

# MAX5395

## Single, 256-Tap Volatile, I<sup>2</sup>C, Low-Voltage Linear Taper Digital Potentiometer

### General Description

The MAX5395 single, 256-tap volatile, low-voltage linear taper digital potentiometer offers three end-to-end resistance values of 10kΩ, 50kΩ, and 100kΩ. Potentiometer terminals are independent of supply for voltages up to 5.25V with single-supply operation from 1.7V to 5.5V (charge pump enabled). User-controlled shutdown modes allow the H, W, or L terminal to be opened with the wiper position set to zero-code, mid-code, full-code, or the value contained in the wiper register. Ultra-low-quiescent supply current (< 1μA) can be achieved for supply voltages between 2.6V and 5.5V by disabling the internal charge pump and not allowing potentiometer terminals to exceed the supply voltage by more than 0.3V. The MAX5395 provides a low 50ppm/°C end-to-end temperature coefficient and features an I<sup>2</sup>C serial interface.

The small package size, low operating supply voltage, low supply current, and automotive temperature range of the MAX5395 make the device uniquely suited for the portable consumer market and battery-backup industrial applications.

The MAX5395 is available in a lead-free, 8-pin TDFN (2mm x 2mm) package. The device operates over the -40°C to +125°C automotive temperature range.

**Ordering Information** appears at end of data sheet.

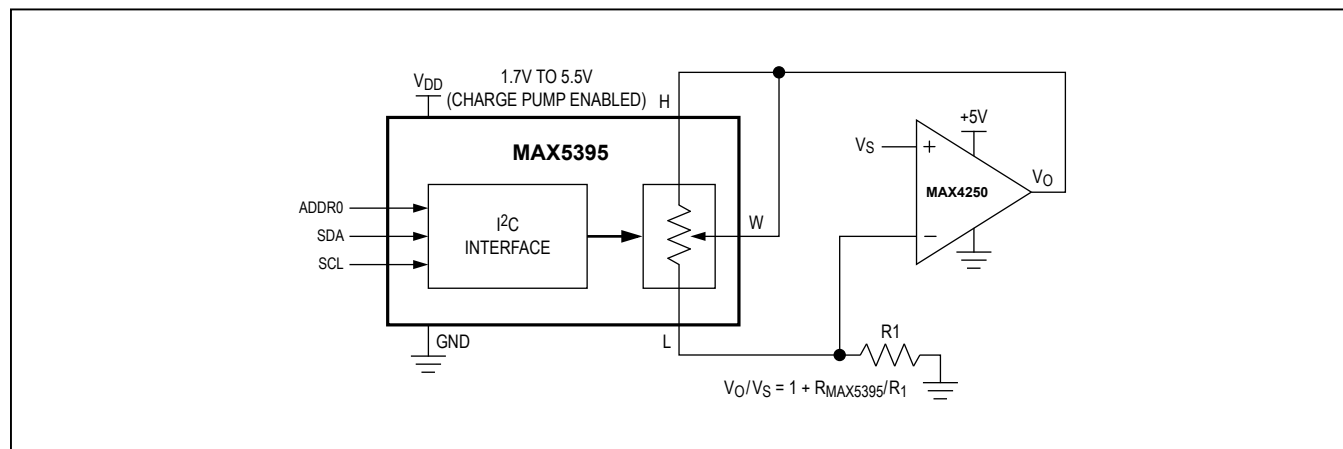
### Benefits and Features

- Single Linear Taper 256-Tap Positions
- 10kΩ, 50kΩ, and 100kΩ End-to-End Resistance
- 1.7V to 5.5V Extended Single Supply
- 0 to 5.25V H, W, L Operating Voltage Independent of V<sub>DD</sub>
- 1μA (typ) Supply Current in Low-Power Mode
- ±1.0 LSB INL, ±0.5 LSB DNL (max) Wiper Accuracy
- Power-On Sets Wiper to Midscale
- 50ppm/°C End-to-End Temperature Coefficient
- 5ppm/°C Ratiometric Temperature Coefficient
- -40°C to +125°C Operating Temperature Range
- 2mm x 2mm, 8-Pin TDFN Package
- I<sup>2</sup>C-Compatible Serial Interface

### Applications

- Portable Electronics
- System Calibration
- Battery-Powered Systems
- Mechanical Potentiometer Replacement

### Typical Operating Circuit



## Absolute Maximum Ratings

(All voltages referenced to GND.)

|                                     |                                                     |
|-------------------------------------|-----------------------------------------------------|
| $V_{DD}$                            | -0.3V to +6V                                        |
| H, W, L (charge pump enabled)       | -0.3V to +5.5V                                      |
| H, W, L (charge pump disabled)      | -0.3V to the lower of<br>( $V_{DD} + 0.3V$ ) or +6V |
| ADDR0                               | -0.3V to the lower of ( $V_{DD} + 0.3V$ ) or +6V    |
| All Other Pins                      | -0.3V to +6V                                        |
| Continuous Current into H, W, and L |                                                     |
| MAX5395L                            | 5mA                                                 |
| MAX5395M                            | 2mA                                                 |
| MAX5395N                            | 1mA                                                 |

|                                                                   |                                             |
|-------------------------------------------------------------------|---------------------------------------------|
| Maximum Current into Any Input                                    | 50mA                                        |
| Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )        |                                             |
| TDFN (derate 11.9mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) | 953.5mW                                     |
| Operating Temperature Range                                       | $-40^\circ\text{C}$ to $+125^\circ\text{C}$ |
| Storage Temperature Range                                         | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Junction Temperature                                              | $+150^\circ\text{C}$                        |
| Lead Temperature (soldering, 10s)                                 | $+300^\circ\text{C}$                        |
| Soldering Temperature (reflow)                                    | $+260^\circ\text{C}$                        |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Package Thermal Characteristics (Note 1)

TDFN

Junction-to-Ambient Thermal Resistance ( $\theta_{JA}$ ) .....83.9 $^\circ\text{C}/\text{W}$

Junction-to-Ambient Thermal Resistance ( $\theta_{JC}$ ) .....37.0 $^\circ\text{C}/\text{W}$

**Note 1:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maximintegrated.com/thermal-tutorial](http://www.maximintegrated.com/thermal-tutorial).

## Electrical Characteristics

( $V_{DD} = 1.7V$  to  $5.5V$ ,  $V_H = V_{DD}$ ,  $V_L = GND$ ,  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ , unless otherwise noted. Typical values are at  $V_{DD} = 1.8V$ ,  $T_A = +25^\circ\text{C}$ .) (Note 2)

| PARAMETER                               | SYMBOL          | CONDITIONS                                                                                              |                      | MIN  | TYP | MAX  | UNITS  |
|-----------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------|----------------------|------|-----|------|--------|
| RESOLUTION                              |                 |                                                                                                         |                      |      |     |      |        |
| 256-Tap Family                          | N               |                                                                                                         |                      | 256  |     |      | Tap    |
| DC PERFORMANCE (Voltage-Divider Mode)   |                 |                                                                                                         |                      |      |     |      |        |
| Integral Nonlinearity (Note 3)          | INL             |                                                                                                         |                      | -1.0 |     | +1.0 | LSB    |
| Differential Nonlinearity               | DNL             | (Note 3)                                                                                                |                      | -0.5 |     | +0.5 | LSB    |
| Ratiometric Resistor Tempco             |                 | (DV <sub>W</sub> /V <sub>W</sub> )/DT, V <sub>H</sub> = V <sub>DD</sub> , V <sub>L</sub> = GND, No Load |                      | 5    |     |      | ppm/°C |
| Full-Scale Error (Code FFh)             |                 | Charge pump enabled, 1.7V < V <sub>DD</sub> < 5.5V                                                      |                      | -0.5 |     |      | LSB    |
|                                         |                 | Charge pump disabled, 2.6V < V <sub>DD</sub> < 5.5V                                                     | MAX5395M<br>MAX5395N | -0.5 |     |      |        |
|                                         |                 |                                                                                                         | MAX5395L             | -1.0 |     |      |        |
| Zero-Scale Error (Code 00h)             |                 | Charge pump enabled, 1.7V < V <sub>DD</sub> < 5.5V                                                      |                      |      |     | +0.5 | LSB    |
|                                         |                 | Charge pump disabled, 2.6V < V <sub>DD</sub> < 5.5V                                                     | MAX5395M<br>MAX5395N |      |     | +0.5 |        |
|                                         |                 |                                                                                                         | MAX5395L             |      |     | +1.0 |        |
| DC PERFORMANCE (Variable Resistor Mode) |                 |                                                                                                         |                      |      |     |      |        |
| Integral Nonlinearity (Note 4)          | R-INL           | Charge pump enabled, 1.7V < V <sub>DD</sub> < 5.5V                                                      |                      | -1.0 |     | +1.0 | LSB    |
|                                         |                 | Charge pump disabled, 2.6V < V <sub>DD</sub> < 5.5V                                                     | MAX5395M<br>MAX5395N | -1.0 |     | +1.0 |        |
|                                         |                 |                                                                                                         | MAX5395L             | -1.5 |     | +1.5 |        |
| Differential Nonlinearity               | R-DNL           | (Note 4)                                                                                                |                      | -0.5 |     | +0.5 | LSB    |
| Wiper Resistance (Note 5)               | R <sub>WL</sub> | Charge pump enabled, 1.7V < V <sub>DD</sub> < 5.5V                                                      |                      | 25   |     | 50   | Ω      |
|                                         |                 | Charge pump disabled, 2.6V < V <sub>DD</sub> < 5.5V                                                     |                      |      |     | 200  |        |

## Electrical Characteristics (continued)

( $V_{DD} = 1.7V$  to  $5.5V$ ,  $V_H = V_{DD}$ ,  $V_L = GND$ ,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted. Typical values are at  $V_{DD} = 1.8V$ ,  $T_A = +25^{\circ}C$ .) (Note 2)

| PARAMETER                                 | SYMBOL                           | CONDITIONS                                          |                        | MIN   | TYP             | MAX                 | UNITS |
|-------------------------------------------|----------------------------------|-----------------------------------------------------|------------------------|-------|-----------------|---------------------|-------|
| DC PERFORMANCE (Resistor Characteristics) |                                  |                                                     |                        |       |                 |                     |       |
| Terminal Capacitance                      | C <sub>H</sub> , C <sub>L</sub>  | Measured to GND                                     |                        | 10    |                 | pF                  |       |
| Wiper Capacitance                         | C <sub>W</sub>                   | Measured to GND                                     |                        | 20    |                 | pF                  |       |
| End-to-End Resistor Tempco                | T <sub>CR</sub>                  | No load                                             |                        | 50    |                 | ppm/°C              |       |
| End-to-End Resistor Tolerance             |                                  | Wiper not connected                                 |                        | -25   | +25             | %                   |       |
| AC PERFORMANCE                            |                                  |                                                     |                        |       |                 |                     |       |
| -3dB Bandwidth                            | BW                               | Code = 80h, 10pF load, V <sub>DD</sub> = 1.8V       | 10kΩ                   | 1600  |                 | kHz                 |       |
|                                           |                                  |                                                     | 50kΩ                   | 340   |                 |                     |       |
|                                           |                                  |                                                     | 100kΩ                  | 165   |                 |                     |       |
| Total Harmonic Distortion Plus Noise      | THD+N                            | (Note 6)                                            |                        | 0.035 |                 | %                   |       |
| Wiper Settling Time                       | t <sub>S</sub>                   | (Note 7)                                            | 10kΩ                   | 190   |                 | ns                  |       |
|                                           |                                  |                                                     | 50kΩ                   | 400   |                 |                     |       |
|                                           |                                  |                                                     | 100kΩ                  | 664   |                 |                     |       |
| Charge-Pump Feedthrough at W              | V <sub>RW</sub>                  |                                                     |                        | 600   |                 | nV <sub>RMS</sub>   |       |
| POWER SUPPLIES                            |                                  |                                                     |                        |       |                 |                     |       |
| Supply Voltage Range                      | V <sub>DD</sub>                  |                                                     |                        | 1.7   | 5.5             | V                   |       |
| Terminal Voltage Range (H, W, L to GND)   |                                  | Charge pump enabled, 1.7V < V <sub>DD</sub> < 5.5V  |                        | 0     | 5.25            | V                   |       |
|                                           |                                  | Charge pump disabled, 2.6V < V <sub>DD</sub> < 5.5V |                        | 0     | V <sub>DD</sub> |                     |       |
| Supply Current (Note 8)                   | I <sub>VDD</sub>                 | Charge pump disabled, 1.7V                          |                        | 0.3   | 1.4             | μA                  |       |
|                                           |                                  | Charge pump disabled, 2.5V                          |                        | 0.4   | 1.7             |                     |       |
|                                           |                                  | Charge pump disabled, 5.5V                          |                        | 1.0   | 4.0             |                     |       |
|                                           |                                  | Charge pump enabled, 1.7V < V <sub>DD</sub> < 5.5V  | V <sub>DD</sub> = 5.5V | 25    | 50              |                     |       |
|                                           |                                  |                                                     | V <sub>DD</sub> = 1.7V | 20    | 45              |                     |       |
| DIGITAL INPUTS                            |                                  |                                                     |                        |       |                 |                     |       |
| Minimum Input High Voltage                | V <sub>IH</sub>                  | 2.6V < V <sub>DD</sub> < 5.5V                       |                        | 70    |                 | % x V <sub>DD</sub> |       |
|                                           |                                  | 1.7V < V <sub>DD</sub> < 2.6V                       |                        | 80    |                 |                     |       |
| Maximum Input Low Voltage                 | V <sub>IL</sub>                  | 2.6V < V <sub>DD</sub> < 5.5V                       |                        |       | 30              | % x V <sub>DD</sub> |       |
|                                           |                                  | 1.7V < V <sub>DD</sub> < 2.6V                       |                        |       | 20              |                     |       |
| Input Leakage Current                     |                                  |                                                     |                        | -1    | +1              | μA                  |       |
| Input Capacitance                         |                                  |                                                     |                        | 5     |                 | pF                  |       |
| ADDR0 Pullup/Pulldown Strength            | R <sub>PUR</sub> R <sub>PD</sub> | (Note 9)                                            |                        | 60    |                 | kΩ                  |       |
| TIMING CHARACTERISTICS (Note 10)          |                                  |                                                     |                        |       |                 |                     |       |
| Maximum SCL Frequency                     | f <sub>SCL</sub>                 |                                                     |                        | 400   |                 | kHz                 |       |
| Setup Time for START Condition            | t <sub>SU:STA</sub>              |                                                     |                        | 0.6   |                 | μs                  |       |

**Electrical Characteristics (continued)**

( $V_{DD} = 1.7V$  to  $5.5V$ ,  $V_H = V_{DD}$ ,  $V_L = GND$ ,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise noted. Typical values are at  $V_{DD} = 1.8V$ ,  $T_A = +25^{\circ}C$ .) (Note 2)

| PARAMETER                                       | SYMBOL       | CONDITIONS | MIN | TYP | MAX | UNITS   |
|-------------------------------------------------|--------------|------------|-----|-----|-----|---------|
| Hold Time for START Condition                   | $t_{HD:STA}$ |            | 0.6 |     |     | $\mu s$ |
| SCL High Time                                   | $t_{HIGH}$   |            | 0.6 |     |     | $\mu s$ |
| SCL Low Time                                    | $t_{LOW}$    |            | 1.3 |     |     | $\mu s$ |
| Data Setup Time                                 | $t_{SU:DAT}$ |            | 100 |     |     | ns      |
| Data Hold Time                                  | $t_{HD:DAT}$ |            | 0   |     |     | $\mu s$ |
| SDA, SCL Rise Time                              | $t_R$        |            |     |     | 0.3 | $\mu s$ |
| SDA, SCL Fall Time                              | $t_F$        |            |     |     | 0.3 | $\mu s$ |
| Setup Time for STOP Conditions                  | $t_{SU:STO}$ |            | 0.6 |     |     | $\mu s$ |
| Bus Free Time Between STOP and START Conditions | $t_{BUF}$    |            | 1.3 |     |     | $\mu s$ |
| Pulse-Suppressed Spike Width                    | $t_{SP}$     |            |     | 50  |     | ns      |
| Capacitive Load for Each Bus                    | $C_B$        |            |     | 400 |     | pF      |

**Note 2:** All devices are production tested at  $T_A = +25^{\circ}C$  and are guaranteed by design and characterization for  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ .

**Note 3:** DNL and INL are measured with the potentiometer configured as a voltage-divider with  $V_H = 5.25V$  (QP enabled) or  $V_{DD}$  (QP disabled) and  $V_L = GND$ . The wiper terminal is unloaded and measured with an ideal voltmeter.

**Note 4:** R-DNL and R-INL are measured with the potentiometer configured as a variable resistor (Figure 1). H is unconnected and  $L = GND$ .

For charge pump enabled,  $V_{DD} = 1.7V$  to  $5.5V$ , the wiper terminal is driven with a source current of  $400\mu A$  for the  $10k\Omega$  configuration,  $80\mu A$  for the  $50k\Omega$  configuration, and  $40\mu A$  for the  $100k\Omega$  configuration.

For charge pump disabled and  $V_{DD} = 5.5V$ , the wiper terminal is driven with a source current of  $400\mu A$  for the  $10k\Omega$  configuration,  $80\mu A$  for the  $50k\Omega$  configuration, and  $40\mu A$  for the  $100k\Omega$  configuration.

For charge pump disabled and  $V_{DD} = 2.6V$ , the wiper terminal is driven with a source current of  $200\mu A$  for the  $10k\Omega$  configuration,  $40\mu A$  for the  $50k\Omega$  configuration, and  $20\mu A$  for the  $100k\Omega$  configuration.

**Note 5:** The wiper resistance is the maximum value measured by injecting the currents given in Note 4 into W with  $L = GND$ .  $R_W = (V_W - V_H)/I_W$ .

**Note 6:** Measured at W with H driven with a 1kHz, 0V to  $V_{DD}$  amplitude tone and  $V_L = GND$ . Wiper at midscale with a  $10pF$  load.

**Note 7:** Wiper-settling time is the worst-case 0-to-50% rise time, measured between tap 0 and tap 127.  $H = V_{DD}$ ,  $L = GND$ , and the wiper terminal is loaded with  $10pF$  capacitance to ground.

**Note 8:** Digital Inputs at  $V_{DD}$  or  $GND$ .

**Note 9:** An unconnected condition on the ADDR0 pin is sensed via a pullup and pulldown operation. For proper operation, the ADDR0 pin should be tied to  $V_{DD}$ ,  $GND$ , or left unconnected with minimal capacitance.

**Note 10:** Digital timing is guaranteed by design and characterization, and is not production tested.

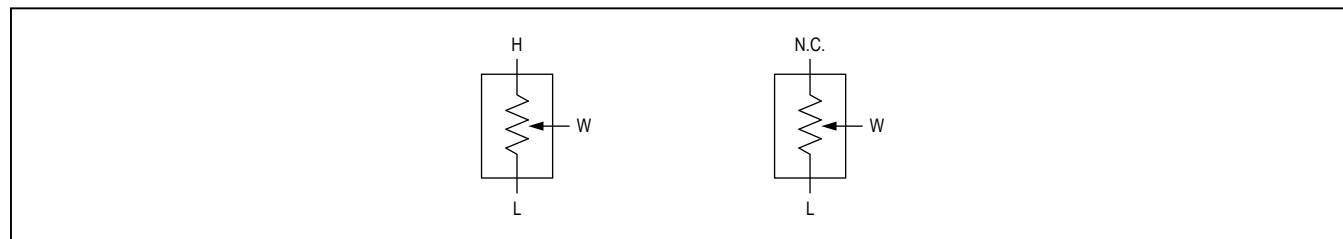
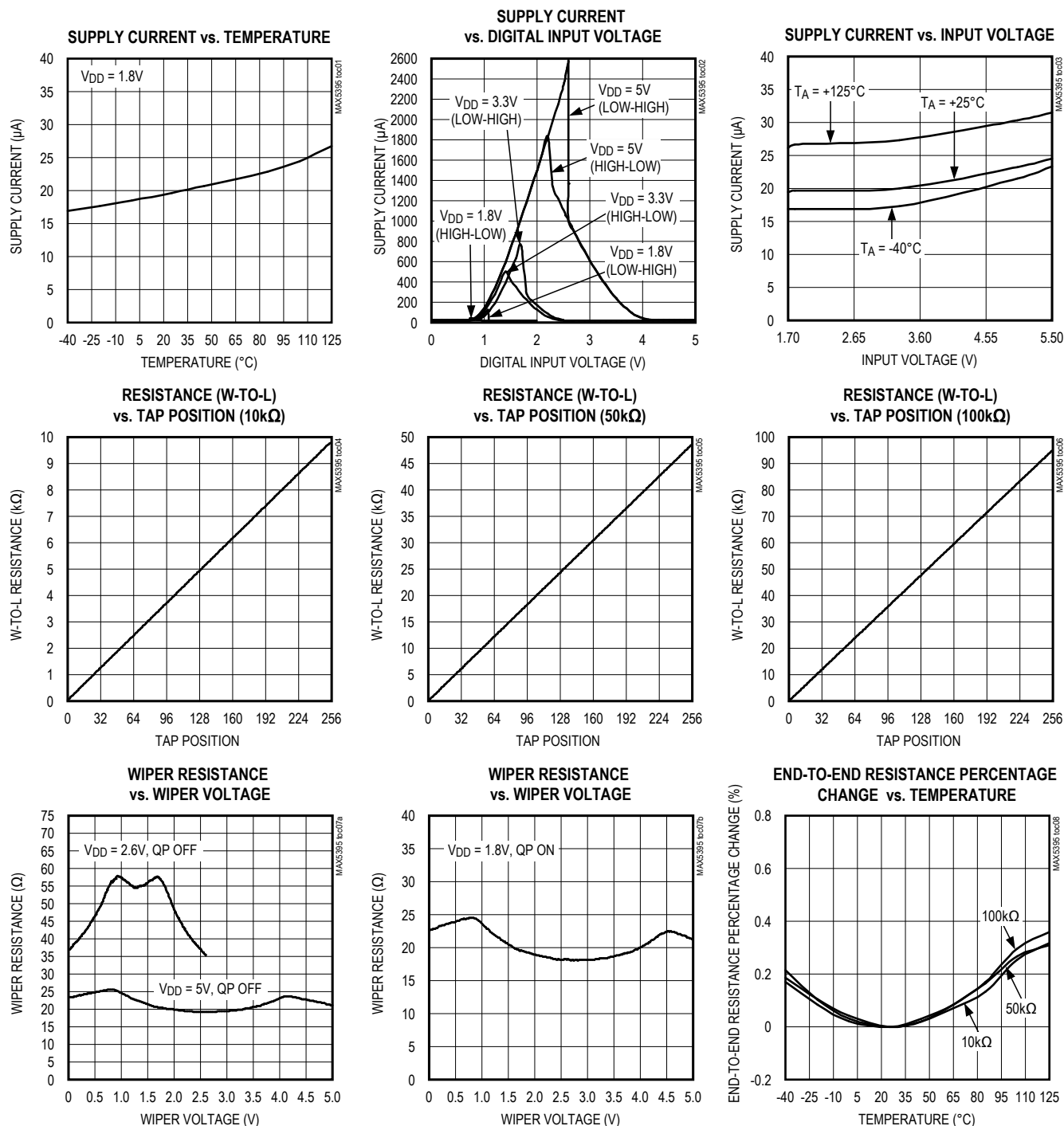
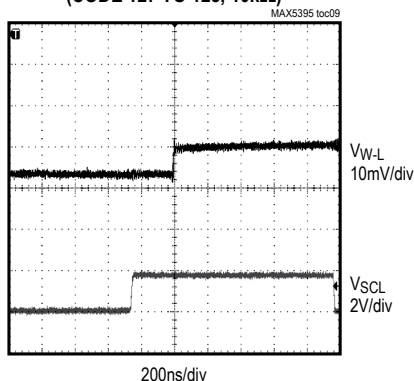
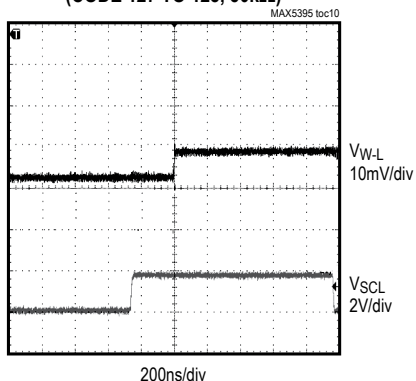
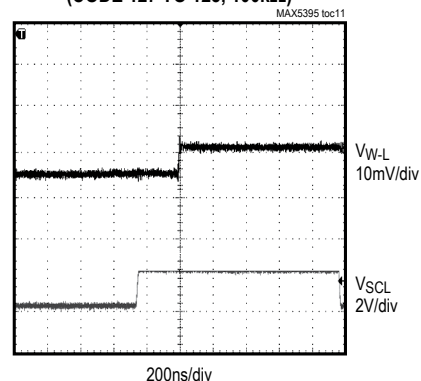


Figure 1. Voltage-Divider and Variable Resistor Configurations

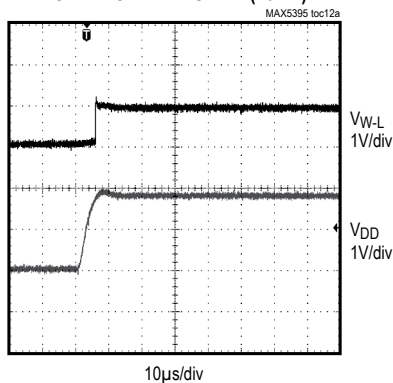
## Typical Operating Characteristics

(V<sub>DD</sub> = 1.8V, T<sub>A</sub> = +25°C, unless otherwise noted.)

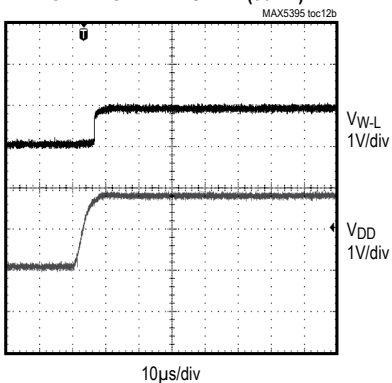
## Typical Operating Characteristics (continued)

(V<sub>DD</sub> = 1.8V, T<sub>A</sub> = +25°C, unless otherwise noted.)TAP-TO-TAP SWITCHING TRANSIENT  
(CODE 127 TO 128, 10kΩ)TAP-TO-TAP SWITCHING TRANSIENT  
(CODE 127 TO 128, 50kΩ)TAP-TO-TAP SWITCHING TRANSIENT  
(CODE 127 TO 128, 100kΩ)

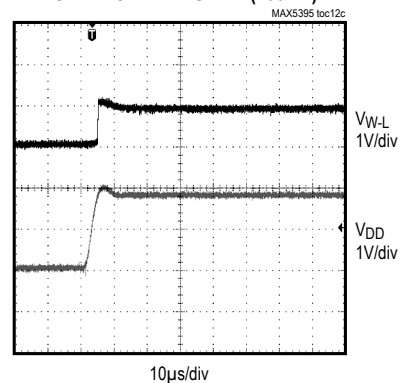
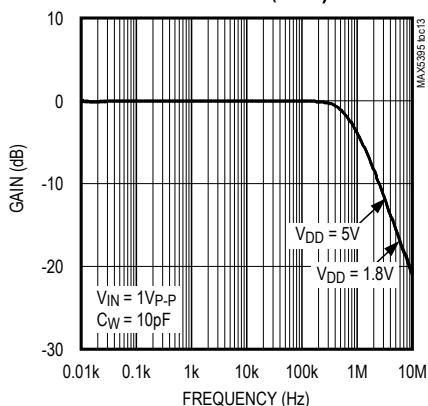
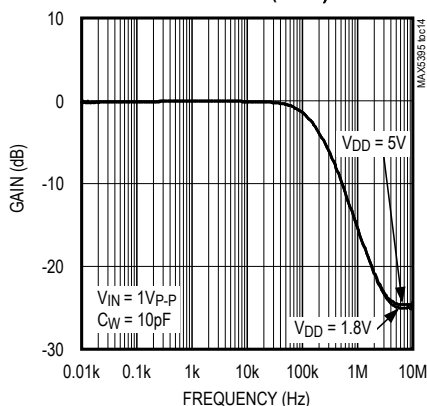
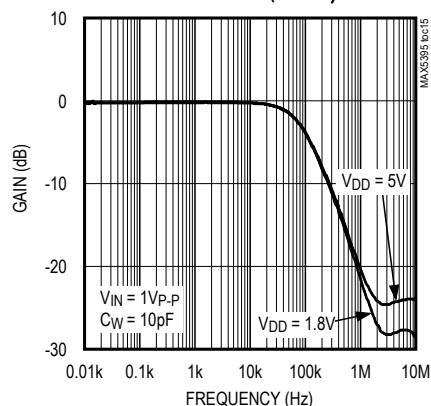
POWER-ON TRANSIENT (10kΩ)



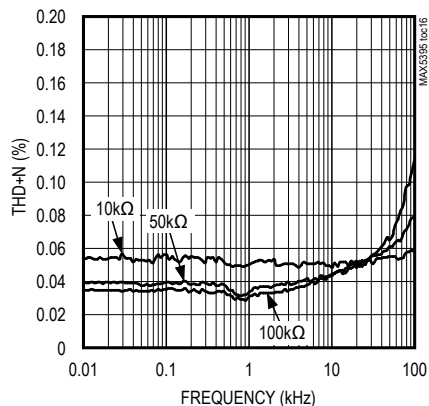
POWER-ON TRANSIENT (50kΩ)



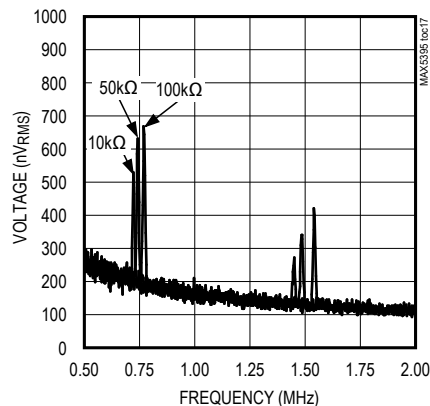
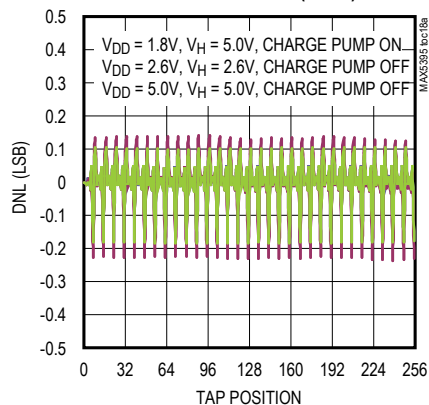
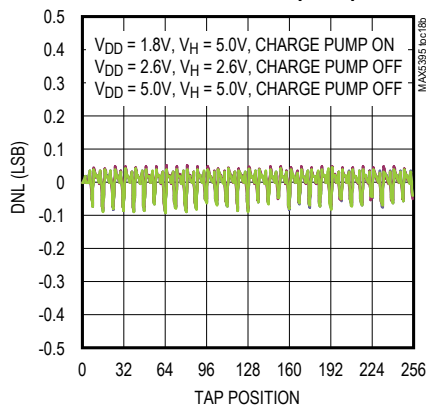
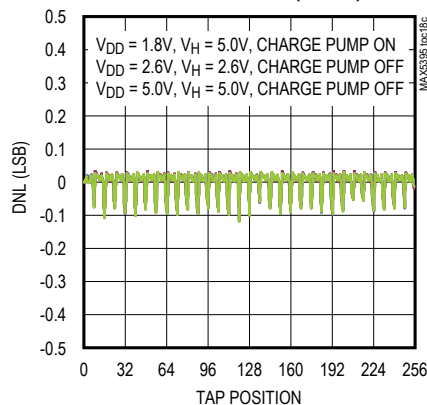
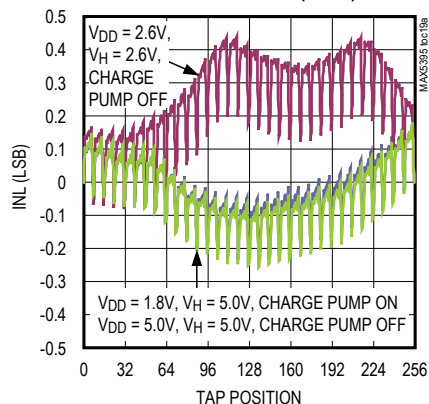
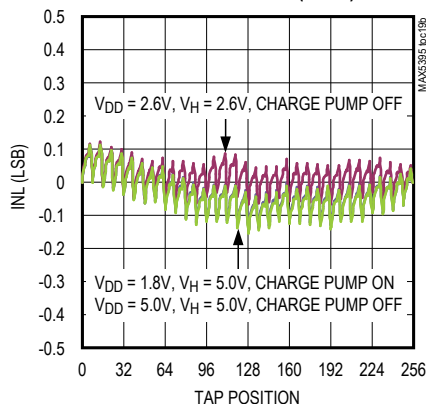
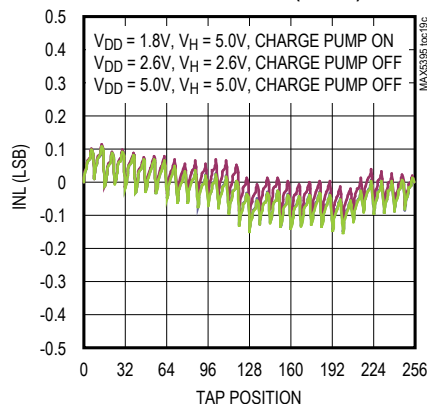
POWER-ON TRANSIENT (100kΩ)

MIDSCALE FREQUENCY  
RESPONSE (10kΩ)MIDSCALE FREQUENCY  
RESPONSE (50kΩ)MIDSCALE FREQUENCY  
RESPONSE (100kΩ)

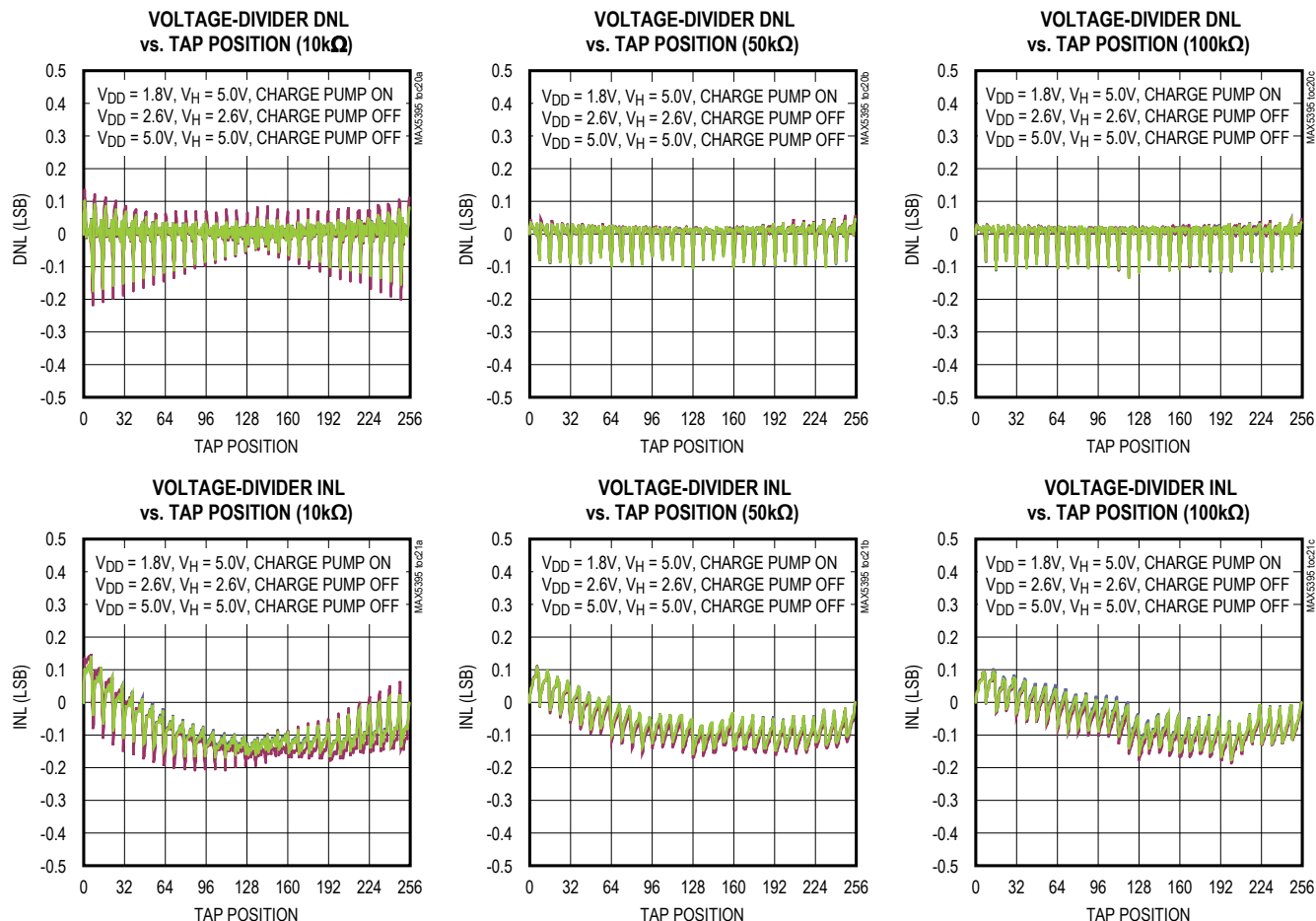
## Typical Operating Characteristics (continued)

(V<sub>DD</sub> = 1.8V, T<sub>A</sub> = +25°C, unless otherwise noted.)TOTAL HARMONIC DISTORTION PLUS NOISE  
vs. FREQUENCY

CHARGE-PUMP FEEDTHROUGH AT W

VARIABLE-RESISTOR DNL  
vs. TAP POSITION (10kΩ)VARIABLE-RESISTOR DNL  
vs. TAP POSITION (50kΩ)VARIABLE-RESISTOR DNL  
vs. TAP POSITION (100kΩ)VARIABLE-RESISTOR INL  
vs. TAP POSITION (10kΩ)VARIABLE-RESISTOR INL  
vs. TAP POSITION (50kΩ)VARIABLE-RESISTOR INL  
vs. TAP POSITION (100kΩ)

## Typical Operating Characteristics (continued)

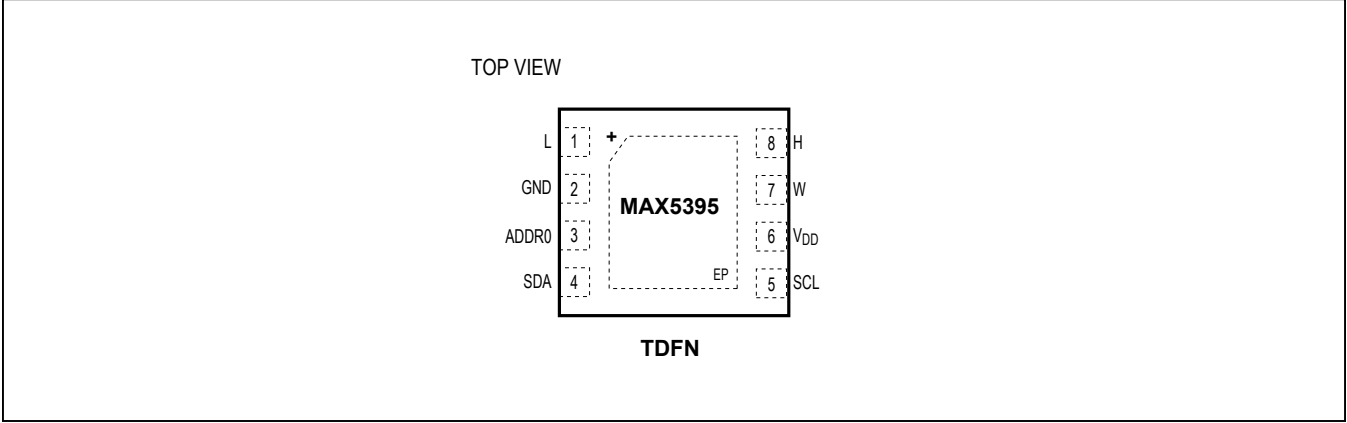
(V<sub>DD</sub> = 1.8V, T<sub>A</sub> = +25°C, unless otherwise noted.)



MAX5395

Single, 256-Tap Volatile, I2C, Low-Voltage Linear  
Taper Digital Potentiometer

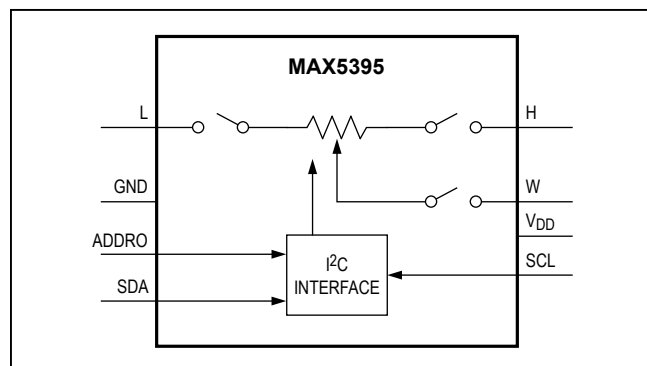
Pin Configuration



Pin Description

| PIN | NAME            | FUNCTION                                                                                                              |
|-----|-----------------|-----------------------------------------------------------------------------------------------------------------------|
| 1   | L               | Low Terminal. The voltage at L can be greater than or less than the voltage at H. Current can flow into or out of L.  |
| 2   | GND             | Ground                                                                                                                |
| 3   | ADDR0           | Address Input 0. Connected to V <sub>DD</sub> , GND, or open.                                                         |
| 4   | SDA             | I <sup>2</sup> C Serial Data Input                                                                                    |
| 5   | SCL             | I <sup>2</sup> C Clock Input                                                                                          |
| 6   | V <sub>DD</sub> | Power Supply                                                                                                          |
| 7   | W               | Wiper Terminal                                                                                                        |
| 8   | H               | High Terminal. The voltage at H can be greater than or less than the voltage at L. Current can flow into or out of H. |
| —   | EP              | Exposed Pad. Internally connected to GND. Connect to ground.                                                          |

## Functional Diagram



## Detailed Description

The MAX5395 single, 256-tap volatile, low-voltage linear taper digital potentiometer offers three end-to-end resistance values of 10k $\Omega$ , 50k $\Omega$ , and 100k $\Omega$ . Potentiometer terminals are independent of supply for voltages up to +5.25V with single-supply operation from 1.7V to 5.5V (charge pump enabled). User-controlled shutdown modes allow the H, W, or L terminals to be opened with the wiper position set to zero-code, midcode, full-code, or the value contained in the wiper register. Ultra-low-quiescent supply current (< 1 $\mu$ A) can be achieved for supply voltages between 2.6V and 5.5V by disabling the internal charge pump and not allowing potentiometer terminals to exceed the supply voltage by more than 0.3V. The MAX5395 provides a low 50ppm/ $^{\circ}$ C end-to-end temperature coefficient and features a I<sup>2</sup>C serial interface.

The small package size, low supply operating voltage, low supply current, and automotive temperature range of the MAX5395 make the device uniquely suited for the portable consumer market and battery-backup industrial applications.

## Charge Pump

The MAX5395 contains an internal charge pump that guarantees the maximum wiper resistance,  $R_{WL}$ , to be less than 50 $\Omega$  (25 $\Omega$  typ) for supply voltages down to 1.7V and allows pins H, W, and L to be driven between GND and 5.25V independent of  $V_{DD}$ . Minimal charge-pump feedthrough is present at the terminal outputs and is illustrated by the Charge-Pump Feedthrough at W vs. Frequency graph in the [Typical Operating Characteristics](#). The charge pump is on by default but

can be disabled with QP\_OFF and enabled with the QP\_ON commands ([Table 1](#)). The MAX5395 minimum supply voltage with charge pump disabled is limited to 2.6V and terminal voltage cannot exceed -0.3V to ( $V_{DD} + 0.3V$ ).

## I<sup>2</sup>C Interface

The MAX5395 feature an I<sup>2</sup>C/SMBus-compatible, 2-wire serial interface consisting of a serial data line (SDA) and a serial clock line (SCL). SDA and SCL enable communication between the MAX5395 and the master at clock rates up to 400kHz. [Figure 1](#) shows the 2-wire interface timing diagram. The master generates SCL and initiates data transfer on the bus. The master device writes data to the MAX5395 by transmitting the proper slave address followed by the command byte and then the data word. Each transmit sequence is framed by a START (S) or Repeated START (Sr) condition and a STOP (P) condition. Each word transmitted to the MAX5395 is 8 bits long and is followed by an acknowledge clock pulse. A master reading data from the MAX5395 must transmit the proper slave address followed by a series of nine SCL pulses for each byte of data requested. The MAX5395 transmit data on SDA in sync with the master-generated SCL pulses. The master acknowledges receipt of each byte of data. Each read sequence is framed by a START or Repeated START condition, a not acknowledge, and a STOP condition. SDA operates as both an input and an open-drain output. A pullup resistor, typically 4.7k $\Omega$ , is required on SDA. SCL operates only as an input. A pullup resistor, typically 4.7k $\Omega$ , is required on SCL if there are multiple masters on the bus, or if the single master has an open-drain SCL output.

Series resistors in line with SDA and SCL are optional. Series resistors protect the digital inputs of the MAX5395 from high voltage spikes on the bus lines and minimize crosstalk and undershoot of the bus signals. The MAX5395 can accommodate bus voltages higher than  $V_{DD}$  up to a limit of +5.5V. Bus voltages lower than  $V_{DD}$  are not recommended and may result in significantly increased interface currents and data corruption.

The MAX5395 with I<sup>2</sup>C interface contains a shift register that decodes the command and address bytes, routing the data to the register. Data written to a memory register immediately updates the wiper position. The wiper powers up in mid position, D[7:0] = 0x80 with charge pump enabled.

**I<sup>2</sup>C START and STOP Conditions**

SDA and SCL idle high when the bus is not in use. A master initiates communication by issuing a START condition. A START condition is a high-to-low transition on SDA with SCL high. A STOP condition is a low-to-high transition on SDA while SCL is high (Figure 2). A START condition from the master signals the beginning of a transmission to the MAX5395. The master terminates transmission and frees the bus, by issuing a STOP condition. The bus remains active if a Repeated START condition is generated instead of a STOP condition.

**I<sup>2</sup>C Early STOP and Repeated START Conditions**

The MAX5395 recognizes a STOP condition at any point during data transmission except if the STOP condition occurs in the same high pulse as a START condition. For proper operation, do not send a STOP condition during the same SCL high pulse as the START condition. Transmissions ending in an early STOP condition will not impact the internal device settings. If the STOP occurs during a readback byte, the transmission is terminated

and a later read mode request will begin transfer of the requested register data from the beginning. See Figure 3.

It is possible to interrupt a transmission to a MAX5395 with a new START (Repeated START) condition (perhaps addressing another device), which leaves the input registers with data that has not been transferred to the internal registers. The unused data will not be stored under these conditions. The aborted MAX5395 I<sup>2</sup>C sequence will have no effect on the part.

**I<sup>2</sup>C Acknowledge**

In write mode, the acknowledge bit (ACK) is a clocked 9th bit that the MAX5395 uses to handshake receipt of each byte of data as shown in Figure 4. The MAX5395 pulls down SDA during the entire master-generated 9th clock pulse if the previous byte is successfully received. Monitoring ACK allows for detection of unsuccessful data transfers. An unsuccessful data transfer occurs if a receiving device is busy or if a system fault has occurred. In the event of an unsuccessful data transfer, the bus master will retry communication.

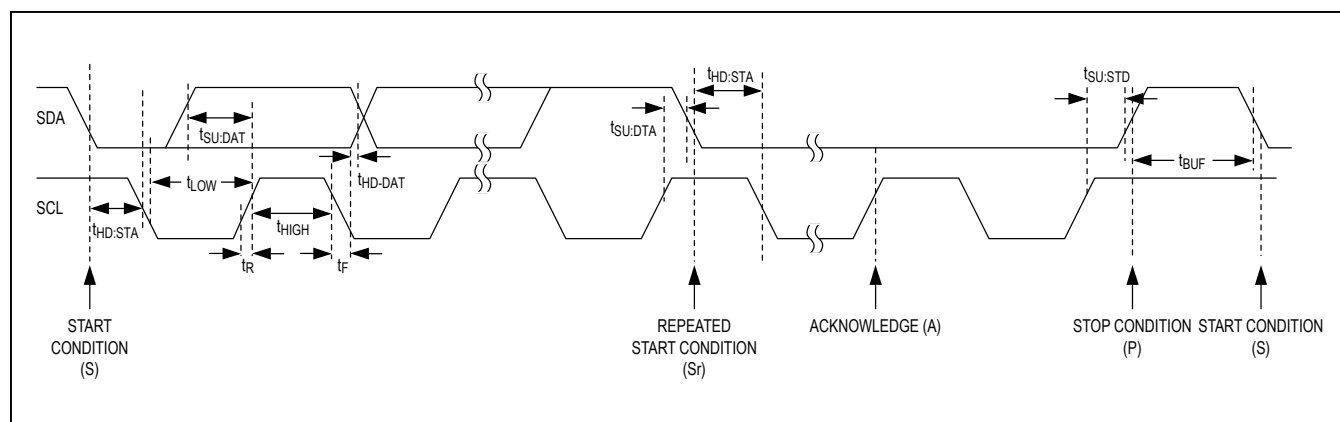


Figure 2. I<sup>2</sup>C Timing Diagram

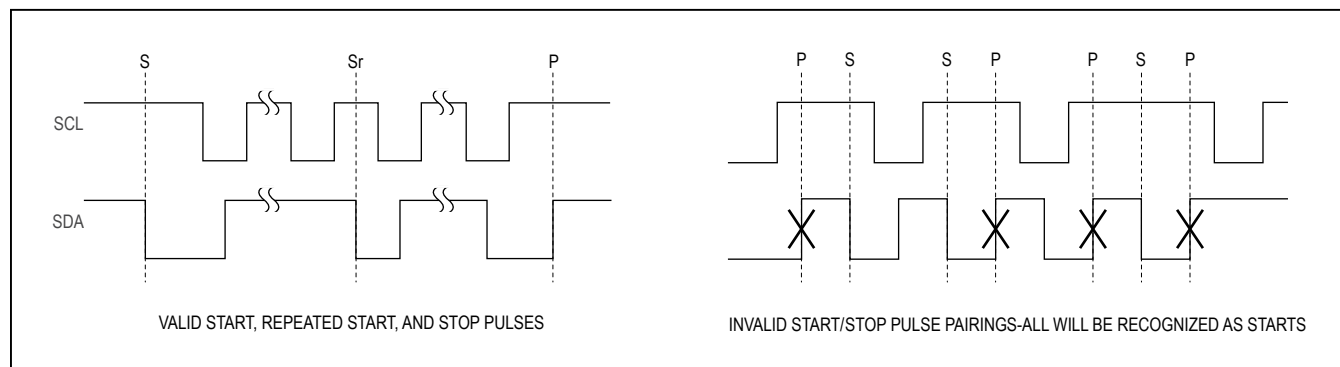


Figure 3. I<sup>2</sup>C START(s), Repeated START(Sr), and STOP(S) Conditions

In read mode, the master pulls down SDA during the 9th clock cycle to acknowledge receipt of data from the MAX5395. An acknowledge is sent by the master after each read byte to allow data transfer to continue. A not-acknowledge is sent when the master reads the final byte of data from the MAX5395, followed by a STOP condition.

I2C Slave Address

The slave address is defined as the seven most significant bits (MSBs) followed by the R/W bit. See Figure 5 and Figure 6. The five most significant bits are 01010 with the 3 LSBs determined ADDR0 as shown in Table 1. Setting the R/W bit to 1 configures the MAX5395 for read mode. Setting the R/W bit to 0 configures the MAX5395 for write mode. The slave address is the first byte of information sent to the MAX5395 after the START condition.

The MAX5395 has the ability to detect an unconnected (N.C.) state on the ADDR0 input for additional address flexibility; if disconnecting the ADDR0 input, be certain to minimize all loading on the ADDR0 input (i.e. provide a landing for ADDR0, but do not allow any board traces).

I2C Message Format for Writing

A master device communicates with the MAX5395 by transmitting the proper slave address followed by command

Table 1. I2C Slave Address LSBs

| ADDR0           | A1 | A0 | SLAVE ADDRESS |
|-----------------|----|----|---------------|
| GND             | 0  | 0  | 0101000       |
| N.C.            | 0  | 1  | 0101001       |
| V <sub>DD</sub> | 1  | 1  | 0101011       |

and data word. Each transmit sequence is framed by a START or Repeated START condition and a STOP condition as described above. Each word is 8 bits long and is always followed by an acknowledge clock (ACK) pulse as shown in Figure 5. The first byte contains the address of the MAX5395 with R/W = 0 to indicate a write. The second byte contains the command to be executed and the third byte contains the data to be written.

I2C Message Format for Readback Operations

Each readback sequence is framed by a START or Repeated START condition and a STOP condition. Each word is 8 bits long and is followed by an acknowledge clock pulse as shown in Figure 6. The first byte contains the address of the MAX5395 with R/W = 0 to indicate a write. The second byte contains the register that is to be read back. There is a Repeated START condition, followed by the device address with R/W = 1 to indicate a

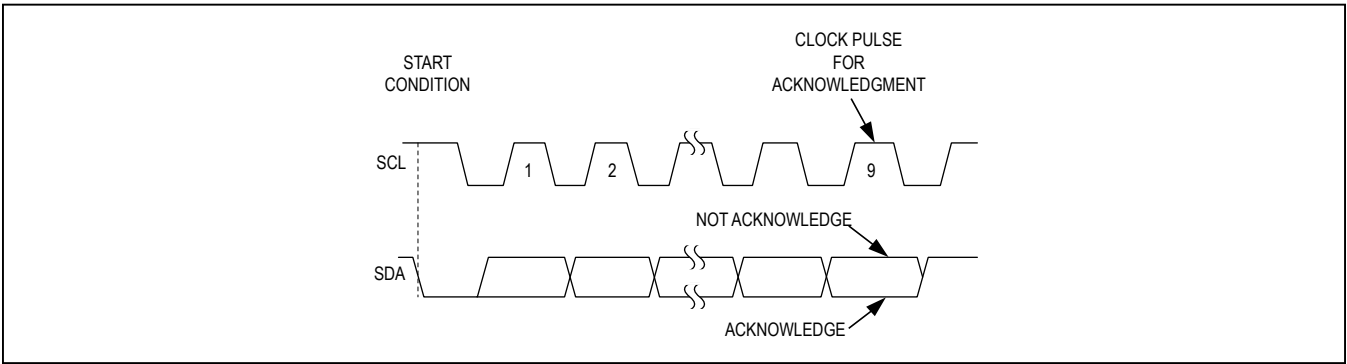


Figure 4. I2C Acknowledge

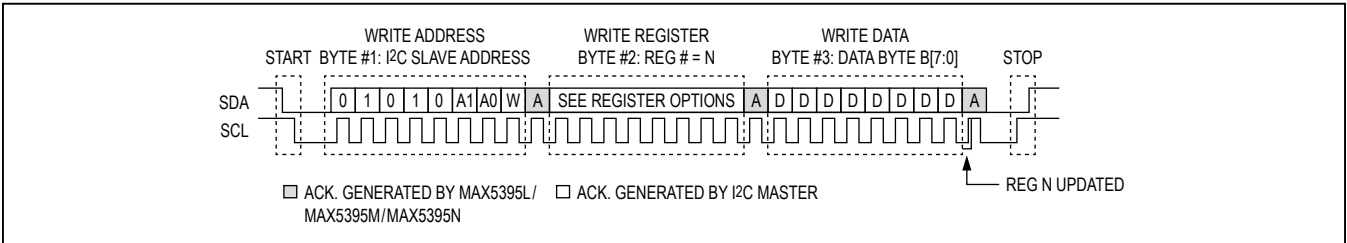


Figure 5. I2C Complete Write Serial Transmission

MAX5395

Single, 256-Tap Volatile, I2C, Low-Voltage Linear

Taper Digital Potentiometer

read and an acknowledge clock. The master has control of the SCL line but the MAX5395 takes over the SDA line. The final byte in the frame contains the register data readback followed by a STOP condition. If additional bytes beyond those required to read back the requested data are provided, the MAX5395 will continue to read back ones.

The wiper register and the configuration register are the only two registers that support readback (Table 2). Readback of all other registers is not supported and results in the readback of ones.

D[7:0]: Wiper position

QP: Charge pump status, 1 is enabled, 0 is disabled.

HSW: H terminal switch status, 0 is closed, 1 is open

WSW: W terminal switch status, 0 is closed, 1 is open

LSW: L terminal switch status, 0 is closed, 1 is open

TSEL[1:0]: Tap select, 00- wiper is at contents of wiper register, 01 – wiper is at 0x00, 10 – wiper is at 0x80, 11 – wiper is at 0xFF.

**General Call Support**

The MAX5395 supports software reset through general call address 0x00 followed by R/W = 0, followed by 0x06 data. A software reset of the MAX5395 will return the part to the power-on default conditions. The MAX5395 will ACK the general call address and any command byte following, but will not support any general call features other than software reset.

Table 2. I2C READ Command Byte Summary

| REGISTER | COMMAND BYTE |    |    |    |    |    |    |    | DATA BYTE |    |    |     |     |     |           |    |
|----------|--------------|----|----|----|----|----|----|----|-----------|----|----|-----|-----|-----|-----------|----|
|          | C7           | C6 | C5 | C4 | C3 | C2 | C1 | C0 | D7        | D6 | D5 | D4  | D3  | D2  | D1        | D0 |
| WIPER    | 0            | 0  | 0  | 0  | 0  | 0  | 0  | 0  | D7        | D6 | D5 | D4  | D3  | D2  | D1        | D0 |
| CONFIG   | 1            | 0  | 0  | 0  | 0  | 0  | 0  | 0  | QP        | 0  | 0  | HSW | LSW | WSW | TSEL[1:0] |    |

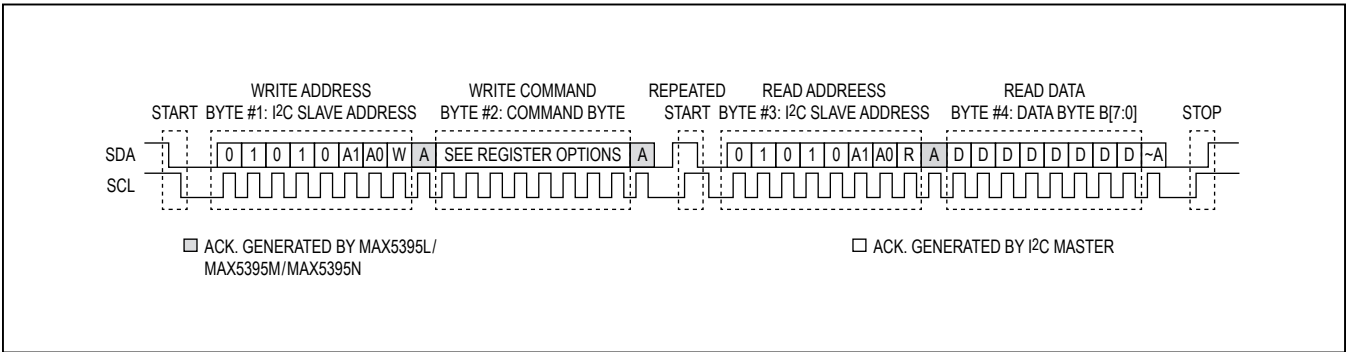


Figure 6. Standard I2C Register Read Sequence

**Table 3. I2C Write Command Byte Summary**

| COMMAND   | ADDRESS BYTE |    |    |    |    |    |    |     | COMMAND BYTE |    |    |    |    |    |    |    | DATA BYTE  |    |    |    |    |    |    |    |  |  |
|-----------|--------------|----|----|----|----|----|----|-----|--------------|----|----|----|----|----|----|----|------------|----|----|----|----|----|----|----|--|--|
|           | A6           | A5 | A4 | A3 | A2 | A1 | A0 | R/W | C7           | C6 | C5 | C4 | C3 | C2 | C1 | C0 | D7         | D6 | D5 | D4 | D3 | D2 | D1 | D0 |  |  |
| WIPER     | See Table 1  |    |    |    |    |    |    | 0   | 0            | 0  | 0  | 0  | 0  | 0  | 0  | 0  | D7         | D6 | D5 | D4 | D3 | D2 | D1 | D0 |  |  |
| SD_CLR    |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 0  | 0  | 0  | 0  | 0  | D7         | D6 | D5 | D4 | D3 | D2 | D1 | D0 |  |  |
| SD_H_WREG |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 1  | 0  | 0  | 0  | 0  | Don't Care |    |    |    |    |    |    |    |  |  |
| SD_H_ZERO |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 1  | 0  | 0  | 0  | 1  |            |    |    |    |    |    |    |    |  |  |
| SD_H_MID  |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 1  | 0  | 0  | 1  | 0  |            |    |    |    |    |    |    |    |  |  |
| SD_H_FULL |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 1  | 0  | 0  | 1  | 1  |            |    |    |    |    |    |    |    |  |  |
| SD_L_WREG |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 0  | 1  | 0  | 0  | 0  |            |    |    |    |    |    |    |    |  |  |
| SD_L_ZERO |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 0  | 1  | 0  | 0  | 1  |            |    |    |    |    |    |    |    |  |  |
| SD_L_MID  |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 0  | 1  | 0  | 1  | 0  |            |    |    |    |    |    |    |    |  |  |
| SD_L_FULL |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 0  | 1  | 0  | 1  | 1  |            |    |    |    |    |    |    |    |  |  |
| SD_W      |              |    |    |    |    |    |    | 0   | 1            | 0  | 0  | 0  | 0  | 1  | X  | X  |            |    |    |    |    |    |    |    |  |  |
| QP_OFF    |              |    |    |    |    |    |    | 0   | 1            | 0  | 1  | 0  | 0  | 0  | 0  | 0  |            |    |    |    |    |    |    |    |  |  |
| QP_ON     |              |    |    |    |    |    |    | 0   | 1            | 0  | 1  | 0  | 0  | 0  | 0  | 1  |            |    |    |    |    |    |    |    |  |  |
| RST       |              |    |    |    |    |    |    | 0   | 1            | 1  | 0  | 0  | 0  | 0  | 0  | 0  |            |    |    |    |    |    |    |    |  |  |

**WIPER Command**

The data byte writes to the wiper register and the potentiometer moves to the appropriate position. D[7:0] indicates the position of the wiper. D[7:0] = 0x00 moves the wiper to the position closest to L. D[7:0] = 0xFF moves the wiper closest to H. D[7:0] = 0x80 following power-on.

**SD\_CLR Command**

Removes any existing shutdown condition. Connects all potentiometer terminals and returns the wiper to the value stored in the wiper register. The command does not affect the current status of the charge pump.

**SD\_H\_WREG Command**

Opens the H terminal and maintains the wiper at the wiper register location. Writes cannot be made to the wiper register while shutdown mode is engaged. Clearing shutdown mode will close the H terminal and allow the wiper register to be written. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_H\_ZERO Command**

Moves wiper to zero-scale position (0x00) and opens the H terminal. The wiper register remains unaltered. Writes cannot be made to the wiper register while shutdown

mode is engaged. Clearing shutdown mode will return the wiper to the position contained in the wiper register and close the H terminal. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_H\_MID Command**

Moves wiper to midscale position (0x80) and opens the H terminal. The wiper register remains unaltered. Writes cannot be made to the wiper register while shutdown mode is engaged. Clearing shutdown mode will return the wiper to the position contained in the wiper register and close the H terminal. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_H\_FULL Command**

Moves wiper to full-scale position (0xFF) and opens the H terminal. The wiper register remains unaltered. Writes cannot be made to the wiper register while shutdown mode is engaged. Clearing shutdown mode will return the wiper to the position contained in the wiper register and close the H terminal. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_L\_WREG Command**

Opens the L terminal and maintains the wiper at the wiper register location. Writes cannot be made to the wiper register while shutdown mode is engaged. Clearing shutdown mode will close the L terminal and allow wiper register to be written. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_L\_ZERO Command**

Moves wiper to zero-scale position (0x00) and opens the L terminal. The wiper register remains unaltered. Writes cannot be made to the wiper register while shutdown mode is engaged. Clearing shutdown mode will return the wiper to the position contained in the wiper register and close the L terminal. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_L\_MID Command**

Moves wiper to midscale position (0x80) and opens the L terminal. The wiper register remains unaltered. Writes cannot be made to the wiper register while shutdown mode is engaged. Clearing shutdown mode will return the wiper to the position contained in the wiper register and close the L terminal. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_L\_FULL Command**

Moves wiper to full-scale position (0xFF) and opens the L terminal. The wiper register remains unaltered. Writes

cannot be made to the wiper register while shutdown mode is engaged. Clearing shutdown mode will return the wiper to the position contained in the wiper register and close the L terminal. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**SD\_W Command**

Opens the W terminal keeping the internal tap position the same as the wiper register. Writes cannot be made to the wiper registers while shutdown mode is engaged. Clearing shutdown mode will return the wiper to the position contained in the wiper register and close W terminal. A RST will also deassert shutdown mode and return the wiper to midscale (0x80). This command does not affect the charge-pump status.

**QP\_OFF Command**

Disables the onboard charge pump and places device in low power mode. Low supply voltage is limited to 2.6V.

**QP\_ON Command**

Enables the onboard charge pump to allow low-supply voltage operation. This is the power-on default condition. Low supply voltage is 1.7V.

**RST Command**

Returns the device to power-on default conditions. Resets the wiper register to midscale (0x80), enables charge pump, and deasserts any shutdown modes.

## Ordering Information

| PART          | PIN-PACKAGE | INTERFACE        | TAPS | END-TO-END RESISTANCE (k $\Omega$ ) |
|---------------|-------------|------------------|------|-------------------------------------|
| MAX5395LATA+T | 8 TDFN-EP*  | I <sup>2</sup> C | 256  | 10                                  |
| MAX5395MATA+T | 8 TDFN-EP*  | I <sup>2</sup> C | 256  | 50                                  |
| MAX5395NATA+T | 8 TDFN-EP*  | I <sup>2</sup> C | 256  | 100                                 |

**Note:** All devices operate over the -40°C to +125°C temperature range.

+Denotes a lead(Pb)-free/RoHS-compliant package.

T = Tape and reel.

\*EP = Exposed pad.

## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

| PACKAGE TYPE | PACKAGE CODE | OUTLINE NO.             | LAND PATTERN NO.        |
|--------------|--------------|-------------------------|-------------------------|
| 8 TDFN-EP    | T822+2       | <a href="#">21-0168</a> | <a href="#">90-0065</a> |



## Revision History

| REVISION<br>NUMBER | REVISION<br>DATE | DESCRIPTION                                            | PAGES<br>CHANGED |
|--------------------|------------------|--------------------------------------------------------|------------------|
| 0                  | 7/12             | Initial release                                        | —                |
| 1                  | 9/12             | Revised the <i>Absolute Maximum Ratings</i>            | 2                |
| 2                  | 11/14            | Removed automotive references from data sheet          | 1, 10            |
| 3                  | 2/16             | Add charge pump current at various disabled conditions | 3                |

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim Integrated's website at [www.maximintegrated.com](http://www.maximintegrated.com).

*Maxim Integrated cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim Integrated product. No circuit patent licenses are implied. Maxim Integrated reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.*