**DESCRIPTION**

The Xicor X9C102/103/104/503 is a solid state nonvolatile potentiometer and is ideal for digitally controlled resistance trimming.

The X9C102/103/104/503 is a resistor array composed of 99 resistive elements. Between each element and at either end are tap points accessible to the wiper element. The position of the wiper element is controlled by the CS, U/D, and INC inputs. The position of the wiper can be stored in nonvolatile memory and then be recalled upon a subsequent power-up operation.

The resolution of the X9C102/103/104/503 is equal to the maximum resistance value divided by 99. As an example, for the X9C503 (50kΩ) each tap point represents 505Ω.

All Xicor nonvolatile memories are designed and tested for applications requiring extended endurance and data retention.

**FEATURES**

- Compatible with X9102/103/104/503
- Low Power CMOS
  - $V_{CC} = 5V$
  - Active Current, 3mA Max
  - Standby Current, 500µA Max
- 99 Resistive Elements
  - Temperature Compensated
  - $\pm 20\%$ End to End Resistance Range
- 100 Wiper Tap Points
  - Wiper Positioned via Three-Wire Interface
  - Similar to TTL Up/Down Counter
  - Wiper Position Stored in Nonvolatile Memory and Recalled on Power-Up
- 100 Year Wiper Position Data Retention
- **X9C102 = 1KΩ**
- **X9C103 = 10KΩ**
- **X9C503 = 50KΩ**
- **X9C104 = 100KΩ**

**FUNCTIONAL DIAGRAM**
PIN DESCRIPTIONS

$V_H$ and $V_L$

The high ($V_H$) and low ($V_L$) terminals of the X9C102/103/104/503 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is $-5V$ and the maximum is $+5V$. It should be noted that the terminology of $V_L$ and $V_H$ references the relative position of the terminal in relation to wiper movement direction selected by the U/D input and not the voltage potential on the terminal.

$V_W$

$V_W$ is the wiper terminal, equivalent to the movable terminal of a mechanical potentiometer. The position of the wiper within the array is determined by the control inputs. The wiper terminal series resistance is typically $40\Omega$.

Up/Down (U/D)

The U/D input controls the direction of the wiper movement and whether the counter is incremented or decremented.

Increment (INC)

The INC input is negative-edge triggered. Toggling INC will move the wiper and either increment or decrement the counter in the direction indicated by the logic level on the U/D input.

Chip Select (CS)

The device is selected when the CS input is LOW. The current counter value is stored in nonvolatile memory when CS is returned HIGH while the INC input is also HIGH. After the store operation is complete the X9C102/103/104/503 will be placed in the low power standby mode until the device is selected once again.

PIN CONFIGURATION

PIN NAMES

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_H$</td>
<td>High Terminal</td>
</tr>
<tr>
<td>$V_W$</td>
<td>Wiper Terminal</td>
</tr>
<tr>
<td>$V_L$</td>
<td>Low Terminal</td>
</tr>
<tr>
<td>$V_{SS}$</td>
<td>Ground</td>
</tr>
<tr>
<td>$V_{CC}$</td>
<td>Supply Voltage</td>
</tr>
<tr>
<td>U/D</td>
<td>Up/Down Input</td>
</tr>
<tr>
<td>INC</td>
<td>Increment Input</td>
</tr>
<tr>
<td>CS</td>
<td>Chip Select Input</td>
</tr>
<tr>
<td>NC</td>
<td>No Connect</td>
</tr>
</tbody>
</table>
DEVICE OPERATION

There are three sections of the X9C102/103/104/503: the input control, counter and decode section; the nonvolatile memory; and the resistor array. The input control section operates just like an up/down counter. The output of this counter is decoded to turn on a single electronic switch connecting a point on the resistor array to the wiper output. Under the proper conditions the contents of the counter can be stored in nonvolatile memory and retained for future use. The resistor array is comprised of 99 individual resistors connected in series. At either end of the array and between each resistor is an electronic switch that transfers the potential at that point to the wiper.

The INC, U/D and CS inputs control the movement of the wiper along the resistor array. With CS set LOW the X9C102/103/104/503 is selected and enabled to respond to the U/D and INC inputs. HIGH to LOW transitions on INC will increment or decrement (depending on the state of the U/D input) a seven-bit counter. The output of this counter is decoded to select one of one-hundred wiper positions along the resistive array.

The wiper, when at either fixed terminal, acts like its mechanical equivalent and does not move beyond the last position. That is, the counter does not wrap around when clocked to either extreme.

The value of the counter is stored in nonvolatile memory whenever CS transitions HIGH while the INC input is also HIGH.

When the X9C102/103/104/503 is powered-down, the last counter position stored will be maintained in the nonvolatile memory. When power is restored, the contents of the memory are recalled and the counter is reset to the value last stored.

OPERATION NOTES

The system may select the X9C102/103/104/503, move the wiper, and deselect the device without having to store the latest wiper, position in nonvolatile memory. The wiper movement is performed as described above; once the new position is reached, the system would keep INC LOW while taking CS HIGH. The new wiper position would be maintained until changed by the system or until a power-down/up cycle recalled the previously stored data.

This would allow the system to always power-up to a preset value stored in nonvolatile memory; then during system operation minor adjustments could be made. The adjustments might be based on user preference: system parameter changes due to temperature drift, etc...

The state of U/D may be changed while CS remains LOW. This allows the host system to enable the X9C102/103/104/503 and then move the wiper up and down until the proper trim is attained.

\( T_{IW}/R_{TOTAL} \)

The electronic switches on the X9C102/103/104/503 operate in a "make before break" mode when the wiper changes tap positions. If the wiper is moved several positions, multiple taps are connected to the wiper for \( t_{IW} \) (INC to \( V_W \) change). The \( R_{TOTAL} \) value for the device can temporarily be reduced by a significant amount if the wiper is moved several positions.

\( R_{TOTAL} \) with \( V_{CC} \) Removed

The end to end resistance of the array will fluctuate once \( V_{CC} \) is removed.

SYMBOL TABLE

<table>
<thead>
<tr>
<th>WAVEFORM</th>
<th>Must be steady</th>
<th>Will be steady</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May change from LOW to HIGH</td>
<td>Will change from LOW to HIGH</td>
</tr>
<tr>
<td></td>
<td>May change from HIGH to LOW</td>
<td>Will change from HIGH to LOW</td>
</tr>
<tr>
<td></td>
<td>Don’t Care: Changes Allowed</td>
<td>Changing: State Not Known</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Center Line is High</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Impedance</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

| SYMBOLS     | |
|-------------| |
|             | |
|             | |
|             | |
|             | |
|             | |

3
**ABSOLUTE MAXIMUM RATINGS***

Temperature under Bias .................. –65°C to +135°C
Storage Temperature ....................... –65°C to +150°C
Voltage on CS, INC, U/D and VCC
  with Respect to VSS ............................... –1V to +7V
Voltage on \( V_H \) and \( V_L \)
  Referenced to VSS ................................. –8V to +8V
\( \Delta V = |V_H - V_L| \)
  X9C102 ............................................................. 4V
  X9C103, X9C503, and X9C104 ...................... 10V
Lead Temperature (Soldering, 10 seconds).... +300°C
Wiper Current .................................................... ±1mA

*COMMENT

Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and the functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**ANALOG CHARACTERISTICS**

**Electrical Characteristics**

End-to-End Resistance Tolerance .................... ±20%
Power Rating at 25°C
  X9C102 ....................................................... 16mW
  X9C103, X9C503, and X9C104 .................. 10mW
Wiper Current .................................................... ±1mA Max.
Typical Wiper Resistance ......................... 40Ω at 1mA
Typical Noise .............................................. < –120dB/√Hz Ref: 1V

**Resolution**

Resistance ............................................................. 1%

**Linearity**

Absolute Linearity\(^{(1)}\) ....................................... ±1.0 Ml\(^{(2)}\)
Relative Linearity\(^{(3)}\) ....................................... ±0.2 Ml\(^{(2)}\)

**Temperature Coefficient**

\((-40°C \text{ to } +85°C)\)
  X9C102 ....................................................... +600 ppm/°C Typical
  X9C103, X9C503, X9C104 ...................... +300 ppm/°C Typical

**Ratiometric Temperature Coefficient**

±20 ppm

**Wiper Adjustability**

Unlimited Wiper Adjustment (Non-Store operation)
Wiper Position Store Operations ................. 10,000 Data Changes

**Physical Characteristics**

Marking Includes
  Manufacturer’s Trademark
  Resistance Value or Code
  Date Code

**Test Circuit #1**

![Test Circuit #1 Diagram]

**Notes:**

1. Absolute Linearity is utilized to determine actual wiper voltage versus expected voltage
   \( (V_{w(n)}(\text{actual}) - V_{w(n)}(\text{expected})) = \pm 1 \text{ Ml Maximum.} \)
2. 1 Ml = Minimum Increment = \( \frac{R_{TOT}}{99} \).
3. Relative Linearity is a measure of the error in step size between taps = \( V_{W(n+1)} - [V_{W(n)} + \text{MI}] = \pm 0.2 \text{ Ml.} \)
## RECOMMENDED OPERATING CONDITIONS

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>0°C</td>
<td>+70°C</td>
</tr>
<tr>
<td>Industrial</td>
<td>–40°C</td>
<td>+85°C</td>
</tr>
<tr>
<td>Military</td>
<td>–55°C</td>
<td>+125°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supply Voltage</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>X9C102/103/104/503</td>
<td>5V ±10%</td>
</tr>
</tbody>
</table>

## D.C. OPERATING CHARACTERISTICS

(Over recommended operating conditions unless otherwise specified.)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Limits</th>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Typ.(4)</td>
</tr>
<tr>
<td>I&lt;sub&gt;CC&lt;/sub&gt;</td>
<td>V&lt;sub&gt;CC&lt;/sub&gt; Active Current</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>I&lt;sub&gt;SB&lt;/sub&gt;</td>
<td>Standby Supply Current</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>I&lt;sub&gt;L&lt;/sub&gt;</td>
<td>CS, INC, U/D Input Leakage Current</td>
<td>±10</td>
<td>μA</td>
</tr>
<tr>
<td>V&lt;sub&gt;IH&lt;/sub&gt;</td>
<td>CS, INC, U/D Input HIGH Voltage</td>
<td>2</td>
<td>V&lt;sub&gt;CC&lt;/sub&gt; + 1</td>
</tr>
<tr>
<td>V&lt;sub&gt;IL&lt;/sub&gt;</td>
<td>CS, INC, U/D Input LOW Voltage</td>
<td>–1</td>
<td>0.8</td>
</tr>
<tr>
<td>R&lt;sub&gt;W&lt;/sub&gt;</td>
<td>Wiper Resistance</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>V&lt;sub&gt;H&lt;/sub&gt;</td>
<td>VH Terminal Voltage</td>
<td>–5</td>
<td>+5</td>
</tr>
<tr>
<td>V&lt;sub&gt;L&lt;/sub&gt;</td>
<td>VL Terminal Voltage</td>
<td>–5</td>
<td>+5</td>
</tr>
<tr>
<td>C&lt;sub&gt;IN&lt;/sub&gt;(5)</td>
<td>CS, INC, U/D Input Capacitance</td>
<td>10</td>
<td>pF</td>
</tr>
</tbody>
</table>

## STANDARD PARTS

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Maximum Resistance</th>
<th>Wiper Increments</th>
<th>Minimum Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X9C102</td>
<td>1KΩ</td>
<td>10.1Ω</td>
<td>40Ω</td>
</tr>
<tr>
<td>X9C103</td>
<td>10KΩ</td>
<td>101Ω</td>
<td>40Ω</td>
</tr>
<tr>
<td>X9C503</td>
<td>50KΩ</td>
<td>505Ω</td>
<td>40Ω</td>
</tr>
<tr>
<td>X9C104</td>
<td>100KΩ</td>
<td>1010Ω</td>
<td>40Ω</td>
</tr>
</tbody>
</table>

**Notes:**

(4) Typical values are for T<sub>A</sub> = 25°C and nominal supply voltage.

(5) This parameter is periodically sampled and not 100% tested.
A.C. CONDITIONS OF TEST

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Pulse Levels</td>
<td>0V to 3V</td>
</tr>
<tr>
<td>Input Rise and Fall Times</td>
<td>10ns</td>
</tr>
<tr>
<td>Input Reference Levels</td>
<td>1.5V</td>
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</table>

MODE SELECTION

<table>
<thead>
<tr>
<th>CS</th>
<th>INC</th>
<th>U/D</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>H</td>
<td>Wiper Up</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
<td>L</td>
<td>Wiper Down</td>
</tr>
<tr>
<td>f</td>
<td>H</td>
<td>X</td>
<td>Store Wiper Position</td>
</tr>
<tr>
<td>H</td>
<td>X</td>
<td>X</td>
<td>Standby Current</td>
</tr>
<tr>
<td>f</td>
<td>L</td>
<td>X</td>
<td>No Store, Return to Standby</td>
</tr>
</tbody>
</table>

A.C. OPERATING CHARACTERISTICS (Over recommended operating conditions unless otherwise specified)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
</tr>
<tr>
<td>tCI</td>
<td>CS to INC Setup</td>
<td>100</td>
</tr>
<tr>
<td>tID</td>
<td>INC HIGH to U/D Change</td>
<td>100</td>
</tr>
<tr>
<td>tDI</td>
<td>U/D to INC Setup</td>
<td>2.9</td>
</tr>
<tr>
<td>tIL</td>
<td>INC LOW Period</td>
<td>1</td>
</tr>
<tr>
<td>tIH</td>
<td>INC HIGH Period</td>
<td>1</td>
</tr>
<tr>
<td>tIC</td>
<td>INC Inactive to CS Inactive</td>
<td>1</td>
</tr>
<tr>
<td>tCPH</td>
<td>CS Deselect Time</td>
<td>20</td>
</tr>
<tr>
<td>tIW</td>
<td>INC to Vw Change</td>
<td>100</td>
</tr>
<tr>
<td>tCYC</td>
<td>INC Cycle Time</td>
<td>4</td>
</tr>
<tr>
<td>tR, tF(7)</td>
<td>INC Input Rise and Fall Time</td>
<td>500</td>
</tr>
<tr>
<td>tPU(7)</td>
<td>Power up to Wiper Stable</td>
<td>500</td>
</tr>
<tr>
<td>tR VCC(7)</td>
<td>VCC Power-up Rate</td>
<td>0.2</td>
</tr>
</tbody>
</table>

A.C. Timing

Notes:
(6) Typical values are for TA = 25°C and nominal supply voltage.
(7) This parameter is periodically sampled and not 100% tested.
(8) MI in the A.C. timing diagram refers to the minimum incremental change in the Vw output due to a change in the wiper position.
Typical Frequency Response for X9C102

TEST CONDITIONS
\[ V_{CC} = 5V \]
Temp. = 25\(^\circ\)C
Wiper @ Tap 50
\[ V_H = 0.5V_{RMS} \]
Normalized (0dB @ 1KHz)
Test Circuit #1

Typical Total Harmonic Distortion for X9C102

TEST CONDITIONS
\[ V_{CC} = 5V \]
Temp. = 25\(^\circ\)C
Wiper @ Tap 50
\[ V_H = 2V_{RMS} \]
Test Circuit #1
Typical Linearity for X9C102

**TEST CONDITIONS**

\( V_{CC} = 5V \)

Temp. = 25°C

Test Circuit #2

**KEY:**
- \( \cdots \cdots \) = ABSOLUTE
- \( \cdot \cdot \cdot \cdot \) = RELATIVE

Typical Frequency Response for X9C103

**TEST CONDITIONS**

\( V_{CC} = 5V \)

Temp. = 25°C

Wiper @ Tap 50

\( V_H = 0.5V_{RMS} \)

Normalized (0dB @ 1KHz)

Test Circuit #1
**Typical Total Harmonic Distortion for X9C103**

**TEST CONDITIONS**

- $V_{CC} = 5V$
- Temp. = 25°C
- Wiper @ Tap 50
- $V_H = 2V_{RMS}$
- Test Circuit #1

![Graph showing THD (%) vs. Frequency in KHz](image)

**Typical Linearity for X9C103**

**TEST CONDITIONS**

- $V_{CC} = 5V$
- Temp. = 25°C
- Test Circuit #2

![Graph showing Percentage Error vs. Wiper Position](image)

**KEY:**

- **-** = ABSOLUTE
- **-** = RELATIVE
**X9C102/103/104/503**

**Typical Frequency Response for X9C503**

![Typical Frequency Response Graph](image)

**TEST CONDITIONS**
- $V_{CC} = 5V$
- Temp. = 25°C
- Wiper @ Tap 50
- $V_H = 0.5V_{RMS}$
- Normalized (0dB @ 1 KHz)
- Test Circuit #1

**Typical Total Harmonic Distortion for X9C503**

![Typical Total Harmonic Distortion Graph](image)

**TEST CONDITIONS**
- $V_{CC} = 5V$
- Temp. = 25°C
- Wiper @ Tap 50
- $V_H = 2V_{RMS}$
- Test Circuit #1
Typical Linearity for X9C503

**TEST CONDITIONS**

- $V_{CC} = 5V$
- Temp. = 25°C
- Test Circuit #2

**KEY:**
- = ABSOLUTE
- = RELATIVE

Typical Frequency Response for X9C104

**TEST CONDITIONS**

- $V_{CC} = 5V$
- Temp. = 25°C
- Wiper @ Tap 50
- $V_H = 0.5V_{RMS}$
- Normalized (0dB @ 1 KHz)
- Test Circuit #1
Typical Total Harmonic Distortion for X9C104

TEST CONDITIONS
V\textsubscript{CC} = 5V
Temp. = 25°C
Wiper @ Tap 50
V\textsubscript{H} = 2V\textsubscript{RMS}
Test Circuit #1

Typical Linearity for X9C104

TEST CONDITIONS
V\textsubscript{CC} = 5V
Temp. = 25°C
Test Circuit #2

KEY:

\begin{itemize}
  \item \textbullet\textcopyright\textbullet\textcopyright\textbullet\textcopyright = ABSOLUTE
  \item \textbullet\textcopyright\textbullet\textcopyright\textbullet\textcopyright = RELATIVE
\end{itemize}
PACKAGING INFORMATION

8-LEAD PLASTIC DUAL IN-LINE PACKAGE TYPE P

NOTE: ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)
PACKAGING INFORMATION

8-LEAD PLASTIC SMALL OUTLINE GULL WING PACKAGE TYPE S

NOTE: ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)
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LIFE RELATED POLICY
In situations where semiconductor component failure may endanger life, system designers using this product should design the system with appropriate error detection and correction, redundancy and back-up features to prevent such an occurrence.

Xicor’s products are not authorized for use in critical components in life support devices or systems.

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.