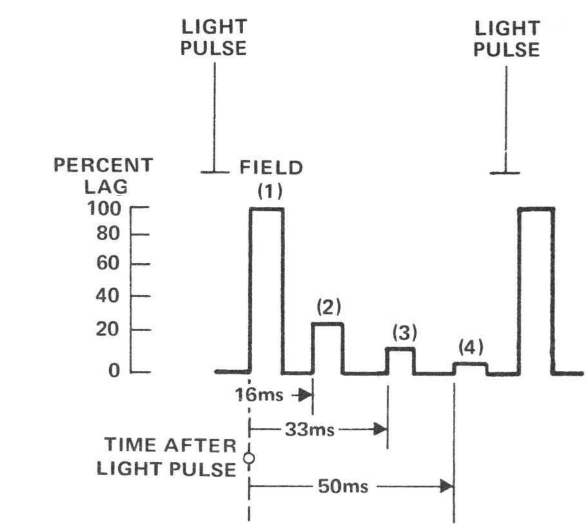


*FIGURE 18. Lag Pulse and Time Sequence Test*

Other tests can also be made but most are too specialized to be included here. Information on these can be obtained from Texas Instruments.

## OPERATING THE TIVICON IMAGE TUBE

The Texas Instruments TIVICON image tube is different from any other image tube you have ever used. While it physically resembles the 1-inch vidicon and, in fact, is intended for use in vidicon cameras, the substitution of a silicon diode array for the photoconductive film gives it substantially different operating conditions. (Typical electrical and physical specifications for Texas Instruments TIVICON image tubes are shown in Figure 19 and Table 2.)

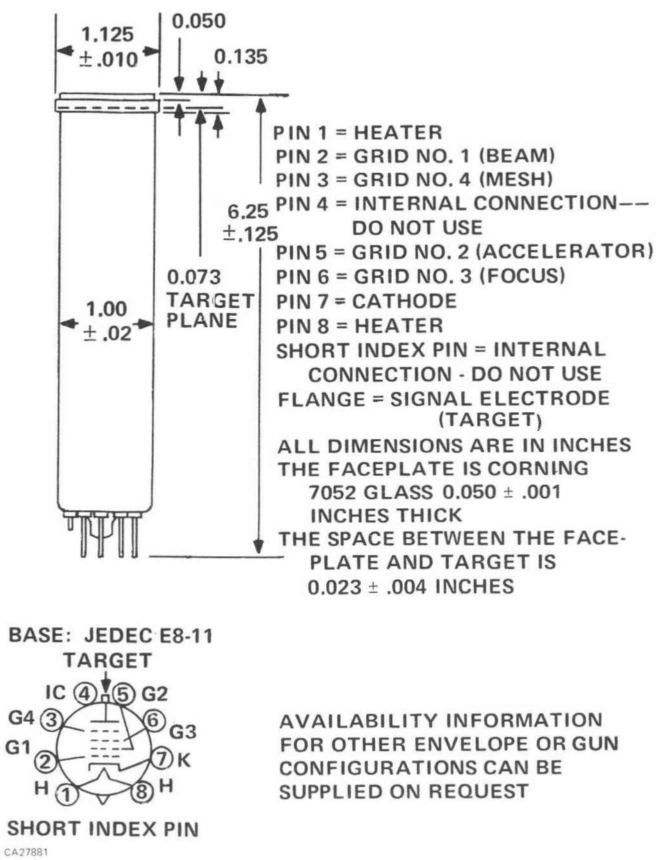


*FIGURE 19. Outline Drawing of Texas Instruments TIVICON Image Tube*

### Camera Modification Necessary to Use TIVICON Image Tube

Some cameras will not operate the TIVICON image tube properly without modification. The most common modification involves disabling the automatic light control (ALC) of the type which raises the target voltage to compensate for decreasing light input. Since the sensitivity of the TIVICON image tube is unaffected by changes in target voltage, the effect of ALC is to raise the target voltage to the point where the target begins secondary emission of electrons. This manifests itself as a blackening of the image, usually in the corners at first. The effect may be eliminated by lowering the target voltage. Secondary emission does not destroy the tube, even if sustained for long period. But to eliminate secondary emissions, the ALC should be disabled and the target adjust pot connected to a supply voltage which will allow reasonably fine adjustment in the 0 to 20 volt range. On many cameras there is a switch, either inside or outside the camera, which allows changing from ALC to manual operation.

In common-mesh cameras there are two approaches to operating the TIVICON image tube: 1) convert the tube to common-mesh operation, or 2) convert the camera to separate-mesh operation. To convert the camera to separate-mesh operation, merely connect pin 3 of the tube socket to the same voltage which is supplied to the focus pot. To convert the tube to common-mesh operation, strap pins 3 and 6 together. If operated in this manner some degradation in distortion and resolution may occur.

In cameras with current-regulated filament supplies an adjustment may be necessary to prevent overdriving the TIVICON image tube heater. Operation of the filament outside the recommended range may severely shorten its life. Cameras with voltage-regulated supplies or filament transformers require no changes.

## VIDEO PROCESSING

### Preamplifiers

Most vidicon preamplifiers can handle the increased signal of the TIVICON image tube, however, some inexpensive preamps have been known to overload, causing clipping. The most serious detriment to good performance of the TIVICON image tube is the extremely high target supply resistors used in some cameras. These large resistors can adversely affect the recharge cycle causing high lag. They also lead to excessive changes in target voltage under high signal conditions. If possible, the target resistor should be no larger than a few megohms. Since the target-to-gun capacitance of the TIVICON image tube is about the same as that of a vidicon, the frequency response of the preamp will not be affected by the tube change.

### Processors

Processing of the TIVICON image tube video signal is handled the same as with vidicon tube signals. For a given light level and lens setting, less gain will be required with the TIVICON image tube because of its increased sensitivity. Because the TIVICON image tube is a constant sensitivity device, AGC is recommended to increase the dynamic range of the TIVICON-image tube camera combination. For scenes with predominantly low luminance but very bright highlights (for example, a parking lot at night with mercury arc lamps) white peak clipping is recommended to prevent streaking due to amplifier overload. A hard clamp is also helpful in this situation. For accurate rendition of gray scale, gamma correction is recommended. Since the TIVICON image tube is linear, a correction of

**Table 2. Description of Texas Instruments TIVICON Image Tube**

| | |
|---|---|
| **GENERAL** | |
| Operating Position | Any |
| Focusing Method | Magnetic |
| Deflection Method | Magnetic |
| Direct Interelectrode Capacitance | |
| Target to all other Electrodes | 4.0 Picofarads |
| Base . . . . . Small Button Ditetrar (JEDEC E-8-11) | 8-Pin |
| Bulb | T8 |
| Weight (Approximately) | 2 Ounces |
| Useful Rectangular Image Diagonal | |
| (4:3 Aspect Ratio) | .625 Inches Standard<br>.70 Inches Maximum |
| Image Orientation | Any |
| Focus and Deflection Components | Celco BWV 232 or Equivalent |
| **ELECTRICAL CHARACTERISTICS** | |
| Maximum Ratings | |
| Grid No. 4 Voltage | 650 Volts |
| Grid No. 3 Voltage | 650 Volts |
| Grid No. 2 Voltage | 650 Volts |
| Grid No. 1 Voltage: | |
| Negative Bias Value | 150 Volts |
| Positive Bias Value | 0 Volts |
| Peak Heater-Cathode Voltage: | |
| Heater Negative to Cathode | 125 Volts |
| Heater Positive to Cathode | 10 Volts |
| Faceplate Temperature: | |
| Operating | 55°C |
| Storage | 200°C |
| Target: | |
| Voltage | 100 Volts |
| Illumination | $10^7$ Foot-Candles |
| Typical Operating (For 1/2" x 3/8" Scanned Area) | |
| Grid No. L (Beam) Voltage (For Signal Cutoff with no Blanking Applied) | −40 to −60 Volts |
| | High-Mode-Low |
| Grid No. 2 (Accelerator) Voltage | 300 Volts 300 Volts |
| Grid No. 3 (Focus) Voltage | 500 Volts 210 Volts |
| Grid No. 4 (Mesh) Voltage | 650 Volts 300 Volts |
| Focus Field | 50 Gauss 35 Gauss |
| Target Voltage | 5 to 15 Volts |
| Target Highlight Current | 500 Nanoamperes |
| Alignment Fields | 0 to 4 Gauss |
| Minimum Blanking Voltage (Peak to Peak) | |
| When Applied to Cathode | 10 Volts |
| When Applied to Grid 1 | 30 Volts |
| Heater | |
| Voltage | 6.3 Volts ac or dc |
| Current | 300 Milliamperes ± 10% |

about 0.5 should closely compensate for the larger-than-unity gamma of the CRT phosphor.

**Light, Lenses and Filters**

The TIVICON image tube works well with most light sources, but only those sources containing infrared can fully utilize the TIVICON image tube's wide spectral bandwidth. Incandescent lights, in particular, allow the TIVICON image tube to "see" in light levels which appear quite low to the eye. Xenon-arc lights also are a good spectral match. Mercury-arc lamps and fluorescent lights are not matched as well due to their low near-infrared content. Figures 6(a) and 6(b) show the spectral emittance of some typical light sources. For operation in the dark, either filtered incandescent, or xenon lamps, or gallium arsenide light-emitting diodes may be used to provide infrared-only illumination. Exotic sources such as the neodymium-glass lasers radiating at 1.06 $\mu$m also fall within the useful bandwidth of the TIVICON image tube.

Proper gray scale rendition can be accomplished only if the infrared is filtered out of the light falling on the TIVICON image tube faceplate. Such effects as whitening of foliage will occur if this is not done. Where sensitivity is more important than gray scale renditions, the infrared should be retained.

Most lenses work extremely well with the TIVICON image tube. The most noticeable difference between a vidicon and TIVICON image tube is a slight shift in focus if the source is changed from visible to infrared. Inexpensive lenses may not be able to present a crisp image at their larger f-stops when wideband sources of illumination are used. Internal lens reflections have about the same effect with the TIVICON image tube as they do with a vidicon, although an apparent increase in reflection intensity may occur in lenses which have poor anti-reflectance coatings. This is a consequence of the infrared sensitivity of the TIVICON image tube.

Because of the small space between the target and faceplate, the mechanical focus point will be shifted slightly. Nearly all cameras can compensate for this shift either by shifting of the lens mount or the coil assembly.

Although the TIVICON image tube cannot be damaged by high light levels, it may be necessary to equip the camera with an automatic-iris lens, or some form of neutral-density wedge, for use where scenes with changing light levels are to be observed. Texas Instruments has studied such techniques for increasing the dynamic range of the device and can make recommendations for many typical situations.

The wide spectral bandwidth of the TIVICON image tube allows a new latitude in spectral shaping. The TIVICON image tube may be used in a visible-only mode (filter: Schott KG-3) or an infrared-only mode (Corning 7-56). It may be used with any of the common color TV separation filters in conjunction with an infrared cutoff filter. In such cases the TIVICON image tube has an advantage of more than 7 to 1 over lead-oxide tubes in the red channel. The TIVICON image tube is better by a 1.2 factor in blue and green. It may be used with a narrow-band interference filter for making real-time thermograms above 200°C. In addition, special tailoring of the target can be done to increase efficiency in the 0.95 to 1.1 $\mu$m range for laser applications. Filters can also be used to increase the contrast ratio in inherently low-contrast scenes. Texas Instruments has experimented with filtration and can recommend proper filtering for your applications.

**Setup**

Once it has been determined that the TIVICON image tube will operate in the camera, the tube should be inserted into the coil and the socket connected. The beam control should be turned down and the target control set on minimum. The lens should be inserted and the camera covered to keep stray light off of the faceplate. Due to the high sensitivity of the tube, it is possible to wash-out the picture with very little stray light. Now the camera may be turned on.

The beam should be set about two-thirds "on". The lens should be adjusted for f/4 in normal room light. The target voltage should be raised until discharge is noted on the picture. This will happen somewhere below 10 volts. The camera should then be focused both electronically and mechanically. The mechanical focus point will be slightly different from the normal vidicon setting due to the space between the faceplate and the target.

The camera controls should be adjusted for best picture, keeping in mind the limits as quoted on the Description Sheet. The manual for the camera should be reviewed for adjustments such as mesh voltage, alignment, focus field and scan size. Picture parameters which should be considered are spots (both size and number), lag, saturated tails, uniformity, and apparent contrast – a function of dark current. The following chart will serve as a guide for achieving optimum performance from the TIVICON image tube.

**Spots–** Normally will not change unless the target voltage is excessively high.

**Lag–** Will decrease with increasing target voltage, and is a minimum for a given target voltage when the beam is set to just discharge the highlights.

**Tails–** Occur only when the target voltage is too high or when the beam is very low. If the target voltage is set excessively high the bright areas may turn black. To cure this, cover the lens and lower the target voltage.

**Uniformity–** Uniformity will generally get better with higher target voltage, at least to the point where dark current variations begin to show. A mesh voltage which is either too high or too low can adversely affect the uniformity.

**Contrast–** The sensitivity of the tube is not a function of target voltage. Increasing this voltage will allow higher peak signal currents, but this will also increase the dark current, causing loss of contrast in dim scenes. The recommended voltage quoted is a good guide for maximum dynamic range.

## REFERENCES


1. M. H. Crowell, T. M. Buck, E. F. LaBuda, J. V. Dalton, and E. J. Walsh, "A Camera Tube with a Silicon Diode Array Target," *BSTJ*, 46, No. 2 (February 1967), 491-495.

2. T. M. Buck, H. C. Casey, Jr., J. V. Dalton, and M. Yamin, "Influence of Bulk and Surface Properties on Image Sensing Silicon Diode Arrays," *BSTJ*, 47, No. 9 (November 1968), 1827-1854.

3. R. S. Levitte, "The Performance and Capabilities of Recently Developed Plumbicon* TV Camera Pick-Up Tubes," 105th Technical Conference SMPTE April, 1969.

4. RCA-8507 R Data Sheet 10-63.

5. G. E. Smith, "The Silicon Diode Array Camera Tube," Bell Telephone Laboratories Proceedings of the 1970 Solid State Circuit Conference.


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