General Description

The DS4301 is a single 32-position linear digital potentiometer with 200k Ω end-to-end resistance. The wiper setting is stored in EEPROM, so the DS4301 powers up with the last stored setting. The position of the wiper is controlled through a simple three-terminal increment/decrement interface. The DS4301 is ideal for white LED backlight brightness control. Its 8-pin µSOP package, 2.4V to 5.5V supply range, and $200k\Omega$ endto-end resistance are especially suited for portable, battery-powered applications such as cellular telephones and PDAs.

Applications

White LED Backlight Brightness Control

Portable Battery-Powered Devices such as PDAs and Cellular Phones

Any Application that Requires a Small, Low-Cost **NV** Potentiometer

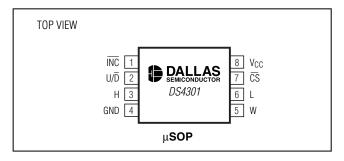
Features

- ♦ Single, 32-Position, 200kΩ Linear Nonvolatile (NV) Potentiometer Ideal for Battery-Powered **Applications**
- ♦ Three-Terminal Increment/Decrement Interface to **Adjust Wiper Position**
- ♦ Wide Voltage Supply Range (2.4V to 5.5V)
- **♦ Command-Initiated NV Wiper Storage**
- ♦ Operates Over the Industrial Temperature Range (-40°C to +85°C)
- ♦ Available in 8-Pin µSOP

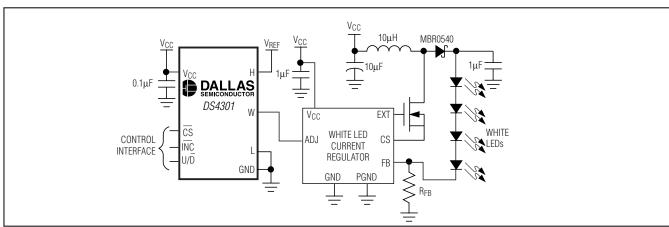
Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
DS4301U-200	-40°C to +85°C	8 µSOP (118 mil)

Pin Configuration



Typical Operating Circuit



ABSOLUTE MAXIMUM RATINGS

Voltage Range on V _{CC} Pin Relative	to Ground0.5V to +6.0V
Voltage Range on CS, INC, U/D, L,	W, H Pins
Relative to Ground*	0.5V to V _{CC} + 0.5V
Wiper Current	±3mA
Operating Temperature Range	

Programming Temperature	0°C to +70°C
Storage Temperature Range	55°C to +125°C
Soldering Temperature	See IPC/JEDEC
	J-STD-020A Specification

*Not to exceed 6.0V

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.

RECOMMENDED DC OPERATION CONDITIONS

(VCC = VCC MIN to VCC MAX; TA = -40°C to +85°C, unless otherwise specified.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP MAX	UNITS
Supply Voltage	Vcc	(Note 1)	+2.4	+5.5	V
Input Logic 1 (CS, INC, U/D)	VIH		0.7 x V _{CC}	V _{CC} + 0.3	V
Input Logic 0 (CS, INC, U/D)	VIL		-0.3	+0.3 x V _{CC}	V
Resistor Inputs	L, H, W		-0.3	V _{CC} + 0.3	V
Wiper Current	IW		-1	+1	mA

DC ELECTRICAL CHARACTERISTICS

 $(V_{CC} = V_{CC MIN} \text{ to } V_{CC MAX}; T_A = -40^{\circ}\text{C} \text{ to } +85^{\circ}\text{C}, \text{ unless otherwise specified.})$

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Leakage	IL		-1		+1	μΑ
Charathan Commant (Niata C)	la==	3V		30	60	
Standby Current (Note 2)	ISTBY	5V		15	60	μΑ
Digital Input Capacitance	C _{I/O}				10	рF

ANALOG RESISTOR CHARACTERISTICS

(V_{CC} = V_{CC MIN} to V_{CC MAX}; T_A = -40°C to +85°C, unless otherwise specified.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
End-to-End Resistor Tolerance		$T_A = +25^{\circ}C$	-20		+20	%
Wiper Resistance	Rw			500	2000	Ω
Absolute Linearity		(Note 3)	-0.5		+0.5	LSB
Relative Linearity		(Note 4)	-0.25		+0.25	LSB
End-to-End Temp Coefficient			-250		+250	ppm/°C
Ratiometric Temp Coefficient				7	•	ppm/°C



AC ELECTRICAL CHARACTERISTICCS

(VCC = VCC MIN to VCC MAX; TA = -40°C to +85°C. See Figure 2 for timing diagram.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CS to INC Setup	tCI		50			ns
U/D to INC Setup	t _{DI}		100			ns
ĪNC Low Period	tıL		50			ns
INC High Period	tıH		100			ns
INC Inactive to CS Inactive	tıc		500			ns
CS Deselect Time	t _{CPH}		100			ns
Wiper Change to INC Low	tıw				200	ns
INC Rise and Fall Times	t _R , t _F				5	μs
ĪNC Low to CS Inactive	tıK	(Note 5)	50			ns
Wiper Storage Time	twst	(Note 6)			10	ms
CS Low Pulse	tCLP		100			ns
Wiper Load Time	twlT	(Note 7)		500		μs
Power-Up Time	t _{PU}	(Note 8)		2		ms

NONVOLATILE MEMORY CHARACTERISTICS

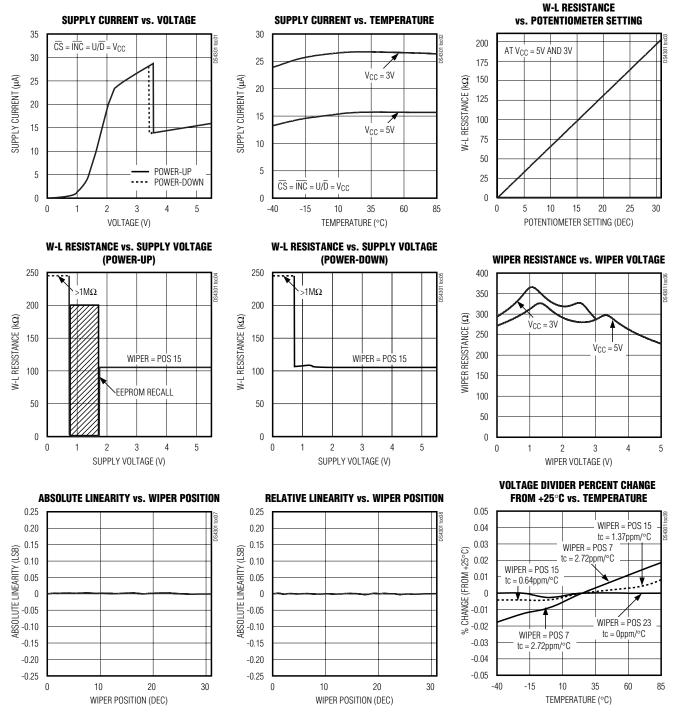
(VCC = VCC MIN to VCC MAX)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
EEPROM Write Cycles		+70°C (Note 9)	50,000			

- Note 1: All voltages are referenced to ground.
- Note 2: STBY specified for Vcc equal to 3.0V and 5.0V while control port logic pins are driven to Vcc or GND.
- Note 3: Absolute linearity is used to determine wiper voltage versus expected voltage as determined by wiper position.
- Note 4: Relative linearity is used to determine the change of wiper voltage between two adjacent wiper positions.
- Note 5: The INC low to CS inactive time is the transition time that allows the three control pins to become inactive without writing the wiper position to the EEPROM.
- **Note 6:** Wiper storage time is the time required for the wiper position to be written to the EEPROM. During this time, the three-terminal interface is inactive.
- **Note 7:** Wiper load time is specified as the time required to load the wiper position stored in EEPROM once V_{CC} has reached a stable operating voltage greater than or equal to V_{CC MIN}.
- **Note 8:** Power-up time is specified as the time required before the three control pins become active once a stable power supply level of at least V_{CC MIN} has been reached.
- Note 9: The maximum number of EEPROM write cycles is guaranteed by design and is not tested in production.

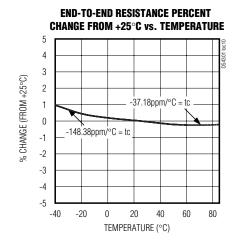
Typical Operating Characteristics

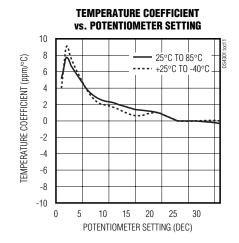
 $(V_{CC} = 5.0V; T_A = +25^{\circ}C, unless otherwise noted.)$



Typical Operating Characteristics (continued)

($V_{CC} = 5.0V$; $T_A = +25$ °C, unless otherwise noted.)





Pin Description

PIN	NAME	FUNCTION
1	ĪNC	Increment/Decrement Wiper Control. When $\overline{\text{INC}}$ transitions from high-to-low, the wiper moves in the direction established by the state of the U/ $\overline{\text{D}}$ pin.
2	U/D	Up/Down Control. Sets the directions of wiper movement. When set to a high state, a high-to-low transition on the INC pin increments the wiper. When set to a low state, a high-to-low transition on the INC pin decrements the wiper.
3	Н	High-End Terminal of the Potentiometer
4	GND	Ground Terminal
5	W	Wiper Terminal of the Potentiometer
6	L	Low-End Terminal of the Potentiometer
7	CS	Chip Select. When set to a low state, the wiper position can be adjusted using U/\overline{D} and \overline{INC}. When in a high-state, activity on \overline{INC} and U/\overline{D} does not affect or change the wiper position.
8	Vcc	Power Supply Terminal

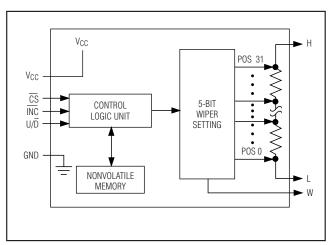


Figure 1. Block Diagram

Detailed Description

The DS4301 is a single nonvolatile digital potentiometer. This 32-position linear potentiometer has an end-to-end resistance of $200 k\Omega,$ and operates over a wide 2.4V to 5.5V supply voltage range. The wiper position is controlled by the three interface pins (U/\overline{D}, \overline{CS}, and \overline{INC}), and the wiper setting can be stored in EEPROM on command.

Power-Up

On power-up, once a stable supply voltage of V_{CC} MIN has been reached, the stored wiper setting is loaded from the EEPROM within tw_T. Also on power-up, the DS4301 wiper control pins become active approximately tp_U after a stable supply voltage of V_{CC} MIN has been reached.

Wiper Control

Adjusting the wiper of the DS4301 involves using the three control pins (U/D, CS, and INC). See the Timing Diagram in Figure 2. To enable wiper adjustment, a high-to-low transition on the \overline{CS} pin is required. Hold CS low for the duration of the communication. Doing this enables the INC pin to change the wiper position. Set the U/D pin high to increment or low to decrement the wiper position. The state of the U/\overline{D} pin should be set more than to before the INC signal is transitioned from high to low. After the CS pin is active low, a highto-low transition on the INC pin moves the wiper in the direction dictated by the U/D pin. Continue to pulse INC (high to low) until the desired wiper position is reached. On the last edge, hold the INC line low. With the desired wiper position set, there are two ways to proceed. One method terminates communication without allowing the value of the current wiper position to be written to the EEPROM. This is done by transitioning the CS signal to the high state before bringing the INC signal high. As long as the state of the CS pin is high before the state of the INC pin goes high, the current wiper setting is not written to EEPROM. Because the current wiper setting was not stored to the NV memory, the previously stored wiper setting, not the current wiper setting, is loaded from memory if power is cycled to the device

The other method is used to store a new wiper setting in the EEPROM. This is done by bringing the state of the INC pin high for a time of t_{IC} before bringing the state of the CS pin high. Once the states of both CS and INC pins are high, the current wiper setting is stored in EEPROM after a time of t_{WST}. If power is

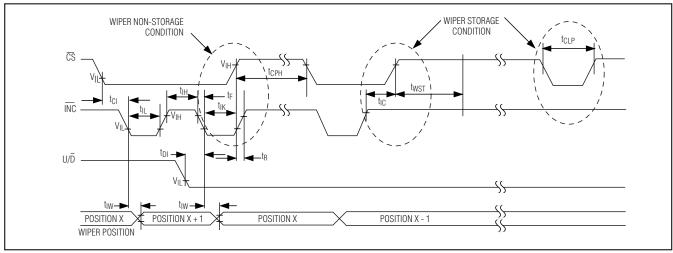


Figure 2. Timing Diagram

cycled to the device, the wiper setting that was just stored is the setting loaded on power-up.

Wiper storage does not have to occur immediately after a change in wiper position. At anytime the current wiper position can be stored to the EEPROM by simply issuing a low pulse to the $\overline{\text{CS}}$ pin for t_{CLP} while the $\overline{\text{INC}}$ pin remains in a high state. The wiper does not move during this action and the current wiper setting is stored in EEPROM after twst.

For applications that require a specific wiper setting to be loaded on power-up and never changed, write the desired wiper setting to the EEPROM, then tie $\overline{\text{CS}}$ to VCC. Every time power is cycled to the DS4301, the desired wiper setting is loaded from EEPROM, and since $\overline{\text{CS}}$ is tied to VCC, no changes can be made to the wiper setting.

EEPROM Characteristics

There is a limit to the number of times the EEPROM can be written to before a wear-out occurs (see the Nonvolatile Memory Characteristics table). After EEP-ROM wear-out occurs, the wiper can still be adjusted, however accurately storing the wiper position is no longer possible. When power is removed from the part, the current wiper position is lost. Upon power-up, the wiper setting stored in EEPROM is loaded within twlt of VCC reaching a stable voltage level greater than or equal to VCC MIN. If EEPROM wear-out has occurred, the wiper setting that is loaded is unknown.

Application Information

To achieve the best results when using the DS4301, decouple the power supply with a $0.01\mu F$ or $0.1\mu F$ capacitor. Use a high-quality ceramic surface-mount capacitor when possible. Surface-mount components minimize lead inductance, improving performace. Ceramic capacitors tend to have adequate high-frequency response for decoupling applications.

Chip Information

TRANSISTOR COUNT: 3512 SUBSTRATE INFO: P-substrate

Package Information

For the latest package outline information, go to www.maxim-ic.com/DallasPackInfo.

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