

# Application of RCA Silicon Diode Array Target Vidicons

By R.E. Johnson  
Camera Tube Application Engineering

## Introduction

The RCA 4532A silicon-target (S-T) vidicon is a very high sensitivity camera tube having extremely broad spectral response, high resolution, low residual signal, and low dark current characteristics. It is similar in all essential respects to the conventional, well-established vidicon class of camera tubes except that the light-sensitive photo-conductive material (e.g., selenium, antimony trisulfide, or lead oxide) has been replaced with an array of discrete silicon photodiodes. Its electron-optical design, mechanical construction and physical appearance is virtually identical to the extremely popular and widely used RCA type 8507A. From the user standpoint, it can, therefore, be regarded as a member of the vidicon family but having significant performance advantages.

The deliberate and exact similarity of the silicon-diode target tube to existing vidicon types allows its use in existing TV cameras. Only two very simple modifications are ordinarily required in most commercial cameras designed to operate the vidicon types 8507 or 7735. Table I lists these modifications. The first category conversion involving target voltage and proper electrical connections is absolutely necessary. When these conversions are made, one may then operate the 4532A in the camera with gratifying evidence of higher performance capabilities in many specific respects. These advantages are described in detail later.

The secondary or "highly recommended" conversion items (Category II) in Table I are not necessary for an initial engineering test or evaluation of tube performance. However, as explained under general operating considerations, the maximum Grid-No. 4 voltage must never exceed 350 volts for type 4532A if maximum life expectancy is to be achieved. Substituting the recommended components and adjusting the electrode voltages to the values indicated will guarantee maximum performance from the type 4532A with regard to resolution and signal

uniformity without, in any way, jeopardizing its normal life expectancy.

Later in this report, some additional advanced electronic techniques will be described which may normally be employed in new camera designs to achieve the ultimate in performance from the S-T vidicon camera tube. To appreciate the value of the more advanced circuit elements, a detailed review of the type 4532A operating characteristics and its mode of operation may be helpful. It should also be noted that the information presented here is generally applicable to the developmental S-T vidicon types C23143, C23161, C23162, C23174 and C23195. These tube types are variants of the standard type 4532A having specialized characteristics.

## Target Structure and Signal Generating Process

The target consists of a two-dimensional array of diodes in an N-type silicon wafer approximately 7/8" in diameter. The active picture area (5/8" diameter minimum) is made very thin with a thicker, narrow rim section which provides additional strength for mechanical mounting in the tube assembly.

The diode array is produced by diffusion of P-type dopant through openings in a silicon oxide film which is formed on the surface. The oxide film separates the diode matrix which is on the surface facing the electron beam, and prevents the beam from striking the N-type material. By means of a unique RCA design, the oxide exposed to the beam is minimized and no resistive sea is necessary. Many of the outstanding properties of the RCA S-T vidicon result from this design.

In operation, the diodes are reverse-biased when a positive (target) voltage is applied to the N-type substrate. Each diode becomes an elemental storage capacitor due to the semiconductor properties of the depletion layer. The

Table I – Vidicon Camera Modification to Accommodate the Type 4532A

Category	7735 Vidicon Camera	8507 Vidicon Camera
I. Absolutely Necessary	<ol style="list-style-type: none"> <li>1. Disconnect Automatic Signal Control Circuit in Target Circuit if any exists.</li> <li>2. Connect Base Pin No. 6 to Base Pin No. 3.</li> <li>3. Connect target to a fixed 8 Volts supply.</li> </ol>	<ol style="list-style-type: none"> <li>1. Disconnect Automatic Signal Control Circuit in Target Circuit if any exists.</li> <li>2. Connect target to a fixed 8 Volts supply.</li> </ol>
II. Highly Recommended	<ol style="list-style-type: none"> <li>1. Substitute Cletron VYLFA-959 or Penn Tran 1465 Deflection/Focusing Coil for existing components.</li> <li>2. Operate G4/G3 at 300 Volts. Focus Coil approximately 44 Gauss.</li> </ol>	<ol style="list-style-type: none"> <li>1. Substitute Cletron VYLFA-959 or Penn Tran 1465 Deflection/Focusing Coil for existing components.</li> <li>2. Operate G4 at 340 Volts, G3 at 300 Volts. Focus Coil, approximately 44 Gauss.</li> </ol>
III. Optional Additions	<ol style="list-style-type: none"> <li>1. Gamma Correction</li> <li>2. Aperture Correction</li> <li>3. Selected Optical Filters</li> <li>4. Automatic Light Control</li> <li>5. Automatic Gain Control</li> <li>6. Bias Lighting (Low Lag)</li> </ol>	<ol style="list-style-type: none"> <li>1. Gamma Correction</li> <li>2. Aperture Correction</li> <li>3. Selected Optical Filters</li> <li>4. Automatic Light Control</li> <li>5. Automatic Gain Control</li> <li>6. Bias Lighting (Low Lag)</li> </ol>

*Special Note: Type 4532A has 0.10 ampere low-power heater requiring no modification in well-regulated 6.3V parallel connection circuits. However, beware of burn-out in poorly regulated or series connected supplies of in circuits regulated for higher currents.*

continuous N-type layer serves as a signal plate while the opposite (diode array) side of the target is stabilized at zero (cathode) potential by the action of the scanning beam. When discrete light quanta are focused onto the target, electron-hole pairs are created in the active silicon diode elements directly under the lighted areas. The holes, generated in the valence band, diffuse through the depletion layer to the P-region of the diodes discharging the diode storage capacitors and building up a charge pattern. The charge pattern (an electron image corresponding to the optical image) is thus stored on the beam side of the target between successive passages of the scanning beam. The output signal is generated by the capacitive displacement current as each elemental capacitor is charged in an orderly sequence by the scanning beam.

### General Operating Considerations

The light excited holes drift through the silicon until they reach the high field region associated with a P-N junction. They are then swept into the P-region where the charge is collected. The electric field at the junction is present even with the target at zero voltage. However, the electron optics of the scanning beam require a more substantial target potential to effectively attract the beam and generate

modulation amplitudes of maximum usefulness, i.e., target voltage swing in the video signal. This voltage should be just high enough to match the peak current capabilities of the signal generating process normally dictated by the electron beam scan charge capabilities. There is no operational advantage in going beyond this point but several good reasons exist for restricting it to this precise value. Specifically, a higher target voltage will increase dark current which is of no value and undesirable without a compensating increase in signal current. Furthermore, a suitably selected target voltage which limits peak storage signals to a value consistent with beam discharge capabilities provides an effective clipping action on overload (specular highlight) signals that could otherwise adversely affect system stability and/or aesthetic utilitarian picture quality. Thus, when properly adjusted, the RCA silicon diode target array vidicon will be essentially free of over-charged white blooming areas on stationary subjects and objectionable comet-tailing on moving objects.

Eight (8) is the magic number of target volts found to be most effective in achieving this optimized mode of operation for the 4532A camera tubes. Therefore, it is recommended that this value be fixed or set at the factory

during camera manufacture. In any event, there should be no external operating control marked target voltage available to the camera user as it will not be an effective operating control and will only create trouble or confusion. It should be clear that no damage to the tube will result if high voltage is deliberately or inadvertently applied to the target provided the normal inter-electrode breakdown limits are not exceeded. In fact, one suggested convenience for camera design consideration directly involving target voltage circuitry should be mentioned at this time. Sometimes operation at elevated target volts may result in the deposition of a charge on the dielectric ( $\text{SiO}_2$ ) between the diodes causing highlight signals to be clipped at normal operating levels. This condition can be corrected, if it occurs, by brief operation with the target set to a high voltage as shown in the following procedure:

- (1) Use maximum target area scan
- (2) Set for maximum beam current, i.e., adjust  $E_{g1} = 0$  Volts
- (3) Raise target for several seconds to 250 – 350 Volts
- (4) Cutoff beam current, i.e., adjust  $E_{g1} = -100$  Volts
- (5) Reset target to normal operating point, i.e.,  $E_{s1} = 8$  Volts
- (6) Reset beam current to normal operating point via  $E_{g1}$

In some sophisticated camera systems, the designer may wish to incorporate this target stabilization procedure via a system of push buttons operated in a certain sequence. A specific illustration of such a system is the silicon optical storage camera described by R. Silver and E. Leudicke in the 1970 IEEE Int. Solid-State Circuit Conference Digest, Vol. 13, pp. 30-31. However, in normal CCTV applications where the vidicon is operating at fixed target voltage as recommended, it is not likely that such a situation will arise for correction and the circuit is **not** normally warranted.

The user should be aware that high Grid-No. 4 field mesh electrode voltages such as those normally used in the vidicon "high voltage mode" have been shown to have a seriously destructive effect on silicon diode structures. The 350-volt absolute-maximum voltage limit published for this device should, therefore, be scrupulously observed. When beam electrons strike the field mesh at velocities in excess of 350 volts, the very low energy x-radiations produced have an adverse affect on the silicon-oxide interface such that the dark current may increase to an unacceptable level over a period of time. For example, useful operating tube life may be reduced to a few hundred hours at 500 volts and to less than 50 hours at 1000 volts. At 350 volts or less, the expectancy appears to be many thousands of hours and tube life should ultimately equal the 10,000 hour average typical of antimony trisulfide vidicon product. Appreciation of how rapidly the life expectancy decreases with voltage should provide maximum incentive to the user to avoid prolonged operation at high voltage. Below 350 volts there is a

negligible effect on dark current with target deterioration no longer a factor in determining end of tube life.

The particular deflection and focusing components referenced in the technical bulletin for the 4532A (Cletron VYLFA-959, Penn Tran 1465, or equivalents) extract the full performance capabilities of the S-T vidicon with  $G_4$  at 340 volts and  $G_3$  at 290 volts. These modern assemblies provide optimum signal uniformity and precise geometrical accuracy with a  $G_3/G_4$  ratio of 0.85 keeping the  $G_4$  voltage below the 350 volts maximum. In this mode, other affected performance characteristics such as resolution are at least equal to established 1" vidicon standards for the same voltage operation and appreciably better than lead oxide. Limiting resolution is largely determined by the discrete silicon diode array. Substantially improved performance could, of course, be achieved with "(1) a larger number of active diode elements in the same target area, (2) smaller diameter electron beams with increased current densities or (3) larger diameter targets and tubes". However, for general CCTV installations, the present design is more than adequate.

### Featured Performance Characteristics

The basic operating characteristics which determine to a very large extent the overall performance of any camera tube are sensitivity, spectral response, gamma, dark current, speed of response and resolution. The silicon diode target vidicon excels in many of these areas with very good performance on all other points relative to existing camera tube devices.

### Sensitivity

The silicon diode target vidicon has extremely high sensitivity with a quantum efficiency of not less than 65% in any part of the visible spectrum. Peak Quantum Efficiency is typically 85% and occurs at 520 nm, a wavelength very close to the normal eye response peak. For a 2854°K tungsten source commonly used as reference, these numbers can be translated into approximately 4000uA/lumen over the total sensitivity band or 900uA/lumen when restricted to the visible spectrum. Lead oxide vidicons have typical sensitivities of only 350uA/lumen with very low red response while antimony trisulfide vidicons, with more nearly panchromatic response, may be 150uA/lumen in an optimum operating mode. In terms of peak signal output and the customary footcandles highlight illumination on the tube face, the following tabulation of typical data is of interest.

To translate the tabulated data into readily usable minimum illumination reference points for camera designers, the S-T vidicon can deliver a very useful 10 nanoamperes peak signal current from a 2854°K tungsten source with (1) 0.002 fc highlight on faceplate, (2) 0.01 fc incident on a KG-3 type filter which restricts response to the visible

Table II. Comparative Performance for Vidicon Target Materials

Parameter	RCA Sb <sub>2</sub> S <sub>3</sub> Type 8507A	RCA Silicon Type 4532A	RCA PbO Type 4592
Target Volts	30 volts	8 volts	50 volts
Dark Current	20nA	7nA	3nA
Residual Signal (3rd field lag) from 300nA level	20%	7%	< 5%
Peak Signal at Ifc Full Spectrum (2854°K)	23nA	6000nA*	750nA*
Peak Signal at Ifc IR excluded (2854°K) with KG-3 filter	150nA	1000nA*	550nA*

\* For comparison of sensitivity only. In actual applications, light level would be reduced on the silicon tubes and the PbO tubes to maintain normal, optimized signal level in the 200 to 500 namp peak signal range.

region or (3) 0.02 fc incident on a Corning No. 7-56 type filter which restricts response to the infrared region. An absolute curve in amperes/watt for radiant sensitivity at all wavelengths is published in the 4532A technical bulletin.

Depending on actual operating conditions and the selected point of comparison, the silicon diode target vidicon may be said to have up to 50 times the sensitivity of the antimony trisulfide vidicon and up to 10 times the sensitivity of the lead oxide vidicon in a normal daylight or tungsten illuminated CCTV installation. On the other hand, for certain special spectral sources in the case of the PbO vidicon (i.e. Blue TV Channel) and certain high dark current operating modes in the Sb<sub>2</sub>S<sub>3</sub> vidicon, sensitivity may be shown to be more nearly equal.

### Spectral Response

The outstanding feature of the type 4532A, as already suggested above, is its extremely broad spectral response characteristic. This response has been shown to be very high in the visible region relative to those provided by alternative target materials. Moreover, this response extends into the near infrared region at an extremely useful level. Quantum Efficiency drops gradually to about 50% at 800 nm to the maximum useful typical limit of approximately 5% at 1100 nm. This near infrared sensitivity is a characteristic long desired by some camera tube users but seldom available in practical designs. Many military applications are expected to benefit greatly from this unusual extended performance capability. This capability is also of importance in other very specialized industrial services.

Before moving on to other subjects, the very attractive flexibility inherent in this particular silicon-diode target

characteristic should be more strongly emphasized. Maximum sensitivity and/or signal output is, of course, achieved when the full energy spectrum between 400 and 1000 nm is employed effectively. In this mode of operation, useful peak signal currents of 5 nA may be generated at  $10^{-3}$  fc highlight illumination on the faceplate yielding a 2:1 peak signal to RMS noise ratio when a well-designed video simplifier system is used. Low light level TV performance of this order compares very favorably with that attainable from the more complicated and expensive signal intensified devices commonly considered in such circumstances.

However, this complete flexibility is appreciated most when the device is operated in either a visible sensitivity system excluding IR or vice versa. An intriguing list of truly optimized and/or mutually complementing industrial system applications suggest themselves at this point. A multitude of selective detection processes can be implemented by a Go-No Go check of different but specific wavelength energies emitted from an object. Of course, one of the most prominent and well-known techniques involves the presence or absence of IR radiation (natural foliage and rock detection). The adaptation of the S-T vidicon to such applications is both convenient and effective. For IR exclusion, a Schott KG-3 filter is inserted in the light path. For visible exclusion and IR transmission only, a filter such as the Corning No. 7-56 is very effective. Alternative optical filters, such as the Kodak filter types 305 and 78 respectively, are available from other manufacturers. Complete light transfer characteristics for the type 4532A using such filter combinations are published for your convenient reference in the RCA technical bulletin for this camera tube type.



## Low Dark Current

The high sensitivity and broad spectral response characteristic of the silicon diode target vidicon is accompanied by very low dark current as shown in Table II. At the 8 volts typical operating target potential, dark current is nominally 7 nA compared to the normally high operating-signal level of 300 to 500 nA. This low level of dark current is also uniformly distributed across the picture area so that there are usually no objectionable shading characteristics introduced into the signal. When operated in the recommended focusing and deflection components referred to earlier, beam landing errors at the target are negligible and extremely uniform signal discharge is evident over the full target area. The video signal thus exhibits a very high degree of signal uniformity at both high and low light levels as well as in the dark so that a need for compensating signal-current-generating circuits is not anticipated in any conventional system.

There is also a negligible amount of video frequency noise generated from vidicon tubes of this type. Consequently, the signal-to-noise ratio of the resultant system will be determined almost entirely by the noise level attainable in the video amplifier design. Modern state-of-the-art systems can be built for a bandpass of 5 to 10 megahertz with noise levels not exceeding 3 to 5 nA rms. Assuming adequate light levels, peak video signals from the type 4532A will be on the order of 300 to 500 nA giving a peak signal to rms noise ratio of 100:1 (40 dB). Because the amplifier noise is concentrated at the higher frequencies, the fine grain random signal resulting is not particularly noticeable to the average viewer. Consequently, from empirical statistical viewer tests, a factor of 3 times in **effective** signal-to-noise ratio has been derived. This, in turn, yields a commonly recognized Visual Equivalent Signal-to-Noise Ratio of 300:1 ( $\approx$ 50 dB) for this class of tube in normal operation.

It is very important that dark current not be confused with noise in the signal for any reason in the mind of the user. Dark current is a relatively constant DC signal acting almost as an auxiliary pedestal level upon which the dynamic video signal is superimposed. Theoretically, the full signal can be completely separated from the constant level dark current in the normal process of signal transmission and this condition is actually realized for all practical purposes in any well designed video system. Consequently, very minute video signals down to the dark current level, and below, may be usefully detected and employed without any appreciable deterioration or masking effect from the dark current per se. It is only at 5 nA, for example, that the video signal level will be approaching the random noise level inherent in even the best video amplifiers and it is this noise that restricts and limits the ability to detect and reproduce luminous information in the televised scene. Specifically, resolution will appear to deteriorate significantly only as the fine detail of the subject is lost in amplifier noise.

One should remember, however, that for other reasons it is advisable to keep the dark current as low as possible. It is, in effect, a dead load which contributes nothing to the video signal, absorbs scanning beam current that could otherwise be used for signal generation, and contributes in some degree, to signal nonuniformity however minute this may be. Because dark current increases with target voltage as shown in the technical bulletin for the type 4532A, it is advisable to keep the target voltage as low as possible. The 8 volts operating potential recommended earlier should therefore be carefully noted and employed. It will allow maximum diode saturation currents to be generated that are slightly in excess of normal scanning beam performance capabilities. Thus, this voltage imposes no restrictions on the quality of the video signal generated yet minimizes dark current levels and provides a highly desirable automatic clipping action on specular reflections and other undesirable highlight overloads. The result is a very stable television picture with very little highlight blooming on stationary pictures and almost no comet tailing on bright moving objects. One may, for example, direct a strong, finite source of illumination into the lens, i.e., automobile headlights. The extreme intensity of the light source will be effectively contained while very good detail will be retained in the very low light areas immediately adjacent to the bright source. This is a very real and appreciated advantage of the silicon diode target vidicon never attained to this extent in any previous storage camera tube design.

## Speed of Response, Residual Signal or Lag

The recovery of the S-T vidicon from exposure to such intense light sources is also immediate and complete for all practical purposes. Tests and demonstrations have been conducted, for example, in which the camera was directed so that a sharply focused image of the sun struck the sensitive target area for extended periods of time. Any extreme signal levels generated under these conditions disappeared almost immediately when the lens was capped up with no apparent damage, even momentarily, to the silicon target surface. The ruggedness and reliability of the tube in extreme environments of this sort, therefore, becomes another exclusive advantage of this particular camera tube over any other. It is expected to be notably free of any image burn-in or target damage effects in almost any conceivable operating situation.

The dynamic signal buildup and decay as determined by conventional camera tube techniques are both finite and measurable. Continuous idealized or typical curves showing this characteristic as light is abruptly applied or terminated appear in published data for RCA 4532A. From Table II, a typical value for residual signal is 7% at the end of the 3rd TV field after illumination has been removed relative to the original, optimized signal level. The measured residual signal or lag as a percentage of original signal decreases,

however, as the active signal is increased to the maximum useful limits of the reading beam. Conversely, lag will be higher at lower light and lower signal levels as illustrated by a set of curves in the 4532A bulletin. Rise curves following the sudden application of light will generally follow these same decay curves in reverse direction so that for fastest response, a high level of peak signal output current should be maintained.

## Resolution

The resolution of the RCA vidicon type 4532A is determined primarily by the pitch or packing density of the diode array. In the present design, over 1800 discrete diodes per linear inch provide 700 to 800 TV lines limiting resolution per picture height in the finished tube. In more quantitative terms, as opposed to subjective viewing, a modulation transfer function, yields a typical 40% response for 400 TV line detail in the subject and 12% at 600 TV lines. This is about equal to a very good average performance from the conventional RCA antimony trisulfide (Type II) photoconductor standard line of 1" vidicons. The match to this performance level is more or less deliberate. It provides an acceptably high-performance level reliably within the present silicon diode technology limits. Because performance is not electron-optically limited, the S-T vidicon cannot reach the extremely high resolution attainable from a conventional 1" vidicon operated in the maximum high-voltage mode. However, its resolution capability is more than enough for the vast majority of television system requirements including high-performance broadcast applications. It is to be noted that camera tubes currently in widespread use in color broadcasting fall significantly short of this mark yet this limitation appears to pose no problems.

It should be emphasized that the silicon diode structure does not impose an inherent and unchangeable limitation on resolution performance as noted above. Technology will undoubtedly advance to make finer structured diode arrays possible along with any improved electron-optics that may be necessary. Also, a larger tube structure to at least double the present performance is immediately feasible and practical in view of the very small size of the present device. However, in the normal TV camera installation, resolution of the 1" S-T vidicon is more than adequate at the present time and is expected to remain so for the immediate future.

## Special Applications Considerations Gamma-Correction Circuits

The silicon diode vidicon has a one-to-one relationship between signal output and light input, i.e., halving or doubling light input will halve or double the signal to the

first approximation. In camera tube terminology this is referred to as a unity gamma characteristic since the exponent ( $\gamma$ ) in the following light transfer equation is 1.

$$I_{sj} = K I_{FP}^{\gamma} \text{ where } I_{sj} = \text{signal current in nanoamperes}$$

$I_{FP}$  = faceplate illumination in footcandles

$K$  = proportionality factor

$\gamma$  = camera tube gamma

A unity gamma characteristic for a camera tube is neither unusual nor inherently normal. Many tubes have a unity gamma characteristic in their normal operating range but others, such as the  $Sb_2S_3$  photoconductive layer vidicons, do not. Gamma values for various devices may vary from about 0.5 to 1.0 depending on the particular photosensitive layer employed.

Several advantages can be claimed for a unity gamma device. For example, signal amplitudes will be larger for small changes in illumination and the slope of the transfer characteristic is probably more constant from tube to tube. Unity gamma, therefore, gives a picture of greater contrast enhancing performance in low light level, low contrast scenes. Also, if the gamma is nearly identical from tube to tube, it facilitates tracking in multiple tube color cameras and other black and white systems where exact signal match is important. On the other hand, the unity gamma device will accommodate a smaller dynamic intrascene light range before overloading either the pickup device or the system. Also, other elements in the television system, i.e., the picture tube usually have a higher than unity gamma characteristic. Consequently, an electronic gamma correction circuit must usually be built into the system if a high fidelity reproduction of colors and/or halftones in the original scene are to be preserved. In most vidicon systems, the fractional gamma characteristic (0.65) closely compensates the picture tube characteristic (1.4), which results in a nearly linear, matching system without special compensation. Unity gamma devices such as the lead-oxide target vidicon and the silicon-diode target vidicon will almost always require gamma correction circuitry in the system. This will improve the dynamic light range to be accommodated as well as the fidelity of scene reproduction. The only exceptions would be in non-critical surveillance applications or in quasi-industrial/military installations where abnormal contrast signals are employed as a deliberate utilitarian advantage. Since variable or fixed gamma correction circuits for conventional video amplifiers are well-known in the industry and fully described in the literature, they will not be discussed in further detail.

## Automatic Light and Gain Controls

Adding gamma-correction circuitry to the video amplifier will extend the dynamic range of the system and provide a

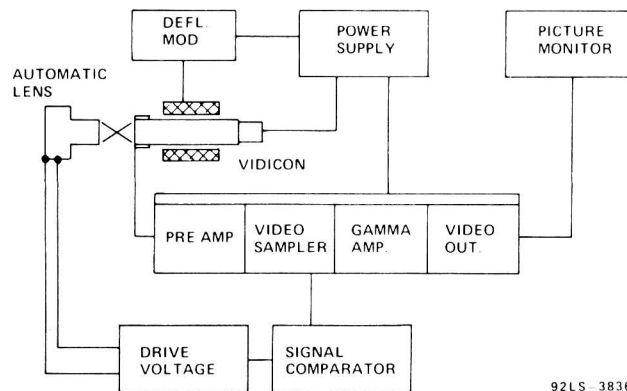
more accurate rendition of halftones in the subject as indicated. However, this after-the-fact electronic operation will not be effective in controlling charge build-up levels on the target itself and so keep them within the finite charge capabilities of the scanning beam. An antimony trisulfide photoconductive layer inherently exerts this effect since the 0.65 gamma function is a part of the light sensing characteristic. Furthermore, target voltages in this class of tube have a pronounced effect on signal output and may be easily employed, either manually or by automatic feedback circuitry, to maintain constant signal currents over a tremendously wide range of illumination, i.e., 4000:1. Lead-oxide vidicons and silicon diode vidicons, with their unity gamma characteristic and fixed target voltage, can only achieve this necessary control of signal levels by externally regulating the amount of light admitted to the sensing element, i.e., the faceplate of the tube.

The most obvious and direct method for maintaining optimum light levels on a camera tube is to manually adjust the iris on the objective lens of the camera. In most artificially lighted areas where the illumination is not subject to any severe excursions, this adjustment is most effective and no problems are encountered in practice. When the iris is properly set, the camera tube and system will normally operate satisfactorily over a 10:1 light or signal range with no obvious degradation in picture quality. Where the illumination level changes by as much as 100:1 over essentially predictable time periods, a manned camera or remotely controlled iris can compensate for this change by using the full iris control range – normally f/2 to f/22. Neutral density filters can, of course, always be judiciously employed to match the average illumination level to the center point of the lens stop range for optimum performance.

Where an Automatic Light Control is necessary or desirable, several alternative systems have been devised in the past and may be reviewed in detail in a number of published articles. For example, a light-intensity sensor can be mounted on the front of the camera and its output converted to activate a drive system which, in turn, rotates the lens iris or a graded neutral-density filter wheel to the correct exposure point. Other automatic systems determine the precise setting by comparison with an optimized, established standard signal reference point.

A very simple, economical form of automatic light control is illustrated in the block diagram of Fig. 1. The commercially available MATI Synchronex or Cosmicar-EE automatic iris lenses are continuously adjustable from f/2 to f/22 by a variable driving signal ranging from 2 to 6 volts. The video signal from the camera tube is continuously monitored and compared to the pre-set constant-signal amplitude which is desired at that particular point in the system. A  $\Delta V$

command voltage of from zero to six volts is then generated by this electronic sensing unit to drive the iris to the correct exposure point.



92LS-3836

**Figure 1 – Simple Automatic Light Control System**

As indicated earlier, these automatic iris systems must be supplemented by appropriate neutral density filters for large ranges of light accommodation, i.e., several thousand to one. Lens stops on conventional lenses limit effective control to a few hundred to one. A further, coarse automatic control can be achieved by incorporating an Automatic Gain Control in the video amplifier stages. This control is normally set at the mid-range point. As the Automatic Light Control system reaches its operational limit, either due to an extreme low light condition or unexpectedly encountered high light overload, the AGC will be activated to provide an extended range of automatic signal control for the system. In most instances, however, this extra sophistication is not required with a well-designed and reliable ALC system that is closely matched to the particular application.

### Environment Effects and Capabilities

The S-T vidicon like all vidicon type camera tubes is a very sturdy device. It will, therefore, take a surprising amount of shock and vibration without catastrophic failure or appreciable degradation in picture quality. However, one should bear in mind that the 4532A is a commercial service product and has not been deliberately ruggedized to withstand severe shocks and vibrations such as those that may be encountered in many industrial or military installations. Although such mechanical designs are apparently feasible and do not represent an inherent limitation in the silicon diode device itself, shock and/or vibration should be limited to a few g's on the present product to avoid potential damage to the device.

The silicon diode target vidicon is also designed to operate in a temperature range just above the normal room ambient of 25°C. All data published are for an assumed operating temperature range of 30° ± 3°C. The device can, of course, survive and operate efficiently at temperatures relatively greater or lesser than the specified range. An absolute maximum of 100°C has been established for shipping and

storage. This is determined by the physical characteristics of the evacuated assembly to prevent fatal accumulations of gas pressure inside the tube and a possible separation of the glass seals themselves. In operation, however, the dark current in the silicon diode target matrix will approximately double for every 10°C rise in temperature. Because the dark current is inherently very low, a significant increase in temperature can be tolerated without an appreciable sacrifice in performance and fairly large increase in temperature can be tolerated before operating conditions become prohibitive. To illustrate, a typical type 4532A camera tube with a dark current of 7 nA at 30°C can be operated at 50°C with no more dark current than is normally accommodated by the conventional vidicon system at room temperature, i.e., 30 nA and 25°C. However, the maximum dark current tolerable in a typically efficient system should be no more than perhaps 150 nA. This level is reached in our typical silicon target example at 70°C. Consequently, this is the normal operating temperature maximum usually recommended in the published data for this class of tube.

At the other extreme, low temperatures are far less critical to the extent that absolute minimum operating temperatures are rarely listed in the data. Dark current continues to decline at progressively lower temperatures so that very low values may actually be obtained to facilitate some special operating modes such as slow scan TV, or other variations where long signal storage is of paramount importance. The lag or residual signal characteristic will, of course, also become more pronounced at lower temperatures placing a practical limit in some cases on the ultimate useful operating point. However, the lower temperature has virtually no effect on other operating characteristics such as sensitivity, resolution, or spectral response and an externally operated bias light can be employed to eliminate the lag problem. Consequently, as long as the thermal shock is not of an abnormal amount such that resultant differential expansions would break the tube apart, there is virtually no lower limit temperature precaution to be scrupulously observed in the application of the vidicon tube.

The silicon diode target vidicon is also almost totally impervious to damage from intense light sources. To illustrate, the image of a bright noonday sun has been focused onto the target of the type 4532A through a standard high speed, wide angle lens for several hours. When the camera was panned away to an earth scene, there was no evidence of permanent damage to the target and the very bright picture of the sun disappeared immediately with no after-image or residual signal effects apparent to the careful observer. This is perhaps one of the most outstanding advantages offered by the new silicon diode target vidicon. For years, camera tube users have been hampered by the burned-in patterns resulting from the accidental exposure to extremely bright sources or the unavoidably prolonged

exposure to more normal high contrast scenes. The new line of vidicons completely eliminates this hazard and, as described earlier, discrete specular highlights may deliberately be included in the scene without significantly degrading the surrounding low light picture areas.

Finally, brief mention should be made of aperture correction circuitry with the type 4532A vidicon. The high resolution of this camera tube which was emphasized in an earlier section as 5% at 700 TV lines or 40% at 400 TV lines must be considered very good performance for the average TV system. However, the silicon target vidicon will respond to artificially accentuated response processes just as readily and approximately to the same extent as other camera tube devices. One may, therefore, introduce a video gain boost in the range of 3 to 6 megahertz to produce an obviously sharper, crisper television picture in the typical CCTV viewing system. This gain in picture sharpness is normally acquired in exchange for a greater amount of video amplifier noise depending on the precise boost level and frequency employed. However, with the normally very high signal-to-noise ratio attainable in well designed vidicon systems, it usually involves a small sacrifice in practice and, if the sharper picture is appreciated, the resultant trade off will be a very desirable one in almost every instance.

### Summary of Application Notes

The type 4532A silicon diode target vidicon has proved to be a very high performance device with several unique advantages in comparison with other camera tube devices currently available. Its resolution is equivalent to the very good average levels established by the conventional vidicon for high-quality TV systems. Its sensitivity, on the other hand, is many times higher, particularly where its full range of spectral sensitivity can be employed. In other applications, its selective response characteristics can be exploited for special applications completely unfeasible with earlier vidicon types including the lead-oxide camera tubes. Dark current and residual signal are both very low and competitive in the practical sense with the very best performance attainable in such devices. The most outstanding advantage, however, lies in its resistance to image burn-in from intense sources of illumination and the associated stable picture characteristics apparent when such discrete light sources are inadvertently included in the scene.

Gamma amplifier correction circuitry is normally recommended for the typical TV system and the need for manual or automatic light control should be anticipated. On the other hand, no shading signal amplifiers should be required and aperture correction circuitry would normally be regarded as an unnecessary refinement. The tube is mechanically sturdy, can be operated successfully over a wide temperature range, and is readily adaptable to existing vidicon TV camera designs (7735, 8507, 8541, etc.). It should, therefore, find widespread use in a wide variety of applications involving TV camera tubes.