19-5141; Rev 1; 4/10

EVALUATION KIT AVAILABLE

Dual, 256-Tap, Volatile, Low-Voltage Linear Taper Digital Potentiometer

MAX5389

General Description

The MAX5389 dual, 256-tap, volatile, low-voltage linear taper digital potentiometer offers three end-to-end resistance values of 10kΩ, 50kΩ, and 100kΩ. Operating from a single +2.6V to +5.5V power supply, the device provides a low 35ppm/°C end-to-end temperature coefficient. The MAX5389 features an up/down interface.

The small package size, low supply operating voltage, low supply current, and automotive temperature range of the MAX5389 make the device uniquely suited for the portable consumer market, battery backup industrial applications, and the automotive market.

The MAX5389 is specified over the automotive -40°C to +125°C temperature range and is available in a 14-pin TSSOP package.

Applications

Audio Mixing

Mechanical Potentiometer Replacement

Low-Drift Programmable Filters and Amplifiers

Adjustable Voltage References/Linear Regulators

Programmable Delays and Time Constants

Automotive Electronics

Low-Voltage Battery Applications

Features

- **Dual, 256-Tap Linear Taper Positions**
- **Single +2.6V to +5.5V Supply Operation**
- **Low (< 1µA) Quiescent Supply Current**
- **10kΩ, 50kΩ, 100kΩ End-to-End Resistance Values**
- **Up/Down Interface**
- **Power-On Sets Wiper to Midscale**
- **-40°C to +125°C Operating Temperature Range**

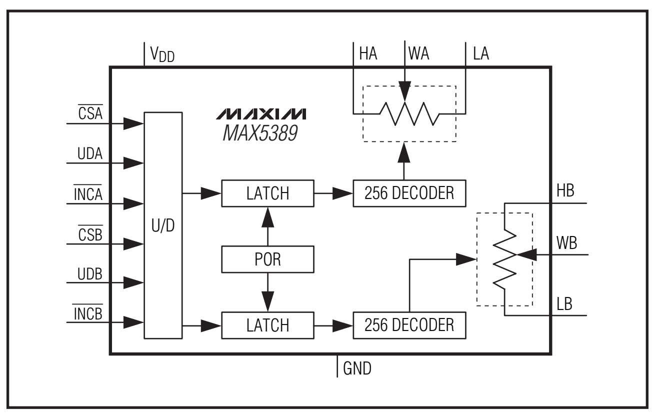
Ordering Information

PART	PIN-PACKAGE	END-TO-END RESISTANCE (kΩ)
MAX5389LAUD+	14 TSSOP	10
MAX5389MAUD+	14 TSSOP	50
MAX5389NAUD+	14 TSSOP	100

Note: *All devices are specified over the -40°C to +125°C operating temperature range*

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

Functional Diagram



ABSOLUTE MAXIMUM RATINGS

V_{DD} to GND ....-0.3V to +6V
H_, W_, L_ to GND.....................................-0.3V to the lower of (V_{DD} + 0.3V) and +6V
All Other Pins to GND ....-0.3V to +6V
Continuous Current into H_, W_, and L_
MAX5389L.. ±5mA
MAX5389M... ±2mA
MAX5389N .... ±1mA
Continuous Power Dissipation (T_A = +70°C)
14-Pin TSSOP (derate 10mW/°C above +70°C)......796.8mW
Operating Temperature Range........................ -40°C to +125°C
Junction Temperature ....+150°C
Storage Temperature Range........................... -65°C to +150°C
Lead Temperature (soldering, 10s) ....+300°C
Soldering Temperature (reflow) ....+260°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.

ELECTRICAL CHARACTERISTICS

(V_{DD} = +2.6V to +5.5V, $V_{H\_}$ = V_{DD}, $V_{L\_}$ = GND, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Resolution	N			256			Taps
DC PERFORMANCE (Voltage-Divider Mode)							
Integral Nonlinearity	INL	(Note 2)		-0.5		+0.5	LSB
Differential Nonlinearity	DNL	(Note 2)		-0.5		+0.5	LSB
Dual Code Matching		Register A = register B		-0.5		+0.5	LSB
Ratiometric Resistor Tempco		$(\Delta V_W/V_W)/\Delta T$, no load			+5		LSB
Full-Scale Error		Code = FFH	MAX5389L	-3	-2.5		LSB
			MAX5389M	-1	-0.5		
			MAX5389N	-0.5	-0.25		
Zero-Scale Error		Code = 00H	MAX5389L		+2.5	+3	LSB
			MAX5389M		+0.5	+1.0	
			MAX5389N		+0.25	+0.5	
DC PERFORMANCE (Variable-Resistor Mode) (Note 3)							
Integral Nonlinearity	R-INL	V_{DD} > +2.6V	MAX5389L		±1.0	±2.5	LSB
			MAX5389M		±0.5	±1.0	
			MAX5389N		±0.25	±0.8	
		V_{DD} > +4.75V	MAX5389L		±0.4	±1.5	
			MAX5389M		±0.3	±0.75	
			MAX5389N		±0.25	±0.5	
Differential Nonlinearity	R-DNL	V_{DD} ≥ 2.6V		-0.5		+0.5	LSB
DC PERFORMANCE (Resistor Characteristics)							
Wiper Resistance (Note 4)	R_{WL}	V_{DD} > 2.6V			250	600	Ω
		V_{DD} > 4.75V			150	200	
Terminal Capacitance	$C_{H\_}$, $C_{L\_}$	Measured to GND			10		pF
Wiper Capacitance	$C_{W\_}$	Measured to GND			50		pF
End-to-End Resistor Tempco	TC_R	No load			35		ppm/°C
End-to-End Resistor Tolerance	ΔR_{HL}	Wiper not connected		-25		+25	%

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +2.6V to +5.5V, $V_{H\_}$ = V_{DD}, $V_{L\_}$ = GND, T_A = -40°C to +125°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
AC PERFORMANCE							
Crosstalk		(Note 5)			-90		dB
-3dB Bandwidth	BW	Code = 80H, 10pF load, V_{DD} = +2.6V	MAX5389L		600		kHz
			MAX5389M		150		
			MAX5389N		75		
Total Harmonic Distortion Plus Noise	THD+N	Measured at W, $V_{H\_}$ = 1V_{RMS} at 1kHz			0.015		%
Wiper Settling Time (Note 6)	t_S	MAX5389L			300		ns
		MAX5389M			1000		
		MAX5389N			2000		
POWER SUPPLIES							
Supply Voltage Range	V_{DD}			2.6		5.5	V
Standby Current		Digital inputs = V_{DD} or GND			1		µA
DIGITAL INPUTS							
Minimum Input High Voltage	V_{IH}			70			% x V_{DD}
Maximum Input Low Voltage	V_{IL}					30	% x V_{DD}
Input Leakage Current				-1		+1	µA
Input Capacitance					5		pF
TIMING CHARACTERISTICS (Note 7)							
Maximum $\overline{INC\_}$ Frequency	f_{MAX}					10	MHz
$\overline{CS}$ to $\overline{INC\_}$ Setup Time	t_{CI}			25			ns
$\overline{CS}$ to $\overline{INC\_}$ Hold Time	t_{IC}			0			ns
$\overline{INC\_}$ Low Period	t_{IL}			25			ns
$\overline{INC\_}$ High Period	t_{IH}			25			ns
UD_ to $\overline{INC\_}$ Setup Time	t_{DI}			50			ns
UD_ to $\overline{INC\_}$ Hold Time	t_{ID}			0			ns

Note 1: All devices are 100% production tested at T_A = +25°C. Specifications over temperature limits are guaranteed by design and characterization.

Note 2: DNL and INL are measured with the potentiometer configured as a voltage-divider (Figure 1) with H_ = V_{DD} and L_ = 0V. The wiper terminal is unloaded and measured with a high-input-impedance voltmeter.

Note 3: R-DNL and R-INL are measured with the potentiometer configured as a variable resistor (Figure 1). DNL and INL are measured with potentiometer configured as a variable resistor. H_ is unconnected and L_ = GND. For V_{DD} = +5V, the wiper terminal is driven with a source current of 400µA for the 10kΩ configuration, 80µA for the 50kΩ configuration, and 40µA for the 100kΩ configuration. For V_{DD} = +2.6V, the wiper terminal is driven with a source current of 200µA for the 10kΩ configuration, 40µA for the 50kΩ configuration, and 20µA for the 100kΩ configuration.

Note 4: The wiper resistance is the worst value measured by injecting the currents given in Note 3 into W_ with L_ = GND. $R_W = (V_W - V_H)/I_W$.

Note 5: Drive HA with a 1kHz, GND to V_{DD} amplitude, tone. LA = LB = GND. No load. WB is at midscale with a 10pF load. Measure WB.

Note 6: The 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 7: Digital timing is guaranteed by design and characterization, not production tested.

Dual, 256-Tap, Volatile, Low-Voltage Linear Taper Digital Potentiometer

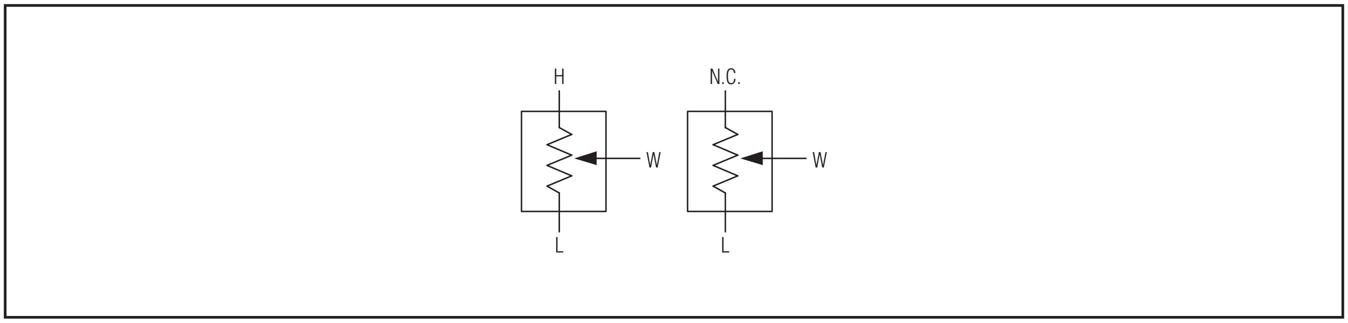
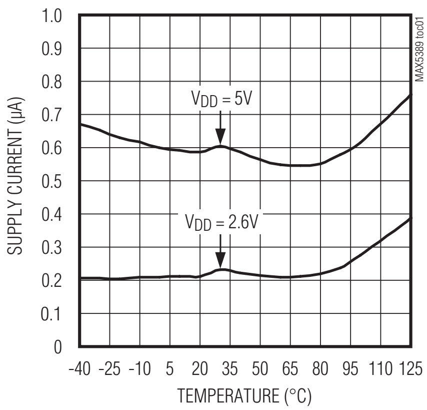


Figure 1. Voltage-Divider and Variable Resistor Configurations

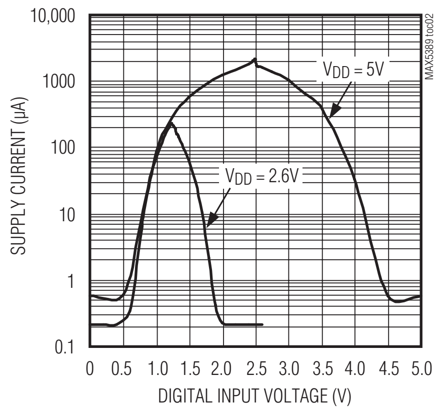
Typical Operating Characteristics

(V_{DD} = +5V, T_A = +25°C, unless otherwise noted.)

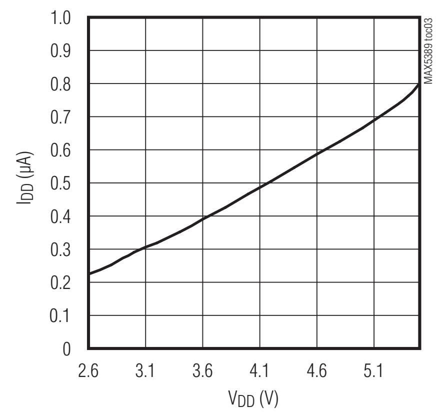
SUPPLY CURRENT vs. TEMPERATURE



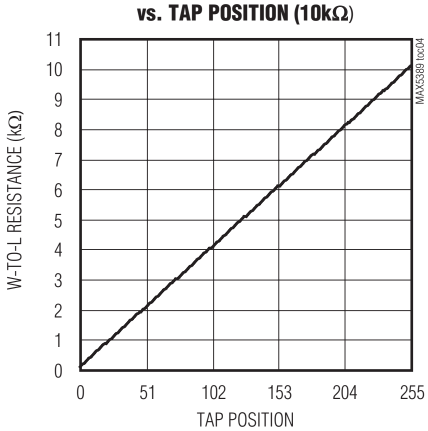
SUPPLY CURRENT vs. DIGITAL INPUT VOLTAGE



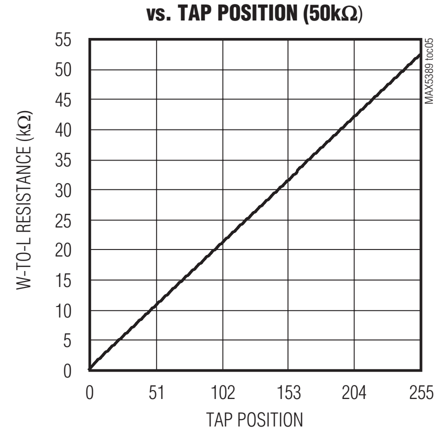
SUPPLY CURRENT vs. SUPPLY VOLTAGE



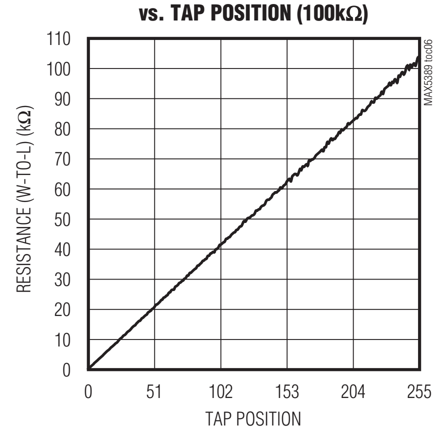
RESISTANCE (W-TO-L) vs. TAP POSITION (10kΩ)



RESISTANCE (W-TO-L) vs. TAP POSITION (50kΩ)



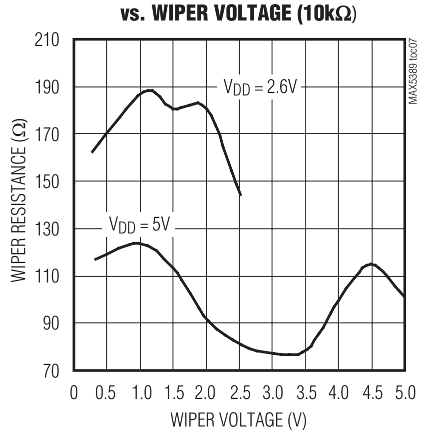
RESISTANCE (W-TO-L) vs. TAP POSITION (100kΩ)



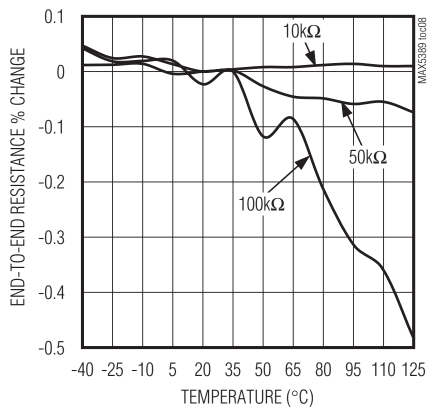
Typical Operating Characteristics (continued)

(V_{DD} = +5V, T_A = +25°C, unless otherwise noted.)

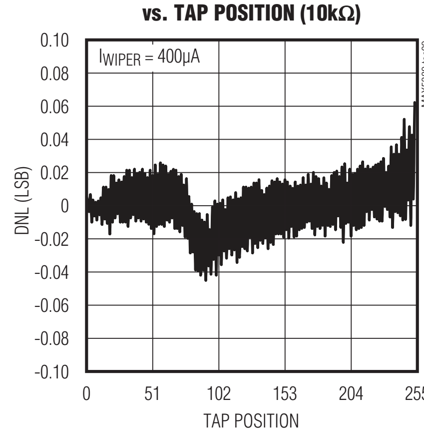
WIPER RESISTANCE vs. WIPER VOLTAGE (10kΩ)



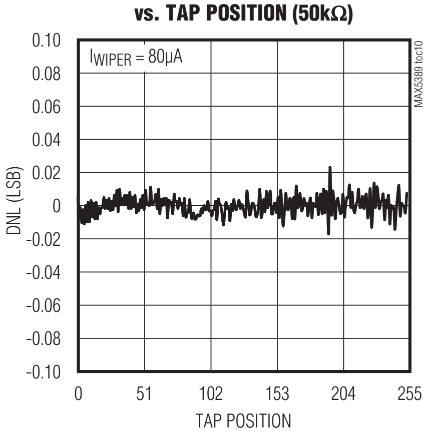
END-TO-END RESISTANCE % CHANGE vs. TEMPERATURE



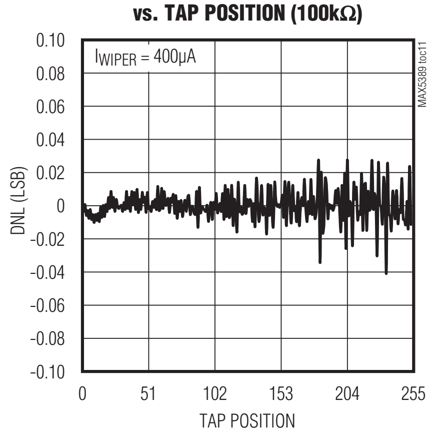
VARIABLE-RESISTOR DNL vs. TAP POSITION (10kΩ)



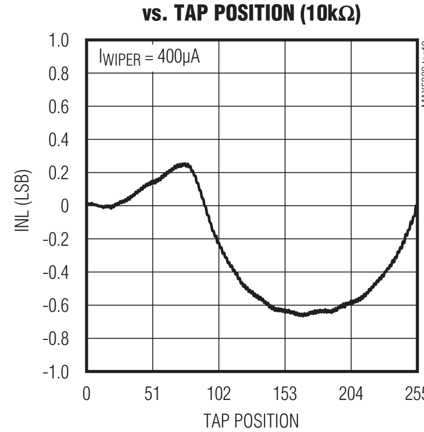
VARIABLE-RESISTOR DNL vs. TAP POSITION (50kΩ)



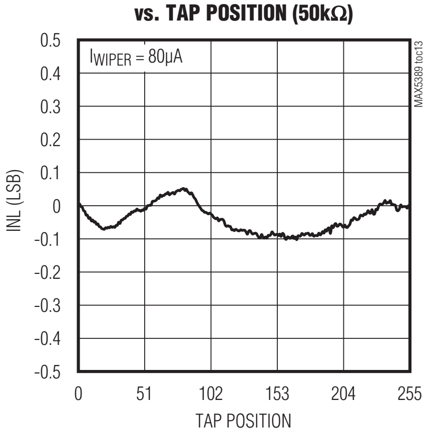
VARIABLE-RESISTOR DNL vs. TAP POSITION (100kΩ)



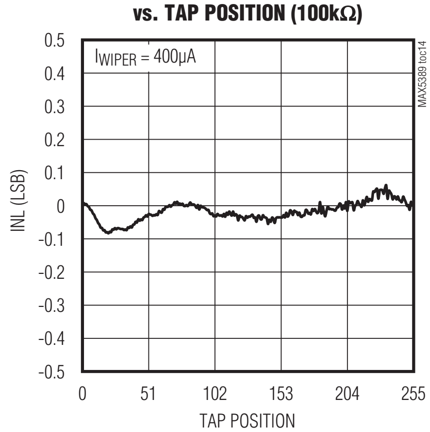
VARIABLE-RESISTOR INL vs. TAP POSITION (10kΩ)



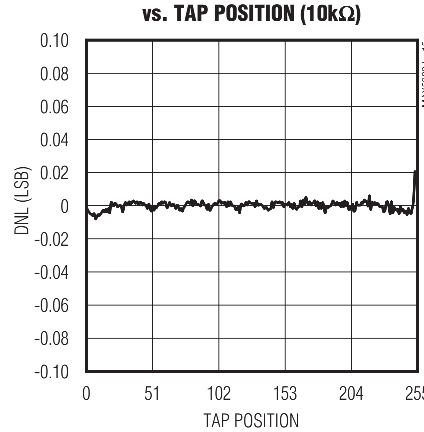
VARIABLE-RESISTOR INL vs. TAP POSITION (50kΩ)



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



VOLTAGE-DIVIDER DNL vs. TAP POSITION (10kΩ)

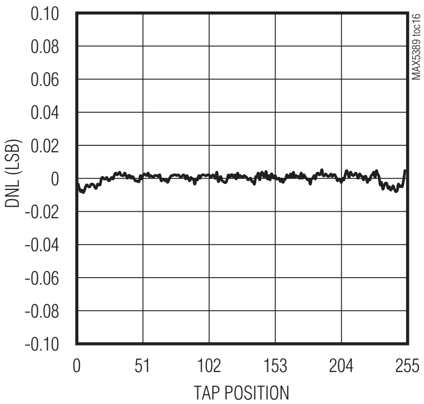


Dual, 256-Tap, Volatile, Low-Voltage Linear Taper Digital Potentiometer

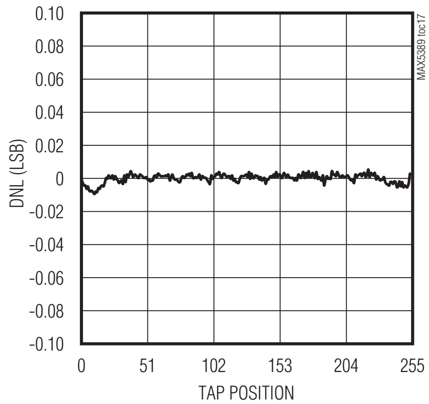
Typical Operating Characteristics (continued)

(V_{DD} = +5V, T_A = +25°C, unless otherwise noted.)

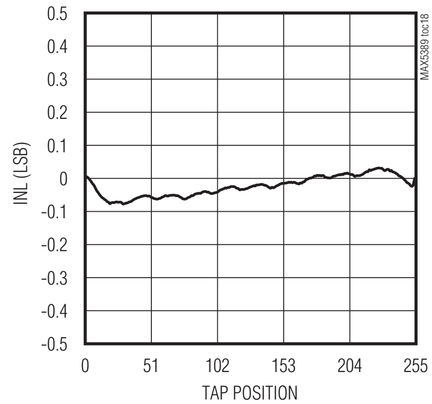
VOLTAGE-DIVIDER DNL vs. TAP POSITION (50kΩ)



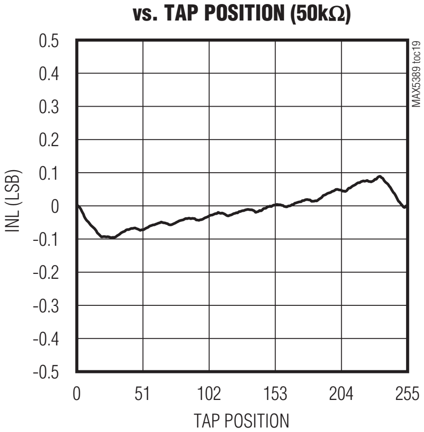
VOLTAGE-DIVIDER DNL vs. TAP POSITION (100kΩ)



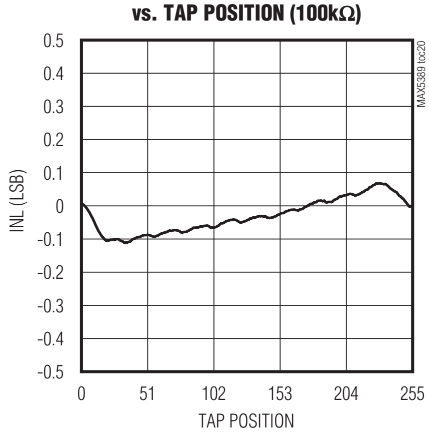
VOLTAGE-DIVIDER INL vs. TAP POSITION (10kΩ)



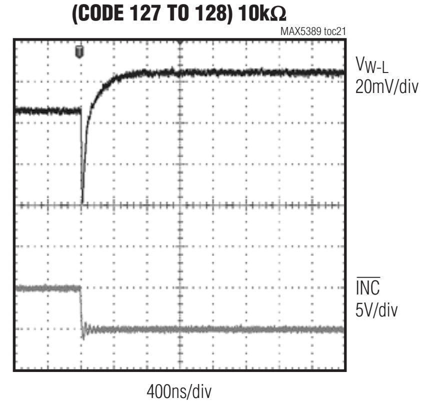
VOLTAGE-DIVIDER INL vs. TAP POSITION (50kΩ)



VOLTAGE-DIVIDER INL vs. TAP POSITION (100kΩ)



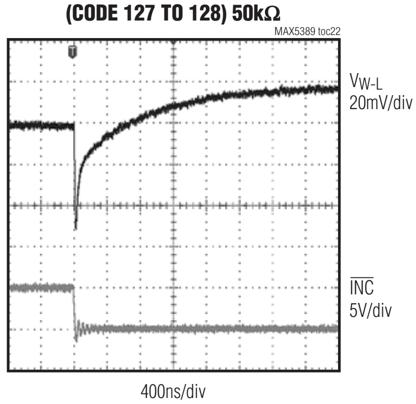
TAP-TO-TAP SWITCHING TRANSIENT (CODE 127 TO 128) 10kΩ



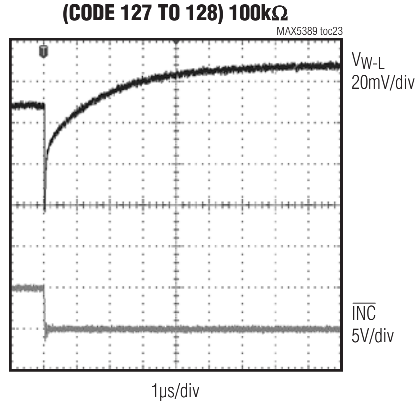
Typical Operating Characteristics (continued)

(V_{DD} = +5V, T_A = +25°C, unless otherwise noted.)

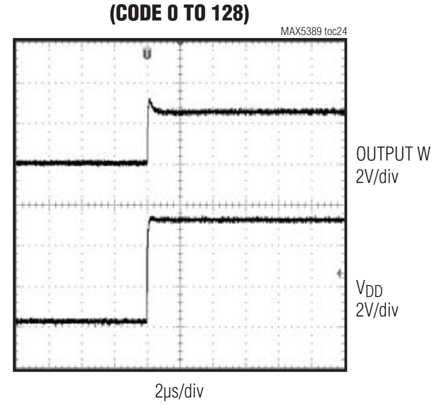
TAP-TO-TAP SWITCHING TRANSIENT (CODE 127 TO 128) 50kΩ



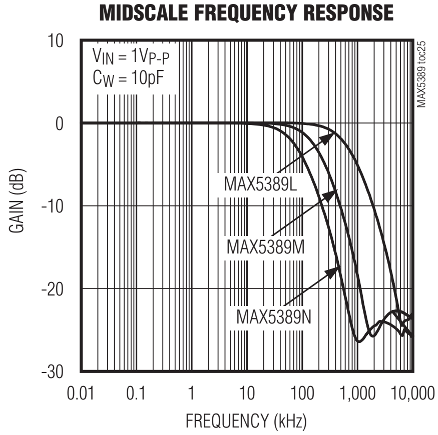
TAP-TO-TAP SWITCHING TRANSIENT (CODE 127 TO 128) 100kΩ



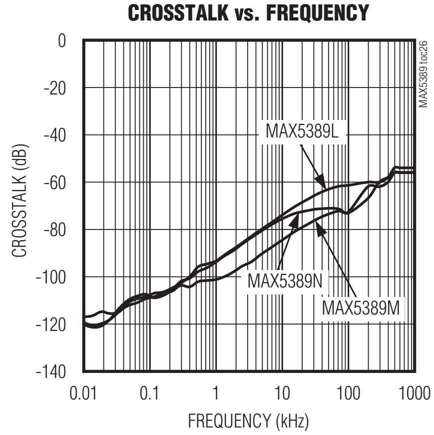
POWER-ON WIPER TRANSIENT (CODE 0 TO 128)



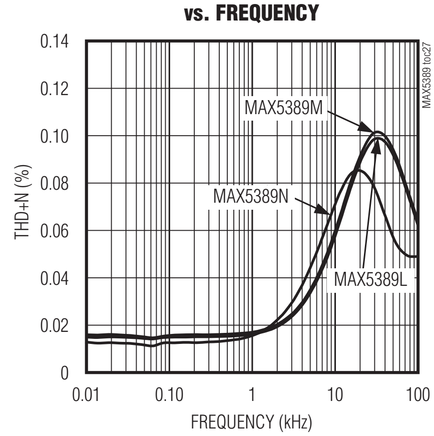
MIDSCALE FREQUENCY RESPONSE



CROSSTALK vs. FREQUENCY

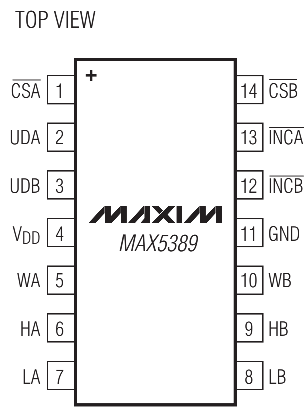


TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY



Dual, 256-Tap, Volatile, Low-Voltage Linear Taper Digital Potentiometer

Pin Configuration



Pin Description

PIN	NAME	FUNCTION
1	$\overline{CSA}$	Active-Low Register A Chip-Select Input. Drive $\overline{CSA}$ low to change wiper position WA through $\overline{INCA}$ and UDA.
2	UDA	Register A Up/Down Control Input. With UDA low, a high-to-low transition at $\overline{INCA}$ decrements the WA position towards LA. With UDA high, a high-to-low transition at $\overline{INCA}$ increments WA position toward HA.
3	UDB	Register B Up/Down Control Input. With UDB low, a high-to-low transition at $\overline{INCB}$ decrements the WB position towards LB. With UDB high, a high-to-low transition at $\overline{INCB}$ increments WB position toward HB.
4	V_{DD}	Power-Supply Input. Bypass V_{DD} to GND with a 0.1µF capacitor close to the device.
5	WA	Resistor A Wiper Terminal
6	HA	Resistor A High Terminal. The voltage at HA can be higher or lower than the voltage at LA. Current can flow into or out of HA.
7	LA	Resistor A Low Terminal. The voltage at LA can be higher or lower than the voltage at HA. Current can flow into or out of LA.
8	LB	Resistor B Low Terminal. The voltage at LB can be higher or lower than the voltage at HB. Current can flow into or out of LB.
9	HB	Resistor B High Terminal. The voltage at HB can be higher or lower than the voltage at LB. Current can flow into or out of HB.
10	WB	Resistor B Wiper Terminal
11	GND	Ground
12	$\overline{INCB}$	Register B Wiper Increment Control Input. With UDB low, a high-to-low transition at $\overline{INCB}$ decrements the WB position towards LB. With UDB high, a high-to-low transition at $\overline{INCB}$ increments WB position toward HB.
13	$\overline{INCA}$	Register A Wiper Increment Control Input. With UDA low, a high-to-low transition at $\overline{INCA}$ decrements the WA position towards LA. With UDA high, a high-to-low transition at $\overline{INCA}$ increments WA position toward HA.
14	$\overline{CSB}$	Active-Low Register B Chip-Select Input. Drive $\overline{CSB}$ low to change wiper position WA through $\overline{INCB}$ and UDB.

Detailed Description

The MAX5389 dual, 256-tap, volatile, low-voltage linear taper digital potentiometer offers three end-to-end resistance values of 10kΩ, 50kΩ, and 100kΩ. The potentiometer consists of 255 fixed resistors in series between terminals H_ and L_. The potentiometer wiper, W_, is programmable to access any one of the 256 tap points on the resistor string. On power-up, the wiper position is set to midscale (tap 128).

The potentiometers are programmable independent of each other. The MAX5389 features an up/down interface.

Up/Down Interface

Logic inputs $\overline{\text{CS\_}}$, UD_, and $\overline{\text{INC\_}}$ determine the wiper position of the device (Table 1). With $\overline{\text{CS\_}}$ low and UD_ high, a high-to-low (falling edge) transition on $\overline{\text{INC\_}}$ increments the internal counter which moves the wiper, W_, closer to H_. When both $\overline{\text{CS\_}}$ and UD_ are low, the falling edge of $\overline{\text{INC\_}}$ decrements the internal counter and moves the tap point, W_ closer to L_, (Figure 2). The wiper performs a make-before-break transition ensuring that W_ is never disconnected from the resistor string during a transition from one tap point to another. When the wiper is at either end of the resistor array additional transitions in the direction of the end point do not change the counter value.

Table 1. Up/Down Control Table

$\overline{\text{CS\_}}$	UD_	$\overline{\text{INC\_}}$	W_
H	X	X	No change
L	L	↑	No change
L	H	↑	No change
L	L	↓	Decrement
L	H	↓	Increment

X = Don't care.
↑ = Low-to-high transition.
↓ = High-to-low transition.

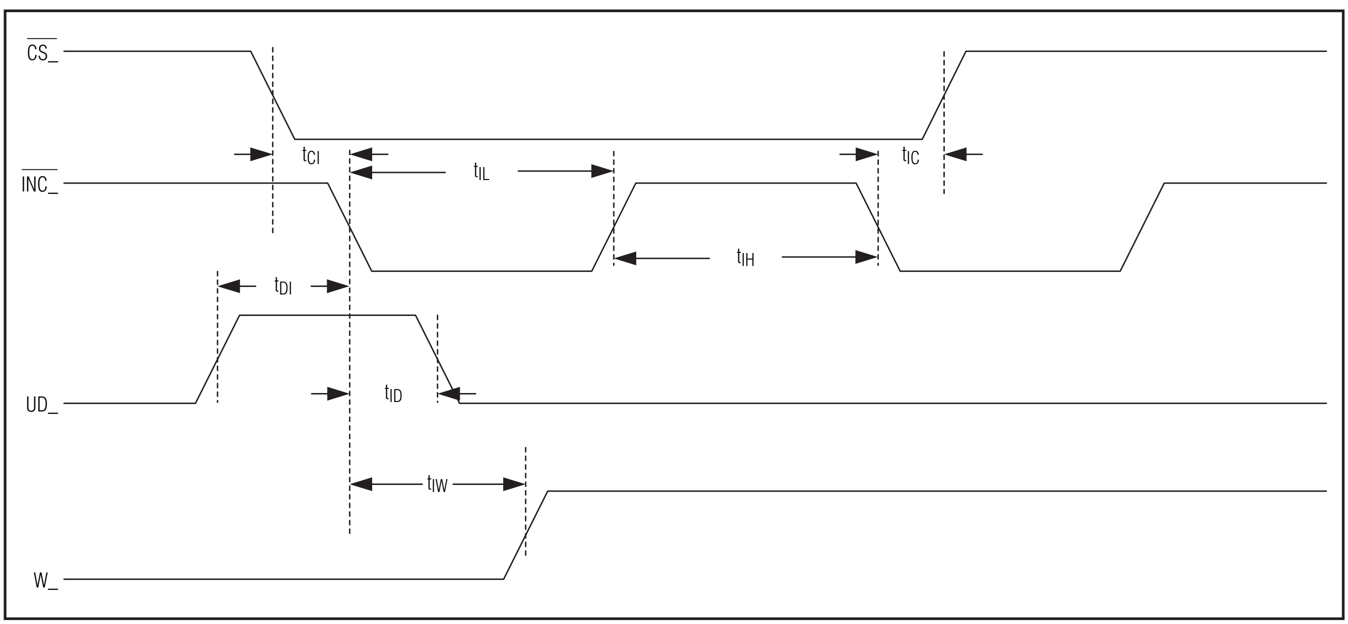


Figure 2. Up/Down Interface Timing Diagram

Dual, 256-Tap, Volatile, Low-Voltage Linear Taper Digital Potentiometer

Applications Information

Variable Gain Amplifier

Figure 3 shows a potentiometer adjusting the gain of a noninverting amplifier. Figure 4 shows a potentiometer adjusting the gain of an inverting amplifier.

Adjustable Dual Linear Regulator

Figure 5 shows an adjustable dual linear regulator using a dual potentiometer as two variable resistors.

Adjustable Voltage Reference

Figure 6 shows an adjustable voltage reference circuit using a potentiometer as a voltage-divider.

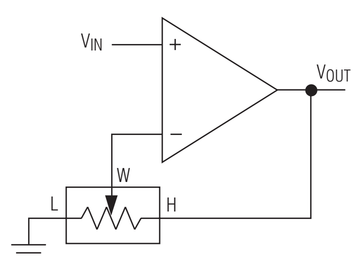


Figure 3. Variable Gain Noninverting Amplifier

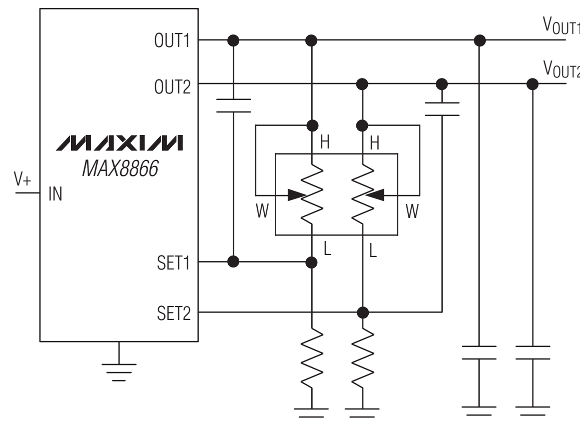


Figure 5. Adjustable Dual Linear Regulator

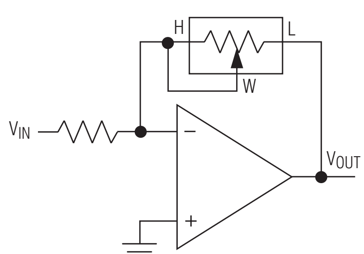


Figure 4. Variable Gain Inverting Amplifier

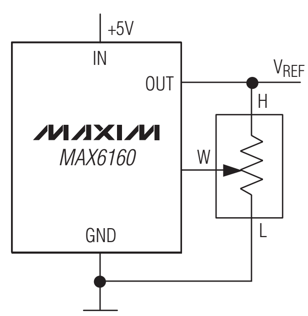


Figure 6. Adjustable Voltage Reference

Variable Gain Current to Voltage Converter

Figure 7 shows a variable gain current to voltage converter using a potentiometer as a variable resistor.

LCD Bias Control

Figure 8 shows a positive LCD bias control circuit using a potentiometer as a voltage-divider.

Figure 9 shows a positive LCD bias control circuit using a potentiometer as a variable resistor

Programmable Filter

Figure 10 shows a programmable filter using a dual potentiometer.

Offset Voltage Adjustment Circuit

Figure 11 shows an offset voltage adjustment circuit using a dual potentiometer.

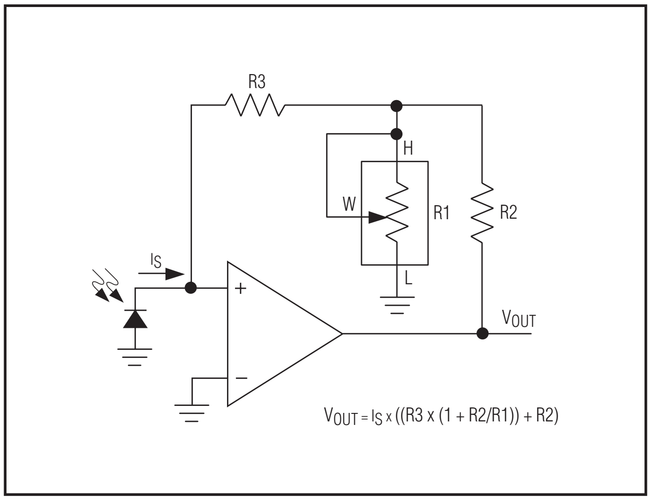


Figure 7. Variable Gain I-to-V Converter

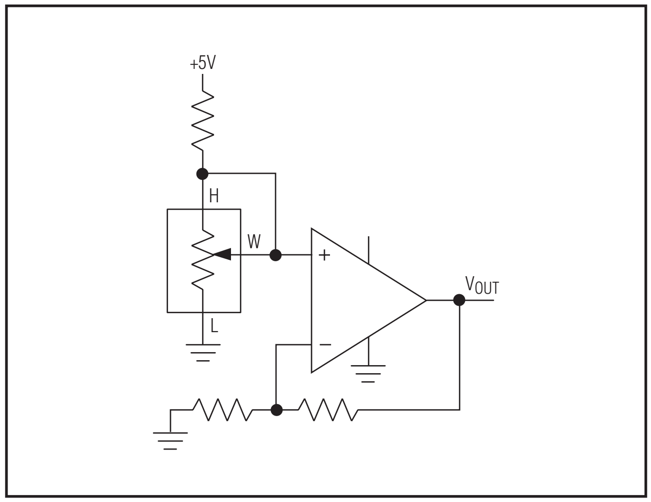


Figure 9. Positive LCD Bias Control Using a Variable Resistor

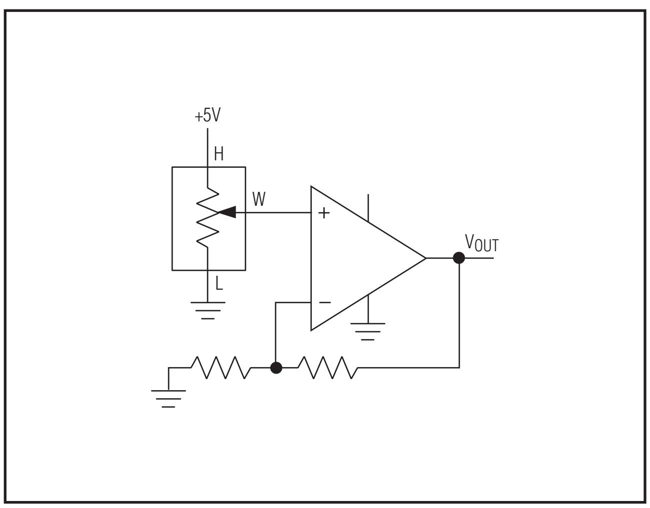


Figure 8. Positive LCD Bias Control Using a Voltage-Divide

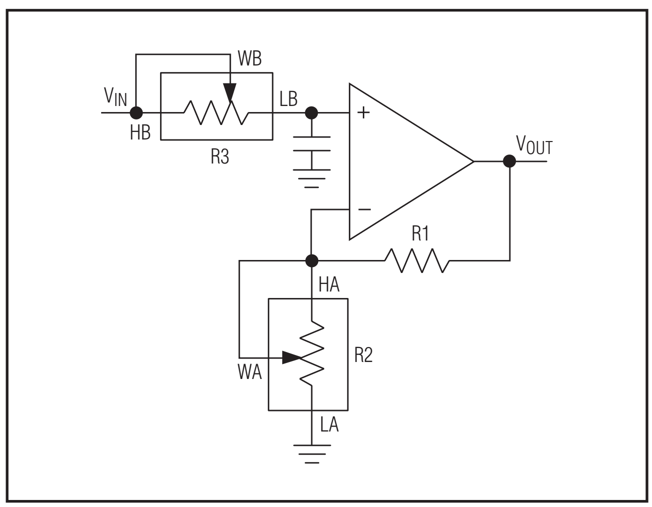


Figure 10. Programmable Filter

Dual, 256-Tap, Volatile, Low-Voltage Linear Taper Digital Potentiometer

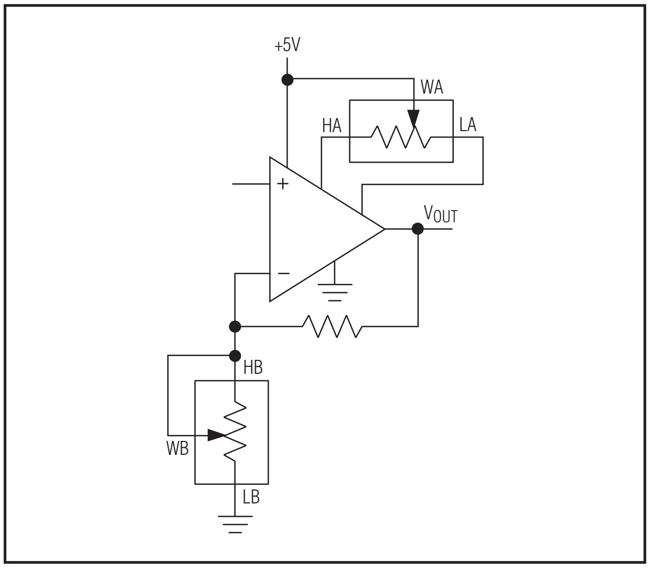


Figure 11. Offset Voltage Adjustment Circuit

Process Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.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	DOCUMENT NO.
14 TSSOP	U14+1	21-0066

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	1/10	Initial release	—
1	4/10	Added Soldering Temperature in *Absolute Maximum Ratings*; corrected code in Conditions of -3dB Bandwidth specification in *Electrical Characteristics*; corrected Table 1 and Figure 5	2, 3, 9, 10