RCA-6499 is a charge storage tube of the barrier-grid type intended for use in a variety of information-processing systems. Information is provided in digital or analogue form in a compact package consuming low power and providing high speed of response.

The 6499 may be operated so that (1) the output signal is linearly related in amplitude to the input signal, or (2) the output signal is proportional to the duration of an input-signal pulse or to several input-signal pulses occurring within a given time interval, or (3) the output signal is proportional to the difference between two successive input signals.

Design features of the 6499 include an electron gun capable of providing an electron beam having high current density and relatively small cross-sectional area at the focus plane, and a storage surface having uniform secondary emission to provide a uniform output signal. Electrostatic deflection of the beam is utilized to permit the design of deflection circuitry having relatively low power consumption and providing high speed of response.

PRINCIPLES OF OPERATION

The 6499 contains an electron gun of the electrostatic-focus and electrostatic-deflection type, a barrier grid (grid No. 5), a dielectric layer, a backing-electrode, and a collector, as shown in Fig. 1. The barrier grid consists of a fine mesh screen very closely spaced to or in contact with the gun side of the dielectric layer. On the opposite side of the layer and in contact with it is placed the backing-electrode which consists of a metal disc. The dielectric layer has high insulating qualities and a maximum secondary-emission ratio greater than unity. The barrier grid, the dielectric layer, and the backing-electrode are collectively referred to as the "target" for convenience in explaining the operating principles of the 6499. The collector is a conductive coating on the inside wall of the large part of the tube. This part of the tube also has an external conductive coating which is connected at the seal flange to the collector and internal shield.

By adjustment of the voltage applied to the focusing electrode (grid No. 3), the electron beam may be focused in the plane coinciding with the exposed surface of the dielectric layer. This surface on which charge storage occurs is known as the storage surface. Adjustment of the control-grid (grid-No. 1) voltage controls the intensity of the beam current impinging on the storage surface. The control grid may be modulated in accord with system requirements. The area of the storage surface bombarded by the electron beam is determined for any specific application by the magnitude of the voltages applied to the deflecting electrodes.

The effect of storage-surface potential in determining the action of the target is illustrated in Figs. 2, 3, and 4. In Fig. 2 the storage surface is instantaneously some tens of volts positive with respect to the barrier grid. When the primary-beam electrons, produced by the electron gun, go through the barrier grid and impinge on the storage surface, they release secondary electrons from the storage surface. The number released depends on the energy of the impinging electrons. The energy of the secondary electrons is not sufficient to overcome the negative gradient existing between the barrier-grid plane and the storage surface. Consequently, after a transit time of a small fraction of a microsecond, the secondary electrons return to the vicinity from which they were released. Under these conditions, a net electron current flows into the target from the beam. This current has

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a value equal to that of the beam current multiplied by the effective transmission of the barrier grid. Because the barrier grid is treated so that it has a secondary-emission ratio of very nearly unity, it contributes nothing to the net electron current flowing into the target.

In Fig.3, the storage surface is instantaneously some tens of volts negative with respect to the barrier grid. When the primary-beam electrons go through the barrier grid and impinge on the storage surface, they release secondary electrons from the storage surface, as in the case of Fig.2. However, unlike the case of Fig.2, the secondary electrons are accelerated from the storage surface, pass through the plane of the barrier grid, and go into the space beyond it. These secondaries together with those released from the barrier grid are then accelerated to the collector which is operated at a positive dc potential. Actually, the barrier grid collects some of the secondaries from the storage surface but these may be neglected in considering first-order effects without introducing appreciable inaccuracy. Under the conditions shown in Fig.3, the net electron current flows away from the target. This current has a value equal to that of the beam current multiplied by the effective transmission ratio of the barrier grid and by the difference between the secondary-emission ratio of the storage surface and unity.

Because the secondary electrons which are liberated from the storage surface have initial energies in the range from 0 to more than 10 electron volts, the transition between the case of Fig.2 and that of Fig.3 is gradual. The exact percentage of the secondaries which escape from the target depends on the magnitude of the potential gradient between the storage surface and the barrier grid.

The magnitude and shape of the transition between the case of Fig.2 and that of Fig.3 is illustrated by the typical target characteristic curves shown in Fig.10.

In Fig.4, the storage surface is several volts positive with respect to the barrier grid. In this case, the escaping secondaries exactly balance those primary-beam electrons arriving at the storage surface. Under these conditions, the net target current is zero, and the potential of the storage surface is known as the equilibrium potential.

The condition shown in Fig.2 is unstable because charge neutrality can not be maintained within the dielectric layer. In order that charge
neutrality be maintained within the dielectric as the beam deposits electrons on the storage surface, it is necessary that a displacement current flow in the storage-surface backing-electrode. As a result of this flow, a voltage gradient is built up across the dielectric. The potential of the storage surface on which the electrons (negative charges) land, becomes more and more negative, assuming that the bombardment is not affected by modulation or deflection of the beam, until the condition shown in Fig. 4 is attained.

Similarly, the condition in Fig. 3 is unstable. However, in this case, the process of charging to the equilibrium potential is in a positive direction.

It is this process of charging, called writing, by means of which the storage of information is effected. A term indicative of the speed of writing is known as discharge factor. It may be defined as the ratio of the shift in potential with respect to equilibrium potential of a given element of the storage surface during a single exposure to the beam, to the potential of the storage surface with respect to equilibrium potential at the beginning of exposure. The concept of discharge factor is usually applied to cases where the storage surface is scanned by the beam. A single exposure is usually interpreted as meaning a single scan of an element of the storage surface. A typical discharge-factor curve for the 6499 is shown in Fig. 11.

An example of a simple writing sequence is as follows: Assume that the storage surface is at equilibrium potential, and that zero potential exists between the backing-electrode and the barrier grid (grid No. 5). A step-function voltage of, say, +50 volts with respect to grid No. 5 is applied to the backing-electrode. Because of the relatively high capacitance between the backing-electrode and the barrier grid, practically all of the step-function voltage appears between the storage surface and the barrier grid. The undeflected beam is now turned on and that part of the storage surface bombarded by it commences to charge negatively toward equilibrium. Assume that bombardment continues until the storage-surface potential, in relation to equilibrium potential, has changed from the +50 volts to -40 volts, whereupon the beam is turned off. A charge sufficient to develop a gradient of 10 volts has now been stored in the dielectric layer. For these conditions, the discharge factor is (50-40)/50 = 0.2. If the step-function voltage is now removed, the storage surface becomes 10 volts more negative than the equilibrium value.

This stored information may now be extracted by a discharging process known as reading. During reading, the backing-electrode is held at the same potential as the barrier grid. When the beam is turned on, the resulting target-current flow is that for the storage surface at -10 volts with respect to the equilibrium potential, and may be determined by reference to a target characteristic curve for the appropriate operating conditions.

Since reading is accomplished by the removal of electrons from the storage surface and its consequent discharge toward equilibrium potential, reading is likewise an erasing process. If the discharge factor during reading is sufficiently high, further erasing is unnecessary. However, in critical applications, a second or possibly more subsequent reading processes at high discharge factor may be necessary to restore the storage surface to equilibrium potential prior to the next writing process. A discharge factor of 1.0 represents complete erasure.

**DATA**

**General,**

Heater, for Unipotential Cathode:

<table>
<thead>
<tr>
<th>Voltage (AC or DC)</th>
<th>6.3 ± 5% volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>0.6 amp</td>
</tr>
</tbody>
</table>

Direct Inter electrode Capacitances (Approx.):

| Grid No. 1 to all other electrodes | 9 µf |
| Deflecting electrode D1 to all other electrodes | 13 µf |
| Deflecting electrode D2 to all other electrodes | 13 µf |
| Deflecting electrode D3 to all other electrodes | 11.5 µf |
| D1 to D2 | 3 µf |
| D2 to D3 | 3 µf |
| Grid No. 5 to backing-electrode | 800 µf |
| Grid No. 5 and backing-electrode to collector | 4 µf |

Collector to all other electrodes See Fig. 5

Focuser Method. Electrostatic

Deflection Method. Electrostatic

Overall Length | 11-27/32 ± 3/8" |

Greatest Diameter of Tube. | 3.30 ± 0.05 " |

Minimum Useable Storage-Surface Diameter. 2-1/4" |

Base: On large end of tube Small-Button Twentyinar 8-Pin (JETEC No.E-19)
On small end of tube Small-Shell Diheptal 14-Pin (JETEC No.B114-45)

Mounting Position. Any except those positions where the diheptal base is up and the tube axis is at an angle of less than 60° from the vertical.

Weight (Approx.) 1 lb.

All voltages are with respect to cathode unless otherwise specified.

**Maximum Ratings, Absolute Values:**

**BACKING-ELECTRODE-TO-GRID No. 5**

| Minimum Voltage | 100 max. volts |
| Backing-electrode positive with respect to grid No. 5 | 100 max. volts |
| Backing-electrode negative with respect to grid No. 5 | 100 max. volts |
| COLLECTOR-TO-GRID No. 5 VOLTAGE: Positive value | 100 max. volts |
| Negative value | 0 max. volts |
| ULTRAVIOLET VOLTAGE to all | 1500 max. volts |
| GRID No. 3 VOLTAGE | 500 max. volts |
| GRID No. 1 VOLTAGE: Negative bias value | 200 max. volts |
| Positive bias value | 0 max. volts |
| Positive peak value | 2 max. volts |
PEAK HEATER-CATHODE VOLTAGE:
- Heater negative with respect to cathode = 125 max. volts
- Heater positive with respect to cathode = 10 max. volts

Equipment Design Ranges:
- For any "ulterior" (ECB) between 1000 and 1500 volts
  - Back electrode to grid No. 5 voltage
    - Collector to grid No. 5 voltage = 0 to 50 volts
    - Grid No. 3 voltage for focus with grid No. 1 = 14% to 26% of ECB volts
  - Grid No. 1 voltage for collector-current cutoff = -2.5% to -4.7% of ECB volts
  - Collector current for grid No. 1 volts = 20 to 50 μamp
  - Max cathode current for grid No. 1

Deflection Factors:
- D1j and D1k = 85 to 105 v dc/in./kv of ECB
- D2j and D2k = 78 to 96 v dc/in./kv of ECB

Examples of Use of Design Ranges:
- For ulterior voltage of 1000 volts
  - Grid No. 3 voltage for focus with grid No. 1 = 140 to 260 volts
  - Grid No. 1 voltage for collector-current cutoff = -25 to -47 volts

Deflection Factors:
- D1j and D1k = 85 to 105 v dc/in.
- D2j and D2k = 78 to 96 v dc/in.

Maximum Circuit Values:
- Grid No. 1 circuit resistance = 1.5 max. megohms
- Resistance in any deflecting-electrode circuit = 1.0 max. megohm

Note 2: With voltages as specified in Note 1, and with a signal written into storage by applying a series of well-formed symmetrical square waves to grid No. 1 such that a series of 25 equally spaced stored elements are written across a single line scan, the ratio of the maximum to minimum signal amplitude observed as the single line scan is moved across the storage surface will not exceed 1:35.

OPERATING CONSIDERATIONS

Handling. The 6499 should always be handled and transported with the large end (twentiethinar-base end) up in order to prevent possible damage to the storage surface caused by any loose particles striking the target and adhering to it.

The maximum ratings shown in the tabulated data are limiting values above which the serviceability of the 6499 may be impaired from the viewpoint of life and satisfactory performance. Therefore, in order not to exceed these absolute
ratings, the equipment designer has the responsibility of determining an average design value for each rating below the absolute value of that rating by an amount such that the absolute values will never be exceeded under any usual condition of supply-voltage variation, load variation, or manufacturing variation in the equipment itself.

**Shielding.** The use of a magnetic shield of high-permeability material surrounding the tube is recommended. This shield prevents the effect of stray fields in causing unwanted deflection of the electron beam.

The heater is designed to be operated at 6.3 volts. The transformer winding supplying the heater power should be designed to operate the heater at the rated voltage under average line-voltage conditions. If the circuit design is such as to cause a high voltage between heater winding and ground, the heater transformer should be adequately insulated to withstand the high voltage.

Although maximum values of peak heater-cathode voltage are specified in the tabulated data, it is recommended that the mid-tap or one side of the heater winding be connected directly to the cathode to minimize the possibility of damage to the tube produced by arcing between heater and cathode when a possible momentary internal arc causes the voltage between heater and cathode to exceed the maximum heater-cathode ratings. When, in some circuit designs, the heater is not connected directly to the cathode, precautions must be taken to hold the peak heater-cathode voltage to the maximum values shown in the tabulated data.

**Grid No. 2.** Connected within the tube to grid No. 4 and operated at grid-No. 4 potential, is incorporated in the electron-gun design so that the beam current and grid-No. 1 cutoff voltage will not be affected by focusing adjustment. Because of the effect of grid No. 2, and the negligible current taken by grid No. 3, the beam can be sharply focused on the storage surface and remains sharp when beam current is varied over a wide range.

**Grid No. 3.** The focusing electrode, is so designed that it takes negligible current. This feature makes possible the use of a low-current voltage-divider system. Focusing of the beam is controlled by adjustment of the ratio of grid-No. 3 voltage to grid-No. 4 voltage. Ordinarily, the ratio is adjusted by variation of grid-No. 3 voltage. For this purpose, a potentiometer adequately insulated is required in the voltage-
divider circuit; the necessary range of adjustment is indicated under Equipment Design Ranges and Examples in the tabulated data.

The external conductive coating serves as a convenient connection to the collector and internal shield. If the coating becomes oxidized, it may be cleaned with a silverware cleaner.

during writing—pulsed approx. 50 volts positive with respect to ultor
during reading—at grid-N25 potential

![Fig. 8 - Resolution Characteristics of Type 6499.](image8)

Each pair of deflecting electrodes is normally operated at an average potential the same as that of grid No.4. The grid-No.4 voltage may be adjusted with respect to the average deflecting-electrode potential to provide control of astigmatism. The resistance in the dc path to each of the deflecting electrodes should not exceed 1 megohm.

The dc voltages for grid No.1, grid No.3, and ultor should be obtained from an extremely well-regulated power supply essentially free of ripple. It is recommended that the power supply be obtained from the ac-supply line with a suitable rectifier and filter. When the 6499 is operated
with an utor voltage near the maximum value of 1500 volts, the dc power supply should be capable of providing the operating value within ± 1 per cent over a current range of 0 to 3 milliamperes (see Fig.6). To insure adequate regulation of the various electrode voltages, the current through the voltage-divider should be at least 30 milliamperes.

In most applications, it is recommended that the utor (grids No.2 and No.4) be grounded in order that the deflecting electrodes may be operated at essentially ground potential. With this method, the cathode and heater are at high negative potential with respect to ground.

The high voltages at which this tube is operated may be very dangerous. Great care should be taken in the design of apparatus to prevent the places the heater and cathode at high negative potential with respect to ground, the dangerous voltages can more easily be made inaccessible.

In the use of high-voltage tubes, it should always be remembered that high voltages may appear at normally low-potential points in the circuit as a result of capacitor breakdown or incorrect circuit connections. Therefore, before any part of the circuit is touched, the power-
supply switch should be turned off, and both terminals of any capacitors grounded.

The undiflected focused beam is normally close to the geometric center of the storage surface. However, to compensate for variation from tube to tube, designers may desire to provide an adjustable and reversible supply of at least 13 volts dc per kilovolt of ultor voltage (balanced to ultor) for application between the two deflecting electrodes of each pair. By adjustment of this dc voltage on each pair of the deflecting electrodes, the beam may be centered.

Do not operate the 6499 continuously for more than a few minutes with an undeflected focused beam or with a stationary single-line scan. Such operation may cause damage to the storage surface.

The resolution capability of the 6499 is dependent upon the beam current and the beam accelerating voltage used in a particular application, as shown in Figs.8 and 9, respectively.

The resolution of the 6499 may be measured by writing in a signal consisting of a sequence of square waves, by observing the amplitude of the ac component of the reading-output, and by plotting relative output as a function of the number of half-cycles (TV lines) stored across the minimum useful diameter of the storage surface.

The shape of the resolution curve is related in a complex manner to the cross-sectional diameter of the focused beam and the current-density distribution within the beam. As an approximation, it may be assumed that the beam density has a Gaussian distribution. For the conditions shown by the upper curve in Fig.8, the width of the Gaussian distribution curve at half amplitude is about 0.010 inch.

The use of 1000 volts as the ultor voltage (beam accelerating voltage) is often a good compromise between resolution and secondary-emission ratio of the storage surface. Within the operating range of the 6499, the secondary emission ratio decreases with increase in ultor voltage.

Typical target-characteristic curves for the 6499 are shown in Fig.10. For an individual tube, the shape of these curves is dependent on ultor voltage, beam current, beam focus, and scanning speed.

The discharge-factor curve for the same operating conditions as used for the middle curve in Fig.10 is shown in Fig.11.

Average transfer characteristic curves for the 6499 are shown in Fig.12. For the conditions indicated, the collector current is identical to the beam current.

The circuit arrangement used with the 6499 will depend on the requirements of the storage application. A discussion of various circuits is given in References 3 and 4.

The sequence of adjustments in operating the 6499 is as follows:

1. With the tube inserted in the equipment, apply rated heater power.
2. Next apply deflecting-electrode voltages and make certain that the deflecting circuits are functioning properly to scan the storage surface.
3. Apply other electrode voltages as indicated under Equipment Design Ranges.
4. Adjust grid-No.1 voltage to operate the tube on the proper portion of its transfer characteristic as required by the application.
5. Adjust grid-No.3 voltage for best focus.
REFERENCES


Devices and arrangements shown or described herein may use patents of RCA or others. Information contained herein is furnished without responsibility by RCA for its use and without prejudice to RCA's patent rights.
NOTE 1: THE ANGLE BETWEEN PLANE THROUGH PIN NO. 6 OF TWENTY-NINAR BASE AND TUBE AXIS, AND PLANE THROUGH PIN NO. 2 OF DIHEPTAL BASE AND TUBE AXIS WILL NOT EXCEED 10°. THE INDICATED PINS ARE BOTH ON THE SAME SIDE OF THE TUBE.

NOTE 2: DEFLECTING ELECTRODES DJ1 & DJ2 ARE NEARER THE TARGET. DEFLECTING ELECTRODES DJ3 AND DJ4 ARE NEARER THE DIHEPTAL BASE.

NOTE 3: ANGLE BETWEEN DJ1 & DJ2 DEFLECTION PATH AND DJ3 & DJ4 DEFLECTION PATH IS 90° ± 3°.
SOCKET CONNECTIONS

Bottom View

SMALL-SHELL DIHEPTAL 14-PIN BASE

View of Diheptal-Base End of Tube

PIN 1: HEATER
PIN 2: CATHODE
PIN 3: GRID No. 1
PIN 4: INTERNAL CONNECTION—DO NOT USE
PIN 5: GRID No. 2
PIN 6: NO CONNECTION
PIN 7: DEFLECTING ELECTRODE DJ1
PIN 8: DEFLECTING ELECTRODE DJ2
PIN 9: ULTOR (Grids No. 2 & No. 4)
PIN 10: DEFLECTING ELECTRODE DJ3
PIN 11: DEFLECTING ELECTRODE DJ4
PIN 12: NO CONNECTION
PIN 13: INTERNAL CONNECTION—DO NOT USE
PIN 14: HEATER
C, CL: EXTERNAL CONDUCTIVE COATING, COLLECTOR, INTERNAL SHIELD, FLANGE BETWEEN NECK AND LARGE PART OF TUBE

SMALL-BUTTON TWENTYNINAR 8-PIN BASE

View of Twentyninar-Base End of Tube

Pins 2, 6, 10, 14, 18: On 1-7/8" Dia. Pin Circle
Pins 21, 25, 28: On 7/8" Dia. Pin Circle

PIN 2: MULTIPLE CONNECTIONS TO BACKING ELECTRODE. ONLY ONE NEED BE USED
PIN 6: NO CONNECTION
PIN 10: NO CONNECTION
PIN 14: ELECTRODE. ONLY ONE NEED BE USED
PIN 21: NO CONNECTION
PIN 25: NO CONNECTION
PIN 28: GRID No. 5