XICOR®

Dual Two-wiper Digitally-Controlled (XDCP™) Potentiometer   X9455

FEATURES

- **Dual Two-wiper solid state potentiometer**
- **256 Resistor tap points–0.4% resolution**
- **2-wire serial interface for Write, Read, and transfer operations of the potentiometer**
- **Up/Down interface for individual potentiometer wipers**
- **Wiper resistance, 40Ω typical**
- **Non-volatile storage of wiper positions**
- **Power On Recall Loads saved wiper position on Power Up.**
- **Standby Current < 20µA Max**
- **Maximum Wiper Current: 3mA**
- **V_{CC}: 2.7V to 5.5V operation**
- **2.8kΩ,10kΩ, 50kΩ, 100kΩ version of total pot resistance**
- **Endurance: 100,000 Data changes per bit per register**
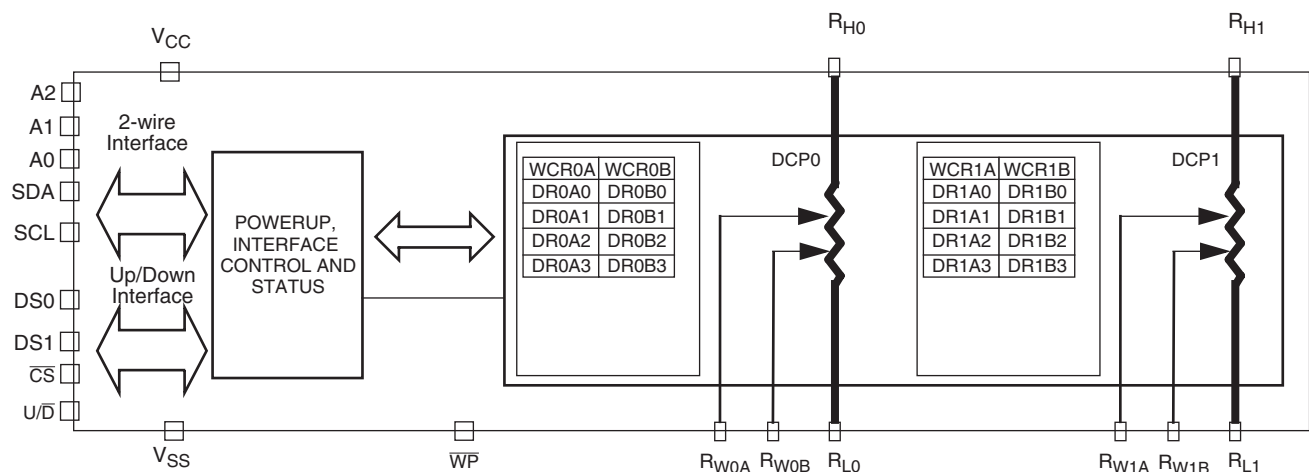- **100 yr. data retention**
- **24-Lead TSSOP**

DESCRIPTION

The X9455 integrates 2 digitally controlled potentiometers (XDCP), each one with dual wipers, on a monolithic CMOS integrated circuit.
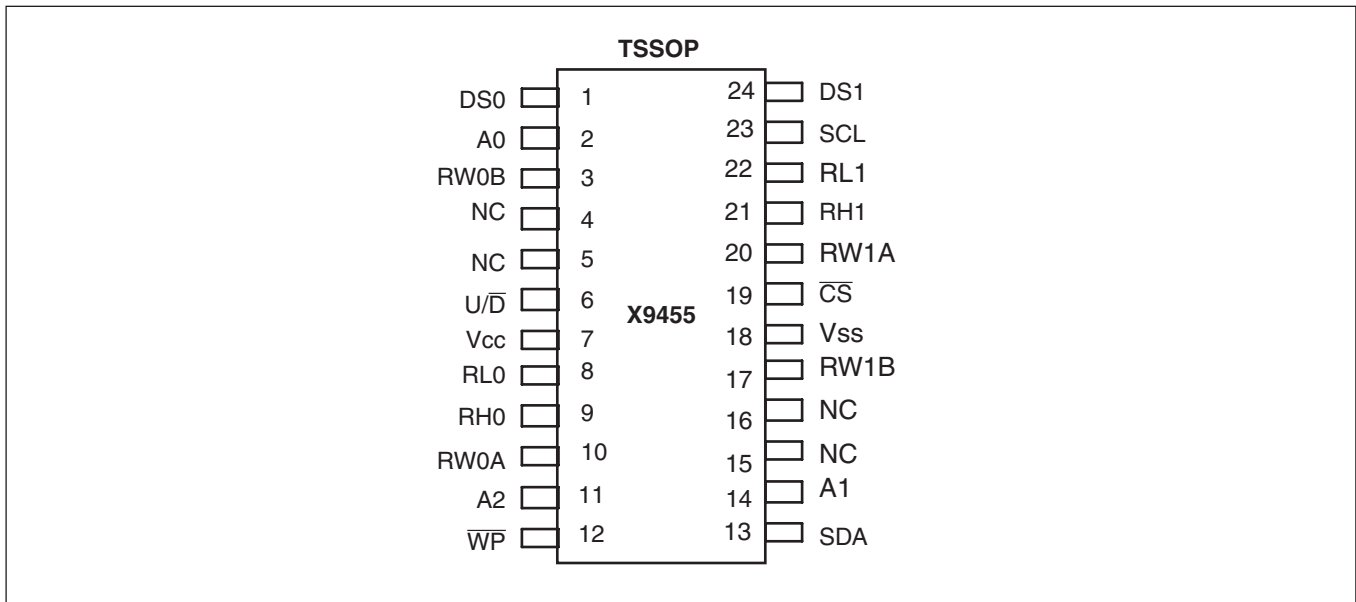
The digitally controlled potentiometer is implemented using 255 resistive elements in a series array. Between each element are tap points connected to wiper terminals through switches. The position of each wiper on the array is controlled by the user through the U/D or 2-wire bus interface. Each potentiometer wiper has associated with it two volatile Wiper Counter Register (WCR) and each WCR has associated with it four nonvolatile Data Registers that can be directly written to and read by the user. The contents of the WCR controls the position of the wiper on the resistor array though the switches. The contents of the default data registers (DR0A0, DR0B0, DR1A0, DR1B0) are loaded into the WCR on power up.

The DCP can be used as a four-terminal potentiometer in a wide variety of applications including the programming of bias voltages, window comparators, and three resistor programmable networks.

FUNCTIONAL DIAGRAM

PIN CONFIGURATION

TSSOP

DS0	1	24	DS1
A0	2	23	SCL
RW0B	3	22	RL1
NC	4	21	RH1
NC	5	20	RW1A
U/$\overline{D}$	6	19	$\overline{CS}$
Vcc	7	18	Vss
RL0	8	17	RW1B
RH0	9	16	NC
RW0A	10	15	NC
A2	11	14	A1
$\overline{WP}$	12	13	SDA

X9455

ORDERING INFORMATION

Ordering Number	RTOTAL	Package	Operating Temperature Range
X9455YV24-2.7	2.8kΩ	24-lead TSSOP	0°C to 70°C
X9455YV24I-2.7	2.8kΩ	24-lead TSSOP	-40°C to +85°C
X9455WV24-2.7	10kΩ	24-lead TSSOP	0°C to 70°C
X9455WV24I-2.7	10kΩ	24-lead TSSOP	-40°C to +85°C
X9455UV24-2.7	50kΩ	24-lead TSSOP	0°C to 70°C
X9455UV24I-2.7	50kΩ	24-lead TSSOP	-40°C to +85°C
X9455TV24-2.7	100kΩ	24-lead TSSOP	0°C to 70°C
X9455TV24I-2.7	100kΩ	24-lead TSSOP	-40°C to +85°C

PIN ASSIGNMENTS

TSSOP pin	Symbol	Brief Description
1	DS0	Wiper Selection input for Up/Down interface
2	A0	Device Address for 2-wire interface
3	RW0B	Second Wiper Terminal of DCP0
4	NC	No Connect
5	NC	No Connect
6	U/$\overline{\text{D}}$	Increment/Decrement for Up/Down interface
7	VCC	System Supply Voltage
8	RL0	Low Terminal of DCP0
9	RH0	High Terminal of DCP0
10	RW0A	First Wiper Terminal of the DCP0
11	A2	Device Address for 2-wire interface
12	$\overline{\text{WP}}$	Hardware Write Protect (Active low)
13	SDA	Serial Data Input/Output for 2-wire interface
14	A1	Device Address for 2-wire interface
15	NC	No Connect
16	NC	No Connect
17	RW1B	Second Wiper Terminal of DCP1
18	VSS	System Ground
19	$\overline{\text{CS}}$	Chip select for Up/Down interface
20	RW1A	First Wiper Terminal of DCP1
21	RH1	High Terminal of DCP1
22	RL1	Low Terminal of DCP1
23	SCL	Serial Clock for 2-wire interface
24	DS1	Wiper selection input for Up/Down interface

ABSOLUTE MAXIMUM RATINGS

Junction Temperature under bias ......–65°C to +135°C
Storage temperature ....–65°C to +150°C
Voltage at any digital interface pin
    with respect to V_{SS}.................................–1V to +7V
V_{CC} ....–1V to +7V
Voltage at any DCP pin with
    respect to V_{SS}...-1V to V_{CC}
Lead temperature (soldering, 10 seconds)........300°C
I_W (10 seconds) .... ±6mA

COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only; 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.

RECOMMENDED OPERATING CONDITIONS

Temp	Min.	Max.
Commercial	0°C	+70°C
Industrial	–40°C	+85°C

Device	Supply Voltage (V_{CC})[4] Limits
X9455	2.7V to 5.5V

ANALOG CHARACTERISTICS
(Over recommended operating conditions unless otherwise stated.)

Symbol	Parameter	Limits			Unit	Test Conditions
		Min.	Typ.[4]	Max.		
R_{TOTAL}	End to end resistance		2.8, 10, 50, 100		kΩ	Y, W, U, T versions respectively
	End to end resistance tolerance	-20		+20	%	
	Power rating			50	mW	25°C, each DCP
R_{TOTAL} Matching	DCP to DCP resistance matching		0.75	2.0	%	
I_W[5]	Wiper current	-3.0		+3.0	mA	See test circuit
R_W	Wiper resistance		50	150	Ω	Wiper current = $\dfrac{V_{CC}}{R_{TOTAL}}$
V_{TERM}	Voltage on any DCP pin	Vss		Vcc	V	
	Noise[5]		-120		dBV	Ref: 1kHz
	Resolution		0.4		%	
	Absolute linearity[1]	−1		+1	MI[3]	
	Relative linearity[2]	−0.3		+0.3	MI[3]	
	Temperature coefficient of resistance[5]		±300		ppm/°C	$V(R_{H0})=V(R_{H1})=V_{CC}$ $V(R_{L0})=V(R_{L1})=V_{SS}$
	Ratiometric Temperature[5] Coefficient	−20		+20	ppm/°C	
$C_H/C_L/C_W$	Potentiometer Capacitance[5]		10/10/25		pF	See equivalent circuit
I_{OL}	Leakage on DCP pins		0.1	10	µA	Voltage at pin from V_{SS} to V_{CC}

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

Symbol	Parameter	Limits			Test Conditions
		Min.	Max.	Units	
I_{CC1}	V_{CC} supply current (Volatile write/read)		3	mA	f_{SCL} = 400kHz; SDA = Open; (for 2-Wire, Active, Read and Volatile Write States only)
I_{CC2}	V_{CC} supply current (active)		3	mA	f_{SCL} = 200kHz; (for U/$\overline{D}$ interface, increment, decrement)
I_{CC3}	V_{CC} supply current (nonvolatile write)		5	mA	f_{SCL} = 400kHz; SDA = Open; (for 2-Wire, Active, Nonvolatile Write State only)
I_{SB}	V_{CC} current (standby)		20	μA	V_{CC} = +5.5V; V_{IN} = V_{SS} or V_{CC}; SDA = V_{CC}; (for 2-Wire, Standby State only)
I_L	Leakage current, bus interface pins	-10	10	μA	Voltage at pin from V_{SS} to V_{CC}
V_{IH}	Input HIGH voltage	V_{CC} x 0.7	V_{CC} + 1	V	
V_{IL}	Input LOW voltage	−1	V_{CC} x 0.3	V	
V_{OL}	SDA pin output LOW voltage		0.4	V	I_{OL} = 3mA

ENDURANCE AND DATA RETENTION

Parameter	Min.	Units
Minimum endurance	100,000	Data changes per bit
Data retention	100	Years

CAPACITANCE

Symbol	Test	Max.	Units	Test Conditions
$C_{IN/OUT}$[5]	Input / Output capacitance (SDA)	8	pF	V_{OUT} = 0V
C_{IN}[5]	Input capacitance (DS0, DS1, $\overline{CS}$, U/$\overline{D}$, SCL, $\overline{WP}$, A2, A1 and A0)	6	pF	V_{IN} = 0V

POWER-UP TIMING

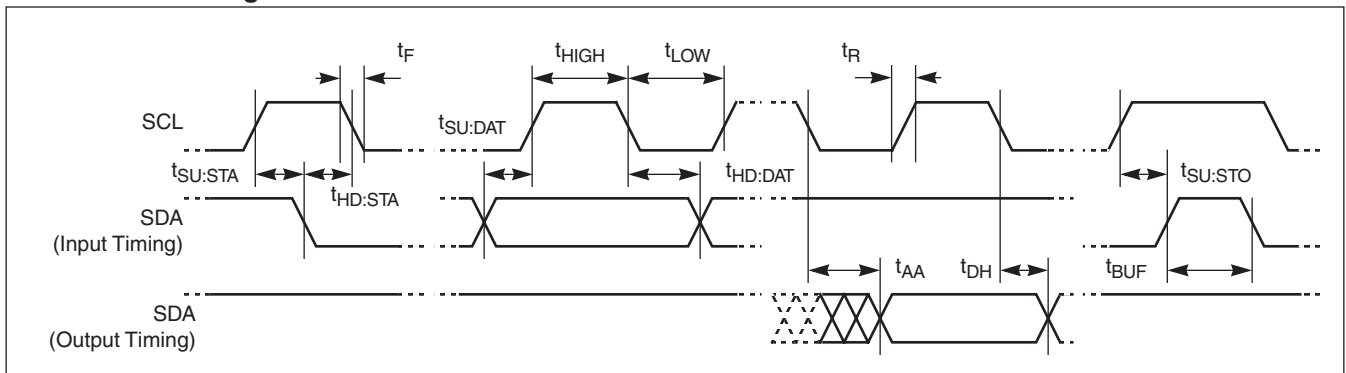| Symbol	Parameter	Max.	Units
t_D[5][9]	Power Up Delay from V_{CC} power up (V_{CC} above 2.7V) to wiper position recall completed, and communication interfaces ready for operation.	2	ms

A.C. TEST CONDITIONS

Input Pulse Levels	V_{CC} x 0.1 to V_{CC} x 0.9
Input rise and fall times	10ns
Input and output timing threshold level	V_{CC} x 0.5
External load at pin SDA	2.3kΩ to V_{CC} and 100 pF to V_{SS}

2-WIRE INTERFACE TIMING(S)

Symbol	Parameter	Min.	Max.	Units
f_{SCL}	Clock Frequency		400	kHz
t_{HIGH}	Clock High Time	600		ns
t_{LOW}	Clock Low Time	1300		ns
$t_{SU:STA}$	Start Condition Setup Time	600		ns
$t_{HD:STA}$	Start Condition Hold Time	600		ns
$t_{SU:STO}$	Stop Condition Setup Time	600		ns
$t_{SU:DAT}$	SDA Data Input Setup Time	100		ns
$t_{HD:DAT}$	SDA Data Input Hold Time	30		ns
t_R[5]	SCL and SDA Rise Time		300	ns
t_F[5]	SCL and SDA Fall Time		300	ns
t_{AA}[5]	SCL Low to SDA Data Output Valid Time		0.9	µs
t_{DH}	SDA Data Output Hold Time	0		ns
t_{IN}[5]	Pulse Width Suppression Time at SCL and SDA inputs		50	ns
t_{BUF}[5]	Bus Free Time (Prior to Any Transmission)	1200		ns
$t_{SU:WPA}$[5]	A0, A1, A2 and $\overline{WP}$ Setup Time	600		ns
$t_{HD:WPA}$[5]	A0, A1, A2 and $\overline{WP}$ Hold Time	600		ns

SDA vs. SCL Timing

$\overline{WP}$, A0, A1, and A2 Pin Timing
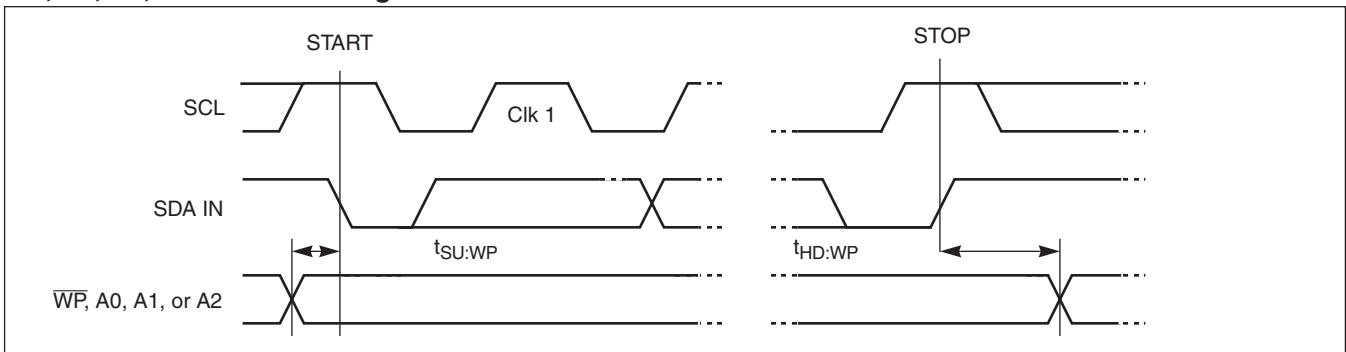
INCREMENT/DECREMENT TIMING

Symbol	Parameter	Min.	Typ.[4]	Max.	Units
t_{CI}	$\overline{CS}$ to SCL Setup	600			ns
t_{ID}[5]	SCL HIGH to U/$\overline{D}$, DS0 or DS1 change	600			ns
t_{DI}[5]	U/$\overline{D}$, DS0 or DS1 to SCL setup	600			ns
t_{IL}	SCL LOW period	2.5			µs
t_{IH}	SCL HIGH period	2.5			µs
t_{IC}	SCL inactive to $\overline{CS}$ inactive (Nonvolatile Store Setup Time)	1			µs
t_{CPHS}	$\overline{CS}$ deselect time (STORE)	10			ms
t_{CPHNS}[5]	$\overline{CS}$ deselect time (NO STORE)	1			µs
t_{IW}[5]	SCL to R_W change		100	500	µs
t_{CYC}	SCL cycle time	5			µs
t_R, t_F[5]	SCL input rise and fall time			500	µs

Increment/Decrement Timing
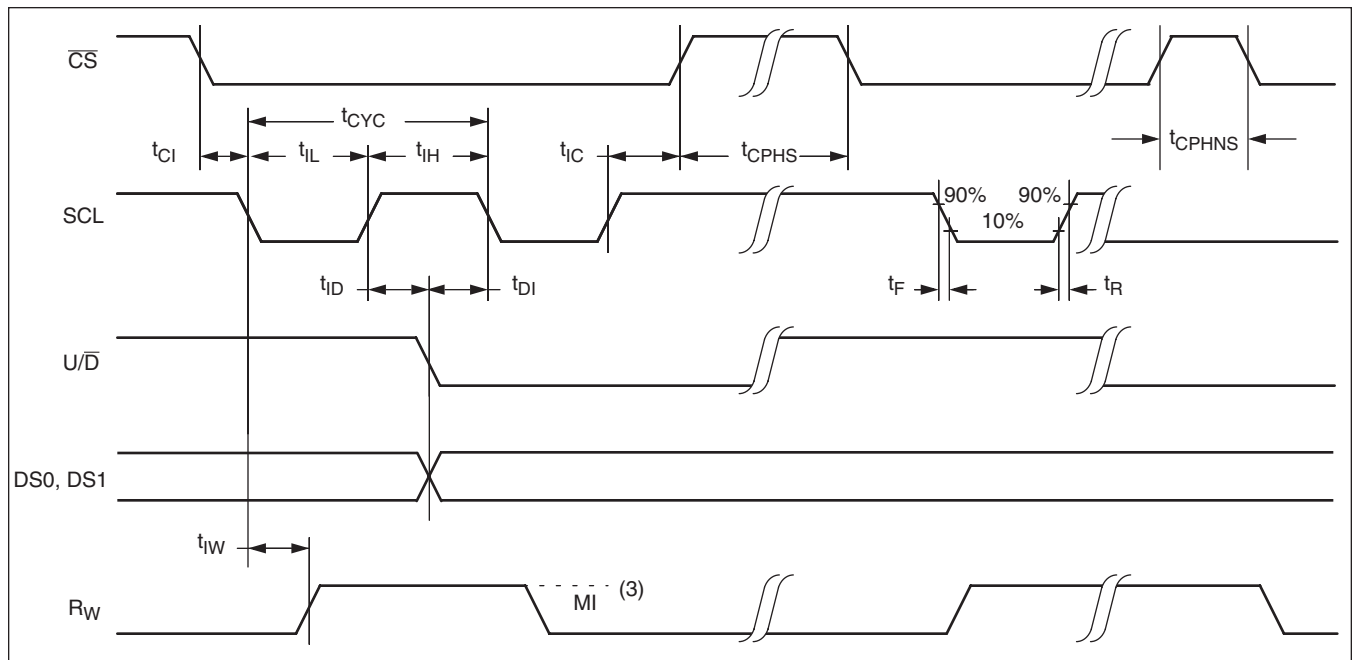
HIGH-VOLTAGE WRITE CYCLE TIMING

Symbol	Parameter	Typ.	Max.	Units
t_{WC}[8][5]	Non-volatile write cycle time	5	10	ms

XDCP TIMING

Symbol	Parameter	Min.	Max.	Units
t_{WRL}[5]	SCL rising edge to wiper code changed, wiper response time after instruction issued (all load instructions)	5	20	µs

Notes: (1) Absolute linearity is utilized to determine actual wiper voltage versus expected voltage = $[V(R_{W(n)(actual)}) - V(R_{W(n)(expected)})]/MI$
$V(R_{W(n)(expected)}) = n(V(R_H) - V(R_L))/255 + V(R_L)$, with n from 0 to 255.

(2) Relative linearity is a measure of the error in step size between taps = $[V(R_{W(n+1)}) - (V(R_{W(n)}) + MI)]/MI$, with n from 0 to 254

(3) 1 MI = Minimum Increment = $[V(R_H) - V(R_L)]/255$.

(4) Typical values are for $T_A = 25°C$ and nominal supply voltage.

(5) This parameter is not 100% tested.

(6) Ratiometric temperature coefficient = $(V(R_W)_{T1(n)} - V(R_W)_{T2(n)})/[V(R_W)_{T1(n)}(T1 - T2)] \times 10^6$, with T1 & T2 being 2 temperatures, and n from 0 to 255.

(7) Measured with wiper at tap position 255, R_L grounded, using test circuit.

(8) t_{WC} is the minimum cycle time to be allowed for any nonvolatile write by the user, unless Acknowledge Polling is used. It is the time from a valid STOP condition at the end of a write sequence of a 2-wire interface write operation, or from the rising edge of $\overline{CS}$ of a valid "Store" operation of the Up/Down interface, to the end of the self-timed internal nonvolatile write cycle.

(9) The recommended power up sequence is to apply V_{CC}/V_{SS} first, then the potentiometer voltages. During power up, the data sheet parameters for the DCP do not fully apply until t_D after V_{CC} reaches its final value. In order to prevent unwanted tap position changes, or an inadvertant store, bring the $\overline{CS}$ pin high before or concurrently with the V_{CC} pin on power up.

Test Circuit
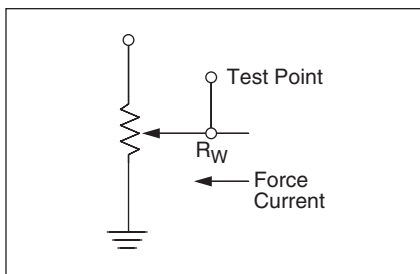
Equivalent Circuit
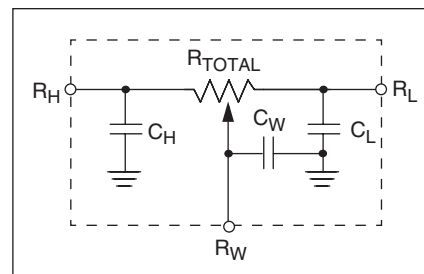
PIN DESCRIPTIONS

Bus Interface Pins

SERIAL DATA INPUT/OUTPUT (SDA)

The SDA is a bidirectional serial data input/output pin for the 2-wire interface. It receives device address, operation code, wiper register address and data from a 2-wire external master device at the rising edge of the serial clock SCL, and it shifts out data after each falling edge of the serial clock SCL.

SDA requires an external pull-up resistor, since it's an open drain output.

SERIAL CLOCK (SCL)

This input is the serial clock of the 2-wire and Up/Down interface.

DEVICE ADDRESS (A2–A0)

The Address inputs are used to set the least significant 3 bits of the 8-bit 2-wire interface slave address. A match in the slave address serial data stream must be made with the Address input pins in order to initiate communication with the X9455. A maximum of 8 devices may occupy the 2-wire serial bus.

CHIP SELECT ($\overline{CS}$)

When the $\overline{CS}$ pin is low, increment or decrement operations are possible using the SCL and U/$\overline{D}$ pins. The 2-wire interface is disabled at this time. When $\overline{CS}$ is high, the 2-wire interface is enabled.

UP OR DOWN CONTROL (U/$\overline{D}$)

The U/$\overline{D}$ input pin is held HIGH during increment operations and held LOW during decrement operations.

DCP SELECT (DS1-DS0)

The DS1-DS0 select one of the four DCPs for an Up/Down interface operation.

HARDWARE WRITE PROTECT INPUT ($\overline{WP}$)

When the $\overline{WP}$ pin is set low, "write" operations to non volatile DCP Data Registers are disabled. This includes both 2-wire interface non-volatile "Write", and Up/Down interface "Store" operations.

DCP Pins

R_{H0}, R_{L0}, R_{H1}, R_{L1}

These pins are equivalent to the terminal connections on mechanical potentiometers. Since there are two DCPs, there is one set of R_H and R_L for each DCP.

R_{W0A}, R_{W0B}, R_{W1A}, AND R_{W1B}

The wiper pins are equivalent to the wiper terminals of mechanical potentiometers. Since there are two wipers per DCP, there are four R_W pins.

PRINCIPLES OF OPERATION

The X9455 is an integrated circuit incorporating two resistor arrays with dual wipers on each array, their associated registers and counters, and the serial interface logic providing direct communication between the host and the digitally controlled potentiometers. This section provides detail description of the following:

– Resistor Array

– Up/Down Interface

– 2-wire Interface

Resistor Array Description

The X9455 is comprised of two resistor arrays. Each array contains 255 discrete resistive segments that are connected in series. The physical ends of each array are equivalent to the fixed terminals of a mechanical potentiometer (R_{Hi} and R_{Li} inputs). (See Figure 1.)

Each array has two independent wipers. At both ends of each array and between each resistor segment are two switches, one connected to each of the wiper pins (R_{WiA} and R_{WiB}).

Within each individual array only one switch of each wiper may be turned on at a time.

These switches are controlled by two Wiper Counter Register (WCR). The 8-bits of the WCR are decoded to select and enable one of 256 switches. Note that each wiper has a dedicated WCR. When all bits of a WCR are zeroes, the switch closest to the corresponding R_L pin is selected. When all bits of a WCR are ones, the switch closest to the corresponding R_H pin is selected.

The WCRs are volatile and may be written directly. There are four non-volatile Data Registers(DR) associated with each WCR. Each DR can be loaded into WCR. All DRs and WCRs can be read or written.

Power Up and Down Requirements

During power up $\overline{CS}$ must be high to avoid inadvertant "store" operations. At power up, the contents of Data Registers Level 0 (DR0A0, DR0B0, DR1A0, and DR1B0), are loaded into the corresponding wiper counter register.

Figure 1. Detailed Block Diagram of one DCP
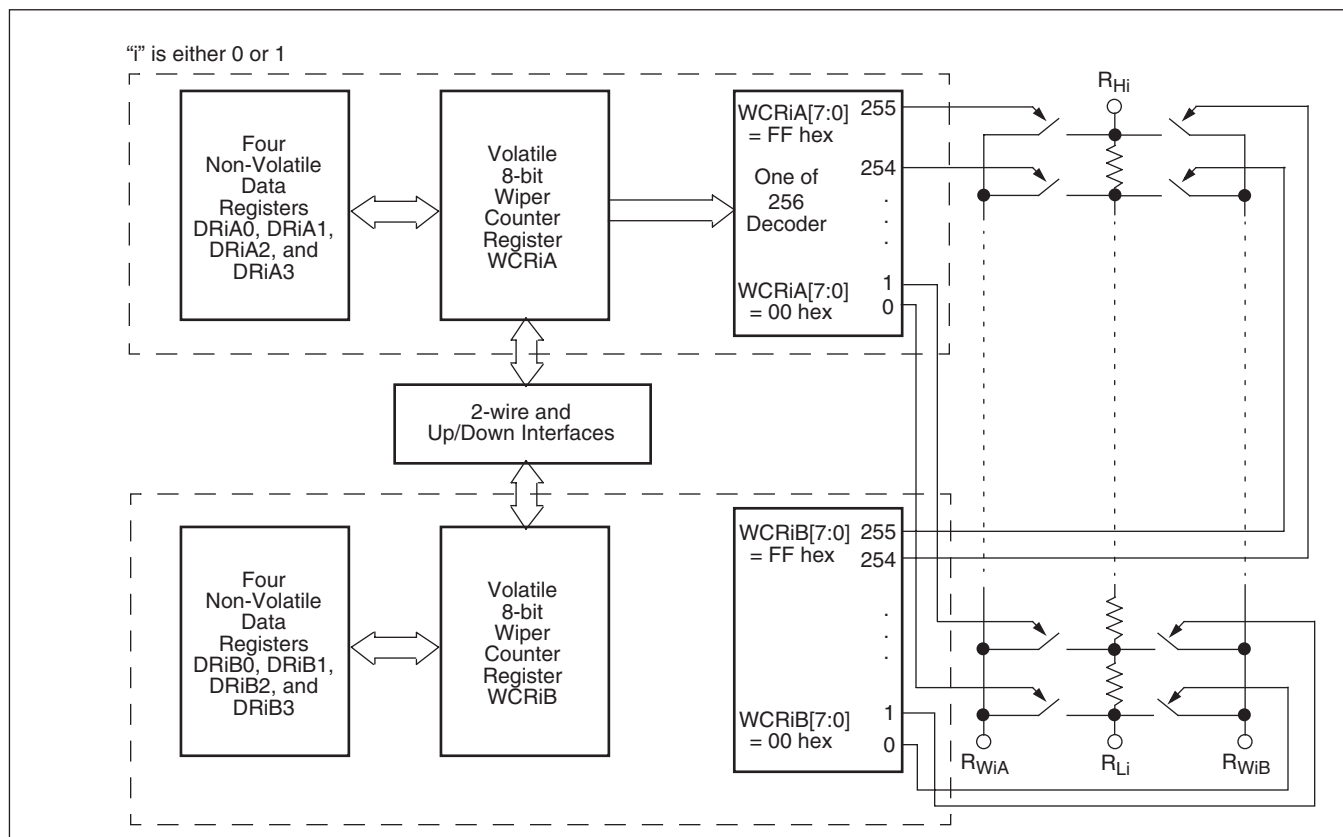
UP/DOWN INTERFACE OPERATION

The SCL, U/$\overline{D}$, $\overline{CS}$, DS0 and DS1 inputs control the movement of the wiper along the resistor array. With $\overline{CS}$ set LOW the device is selected and enabled to respond to the U/$\overline{D}$ and SCL inputs. HIGH to LOW transitions on SCL will increment or decrement (depending on the state of the U/$\overline{D}$ input) a wiper counter register selected by DS0 and DS1. The output of this counter is decoded to select one of 256 wiper positions along the resistor array.

The value of the counter is stored in nonvolatile data register Level 0 of the corresponding WCR whenever $\overline{CS}$ transitions HIGH while the SCL and $\overline{WP}$ inputs are HIGH (See Table 1). During a "Store" operation bits WCRSel1 and WCRSel0 in the status register must be both "0", which is their power up default value. Other combinations are reserved and must not be used.

The system may select the X9455, move a wiper, and deselect the device without having to store the latest wiper position in nonvolatile memory. After the wiper movement is performed as described above and once the new position is reached, the system must keep SCL LOW while taking $\overline{CS}$ HIGH. The new wiper position is maintained until changed by the system or until a power-down/up cycle recalled the previously stored data.

This procedure allows 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 temperaure drift, etc.

The state of U/$\overline{D}$ may be changed while $\overline{CS}$ remains LOW. This allows the host system to enable the device and then move the wiper up and down until the proper trim is attained. The 2-wire interface is disabled while $\overline{CS}$ remains LOW.

Table 1. DCP Selection for Up/Down Control

DS1	DS0	Selected Wiper Control Register
0	0	Wiper A of DCP0
1	1	Wiper B of DCP0
1	0	Wiper A of DCP1
0	1	Wiper B of DCP1

MODE SELECTION FOR UP/DOWN CONTROL

$\overline{CS}$	SCL	U/$\overline{D}$	Mode
L	⌐_	H	Wiper Up
L	⌐_	L	Wiper Down
_/	H	X	Store Wiper Position to non-volatile memory if $\overline{WP}$ pin is high. No store, return to stand-by, if $\overline{WP}$ pin is low.
H	X	X	Standby*
_/	L	X	No Store, Return to Standby
⌐_	L	H	Wiper Up (not recommended)
⌐_	L	L	Wiper Down (not recommended)

*While in Standby, the 2-wire interface is enabled

2-WIRE SERIAL INTERFACE

Protocol Overview

The device supports a bidirectional bus oriented protocol. The protocol defines any device that sends data onto the bus as a transmitter, and the receiving device as the receiver. The device controlling the transfer is called the master and the device being controlled is called the slave. The master always initiates data transfers, and provides the clock for both transmit and receive operations. The X9455 operates as a slave in all applications.

All 2-wire interface operations must begin with a START, followed by a Slave Address byte. The Slave Address selects the X9455, and specifies if a Read or Write operation is to be performed.

All Communication over the 2-wire interface is conducted by sending the MSB of each byte of data first.

Serial Clock and Data

Data states on the SDA line can change only while SCL is LOW. SDA state changes while SCL is HIGH are reserved for indicating START and STOP conditions. See Figure 2. On power up of the X9455, the SDA pin is in the input mode.

Serial Start Condition

All commands are preceded by the START condition, which is a HIGH to LOW transition of SDA while SCL is HIGH. The device continuously monitors the SDA and SCL lines for the START condition and does not respond to any command until this condition has been met. See Figure 2.

Serial Stop Condition

All communications must be terminated by a STOP condition, which is a LOW to HIGH transition of SDA while SCL is HIGH. The STOP condition is also used to place the device into the Standby power mode after a read sequence. A STOP condition can only be issued after the transmitting device has released the bus. See Figure 2.

Figure 2. Valid Data Changes, Start, and Stop Conditions
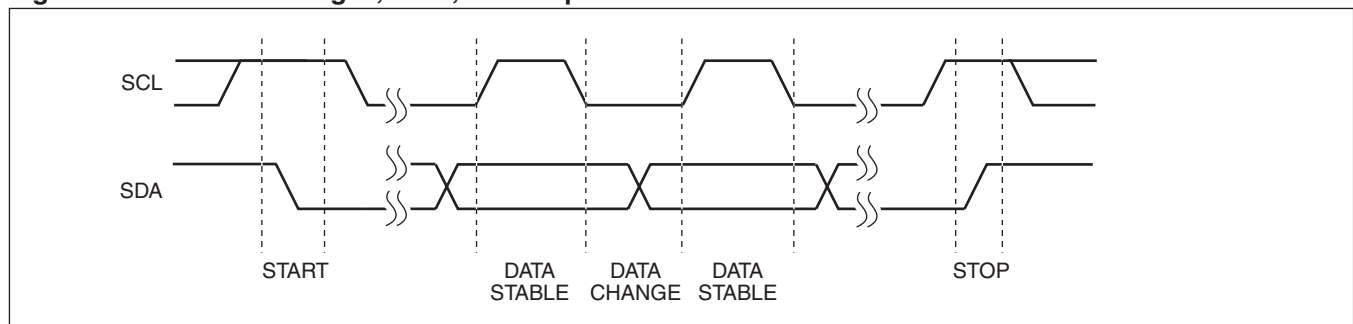
Serial Acknowledge

An ACK (Acknowledge), is a software convention used to indicate a successful data transfer. The transmitting device, either master or slave, releases the bus after transmitting eight bits. During the ninth clock cycle, the receiver pulls the SDA line LOW to acknowledge the reception of the eight bits of data. See Figure 3.

The device responds with an ACK after recognition of a START condition followed by a valid Slave Address byte. A valid Slave Address byte must contain the Device Type Identifier 0101, and the Device Address bits matching the logic state of pins A2, A1, and A0. See Figure 4.

If a write operation is selected, the device responds with an ACK after the receipt of each subsequent eight-bit word.

In the read mode, the device transmits eight bits of data, releases the SDA line, and then monitors the line for an ACK. The device continues transmitting data if an ACK is detected. The device terminates further data transmissions if an ACK is not detected. The master must then issue a STOP condition to place the device into a known state.

Figure 3. Acknowledge Response From Receiver
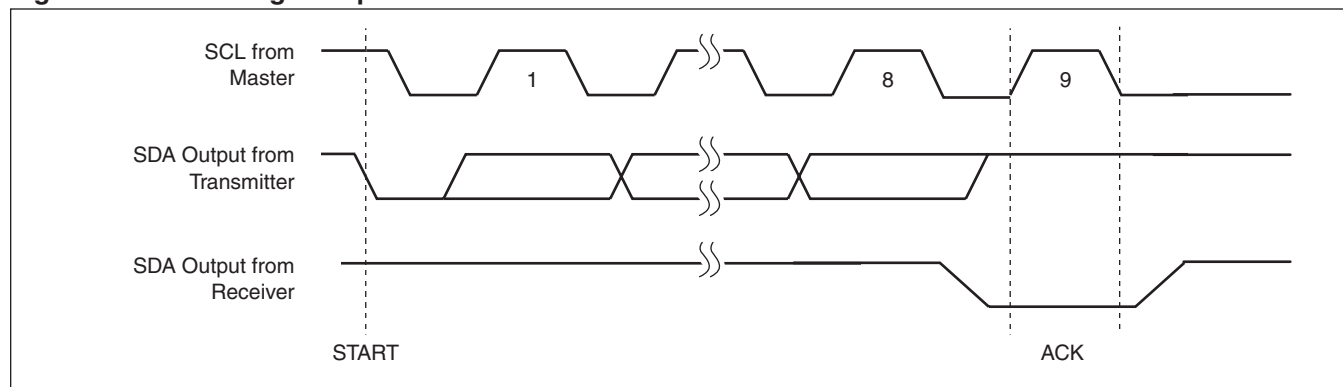
Slave Address Byte

Following a START condition, the master must output a Slave Address Byte (Refer to figure 4.). This byte includes three parts:

– The four MSBs (SA7-SA4) are the Device Type Identifier, which must always be set to 0101 in order to select the X9455.

– The next three bits (SA3-SA1) are the Device Address bits (AS2-AS0). To access any part of the X9455's memory, the value of bits AS2, AS1, and AS0 must correspond to the logic levels at pins A2, A1, and A0 respectively.

– The LSB (SA0) is the $R/\overline{W}$ bit. This bit defines the operation to be performed on the device being addressed. When the $R/\overline{W}$ bit is "1", then a Read operation is selected. A "0" selects a Write operation**.**

Figure 4. Slave Address (SA) Format

Slave Address Bit(s)	Description
SA7–SA4	Device Type Identifier
SA3–SA1	Device Address
SA0	Read or Write Operation Select
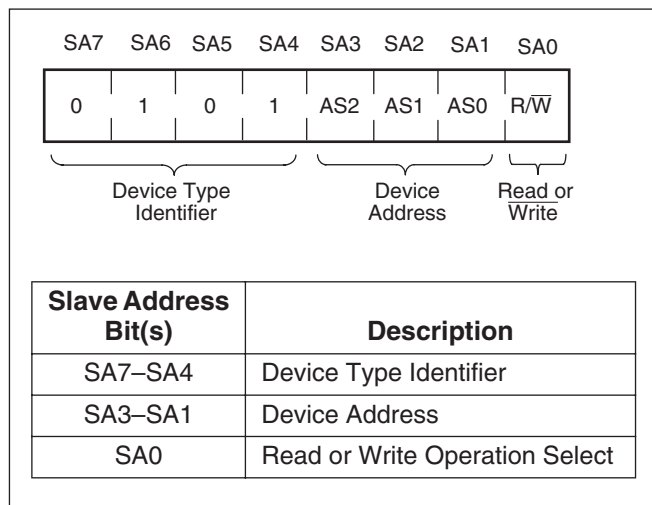
Nonvolatile Write Acknowledge Polling

After a nonvolatile write command sequence is correctly issued (including the final STOP condition), the X9455 initiates an internal high voltage write cycle. This cycle typically requires 5 ms. During this time, any Read or Write command is ignored by the X9455. Write Acknowledge Polling is used to determine whether a high voltage write cycle is completed.

During acknowledge polling, the master first issues a START condition followed by a Slave Address Byte. The Slave Address Byte contains the X9455's Device Type Identifier and Device Address. The LSB of the Slave Address ($R/\overline{W}$) can be set to either 1 or 0 in this case. If the device is busy within the high voltage cycle,

then no ACK is returned. If the high voltage cycle is completed, an ACK is returned and the master can then proceed with a new Read or Write operation. (Refer to figure 5.)

Figure 5. Acknowledge Polling Sequence
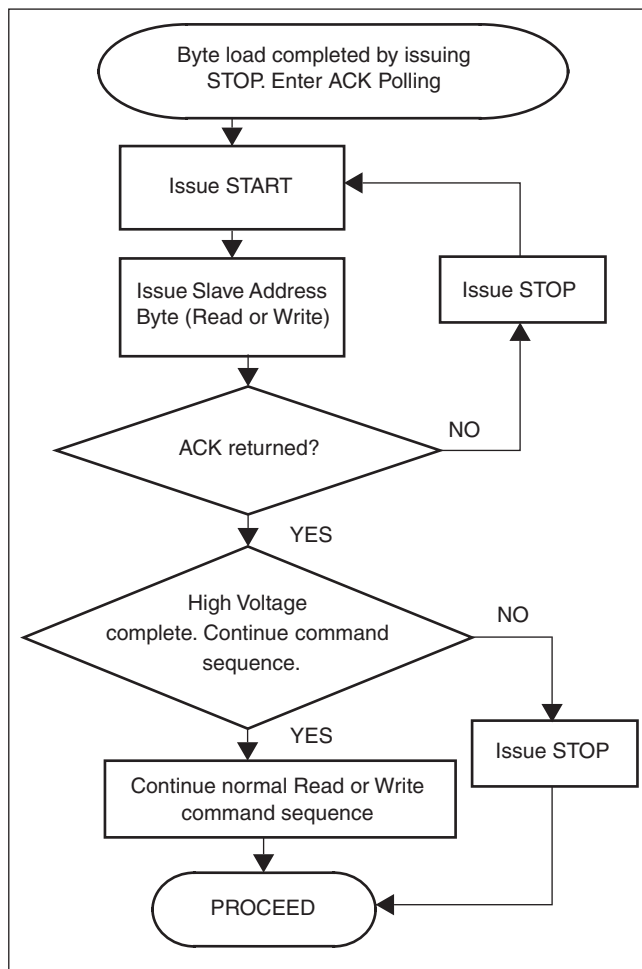
2-WIRE SERIAL INTERFACE OPERATION

X9455 Digital Potentiometer Register Organization

Refer to the Functional Diagram on page 1. There are 2 Digital Potentiometers, referred to as DCP0, and DCP1. Each potentiometer has two volatile Wiper Control Registers (WCRs). Each wiper has four non-volatile registers to store wiper position or general data. See Table 2 for register numbering.

Table 2. Register Numbering

Wiper Reg.	DCP0		DCP1	
	WCR0A	**WCR0B**	**WCR1A**	**WCR1B**
Level 0	DR0A0	DR0B0	DR1A0	DR1B0
Level 1	DR0A1	DR0B1	DR1A1	DR1B1
Level 2	DR0A2	DR0B2	DR1A2	DR1B2
Level 3	DR0A3	DR0B3	DR1A3	DR1B3

The registers are organized in pages of four, with one page consisting of the four volatile WCRs, a second page consisting of the Level 0 Data Registers, and so forth. These pages can be written four bytes at at time. In this manner all four potentiometer WCRs can be updated in a single serial write (see Page Write Operation), as well as all four registers of a given page in the DR array.

The unique feature of the X9455 device is that writing or reading to a Data Register of a given wiper automatically updates the WCR of that wiper with the new value. In this manner data can be moved from a particular wiper register to that wiper's WCR just by performing a 2-wire read operation. Simultaneously, that data byte can be utilized by the host.

Status Register Organization

The Status Register (SR) is used in read and write operations to select the appropriate wiper register. Before any wiper register can be accessed, the SR must be set to the correct value. It is accessed by setting the Address Byte to 07h (Write to slave address, then to address 07h). The SR is volatile and defaults to 00h on power up. It is an 8-bit register containing three control bits in the 3 LSBs as follows:

7	6	5	4	3	2	1	0
Reserved					WCRSel1	WCRSel0	NVEnable

Bits WCRSel0 and WCRSel1 determine which Data Register of a wiper is selected in a given operation. NVEnable is used to select the volatile WCR if "0", and one of the non volatile wiper registers if "1". Table 3 shows this register organization.

Table 3. Status Register Contents for WCR and DR Selection for 2-Wire Interface

Register Selected	WCRSel1	WCRSel0	NVEnable
WCRnn	X	X	0
DRnn0	0	0	1
DRnn1	0	1	1
DRnn2	1	0	1
DRnn3	1	1	1

Note: X means either 0 or 1, nn = 0A, 0B, 1A, or 1B

Wiper Addressing for 2-wire Interface

Once the Data Register Level has been selected by a 2-wire instruction, then the wiper is determined by the Address Byte of the following instruction. Note again that this enables a complete page write of all four potentiometers at once a particular Wiper Register has been chosen. The register addresses accessible in the X9455 include:

Table 4. Addressing for 2-wire Interface Address Byte

Address (hex)	Contents
0	Wiper 0A
1	Wiper 1B
2	Wiper 1A
3	Wiper 0B
4	Not Used
5	Not Used
6	Not Used
7	Status Register

All other address bits in the address byte must be set to "0" during 2-wire write operations and their value should be ignored when read.

Byte Write Operation

For any Byte Write operation, the X9455 requires the Slave Address byte, an Address Byte, and a Data Byte (See Figure 6). After each of them, the X9455 responds with an ACK. The master then terminates the transfer by generating a STOP condition. At this time, if the write operation is to a volatile register (WCR, or SR), the X9455 is ready for the next read or write operation. If the write operation is to a nonvolatile register (DR), and the $\overline{WP}$ pin is high, the X9455 begins the internal write cycle to the nonvolatile memory. During the internal nonvolatile write cycle, the X9455 does not respond to any requests from the master. The SDA output is at high impedance.

The SR bits and $\overline{WP}$ pin determine the register being accessed through the 2-wire interface. See Table 1 on page 11.

As noted before, any write operation to a Data Register (DR), also writes to the corresponding WCR.

For example, to write 3Ahex to the Level 1 Data Register of wiper 1A (DR1A1) the following sequence is required:

START		
Slave Address	0101 0000	(Hardware Address = 000, and a Write command)
ACK		
Address Byte	0000 0111	(Indicates Status Register address)
ACK		
Data Byte	0000 0011	(Data Register Level 1 and NVEnable selected)
ACK		
STOP		
START		
Slave Address	0101 0000	(Hardware address = 000, Write command)
ACK		
Address Byte	0000 0010	(Access Wiper 1A)
ACK		
Data Byte	0011 1010	(Write Data Byte 3Ah)
ACK		
STOP		

During the sequence of this example, $\overline{WP}$ pin must be high, and A0, A1, and A2 pins must be low. When completed, the DR1A1 register of Wiper 1A will be set to 3Ah, and also the WCR1A.

Figure 6. Byte Write Sequence
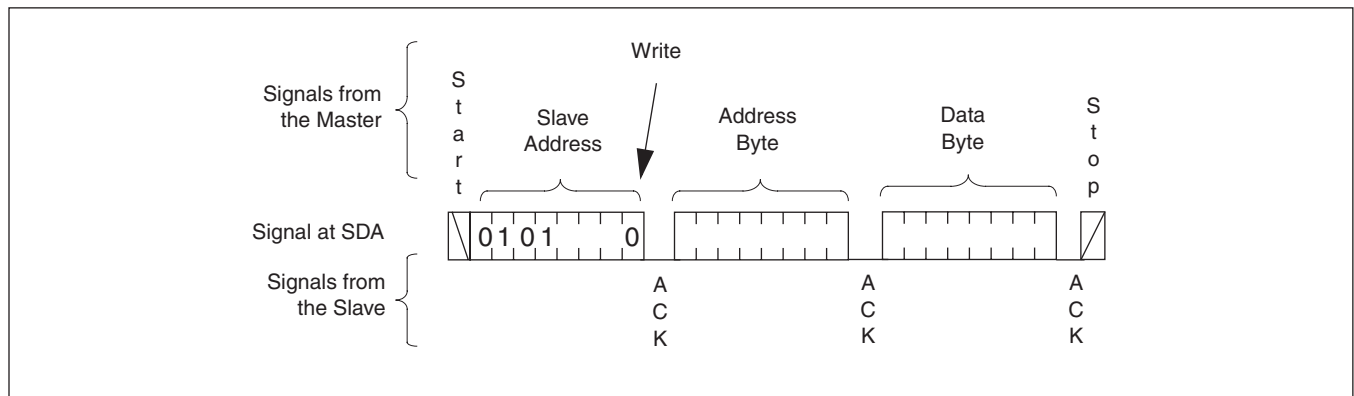
Page Write Operation

As stated previously, the memory is organized as a single Status Register (SR), and four pages of four registers each. Each page contains one Data Register for each wiper. Normally a page write operation will be used to efficiently update all four Data Registers and WCR in a single Write command. Note the special sequence for writing to a page: First wiper 0A, then 1B, then 1A, then 0B as shown in figure 7.

Figure 7. Page Write Sequence*

WCR	WCR0A $\rightarrow$ WCR1B $\rightarrow$ WCR1A $\rightarrow$ WCR0B
DR Level 0	DR0A0 $\rightarrow$ DR1B0 $\rightarrow$ DR1A0 $\rightarrow$ DR0B0
DR Level 1	DR0A1 $\rightarrow$ DR1B1 $\rightarrow$ DR1A1 $\rightarrow$ DR0B1
DR Level 2	DR0A2 $\rightarrow$ DR1B2 $\rightarrow$ DR1A2 $\rightarrow$ DR0B2
DR Level 3	DR0A3 $\rightarrow$ DR1B3 $\rightarrow$ DR1A3 $\rightarrow$ DR0B3

*Page writes may wrap around to the first address on a page from the last address.

In order to perform a Page Write operation to the memory array, the NVEnable bit in the SR must first be set to "1".

A Page Write operation is initiated in the same manner as the Byte Write operation; but instead of terminating the write cycle after the first data byte is transferred, the master can transmit up to 4 bytes (See Figure 8). After the receipt of each byte, the X9455 responds with an ACK, and the internal WCR address is incremented by one. The page address remains constant. When the address reaches the end of the page, it "rolls over" and goes back to the first byte of the same page.

For example, if the master writes three bytes to a page starting at location DR1A2, the first two bytes are written to locations DR1A2 and DR0B2, while the last byte is written to location DR0A2. Afterwards, the WCR address would point to location DR1B2. If the master supplies more than four bytes of data, then new data overwrites the previous data, one byte at a time.

The master terminates the loading of Data Bytes by issuing a STOP condition, which initiates the nonvolatile write cycle. As with the Byte Write operation, all inputs are disabled until completion of the internal write cycle. If the $\overline{WP}$ pin is high, the nonvolatile write cycle doesn't start and the bytes are discarded.

Notice that the Data Bytes are also written to the WCR of the corresponding WCRs, therefore in the above example, WCR1A, WCR0B, and WCR0A are also written.

Figure 8. Page Write Operation
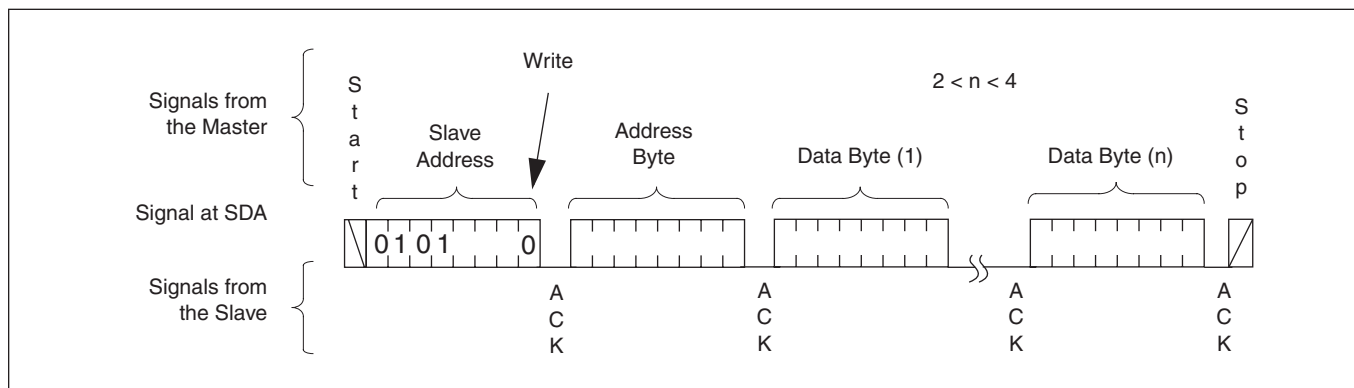
Move/Read Operation

The Move/Read operation simultaneously reads the contents of a data register and moves the contents into the corresponding DCP's WCR. If more than one data register byte is read, then all wipers accessed will have their WCR's updated with the data register values that were read. Move/Read operation consists of a one byte, or three byte instruction followed by one or more Data Bytes (See Figure 9). To read an arbitrary byte, the master initiates the operation issuing the following sequence: a START, the Slave Address byte with the R/$\overline{W}$ bit set to "0", an Address Byte, a second START, and a second Slave Address byte with the R/W bit set to "1". After each of the three bytes, the X9455 responds with an ACK. Then the X9455 transmits Data

Bytes as long as the master responds with an ACK during the SCL cycle following the eighth bit of each byte. The master terminates the Move/Read operation (issuing a STOP condition) following the last bit of the last Data Byte.

The first byte being read is determined by the current wiper address and by the Status Register bits, according to Table 1 on page 11. If more than one byte is read, the WCR address is incremented by one after each byte, in the same way as during a Page Write operation. After reaching WCR0B, the WCR address "rolls over" to WCR0A.

On power up, the Address pointer is set to the Data Register 0 of WCR0A.

Figure 9. Move/Read Sequence
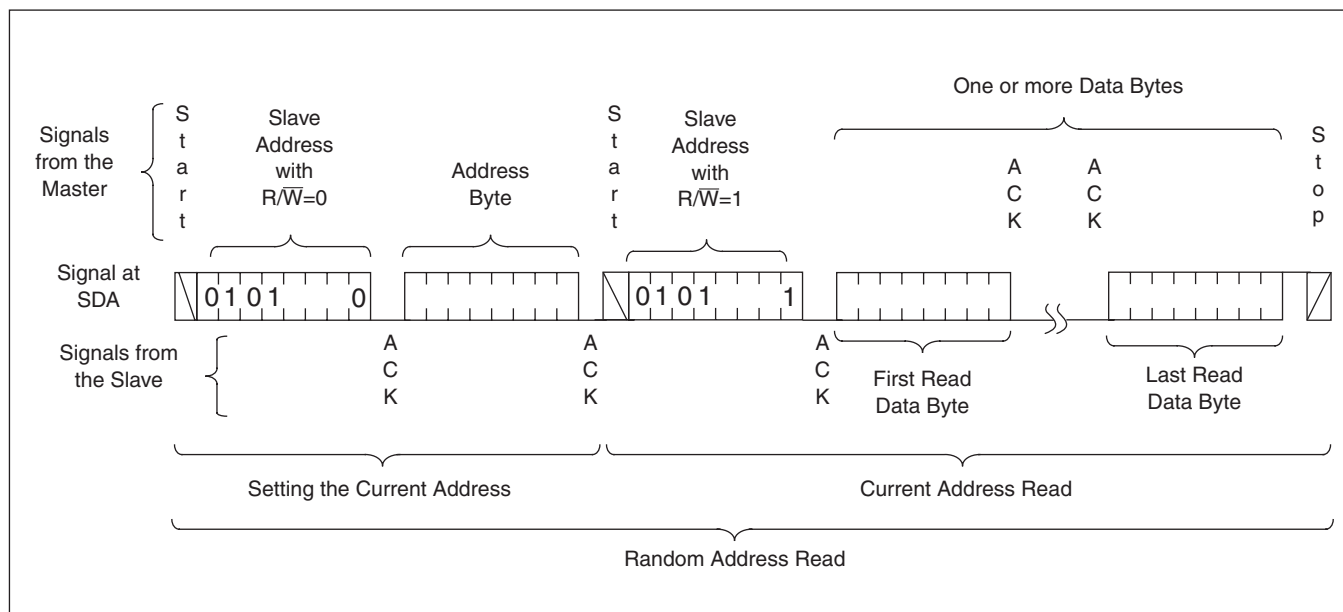
APPLICATIONS INFORMATION

Basic Configurations of Electronic Potentiometers
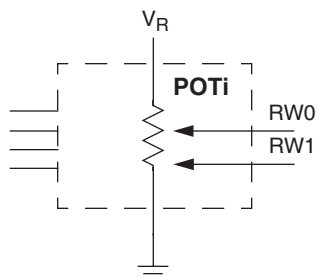
Four terminal Potentiometer;
Variable voltage divider
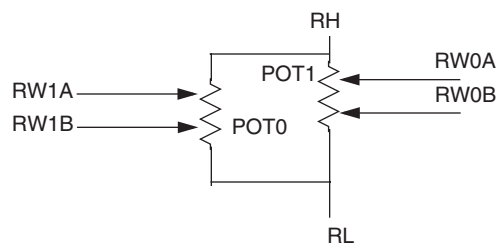
Four-Wiper DCP

Application Circuits
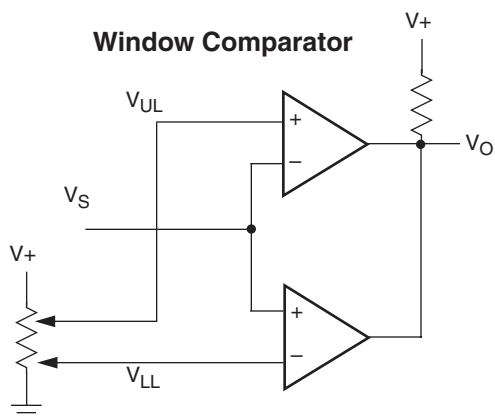
Window Comparator
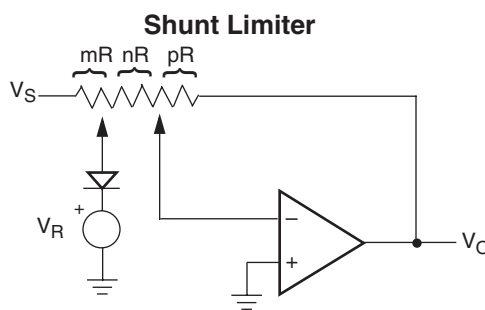
Shunt Limiter
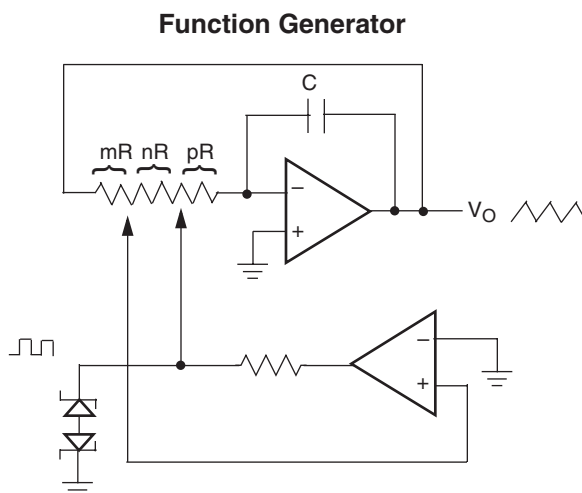
Function Generator

Programmable State Variable Filter
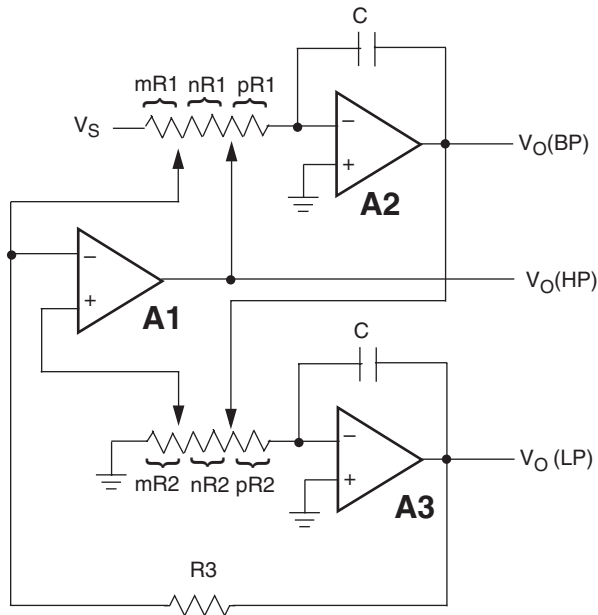
Programmable Ladder Networks
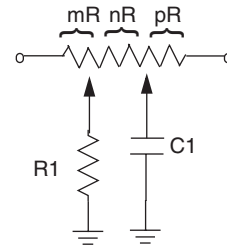
Wien Bridge Oscillator
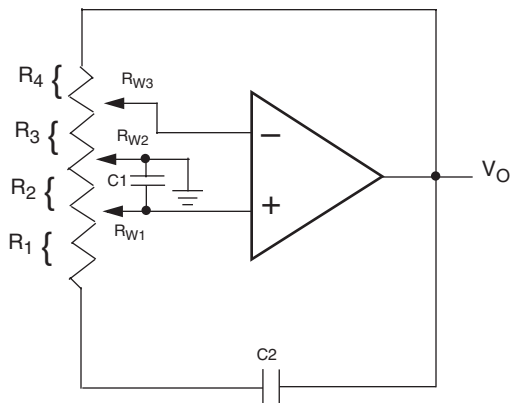
Generalized Impedance Converter

$$Z_{IN} = \frac{Z_1}{Z_2} * \left(\frac{R_3 * R_5}{R_4}\right)$$

Two Wiper DCP
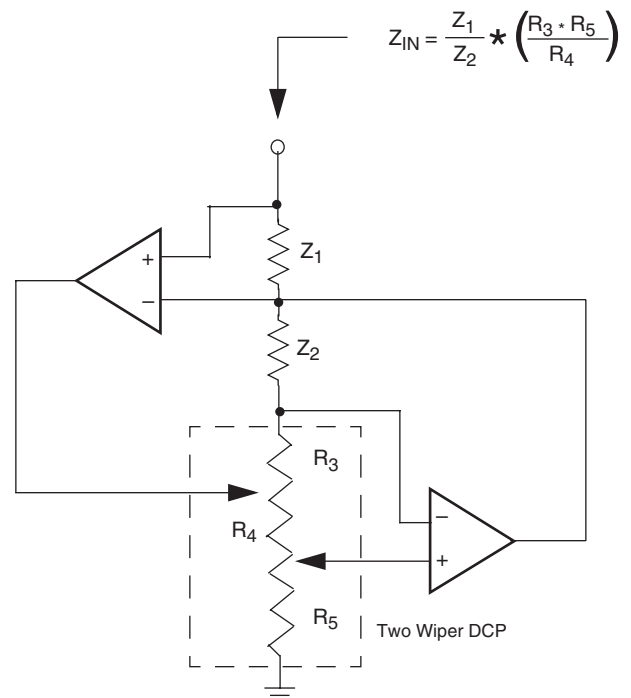
PACKAGING INFORMATION

24-Lead Plastic, TSSOP, Package Code V24

.026 (.65) BSC

.169 (4.3) / .177 (4.5)   .252 (6.4) BSC

.303 (7.70) / .311 (7.90)

.047 (1.20)

.0075 (.19) / .0118 (.30)

.002 (.06) / .005 (.15)

.010 (.25)

Gage Plane

Seating Plane

0°–8°

.020 (.50) / .030 (.75)

Detail A (20X)

(4.16) (7.72)

(1.78)

(0.42)

(0.65)

ALL MEASUREMENTS ARE TYPICAL

.031 (.80) / .041 (1.05)

See Detail "A"
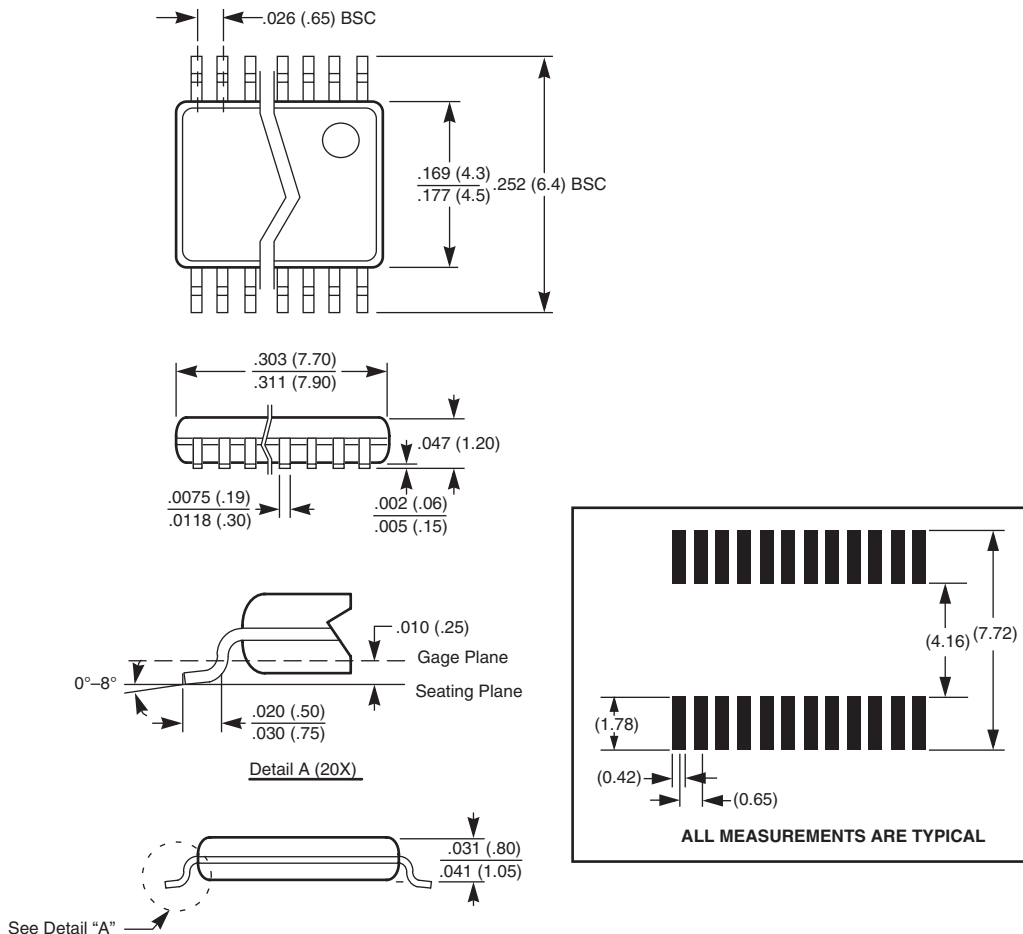
NOTE: ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)