

Quad Digitally-Controlled (XDCP™) Potentiometers

The X9259 integrates four digitally controlled potentiometers (XDCP) on a monolithic CMOS integrated circuit.

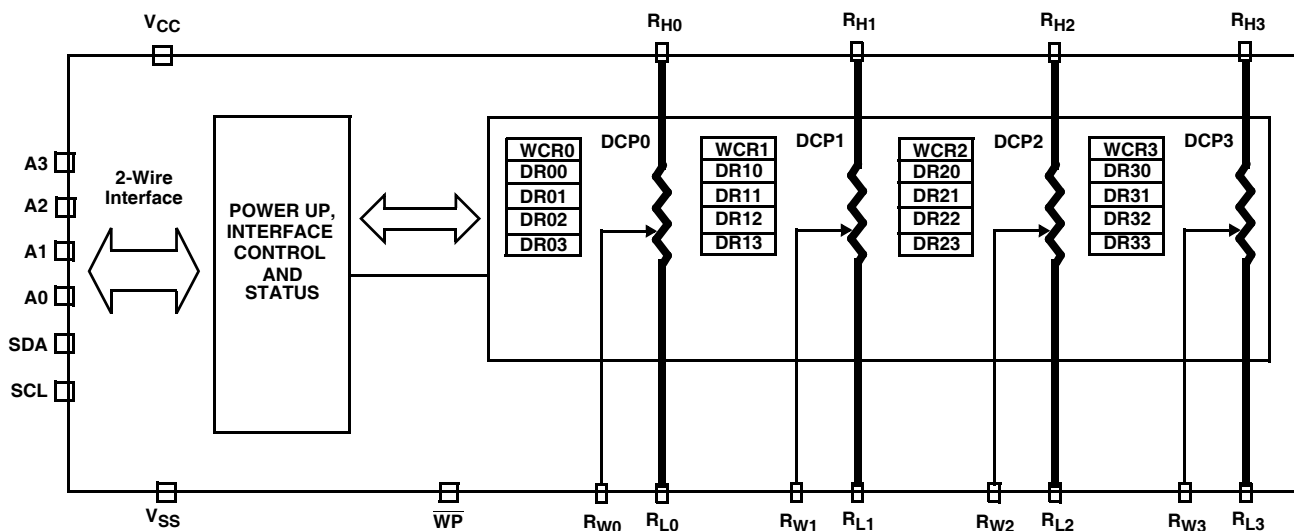
The digitally controlled potentiometers are implemented with a combination of resistor elements and CMOS switches. The position of the wipers are controlled by the user through the 2-wire bus interface. Each potentiometer has associated with it a volatile Wiper Counter Register (WCR) and four non-volatile Data Registers that can be directly written to and read by the user. The content of the WCR controls the position of the wiper. At power-up, the device recalls the content of the default Data Registers of each DCP (DR00, DR10, DR20, and DR30) to the corresponding WCR.

The XDCP can be used as a three-terminal potentiometer or as a two terminal variable resistor in a wide variety of applications including control, parameter adjustments, and signal processing.

Features

- Four Separate Potentiometers in One Package
- 256 Resistor Taps–0.4% Resolution
- 2-Wire Serial Interface for Write, Read, and Transfer Operations of the Potentiometer
- Wiper Resistance: 100Ω typical @ V_{CC} = 5V
- 4 Non-volatile Data Registers for Each Potentiometer
- Non-volatile Storage of Multiple Wiper Positions
- Standby Current <5μA Max
- V_{CC}: 2.7V to 5.5V Operation
- 50kΩ, 100kΩ versions of Total Resistance
- Endurance: 100,000 Data Changes per Bit per Register
- 100 year Data Retention
- Single Supply Version of X9258
- 24 Ld SOIC, 24 Ld TSSOP
- Low Power CMOS
- Pb-Free Plus Anneal Available (RoHS Compliant)

Functional Diagram



Ordering Information

| PART NUMBER | PART MARKING | V _{CC} LIMITS (V) | R _{TOTAL} (kΩ) | TEMPERATURE RANGE (°C) | PACKAGE | PKG. DWG. # | | |
|-------------------------|--------------|----------------------------|-------------------------|------------------------|-----------------------|-----------------------|-----------------------|---------|
| X9259TS24 | X9259TS | 5 ±10% | 100 | 0 to +70 | 24 Ld SOIC | M24.3 | | |
| X9259TS24Z (Note) | X9259TS Z | | | 0 to +70 | 24 Ld SOIC (Pb-free) | M24.3 | | |
| X9259TS24I | X9259TS I | | | -40 to +85 | 24 Ld SOIC | M24.3 | | |
| X9259TS24IZ (Note) | X9259TS ZI | | | -40 to +85 | 24 Ld SOIC (Pb-free) | M24.3 | | |
| X9259TV24I | X9259TV I | | | -40 to +85 | 24 Ld TSSOP | MDP0044 | | |
| X9259TV24IZ (Note) | X9259TV ZI | | | -40 to +85 | 24 Ld TSSOP (Pb-free) | MDP0044 | | |
| X9259US24* | X9259US | | 2.7 to 5.5 | 50 | 0 to +70 | 24 Ld SOIC | M24.3 | |
| X9259US24Z* (Note) | X9259US Z | | | | 0 to +70 | 24 Ld SOIC (Pb-free) | M24.3 | |
| X9259US24I | X9259US I | | | | -40 to +85 | 24 Ld SOIC | M24.3 | |
| X9259US24IZ (Note) | X9259US ZI | | | | -40 to +85 | 24 Ld SOIC (Pb-free) | M24.3 | |
| X9259UV24I* | X9259UV I | | | | -40 to +85 | 24 Ld TSSOP | MDP0044 | |
| X9259UV24IZ* (Note) | X9259UV Z I | | | | -40 to +85 | 24 Ld TSSOP (Pb-free) | MDP0044 | |
| X9259TS24-2.7* | X9259TS F | | | 100 | 100 | 0 to +70 | 24 Ld SOIC | M24.3 |
| X9259TS24Z-2.7* (Note) | X9259TS ZF | | | | | 0 to +70 | 24 Ld SOIC (Pb-free) | M24.3 |
| X9259TS24I-2.7 | X9259TS G | -40 to +85 | | | | 24 Ld SOIC | M24.3 | |
| X9259TS24IZ-2.7 (Note) | X9259TS ZG | -40 to +85 | | | | 24 Ld SOIC (Pb-free) | M24.3 | |
| X9259TV24-2.7 | X9259TV F | 0 to +70 | | | | 24 Ld TSSOP | MDP0044 | |
| X9259TV24Z-2.7 (Note) | X9259TV ZF | 0 to +70 | | | | 24 Ld TSSOP (Pb-free) | MDP0044 | |
| X9259US24-2.7 | X9259US F | 50 | | | 50 | 0 to +70 | 24 Ld SOIC | M24.3 |
| X9259US24Z-2.7 (Note) | X9259US ZF | | | | | 0 to +70 | 24 Ld SOIC (Pb-free) | M24.3 |
| X9259US24I-2.7 | X9259US G | | -40 to +85 | | | 24 Ld SOIC | M24.3 | |
| X9259US24IZ-2.7 (Note) | X9259US ZG | | -40 to +85 | | | 24 Ld SOIC (Pb-free) | M24.3 | |
| X9259UV24-2.7* | X9259UV F | | 0 to +70 | | | 24 Ld TSSOP | MDP0044 | |
| X9259UV24Z-2.7 (Note) | X9259UV ZF | | 0 to +70 | | | 24 Ld TSSOP (Pb-free) | MDP0044 | |
| X9259UV24I-2.7* | X9259UV G | | -40 to +85 | | 24 Ld TSSOP | 24 Ld TSSOP | 24 Ld TSSOP (Pb-free) | MDP0044 |
| X9259UV24IZ-2.7* (Note) | X9259UV ZG | | | | | | | |

NOTE: Intersil Pb-free plus anneal products employ special Pb-free material sets; molding compounds/die attach materials and 100% matte tin plate termination finish, which are RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.

*Add "T1" suffix for tape and reel.

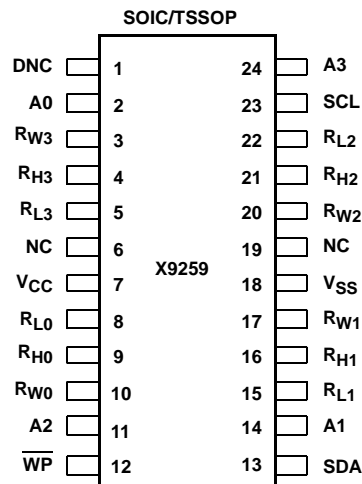
Circuit Level Applications

- Vary the gain of a voltage amplifier
- Provide programmable dc reference voltages for comparators and detectors
- Control the volume in audio circuits
- Trim out the offset voltage error in a voltage amplifier circuit
- Set the output voltage of a voltage regulator
- Trim the resistance in Wheatstone bridge circuits
- Control the gain, characteristic frequency and Q-factor in filter circuits
- Set the scale factor and zero point in sensor signal conditioning circuits
- Vary the frequency and duty cycle of timer ICs
- Vary the dc biasing of a pin diode attenuator in RF circuits
- Provide a control variable (I, V, or R) in feedback circuits

System Level Applications

- Adjust the contrast in LCD displays
- Control the power level of LED transmitters in communication systems
- Set and regulate the DC biasing point in an RF power amplifier in wireless systems
- Control the gain in audio and home entertainment systems
- Provide the variable DC bias for tuners in RF wireless systems
- Set the operating points in temperature control systems
- Control the operating point for sensors in industrial systems
- Trim offset and gain errors in artificial intelligent systems

Pin Configuration



Pin Assignments

| PIN (SOIC/TSSOP) | SYMBOL | FUNCTION |
|------------------|-----------------|---|
| 2 | A0 | Device Address for 2-Wire bus. (See Note 1) |
| 3 | R _{W3} | Wiper Terminal of DCP3 |
| 4 | R _{H3} | High Terminal of DCP3 |
| 5 | R _{L3} | Low Terminal of DCP3 |
| 6 | NC1 | Must be left unconnected |
| 7 | V _{CC} | System Supply Voltage |
| 8 | R _{L0} | Low Terminal of DCP0 |
| 9 | R _{H0} | High Terminal of DCP0 |
| 10 | R _{W0} | Wiper Terminal of DCP0 |
| 11 | A2 | Device Address for 2-Wire bus. (See Note 1) |
| 12 | \overline{WP} | Hardware Write Protect – Active Low |
| 13 | SDA | Serial Data Input/Output for 2-Wire bus. |
| 14 | A1 | Device Address for 2-Wire bus. (See Note 1) |
| 15 | R _{L1} | Low Terminal of DCP1 |
| 16 | R _{H1} | High Terminal of DCP1 |
| 17 | R _{W1} | Wiper Terminal of DCP1 |
| 18 | V _{SS} | System Ground |
| 20 | R _{W2} | Wiper Terminal of DCP2 |
| 21 | R _{H2} | High Terminal of DCP2 |
| 22 | R _{L2} | Low Terminal of DCP2 |
| 23 | SCL | Serial Clock for 2-Wire bus. |
| 24 | A3 | Device Address for 2-Wire bus. (See Note 1) |
| 6, 19 | NC | No Connect |
| 1 | DNC | Do Not Connect |

Note 1: A0 through A3 Device address pins must be tied to a logic level.

Pin Descriptions

Bus Interface Pins

SERIAL DATA INPUT/OUTPUT (SDA)

The SDA is a bidirectional serial data input/output pin for a 2-Wire slave device and is used to transfer data into and out of the device. It receives device address, opcode, wiper register address and data sent from a 2-Wire master at the rising edge of the serial clock SCL, and it shifts out data after each falling edge of the serial clock SCL.

It is an open drain output and may be wire-ORed with any number of open drain or open collector outputs. An open drain output requires the use of a pull-up resistor.

SERIAL CLOCK (SCL)

This input is used by 2-Wire master to supply 2-Wire serial clock to the X9259.

DEVICE ADDRESS (A3 THROUGH A0)

The Address inputs are used to set the least significant 4 bits of the 8-bit slave address. A match in the slave address serial data stream must be made with the Address input in order to initiate communication with the X9259. A maximum of 16 devices may occupy the 2-Wire serial bus. Device pins A3 through A0 must be tied to a logic level which specifies the external address of the device, see Figures 3, 4, and 5.

Potentiometer Pins

R_H, R_L

The R_H and R_L pins are equivalent to the terminal connections on a mechanical potentiometer. Since there are 4 potentiometers, there are 4 sets of R_H and R_L such that R_{H0} and R_{L0} are the terminals of DCP0 and so on.

R_W

The wiper pin are equivalent to the wiper terminal of a mechanical potentiometer. Since there are 4 potentiometers, there are 4 sets of R_W such that R_{W0} is the terminal of DCP0 and so on.

Bias Supply Pins

SYSTEM SUPPLY VOLTAGE (V_{CC}) AND SUPPLY GROUND (V_{SS})

The V_{CC} pin is the system supply voltage. The V_{SS} pin is the system ground.

Other Pins

NO CONNECT

No connect pins should be left open. This pins are used for Intersil manufacturing and testing purposes.

HARDWARE WRITE PROTECT INPUT (\overline{WP})

The \overline{WP} pin when LOW prevents non-volatile writes to the Data Registers.

One of Four Potentiometers

#: 0, 1, 2, or 3

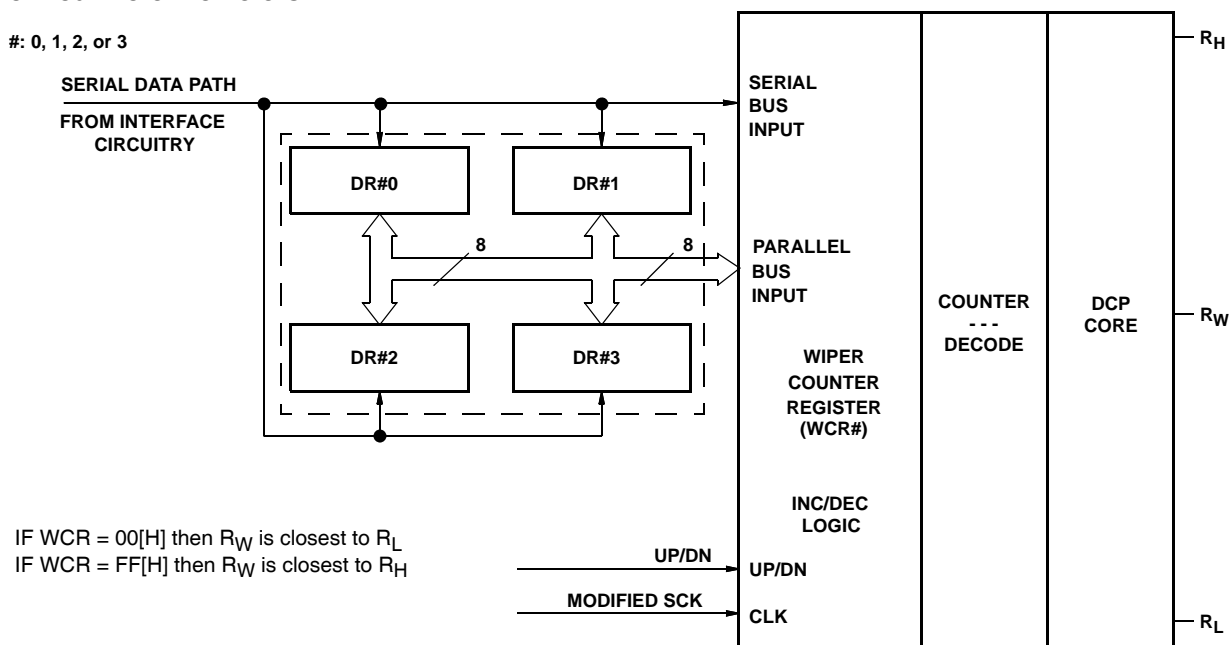


FIGURE 1. DETAILED POTENTIOMETER BLOCK DIAGRAM

Principles of Operation

The X9259 is an integrated circuit incorporating four DCPs and their associated registers and counters, and the serial interface providing direct communication between a host and the potentiometers.

DCP Description

Each DCP is implemented with a combination of resistor elements and CMOS switches. The physical ends of each DCP are equivalent to the fixed terminals of a mechanical potentiometer (R_H and R_L pins). The RW pin is an intermediate node, equivalent to the wiper terminal of a mechanical potentiometer.

The position of the wiper terminal within the DCP is controlled by an 8-bit volatile Wiper Counter Register (WCR).

Power Up and Down Recommendations

There are no restrictions on the power-up or power-down conditions of V_{CC} and the voltages applied to the potentiometer pins provided that V_{CC} is always more positive than or equal to V_H , V_L , and V_W , i.e., $V_{CC} \geq V_H, V_L, V_W$. The V_{CC} ramp rate specification is always in effect.

Wiper Counter Register (WCR)

The X9259 contains four Wiper Counter Registers, one for each potentiometer. The Wiper Counter Register can be envisioned as a 8-bit parallel and serial load counter with its outputs decoded to select one of 256 wiper positions along its resistor array. The contents of the WCR can be altered in four ways: it may be written directly by the host via the Write Wiper Counter Register instruction (serial load); it may be

written indirectly by transferring the contents of one of four associated data registers via the XFR Data Register instruction (parallel load); it can be modified one step at a time by the Increment/Decrement instruction (see Instruction section for more details). Finally, it is loaded with the contents of its data register zero (DR#0) upon power-up. (See Figure 1)

The Wiper Counter Register is a volatile register; that is, its contents are lost when the X9259 is powered-down. Although the register is automatically loaded with the value in DR#0 upon power-up, this may be different from the value present at power-down. Power-up guidelines are recommended to ensure proper loadings of the DR#0 value into the WCR# (See Design Considerations Section).

Data Registers (DR)

Each of the four DCPs has four 8-bit non-volatile Data Registers. These can be read or written directly by the host. Data can also be transferred between any of the four data registers and the associated Wiper Counter Register. All operations changing data in one of the data registers is a non-volatile operation and takes a maximum of 10ms.

If the application does not require storage of multiple settings for the potentiometer, the Data Registers can be used as regular memory locations for system parameters or user preference data.

Bit [7:0] are used to store one of the 256 wiper positions (0 ~ 255).

TABLE 1. WIPER COUNTER REGISTER, WCR (8-bit), WCR[7:0]: Used to store the current wiper position (Volatile).

| | | | | | | | |
|-------|------|------|------|------|------|------|-------|
| WCR7 | WCR6 | WCR5 | WCR4 | WCR3 | WCR2 | WCR1 | WCR0 |
| (MSB) | | | | | | | (LSB) |

TABLE 2. DATA REGISTER, DR (8-BIT), BIT [7:0]: Used to store wiper positions or data (Non-volatile).

| | | | | | | | |
|-------|-------|-------|-------|-------|-------|-------|-------|
| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| (MSB) | | | | | | | (LSB) |

Serial Interface

The X9259 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 a master and the device being controlled is the slave. The master always initiates data transfers and provide the clock for both transmit and receive operations. Therefore, the X9259 operates as a slave device in all applications.

All 2-wire interface operations must begin with a START, followed by an Identification Byte, that selects the X9259. All communication over the 2-wire interface is conducted by sending the MSB of each byte of data first.

Clock and Data Conventions

Data states on the SDA line can change only during SCL LOW periods. SDA state changes during SCL HIGH are reserved for indicating START and STOP conditions. See Figure 2. On power up of the X9259 the SDA pin is in the input mode.

START Condition

All commands to the X9259 are preceded by the start condition, which is a HIGH to LOW transition of SDA while SCL is HIGH. The X9259 continuously monitors the SDA and SCL lines for the START condition and does not respond to any command until this condition is met. See Figure 2.

STOP Condition

All communications must be terminated by a STOP condition, which is a LOW to HIGH transition of SDA while SCL is HIGH. See Figure 2. 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.

Acknowledge

An ACK, Acknowledge, is a software convention used to indicate a successful data transfer. The transmitting device, either master or slave, releases the SDA 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 X9259 responds with an ACK after recognition of a START condition followed by a valid Identification Byte, and once again after successful receipt of an Instruction Byte. The X9259 also responds with an ACK after receiving a Data Byte after a Write Instruction.

A valid Identification Byte contains the Device Type Identifier 0101, as the four MSBs, and the Device Address bits matching the logic states of pins A3, A2, A1, and A0, as the four LSBs. See Figure 4.

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.

During the internal non-volatile Write operation, the X9259 ignores the inputs at SDA and SCL, and does not issue an ACK after Identification bytes.

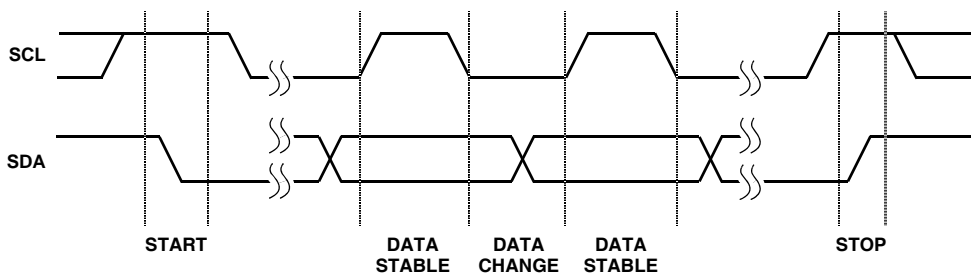


FIGURE 2. VALID DATA CHANGES, START, AND STOP CONDITIONS

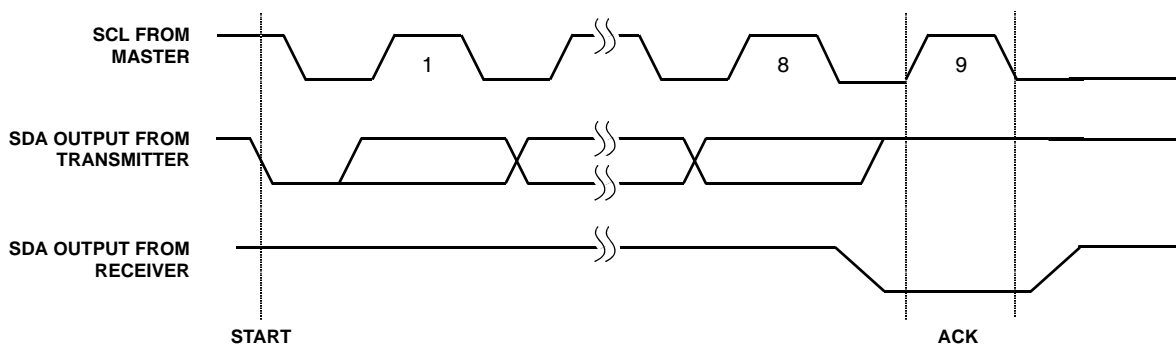


FIGURE 3. ACKNOWLEDGE RESPONSE FROM RECEIVER

Identification Byte

The first byte sent to the X9259 from the host is called the Identification Byte. The most significant four bits are a Device Type Identifier, ID[3:0] bits, which must be 0101. Refer to Table 3.

Only the device which Slave Address matches the incoming device address sent by the master executes the instruction. The A3 - A0 inputs can be actively driven by CMOS input signals or tied to V_{CC} or V_{SS}.

INSTRUCTION BYTE (I)

The next byte sent to the X9259 contains the instruction and register pointer information. The four most significant bits are used provide the instruction opcode I [3:0]. The RB and RA bits point to one of the four data registers of each associated XDCCP. The least two significant bits point to one of four Wiper Counter Registers or DCPs. The format is shown in Table 4.

Data Register Selection

| REGISTER | RB | RA |
|----------|----|----|
| DR#0 | 0 | 0 |
| DR#1 | 0 | 1 |
| DR#2 | 1 | 0 |
| DR#3 | 1 | 1 |

#: 0, 1, 2, or 3

The least significant four bits of the Identification Byte are the Slave Address bits, AD[3:0]. To access the X9259, these four bits must match the logic values of pins A3, A2, A1, and A0.

TABLE 3. IDENTIFICATION BYTE FORMAT

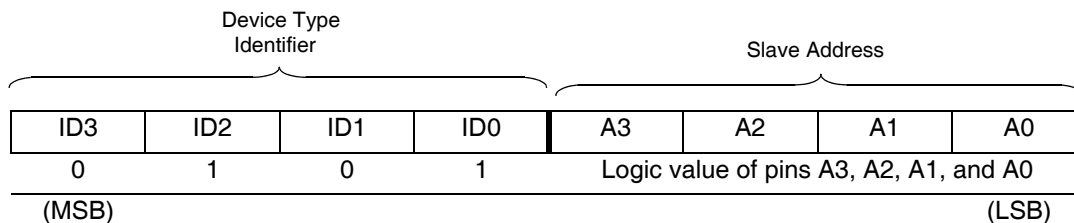


TABLE 4. INSTRUCTION BYTE FORMAT

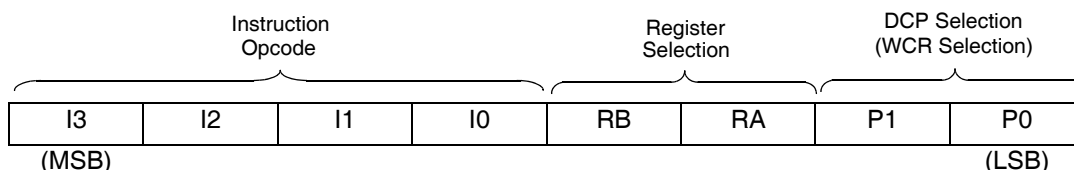


TABLE 5. INSTRUCTION SET

| INSTRUCTION | INSTRUCTION SET | | | | | | | | OPERATION |
|--|-----------------|----|----|----|-----|-----|-----|-----|---|
| | I3 | I2 | I1 | I0 | RB | RA | P1 | P0 | |
| Read Wiper Counter Register | 1 | 0 | 0 | 1 | 0 | 0 | 1/0 | 1/0 | Read the contents of the Wiper Counter Register pointed to by P1 - P0 |
| Write Wiper Counter Register | 1 | 0 | 1 | 0 | 0 | 0 | 1/0 | 1/0 | Write new value to the Wiper Counter Register pointed to by P1 - P0 |
| Read Data Register | 1 | 0 | 1 | 1 | 1/0 | 1/0 | 1/0 | 1/0 | Read the contents of the Data Register pointed to by P1 - P0 and RB - RA |
| Write Data Register | 1 | 1 | 0 | 0 | 1/0 | 1/0 | 1/0 | 1/0 | Write new value to the Data Register pointed to by P1 - P0 and RB - RA |
| XFR Data Register to Wiper Counter Register | 1 | 1 | 0 | 1 | 1/0 | 1/0 | 1/0 | 1/0 | Transfer the contents of the Data Register pointed to by P1 - P0 and RB - RA to its associated Wiper Counter Register |
| XFR Wiper Counter Register to Data Register | 1 | 1 | 1 | 0 | 1/0 | 1/0 | 1/0 | 1/0 | Transfer the contents of the Wiper Counter Register pointed to by P1 - P0 to the Data Register pointed to by RB - RA |
| Global XFR Data Registers to Wiper Counter Registers | 0 | 0 | 0 | 1 | 1/0 | 1/0 | 0 | 0 | Transfer the contents of the Data Registers pointed to by RB - RA of all four pots to their respective Wiper Counter Registers |
| Global XFR Wiper Counter Registers to Data Register | 1 | 0 | 0 | 0 | 1/0 | 1/0 | 0 | 0 | Transfer the contents of both Wiper Counter Registers to their respective data Registers pointed to by RB - RA of all four DCPs |
| Increment/Decrement Wiper Counter Register | 0 | 0 | 1 | 0 | 0 | 0 | 1/0 | 1/0 | Enable Increment/decrement of the Control Latch pointed to by P1 - P0 |

Note: 1/0 = data is one or zero

Instructions

Four of the nine instructions are three bytes in length. These instructions are:

- **Read Wiper Counter Register** – read the current wiper position of the selected potentiometer,
- **Write Wiper Counter Register** – change current wiper position of the selected potentiometer,
- **Read Data Register** – read the contents of the selected Data Register;
- **Write Data Register** – write a new value to the selected Data Register.

The basic sequence of the three byte instructions is illustrated in Figure 5. These three-byte instructions exchange data between the WCR and one of the Data Registers. A transfer from a Data Register to a WCR is essentially a write to a static RAM, with the static RAM controlling the wiper position. The response of the wiper to this action is delayed by t_{WRL} . A transfer from the WCR (current wiper position), to a Data Register is a write to non-volatile memory and takes a minimum of t_{WR} to complete. The transfer can occur between one of the four potentiometer’s WCR, and one of its associated registers, DRs; or it may occur globally, where the transfer occurs between all potentiometers and one associated register.

Four instructions require a two-byte sequence to complete. These instructions transfer data between the host and the X9259; either between the host and one of the data registers

or directly between the host and the Wiper Counter Register. These instructions are:

- **XFR Data Register to Wiper Counter Register** – This transfers the contents of one specified Data Register to the associated Wiper Counter Register.
- **XFR Wiper Counter Register to Data Register** – This transfers the contents of the specified Wiper Counter Register to the specified associated Data Register.
- **Global XFR Data Register to Wiper Counter Register** – This transfers the contents of all specified Data Registers to the associated Wiper Counter Registers.
- **Global XFR Wiper Counter Register to Data Register** – This transfers the contents of all Wiper Counter Registers to the specified associated Data Registers.

Increment/Decrement Command

The final command is Increment/Decrement (Figure 6 and 7). The Increment/Decrement command is different from the other commands. Once the command is issued and the X9259 has responded with an Acknowledge, the master can clock the selected wiper up and/or down in one segment steps; thereby, providing a fine tuning capability to the host. For each SCL clock pulse (t_{HIGH}) while SDA is HIGH, the selected wiper moves one wiper position towards the R_H terminal. Similarly, for each SCL clock pulse while SDA is LOW, the selected wiper moves one resistor wiper position towards the R_L terminal.

See Instruction format for more details.

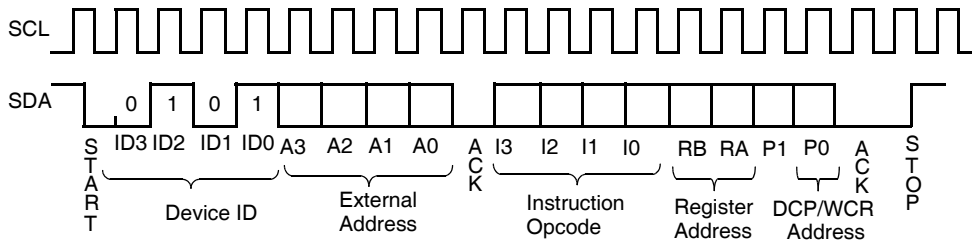


FIGURE 4. TWO-BYTE INSTRUCTION SEQUENCE

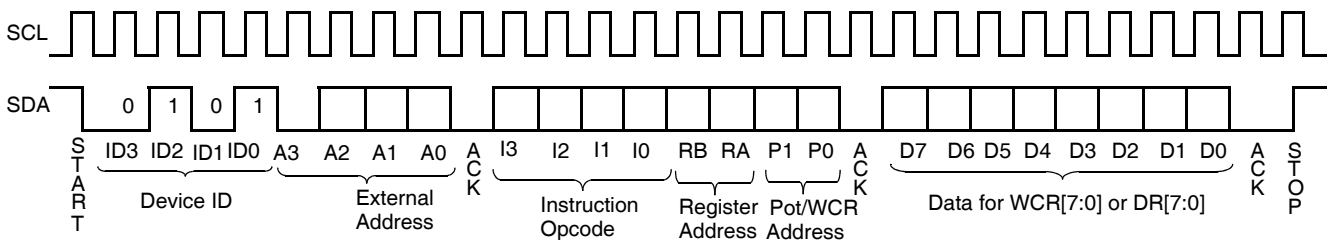


FIGURE 5. THREE-BYTE INSTRUCTION SEQUENCE 2-WIRE INTERFACE

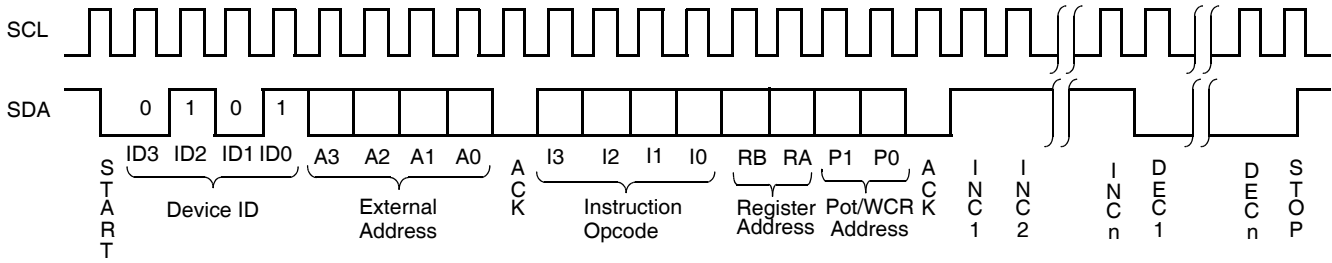


FIGURE 6. INCREMENT/DECREMENT INSTRUCTION SEQUENCE 2-WIRE INTERFACE

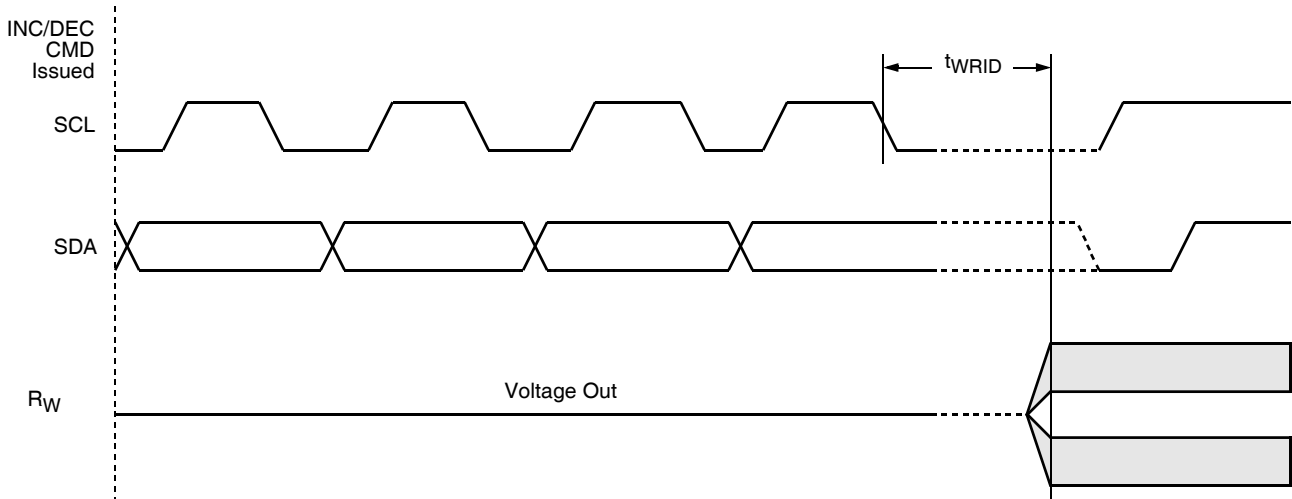


FIGURE 7. INCREMENT/DECREMENT TIMING SPEC

Instruction Format

Read Wiper Counter Register (WCR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | Wiper Position (Sent by X9259 on SDA) | | | | | | | | M A C K | S T O P |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|---|----|----|------------------|---------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 0 | 1 | 0 | 0 | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 0 | 1 | 0 | 0 | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | |

Write Wiper Counter Register (WCR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | Wiper Position (Sent by Master on SDA) | | | | | | | | S A C K | S T O P |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|---|----|----|------------------|--|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 1 | 0 | 0 | 0 | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 1 | 0 | 0 | 0 | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | |

Read Data Register (DR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | Wiper Position (Sent by X9259 on SDA) | | | | | | | | M A C K | S T O P |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|----|----|----|------------------|---------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 1 | 1 | RB | RA | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 1 | 1 | RB | RA | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | |

Write Data Register (DR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | Wiper Position (Sent by Master on SDA) | | | | | | | | S A C K | S T O P | H I G H- V O L T A G E W R I T E C Y C L E |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|----|----|----|------------------|--|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|--|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 1 | 0 | 0 | RB | RA | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 1 | 0 | 0 | RB | RA | P1 | P0 | | W C R 7 | W C R 6 | W C R 5 | W C R 4 | W C R 3 | W C R 2 | W C R 1 | W C R 0 | | | |

Global XFR Data Register (DR) to Wiper Counter Register (WCR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | S T O P |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|----|---|---|------------------|------------------|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 0 | 0 | 0 | 1 | RB | RA | 0 | 0 | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 0 | 0 | 0 | 1 | RB | RA | 0 | 0 | | |

- Notes: (1) "MACK"/"SACK": stands for the acknowledge sent by the Master/Slave.
 (2) "A3 ~ A0": stands for the device addresses sent by the master.
 (3) "X": indicates that it is a "0" for testing purpose but physically it is a "don't care" condition.
 (4) "I": stands for the increment operation, SDA held high during active SCL phase (high).
 (5) "D": stands for the decrement operation, SDA held low during active SCL phase (high).

Global XFR Wiper Counter Register (WCR) to Data Register (DR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | S T O P | HIGH-VOLTAGE WRITE CYCLE |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|----|---|---|------------------|------------------|--------------------------|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 0 | 0 | RB | RA | 0 | 0 | | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 0 | 0 | 0 | RB | RA | 0 | 0 | | | |

Transfer Wiper Counter Register (WCR) to Data Register (DR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | S T O P | HIGH-VOLTAGE WRITE CYCLE |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|----|----|----|------------------|------------------|--------------------------|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 1 | 1 | 0 | RB | RA | P1 | P0 | | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 1 | 1 | 0 | RB | RA | P1 | P0 | | | |

Transfer Data Register (DR) to Wiper Counter Register (WCR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | S A C K | S T O P | |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|----|----|----|------------------|------------------|--|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 1 | 0 | 1 | RB | RA | P1 | P0 | | | |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 1 | 1 | 0 | 1 | RB | RA | P1 | P0 | | | |

Increment/Decrement Wiper Counter Register (WCR)

| S T A R T | Device Type Identifier | | | | Device Addresses | | | | S A C K | Instruction Opcode | | | | DR/WCR Addresses | | | | Increment/Decrement (Sent by Master on SDA) | | | | | | S T O P | | |
|-----------------------|------------------------|---|---|---|------------------|----|----|----|------------------|--------------------|---|---|---|------------------|---|----|----|---|-----|---|---|---|---|------------------|-----|-----|
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 0 | 0 | 1 | 0 | 0 | 0 | P1 | P0 | I/D | I/D | . | . | . | . | | I/D | I/D |
| | 0 | 1 | 0 | 1 | A3 | A2 | A1 | A0 | | 0 | 0 | 1 | 0 | 0 | 0 | P1 | P0 | I/D | I/D | . | . | . | . | I/D | I/D | |

- Notes: (1) "MACK"/"SACK": stands for the acknowledge sent by the Master/Slave.
 (2) "A3 ~ A0": stands for the device addresses sent by the master.
 (3) "X": indicates that it is a "0" for testing purpose but physically it is a "don't care" condition.
 (4) "I": stands for the increment operation, SDA held high during active SCL phase (high).
 (5) "D": stands for the decrement operation, SDA held low during active SCL phase (high).

Absolute Maximum Ratings

Temperature under bias -65°C to +135°C
 Storage temperature -65°C to +150°C
 Voltage on SCL, SDA, any address input, V_{CC}
 with respect to V_{SS} -1V to +7V
 $\Delta V = | (V_H - V_L) |$ 5.5V
 Lead temperature (soldering, 10 seconds) 300°C
 I_W (10 seconds) ±6mA

Recommended Operating Conditions

Temperature (Commercial) 0°C to +70°C
 Temperature (Industrial) -40°C to +85°C
 Supply Voltage (V_{CC}) (Note 4) Limits
 X9259 5V ± 10%
 X9259-2.7 2.7V to 5.5V
 Wiper current ±3mA
 Power rating (each pot) 50mW

CAUTION: 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.

Analog Specifications Over recommended industrial (2.7V) operating conditions unless otherwise stated.

| SYMBOL | PARAMETER | TEST CONDITIONS | LIMITS | | | |
|--|--|--|-----------------|----------|-----------------|-------------|
| | | | MIN | TYP | MAX | UNITS |
| R _{TOTAL} | End to End Resistance | T version | | 100 | | kΩ |
| R _{TOTAL} | End to End Resistance | U version | | 50 | | kΩ |
| | End to End Resistance Tolerance | | | | ±20 | % |
| R _W | Wiper Resistance | $I_W = \frac{V(V_{CC})}{R_{TOTAL}} @ V_{CC} = 3V$ | | | 300 | Ω |
| | | $I_W = \frac{V(V_{CC})}{R_{TOTAL}} @ V_{CC} = 5V$ | | | 220 | Ω |
| V _{TERM} | Voltage on any R _H or R _L Pin | V _{SS} = 0V | V _{SS} | | V _{CC} | V |
| | Noise (Note 6) | Ref: 1V | | -120 | | dB/√Hz |
| | Resolution | | | 0.4 | | % |
| | Absolute Linearity (Note 1) | R _{w(n)(actual)} - R _{w(n)(expected)} (Note 5) | -1 | | +1 | MI (Note 3) |
| | Relative Linearity (Note 2) | R _{w(n+1)} - [R _{w(n)} + MI] (Note 5) | -0.6 | | +0.6 | MI (Note 3) |
| | Temperature Coefficient of R _{TOTAL} (Note 6) | | | ±300 | | ppm/°C |
| | Ratiometric Temp. Coefficient (Note 6) | | | ±20 | | ppm/°C |
| C _H /C _L /C _W | Potentiometer Capacitances (Note 6) | See Macro model | | 10/10/25 | | pF |

NOTES:

1. Absolute linearity is utilized to determine actual wiper voltage versus expected voltage as determined by wiper position when used as a potentiometer.
2. Relative linearity is utilized to determine the actual change in voltage between two successive tap positions when used as a potentiometer. It is a measure of the error in step size.
3. MI = RTOT / 255 or (R_H - R_L) / 255, single pot
4. During power up V_{CC} > V_H, V_L, and V_W.
5. n = 0, 1, 2, ..., 255; m = 0, 1, 2, ..., 254.

DC Electrical Specifications Over the recommended operating conditions unless otherwise specified.

| SYMBOL | PARAMETER | TEST CONDITIONS | LIMITS | | | |
|------------------|---|--|-----------------------|-----|-----------------------|-------|
| | | | MIN | TYP | MAX | UNITS |
| I _{CC1} | V _{CC} supply current (active) | f _{SCL} = 400kHz; V _{CC} = +6V; SDA = Open; (for 2-Wire, Active, Read and Volatile Write States only) | | | 3 | mA |
| I _{CC2} | V _{CC} supply current (non-volatile write) | f _{SCL} = 400kHz; V _{CC} = +6V; SDA = Open; (for 2-Wire, Active, Non-volatile Write State only) | | | 5 | mA |
| I _{SB} | V _{CC} current (standby) | V _{CC} = +6V; V _{IN} = V _{SS} or V _{CC} ; SDA = V _{CC} ; (for 2-Wire, Standby State only) | | | 5 | μA |
| I _{LI} | Input leakage current | V _{IN} = V _{SS} to V _{CC} | | | 10 | μA |
| I _{LO} | Output leakage current | V _{OUT} = V _{SS} to V _{CC} | | | 10 | μA |
| V _{IH} | Input HIGH voltage | | V _{CC} × 0.7 | | | V |
| V _{IL} | Input LOW voltage | | | | V _{CC} × 0.3 | V |
| V _{OL} | Output LOW voltage | I _{OL} = 3mA | | | 0.4 | V |
| V _{OH} | Output HIGH voltage | I _{OH} = -1mA, V _{CC} ≥ +3V | V _{CC} - 0.8 | | | V |
| V _{OH} | Output HIGH voltage | I _{OH} = -0.4mA, V _{CC} ≤ +3V | V _{CC} - 0.4 | | | V |

Endurance and Data Retention

| PARAMETER | MIN | UNITS |
|-------------------|---------|-----------------------------------|
| Minimum endurance | 100,000 | Data changes per bit per register |
| Data retention | 100 | years |

Capacitance

| SYMBOL | TEST | MAX | UNITS | TEST CONDITIONS |
|------------------------------|--|-----|-------|-----------------------|
| C _{IN/OUT} (Note 6) | Input / Output capacitance (SDA) | 8 | pF | V _{OUT} = 0V |
| C _{IN} (Note 6) | Input capacitance (SCL, \overline{WP} , A2, A1 and A0) | 6 | pF | V _{IN} = 0V |

Power-up Timing

| SYMBOL | PARAMETER | MIN | MAX | UNITS |
|-----------------------------|---|-----|-----|-------|
| t _{r VCC} (Note 6) | V _{CC} Power-up rate | 0.2 | | V/ms |
| t _{PUR} (Note 7) | Power-up to initiation of read operation | | 1 | ms |
| t _{PUW} (Note 7) | Power-up to initiation of write operation | | 50 | ms |

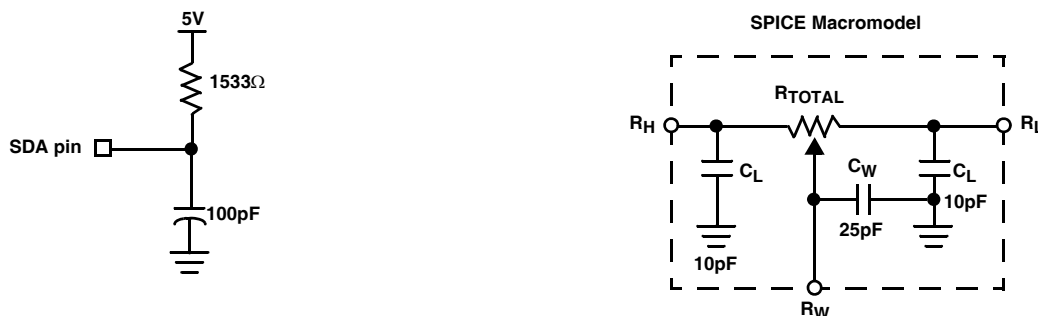
A.C. Test Conditions

| | |
|-------------------------------|--|
| Input Pulse Levels | V _{CC} × 0.1 to V _{CC} × 0.9 |
| Input rise and fall times | 10ns |
| Input and output timing level | V _{CC} × 0.5 |

NOTES:

- This parameter is not 100% tested
- t_{PUR} and t_{PUW} are the delays required from the time the power supply (V_{CC}) is stable until the specific instruction can be issued. These parameters are periodically sampled and not 100% tested.

Equivalent A.C. Load Circuit



AC Timing

| SYMBOL | PARAMETER | MIN | MAX | UNITS |
|--------------|---|------|-----|---------|
| f_{SCL} | Clock Frequency | | 400 | kHz |
| t_{CYC} | Clock Cycle Time | 2500 | | ns |
| t_{HIGH} | Clock High Time | 600 | | ns |
| t_{LOW} | Clock Low Time | 1300 | | ns |
| $t_{SU:STA}$ | Start Setup Time | 600 | | ns |
| $t_{HD:STA}$ | Start Hold Time | 600 | | ns |
| $t_{SU:STO}$ | Stop 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 | SCL and SDA Rise Time | | 300 | ns |
| t_F | SCL and SDA Fall Time | | 300 | ns |
| t_{AA} | SCL Low to SDA Data Output Valid Time | | 0.9 | μ s |
| t_{DH} | SDA Data Output Hold Time | 0 | | ns |
| T_I | Noise Suppression Time Constant at SCL and SDA inputs | 50 | | ns |
| t_{BUF} | Bus Free Time (Prior to Any Transmission) | 1200 | | ns |
| $t_{SU:WPA}$ | A0, A1 Setup Time | 0 | | ns |
| $t_{HD:WPA}$ | A0, A1 Hold Time | 0 | | ns |

High-Voltage Write Cycle Timing

| SYMBOL | PARAMETER | TYP | MAX | UNITS |
|----------|--|-----|-----|-------|
| t_{WR} | High-voltage write cycle time (store instructions) | 5 | 10 | ms |

XDCP Timing

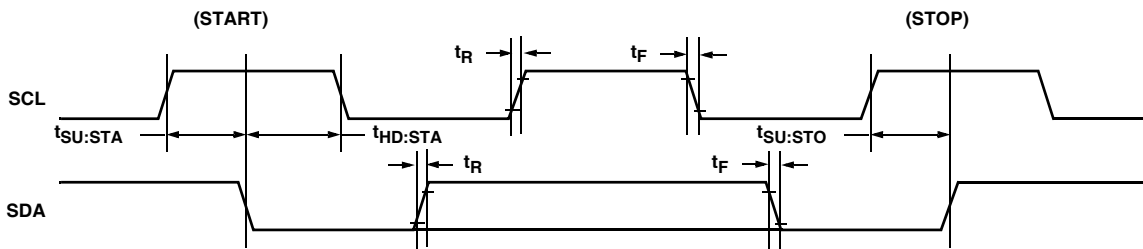
| SYMBOL | PARAMETER | MIN | MAX | UNITS |
|------------|--|-----|-----|---------|
| t_{WRPO} | Wiper response time after the third (last) power supply is stable | 5 | 10 | μ s |
| t_{WRL} | Wiper response time after instruction issued (all load instructions) | 5 | 10 | μ s |

Symbol Table

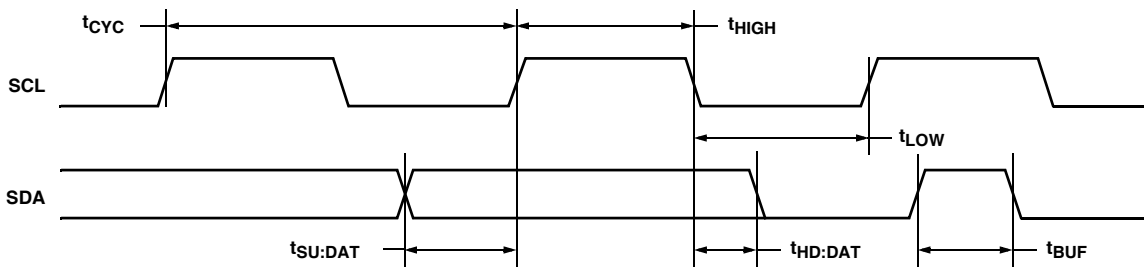
| WAVEFORM | INPUTS | OUTPUTS |
|----------|-----------------------------|-------------------------------|
| | Must be steady | Will be steady |
| | May change from Low to High | Will change from Low to High |
| | May change from High to Low | Will change from High to Low |
| | Don't Care: Changes Allowed | Changing: State Not Known |
| | N/A | Center Line is High Impedance |

Timing Diagrams

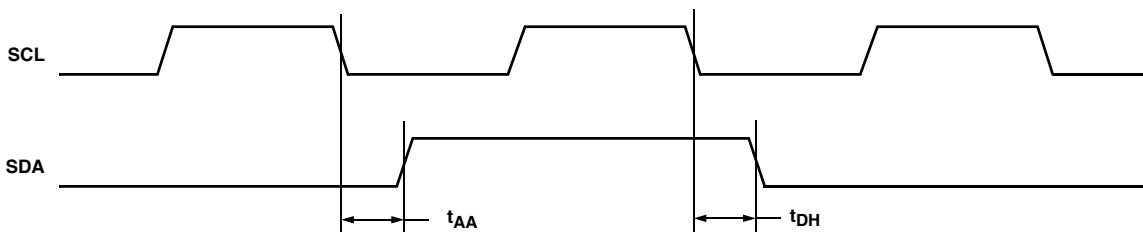
Start and Stop Timing



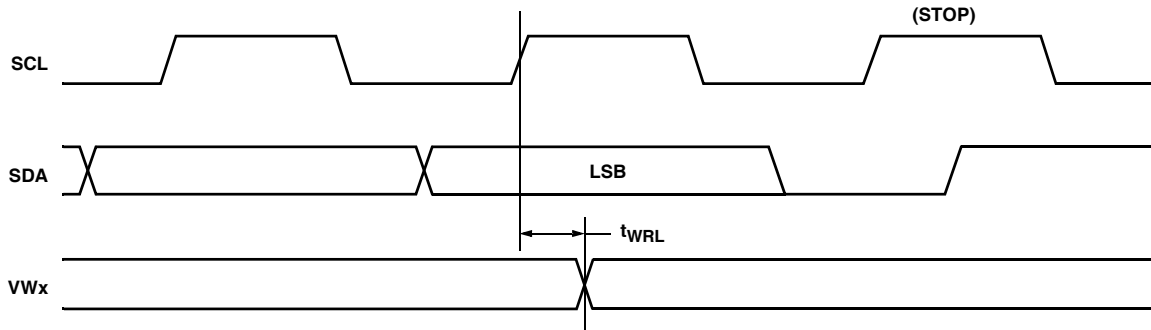
Input Timing



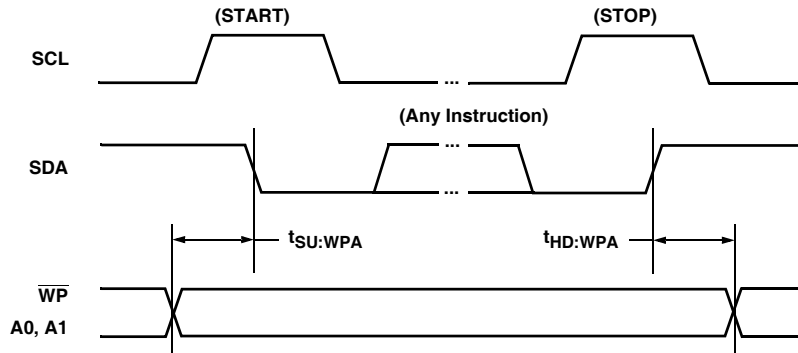
Output Timing



XDCP Timing (for All Load Instructions)

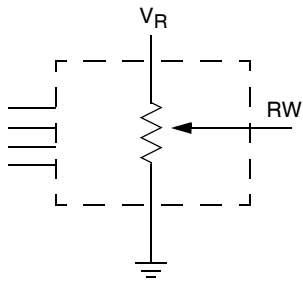


Write Protect and Device Address Pins Timing

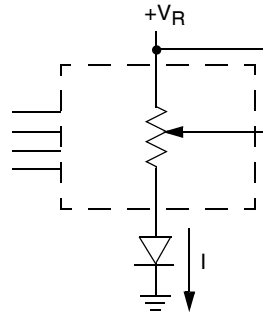


Applications Information

Basic Configurations of Electronic Potentiometers



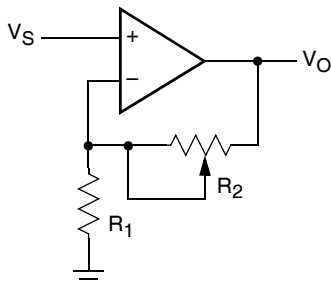
Three terminal Potentiometer;
Variable voltage divider



Two terminal Variable Resistor;
Variable current

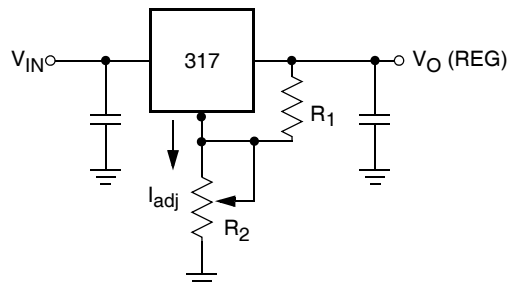
Application Circuits

Non inverting Amplifier



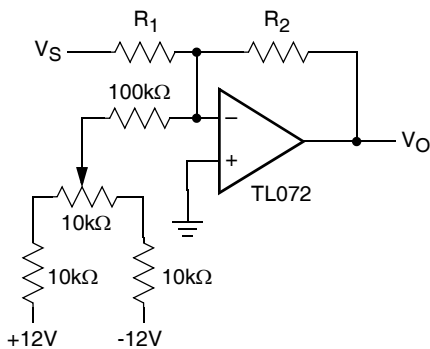
$$V_O = (1 + R_2/R_1)V_S$$

Voltage Regulator

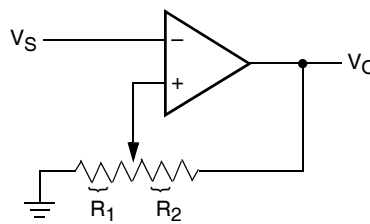


$$V_O (REG) = 1.25V (1 + R_2/R_1) + I_{adj} R_2$$

Offset Voltage Adjustment



Comparator with Hysteresis

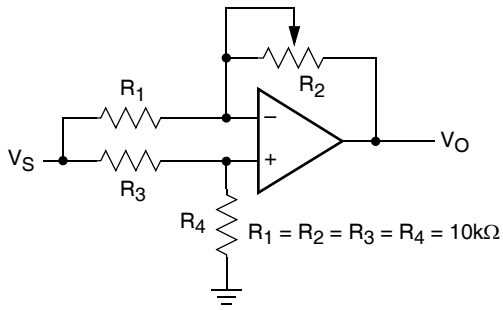


$$V_{UL} = \{R_1/(R_1+R_2)\} V_O(max)$$

$$V_{LL} = \{R_1/(R_1+R_2)\} V_O(min)$$

Application Circuits (continued)

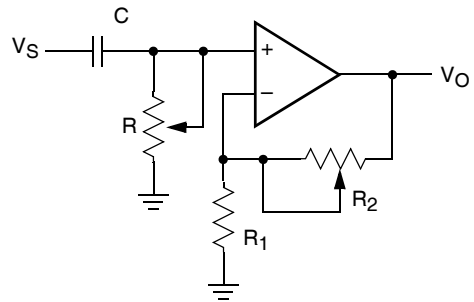
Attenuator



$$V_O = G V_S$$

$$-1/2 \leq G \leq +1/2$$

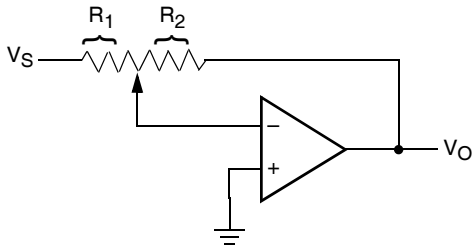
Filter



$$G_O = 1 + R_2/R_1$$

$$f_c = 1/(2\pi RC)$$

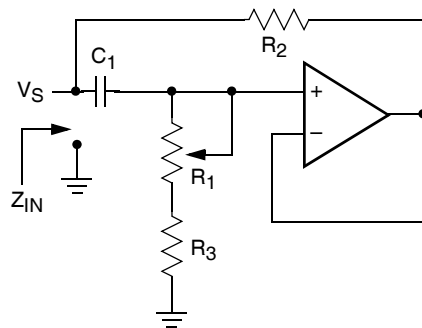
Inverting Amplifier



$$V_O = G V_S$$

$$G = -R_2/R_1$$

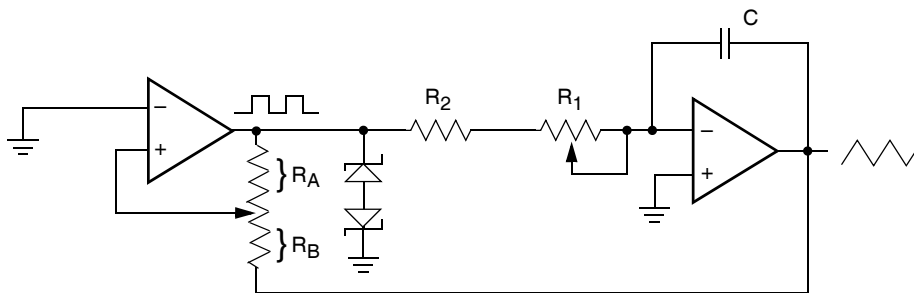
Equivalent L-R Circuit



$$Z_{IN} = R_2 + s R_2 (R_1 + R_3) C_1 = R_2 + s L_{eq}$$

$$(R_1 + R_3) \gg R_2$$

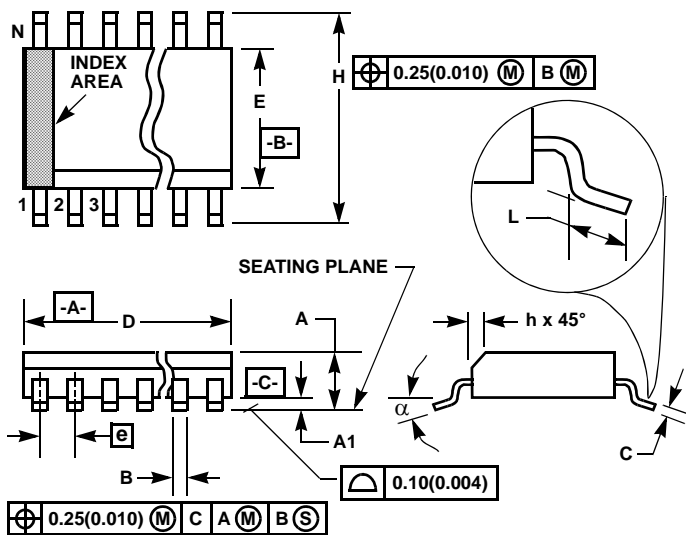
Function Generator



$$\text{frequency} \propto R_1, R_2, C$$

$$\text{amplitude} \propto R_A, R_B$$

Small Outline Plastic Packages (SOIC)



**M24.3 (JEDEC MS-013-AD ISSUE C)
24 LEAD WIDE BODY SMALL OUTLINE PLASTIC PACKAGE**

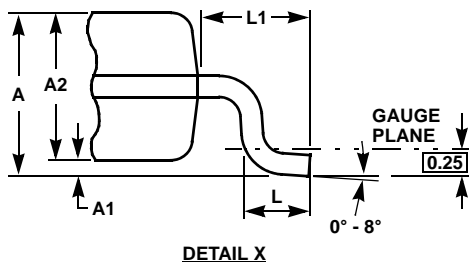
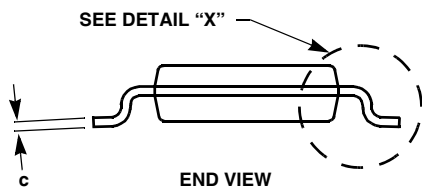
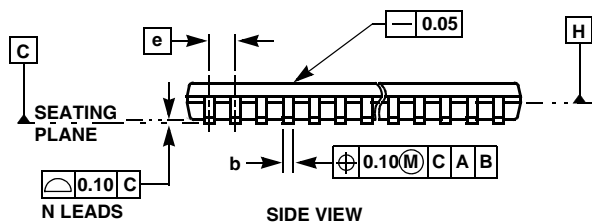
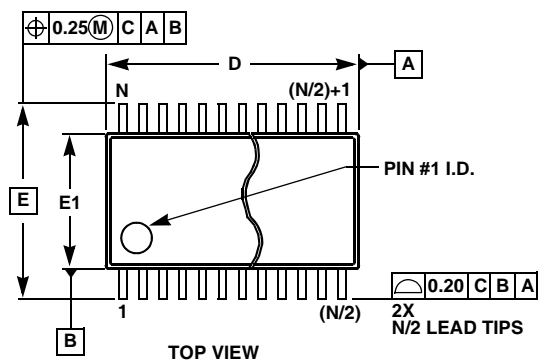
| SYMBOL | INCHES | | MILLIMETERS | | NOTES |
|--------|----------|--------|-------------|-------|-------|
| | MIN | MAX | MIN | MAX | |
| A | 0.0926 | 0.1043 | 2.35 | 2.65 | - |
| A1 | 0.0040 | 0.0118 | 0.10 | 0.30 | - |
| B | 0.013 | 0.020 | 0.33 | 0.51 | 9 |
| C | 0.0091 | 0.0125 | 0.23 | 0.32 | - |
| D | 0.5985 | 0.6141 | 15.20 | 15.60 | 3 |
| E | 0.2914 | 0.2992 | 7.40 | 7.60 | 4 |
| e | 0.05 BSC | | 1.27 BSC | | - |
| H | 0.394 | 0.419 | 10.00 | 10.65 | - |
| h | 0.010 | 0.029 | 0.25 | 0.75 | 5 |
| L | 0.016 | 0.050 | 0.40 | 1.27 | 6 |
| N | 24 | | 24 | | 7 |
| alpha | 0° | 8° | 0° | 8° | - |

NOTES:

1. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication Number 95.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension "E" does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
5. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
6. "L" is the length of terminal for soldering to a substrate.
7. "N" is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. The lead width "B", as measured 0.36mm (0.014 inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch)
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

Rev. 1 4/06

Thin Shrink Small Outline Package Family (TSSOP)



MDP0044

THIN SHRINK SMALL OUTLINE PACKAGE FAMILY

| SYMBOL | MILLIMETERS | | | | | TOLERANCE |
|--------|-------------|-------|-------|-------|-------|-------------|
| | 14 LD | 16 LD | 20 LD | 24 LD | 28 LD | |
| A | 1.20 | 1.20 | 1.20 | 1.20 | 1.20 | Max |
| A1 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | ±0.05 |
| A2 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | ±0.05 |
| b | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | +0.05/-0.06 |
| c | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | +0.05/-0.06 |
| D | 5.00 | 5.00 | 6.50 | 7.80 | 9.70 | ±0.10 |
| E | 6.40 | 6.40 | 6.40 | 6.40 | 6.40 | Basic |
| E1 | 4.40 | 4.40 | 4.40 | 4.40 | 4.40 | ±0.10 |
| e | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | Basic |
| L | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | ±0.15 |
| L1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | Reference |

Rev. F 2/07

NOTES:

1. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.15mm per side.
2. Dimension "E1" does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm per side.
3. Dimensions "D" and "E1" are measured at dAtum Plane H.
4. Dimensioning and tolerancing per ASME Y14.5M-1994.

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