19-3185; Rev 2; 8/04

MAXIM

256抽头、非易失、I²C接口数字电位器

概述

MAX5417/MAX5418/MAX5419是非易失、线性数字电位器，与机械电位器功能相似，但可通过简单的2线数字接口控制，允许多个器件进行通信。每个器件具有分离电位器或可变电阻的功能，具有256个抽头点。

这些器件内置非易失EEPROM，用于存储滑动端的位置，上电时进行初始化处理。快速模式I²C™兼容接口允许400kbps的通信速率，在许多应用场合可有效减小电路板面积，简化电路连接。每个器件有一个工厂预置地址，有四种地址选择(见*选择指南*)，配合地址选择输入，共提供八个唯一的地址组合。

MAX5417/MAX5418/MAX5419提供了三个标称阻值：50kΩ (MAX5417)、100kΩ (MAX5418)和200kΩ (MAX5419)。标称电阻的端到端温度系数为35ppm/°C，比率温度系数仅为5ppm/°C，非常适合低温漂可变电阻的应用，如低漂移、可编程增益放大器。

MAX5417/MAX5418/MAX5419采用3mm x 3mm、8引脚TDFN封装，工作在-40°C至+85°C扩展级温度范围。

应用

替代机械电位器

低漂移可编程增益放大器

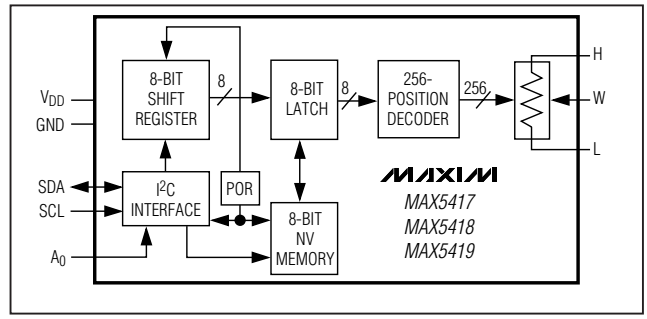
音量控制

液晶显示屏(LCD)对比度控制

特性

- 上电后从非易失存储器调用滑动端位置
- 微型3mm x 3mm、8引脚TDFN封装
- 端到端电阻温度系数：35ppm/°C
- 比率温度系数：5ppm/°C
- 阻值：50kΩ/100kΩ/200kΩ
- 快速I²C兼容串行接口
- 500nA (典型值)静态电流
- 单电源+2.7V至+5.25V供电
- 256抽头
- 分压模式下DNL为：±0.5 LSB
- 分压模式下INL为：±0.5 LSB

功能图



I²C是Philips Corp.的一个商标。

购买Maxim Integrated Products, Inc.或其从属授权公司的I²C产品，即得到了Philips I²C的专利许可、将这些产品用于符合Philips定义的I²C标准规范的系统。

定购信息/选择指南

PART	TEMP RANGE	I²C ADDRESS	R (kΩ)	PIN-PACKAGE	TOP MARK
MAX5417LETA	-40°C to +85°C	010100A_0	50	8 TDFN-EP**	AIB
MAX5417META*	-40°C to +85°C	010101A_0	50	8 TDFN-EP**	ALS
MAX5417NETA*	-40°C to +85°C	010110A_0	50	8 TDFN-EP**	ALT
MAX5417PETA*	-40°C to +85°C	010111A_0	50	8 TDFN-EP**	ALU
MAX5418LETA	-40°C to +85°C	010100A_0	100	8 TDFN-EP**	AIC
MAX5418META*	-40°C to +85°C	010101A_0	100	8 TDFN-EP**	ALV
MAX5418NETA*	-40°C to +85°C	010110A_0	100	8 TDFN-EP**	ALW
MAX5418PETA*	-40°C to +85°C	010111A_0	100	8 TDFN-EP**	ALX
MAX5419LETA	-40°C to +85°C	010100A_0	200	8 TDFN-EP**	AID
MAX5419META*	-40°C to +85°C	010101A_0	200	8 TDFN-EP**	ALY
MAX5419NETA*	-40°C to +85°C	010110A_0	200	8 TDFN-EP**	ALZ
MAX5419PETA*	-40°C to +85°C	010111A_0	200	8 TDFN-EP**	AMA

**Future product—contact factory for availability.*

***Exposed pad.*

引脚配置见本文的最后部分。

ABSOLUTE MAXIMUM RATINGS

V_{DD} to GND .....-0.3V to +6.0V
All Other Pins to GND .....-0.3V to (V_{DD} + 0.3V)
Maximum Continuous Current into H, L, and W
MAX5417 .....±1.3mA
MAX5418 .....±0.6mA
MAX5419 .....±0.3mA

Continuous Power Dissipation (T_A = +70°C)
8-Pin TDFN (derate 24.4mW/°C above +70°C) 1951mW
Operating Temperature Range .....-40°C to +85°C
Junction Temperature .....+150°C
Storage Temperature Range .....-60°C to +150°C
Lead Temperature (soldering, 10s) .....+300°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} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DC PERFORMANCE (VOLTAGE-DIVIDER MODE)						
Resolution			256			Taps
Integral Nonlinearity	INL	(Note 1)			±0.5	LSB
Differential Nonlinearity	DNL	(Note 1)			±0.5	LSB
End-to-End Temperature Coefficient	TC_R			35		ppm/°C
Ratiometric Temperature Coefficient				5		ppm/°C
Full-Scale Error		MAX5417_, 50Ω		-0.6		LSB
		MAX5418_, 100kΩ		-0.3		
		MAX5419_, 200kΩ		-0.15		
Zero-Scale Error		MAX5417_, 50kΩ		0.6		LSB
		MAX5418_, 100kΩ		0.3		
		MAX5419_, 200kΩ		0.15		
DC PERFORMANCE (VARIABLE-RESISTOR MODE)						
Integral Nonlinearity (Note 2)	INL	V_{DD} = 3V			±3	LSB
		V_{DD} = 5V			±1.5	
Differential Nonlinearity (Note 2)	DNL	V_{DD} = 3V, MAX5417_, 50kΩ, guaranteed monotonic	-1		+2	LSB
		V_{DD} = 3V, MAX5418_, 100kΩ			±1	
		MAX5419_, 200kΩ			±1	
		V_{DD} = 5V			±1	
DC PERFORMANCE (RESISTOR CHARACTERISTICS)						
Wiper Resistance	R_W	V_{DD} = 3V to 5.25V (Note 3)		325	675	Ω
Wiper Capacitance	C_W			10		pF
End-to-End Resistance	R_{HL}	MAX5417_	37.5	50	62.5	kΩ
		MAX5418_	75	100	125	
		MAX5419_	150	200	250	

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGITAL INPUTS						
Input High Voltage (Note 4)	V_{IH}	V_{DD} = 3.4V to 5.25V	2.4			V
		V_{DD} < 3.4V	0.7 x V_{DD}			
Input Low Voltage	V_{IL}	V_{DD} = 2.7V to 5.25V (Note 4)			0.8	V
Low-Level Output Voltage	V_{OL}	3mA sink current			0.4	V
Input Leakage Current	I_{LEAK}				±1	µA
Input Capacitance				5		pF
DYNAMIC CHARACTERISTICS						
Wiper -3dB Bandwidth (Note 5)		MAX5417_		100		kHz
		MAX5418_		50		
		MAX5419_		25		
NONVOLATILE MEMORY						
Data Retention		T_A = +85°C		50		Years
Endurance		T_A = +25°C		200,000		Stores
		T_A = +85°C		50,000		
POWER SUPPLY						
Power-Supply Voltage	V_{DD}		2.70		5.25	V
Standby Current	I_{DD}	Digital inputs = V_{DD} or GND, T_A = +25°C		0.5	1	µA
Programming Current		During nonvolatile write; digital inputs = V_{DD} or GND (Note 6)		200	400	µA

TIMING CHARACTERISTICS

(V_{DD} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C. See Figures 1 and 2.) (Note 7)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ANALOG SECTION						
Wiper Settling Time (Note 8)	t_{IL}	MAX5417_		500		ns
		MAX5418_		600		
		MAX5419_		1000		
DIGITAL SECTION						
SCL Clock Frequency	f_{SCL}				400	kHz
Setup Time for START Condition	t_{SU-STA}		0.6			µs
Hold Time for START Condition	t_{HD-STA}		0.6			µs
CLK High Time	t_{HIGH}		0.6			µs
CLK Low Time	t_{LOW}		1.3			µs

TIMING CHARACTERISTICS (continued)

(V_{DD} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C. See Figures 1 and 2.) (Note 7)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Data Setup Time	t_{SU-DAT}		100			ns
Data Hold Time	t_{HD-DAT}		0		0.9	µs
SDA, SCL Rise Time	t_R				300	ns
SDA, SCL Fall Time	t_F				300	ns
Setup Time for STOP Condition	t_{SU-STO}		0.6			µs
Bus Free Time Between STOP and START Condition	t_{BUF}	Minimum power-up rate = 0.2V/ms	1.3			µs
Pulse Width of Spike Suppressed	t_{SP}				50	ns
Maximum Capacitive Load for Each Bus Line	C_B	(Note 9)		400		pF
Write NV Register Busy Time	t_{BUSY}	(Note 10)			12	ms

Note 1: The DNL and INL are measured with the potentiometer configured as a voltage-divider with H = V_{DD} and L = GND. The wiper terminal is unloaded and measured with a high-input-impedance voltmeter.

Note 2: The DNL and INL are measured with the potentiometer configured as a variable resistor. H is unconnected and L = GND. For the 5V condition, the wiper terminal is driven with a source current of 80µA for the 50kΩ configuration, 40µA for the 100kΩ configuration, and 20µA for the 200kΩ configuration. For the 3V condition, the wiper terminal is driven with a source current of 40µA for the 50kΩ configuration, 20µA for the 100kΩ configuration, and 10µA for the 200kΩ configuration.

Note 3: The wiper resistance is measured using the source currents given in Note 2. For operation to V_{DD} = 2.7V, see Wiper Resistance vs. Temperature in the *Typical Operating Characteristics.*

Note 4: The device draws higher supply current when the digital inputs are driven with voltages between (V_{DD} - 0.5V) and (GND + 0.5V). See Supply Current vs. Digital Input Voltage in the *Typical Operating Characteristics.*

Note 5: Wiper at midscale with a 10pF load (DC measurement). L = GND; an AC source is applied to H; and the W output is measured. A 3dB bandwidth occurs when the AC W/H value is 3dB lower than the DC W/H value.

Note 6: The programming current operates only during power-up and NV writes.

Note 7: SCL clock period includes rise and fall times t_R and t_F. All digital input signals are specified with t_R = t_F = 2ns and timed from a voltage level of (V_{IL} + V_{IH}) / 2.

Note 8: Wiper settling time is the worst-case 0% to 50% rise time measured between consecutive wiper positions. H = V_{DD}, L = GND, and the wiper terminal is unloaded and measured with a 10pF oscilloscope probe (see the *Typical Operating Characteristics* for the tap-to-tap switching transient).

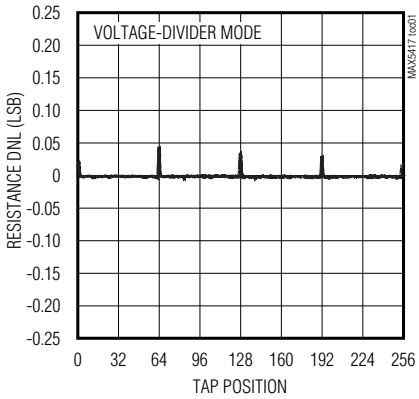
Note 9: An appropriate bus pullup resistance must be selected depending on board capacitance. Refer to the document linked to this web address: www.semiconductors.philips.com/acrobat/literature/9398/39340011.pdf.

Note 10: The idle time begins from the initiation of the stop pulse.

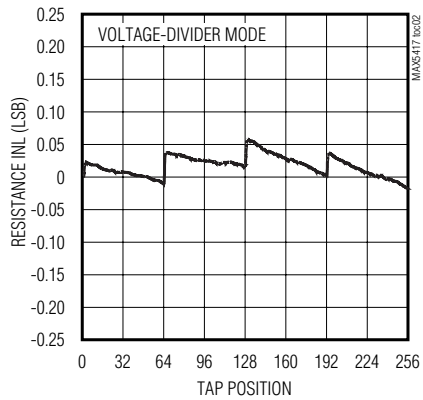
典型工作特性

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

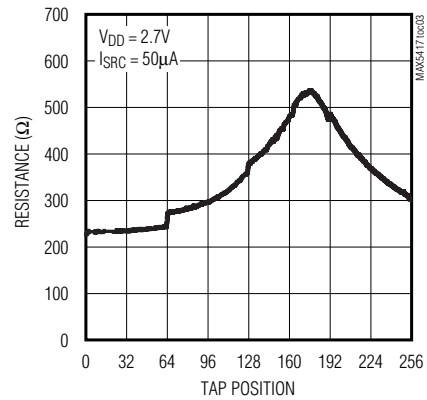
DNL vs. TAP POSITION



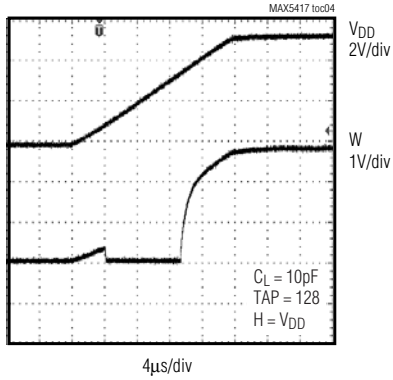
INL vs. TAP POSITION



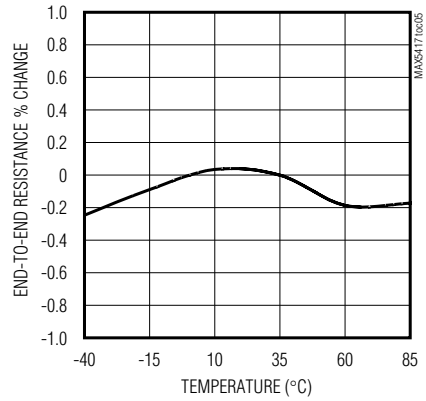
WIPER RESISTANCE vs. TAP POSITION



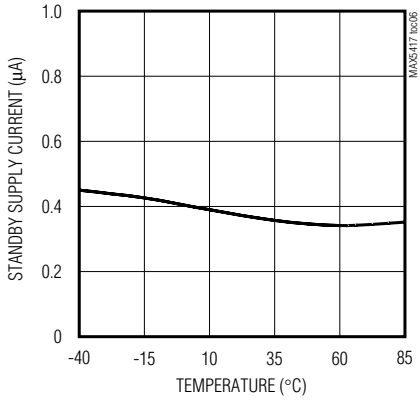
WIPER TRANSIENT AT POWER-ON



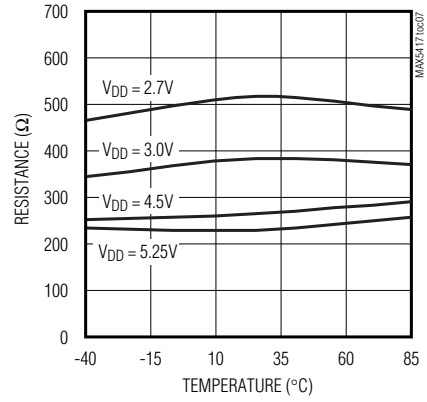
END-TO-END RESISTANCE % CHANGE vs. TEMPERATURE



STANDBY SUPPLY CURRENT vs. TEMPERATURE



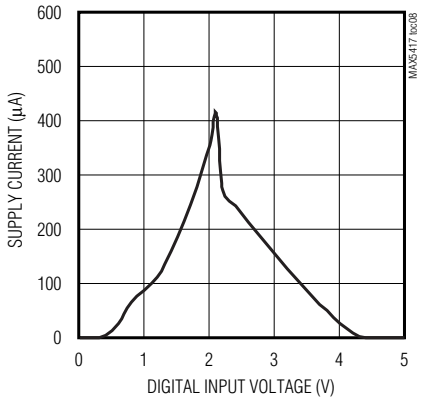
WIPER RESISTANCE vs. TEMPERATURE



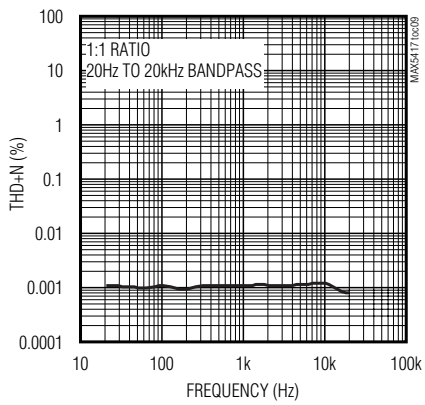
典型工作特性 (续)

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

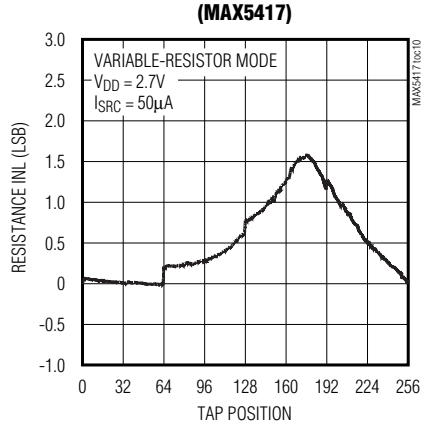
SUPPLY CURRENT vs. DIGITAL INPUT VOLTAGE



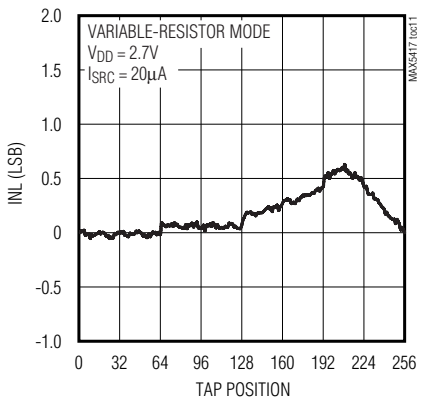
THD+N RESPONSE



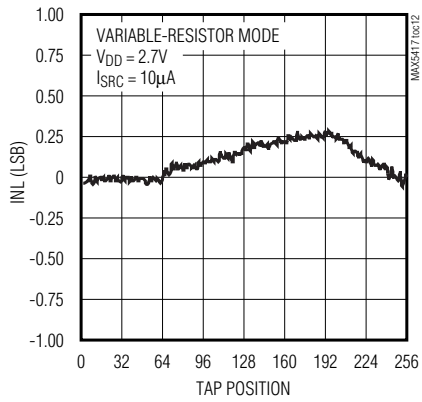
INL vs. TAP POSITION (MAX5417)



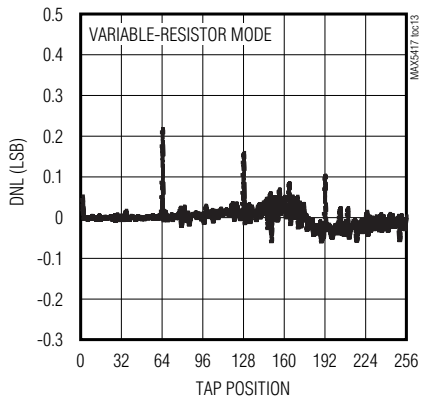
INL vs. TAP POSITION (MAX5418)



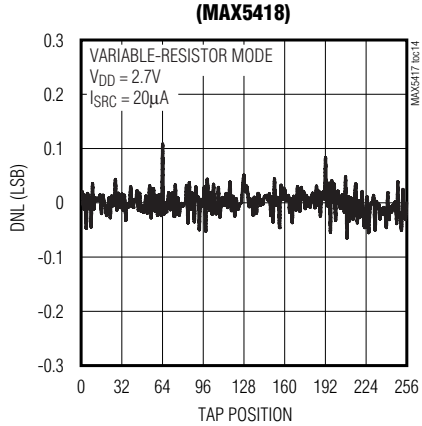
INL vs. TAP POSITION (MAX5419)



DNL vs. TAP POSITION (MAX5417)



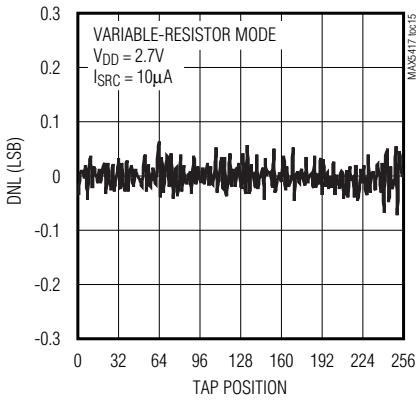
DNL vs. TAP POSITION (MAX5418)



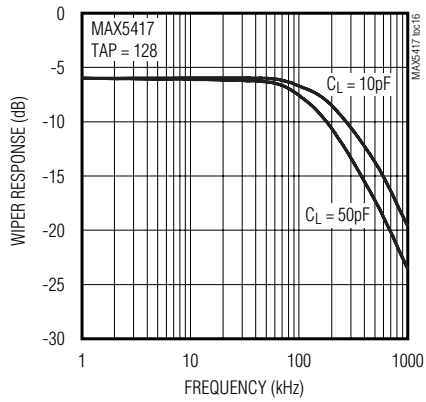
典型工作特性 (续)

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

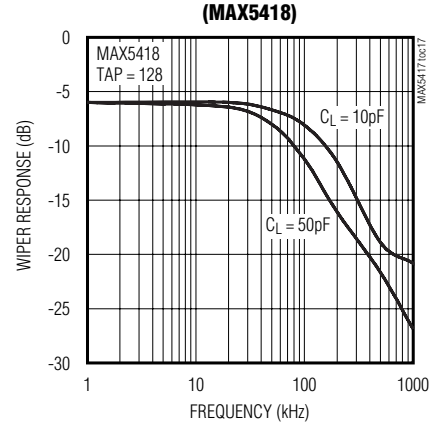
DNL vs. TAP POSITION (MAX5419)



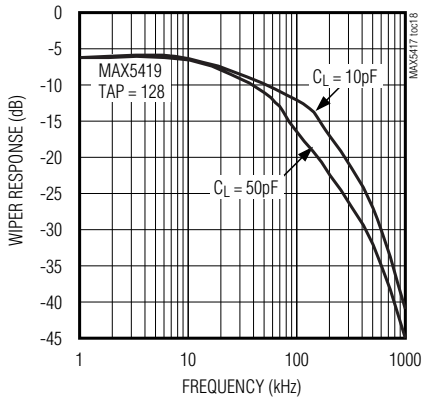
MIDSCALE WIPER RESPONSE vs. FREQUENCY (MAX5417)



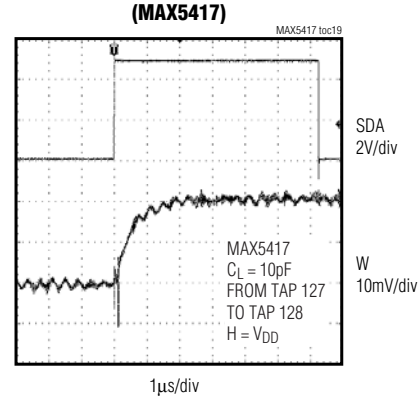
MIDSCALE WIPER RESPONSE vs. FREQUENCY (MAX5418)



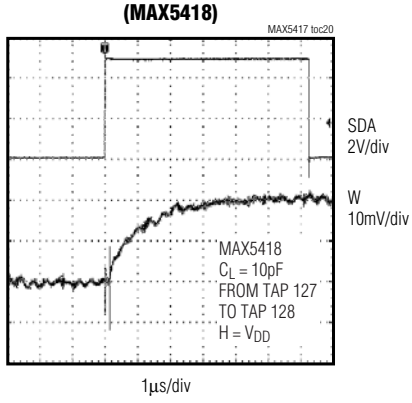
MIDSCALE WIPER RESPONSE vs. FREQUENCY (MAX5419)



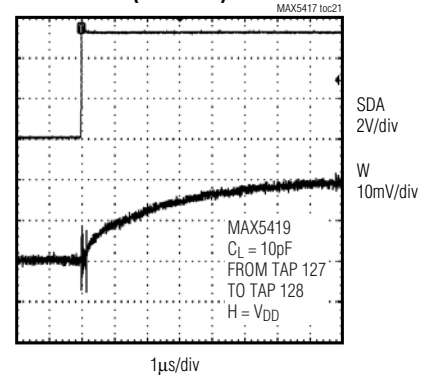
TAP-TO-TAP SWITCHING TRANSIENT (MAX5417)



TAP-TO-TAP SWITCHING TRANSIENT (MAX5418)



TAP-TO-TAP SWITCHING TRANSIENT (MAX5419)



256抽头、非易失、I²C接口数字电位器

引脚说明

引脚	名称	功能
1	V_{DD}	电源输入，电压范围：2.7V至5.25V。用0.1µF电容旁路V_{DD}至GND。
2	SCL	I²C接口时钟输入
3	SDA	I²C接口数据输入
4	A0	地址输入端，设置器件ID的A0位。
5	GND	地
6	L	低端
7	W	滑动端
8	H	高端
—	EP	裸露焊盘

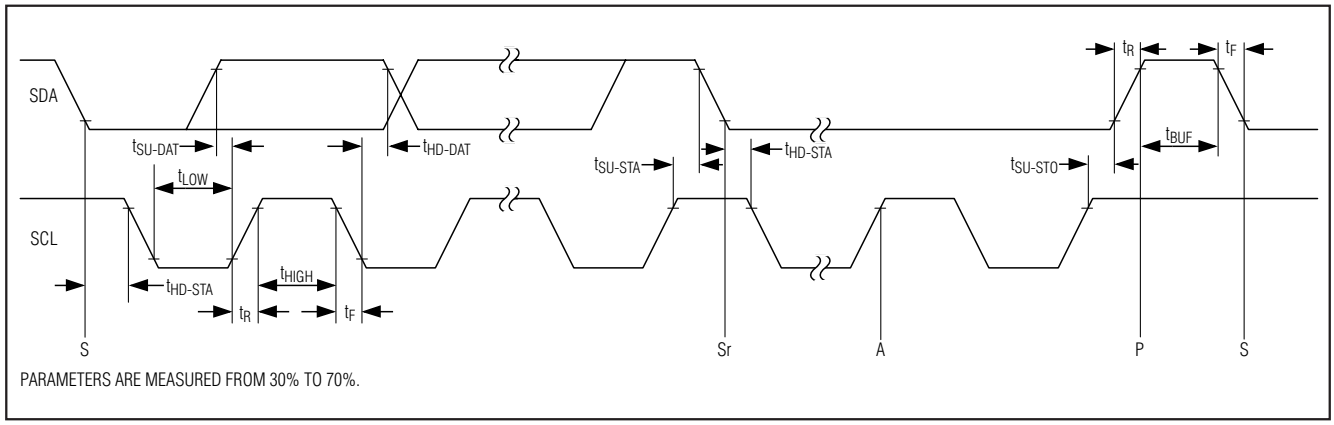


图1. I²C串行接口时序

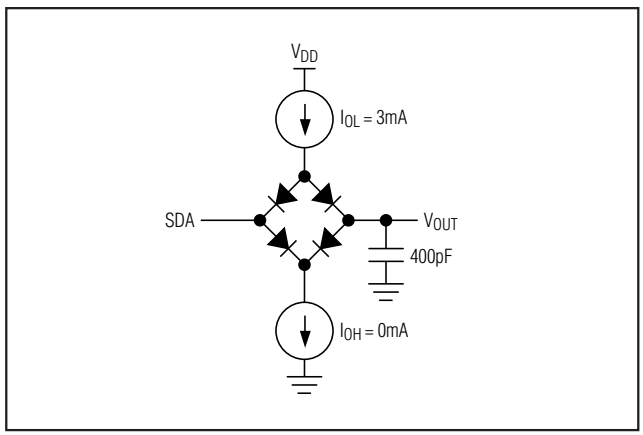


图2. 负载电路

详细说明

MAX5417/MAX5418/MAX5419内置电阻阵列，包含255个电阻单元。MAX5417端到端阻值为50kΩ，MAX5418端到端阻值为100kΩ，MAX5417端到端阻值为200kΩ。MAX5417/MAX5418/MAX5419通过连接高端、低端和滑动端可以构成标准的分压器，H、L和W端可以任意配置，只需保证各端电压在GND和V_{DD}之间。

简单的2线I²C兼容串行接口可以在256个触点间调节滑动端。非易失存储器储存并在上电时恢复滑动端的位置。非易失存储器确保200,000次抽头读写，寄存器数据可保持50年。

模拟电路

MAX5417/MAX5418/MAX5419内置一个电阻阵列，包含255个电阻单元；256个抽头点可以沿着H、L之间的电阻串接至滑动端 (W)。滑动端的位置选择通过 2线 (I²C)接口对数字电位器编程实现。8位数据，一个地址字节，和一个控制字节设置抽头位置。MAX5417/MAX5418/MAX5419的 H、L端与机械电位器的两个端点相同。MAX5417/MAX5418/MAX5419带有上电复位电路，在上电时从非易失存储器自动装载滑动端的位置。

数字接口

MAX5417/MAX5418/MAX5419内置非易失 EEPROM，用于存储滑动端的位置，以便上电时的初始化处理。移位寄存器对控制位和地址位进行解码，将数据写入适当的数据寄存器。数据可以写入易失存储寄存器，立即更新滑动端的位置，也可以写入非易失寄存器存储。

易失寄存器在系统加电期间能够保持数据。一旦系统断电，易失寄存器的内容被清除。非易失寄存器在系统断电时仍能保存数据。一旦上电，上电复位电路将非易失存储器的内容自动传送到易失寄存器中，更新滑动端的位置。

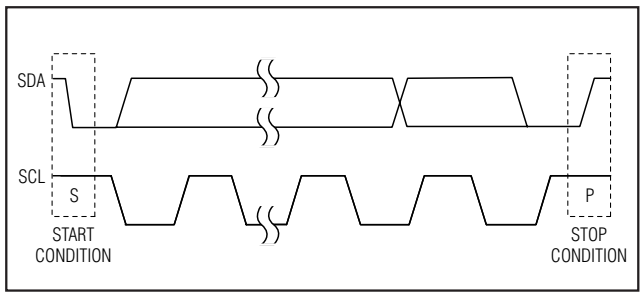


图 3. 启动条件和停止条件

串行寻址

MAX5417/MAX5418/MAX5419作为从设备从 I²C或SMBus™兼容的 2线接口接收数据，该接口采用串行数据线 (SDA)和串行时钟线 (SCL)实现主、从设备之间的通信。主设备通常是微控制器，启动MAX5417/MAX5418/MAX5419的全部数据传输，并产生 SCL时钟，同步数据传输 (见图 1)。

MAX5417/MAX5418/MAX5419的 SDA可作为输入或漏极开路输出，SDA线上需要一个典型值为 4.7kΩ的上拉电阻。MAX5417/MAX5418/MAX5419的 SCL只能作为输入端。若 2线接口挂接有多个主机，或者是具有 SCL漏极开路输出的单主机系统，SCL线上需接典型值为 4.7kΩ的上拉电阻。

每次数据传输先由主机发送启动 (START)条件 (S) (图 3)，然后发送 MAX5417/MAX5418/MAX5419的7位从地址和第8位 (图 4)，1个命令字节 (图 7)和1个数据字节，最后是停止 (STOP)条件 (P) (图 3)。

启动条件和停止条件

接口不工作时 SCL和 SDA均为高。主机发送启动条件开始数据传输，即 SCL为高电平时 SDA出现由高至低的下降沿。当主机完成与从机的通信后发送停止条件，即在SCL为高电平时 SDA出现由低至高的上升沿。然后释放总线，进行另外的传输 (图 3)。

位传输

每个时钟传输一个数据位。SCL为高时，SDA上的数据必需保持稳定 (图 5)。

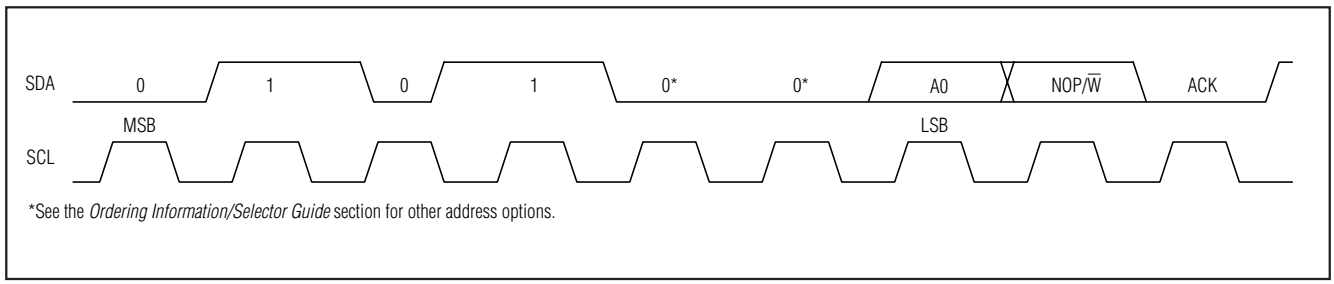


图 4. 从地址

SMBus是 Intel Corporation的一个商标。

表1. MAX5417/MAX5418/MAX5419的地址码

ADDRESS BYTE								
PART SUFFIX	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**NOP/$\overline{W}$**
L	0	1	0	1	0	0	0	NOP/$\overline{W}$
L	0	1	0	1	0	0	1	NOP/$\overline{W}$
M	0	1	0	1	0	1	0	NOP/$\overline{W}$
M	0	1	0	1	0	1	1	NOP/$\overline{W}$
N	0	1	0	1	1	0	0	NOP/$\overline{W}$
N	0	1	0	1	1	0	1	NOP/$\overline{W}$
P	0	1	0	1	1	1	0	NOP/$\overline{W}$
P	0	1	0	1	1	1	1	NOP/$\overline{W}$

应答信号

应答位是第 9个时钟位，它是收到每个数据字节的应答握手信号 (图 6)。因此，每个字节的有效传输需要 9位。主机产生第 9个时钟脉冲，接收端在应答时钟周期内将SDA拉低，所以，在时钟为高电平期间 SDA必须稳定在低电平。当主机向 MAX5417/MAX5418/MAX5419传输数据时，MAX5417/MAX5418/MAX5419产生应答信号，因为它们是数据的接收者。

从地址

MAX5417/MAX5418/MAX5419具有 7位从地址 (图 4)。紧随 7位从地址的第 8位是 NOP/$\overline{W}$位，NOP/$\overline{W}$位置低表示写操作，置高表示空操作。

MAX5417/MAX5418/MAX5419提供四种从地址 (表 1)。MAX5417/MAX5418/MAX5419的高 4位地址始终为 0101，接下来的 2位由工厂设置 (见表 1)。将 A0输入接 GND或 V_{DD}，可以在两个唯一地址中为器件选择做出选择。只有具有唯一地址的器件才能共享总线。因此，最多可以有 8个 MAX5417/MAX5418/MAX5419挂接在同一总线上。

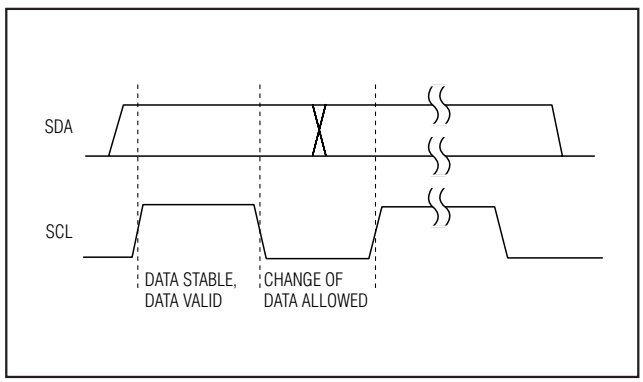


图 5. 位传输

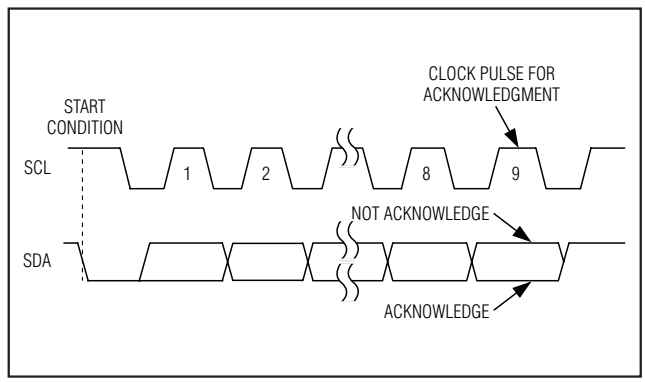


图 6. 应答信号

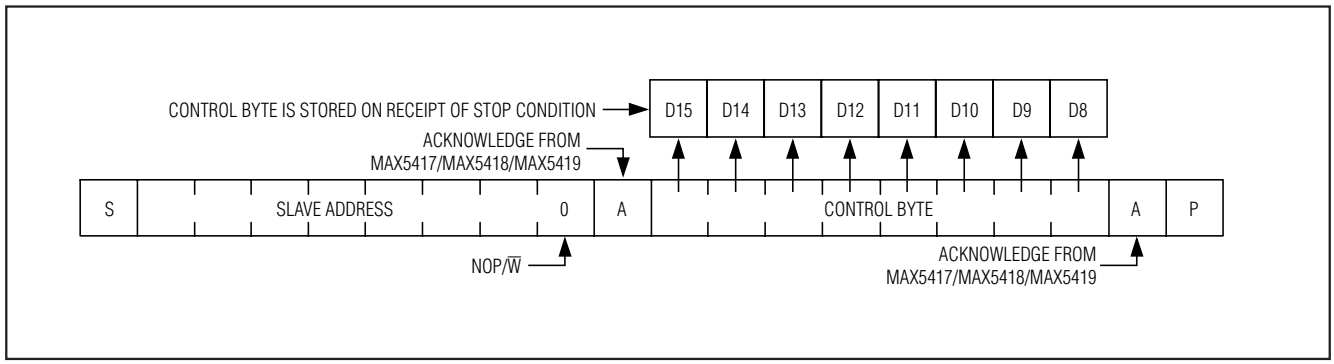


图 7. 接收到的命令字节

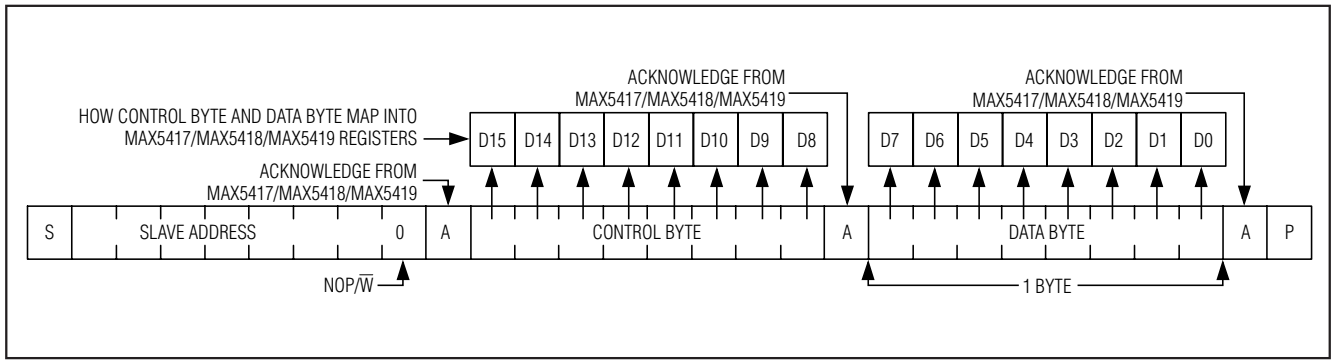


图 8. 接收到的命令和单个数据字节

写数据格式

向 MAX5417/MAX5418/MAX5419写入数据时，传输内容包括器件从地址字节 (第 8位置零)和至少一个字节的信息 (图 7)。第 1个信息字节为命令字节，命令字节之后是数据字节。第一个数据字节按照命令字节的选择写入内部寄存器 (图 8)。

命令字节

命令字节用于选择滑动端数据的源地址和目的地址 (非易失或易失存储寄存器)，或在非易失或易失存储寄存器之间交换数据 (见表 2)。

命令说明

VREG：数据字节写入易失存储寄存器，滑动端位置更新为易失存储寄存器中的数据。

NVREG：数据字节写入非易失存储寄存器，滑动端位置保持不变。

NVREGxVREG：数据从非易失存储寄存器传送到易失寄存器 (滑动端位置更新)。

VREGxNVREG：数据从易失寄存器传送到非易失存储寄存器。

256抽头、非易失、I²C接口数字电位器

表2. 命令字节

		ADDRESS BYTE									CONTROL BYTE									DATA BYTE									
SCL CYCLE NUMBER	S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	P
		A6	A5	A4	A3	A2	A1	A0		ACK		TX	NV	V	R3	R2	R1	R0	ACK	D7	D6	D5	D4	D3	D2	D1	D0	ACK	
VREG		0	1	0	1	A2	A1	A0	0		0	0	0	1	0	0	0	1		D7	D6	D5	D4	D3	D2	D1	D0		
NVREG		0	1	0	1	A2	A1	A0	0		0	0	1	0	0	0	0	1		D7	D6	D5	D4	D3	D2	D1	D0		
NVREGxVREG		0	1	0	1	A2	A1	A0	0		0	1	1	0	0	0	0	1		D7	D6	D5	D4	D3	D2	D1	D0		
VREGxNVREG		0	1	0	1	A2	A1	A0	0		0	1	0	1	0	0	0	1		D7	D6	D5	D4	D3	D2	D1	D0		

非易失存储器

内置 EEPROM包含一个 8位非易失寄存器，保留断电前写入的数据。非易失寄存器在工厂预置为零值。

上电

上电时，MAX5417/MAX5418/MAX5419将存储在非易失寄存器的数据装入易失寄存器内，并随之更新抽头位置。初始化过程需要 10µs。

待机

MAX5417/MAX5418/MAX5419具有低功耗待机模式。器件没有编程时，进入待机模式，电流消耗典型值为500nA。

应用信息

MAX5417/MAX5418/MAX5419用于需要数控调节电阻的系统，如 LCD对比度调节 (利用偏置电压调节显示器对比度)，可调增益和/或截止频率的可编程滤波器等。

LCD正偏置控制

图 9和图 10显示了用分压器或可变电阻调节 LCD正向偏置电压的应用电路图。运放提供电阻分压电路的缓冲和放大，电阻分压电路可以由电位器构成 (图 9)，或由一个固定电阻串联一个可变电阻构成 (图 10)。

可编程滤波器

图 11为一阶可编程滤波器电路。滤波器的增益由 R2调节，截止频率通过 R3调节。利用下式计算增益 (G)和 3dB截止频率 (f_C)：

$$G = 1 + \frac{R1}{R2}$$

$$f_C = \frac{1}{2\pi \times R3 \times C}$$

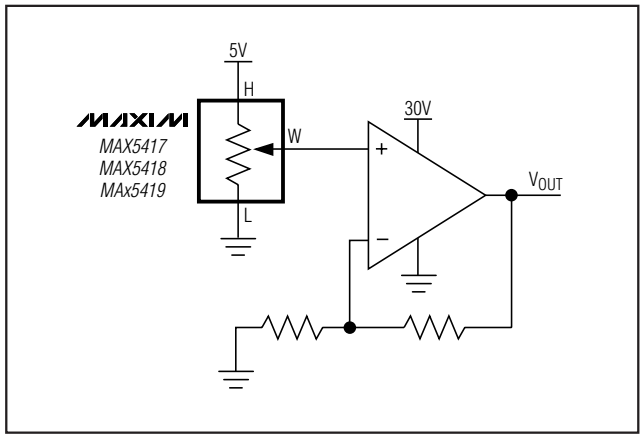


图 9. 用分压器实现 LCD正偏调节

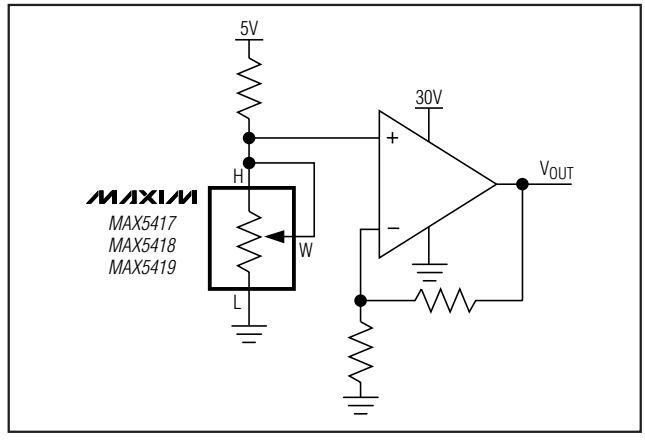


图 10. 用可变电阻实现 LCD正偏调节

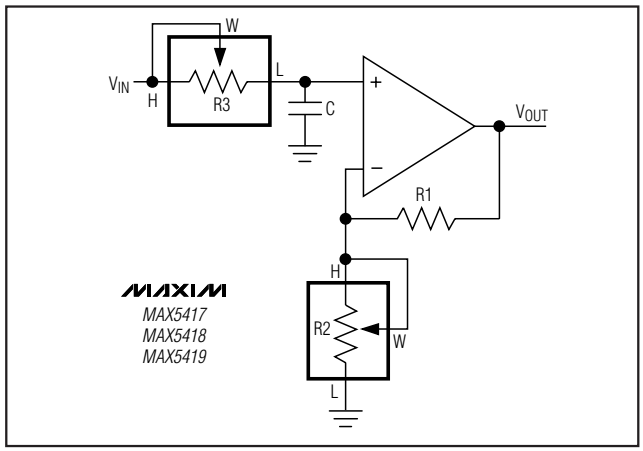


图 11. 可编程滤波器

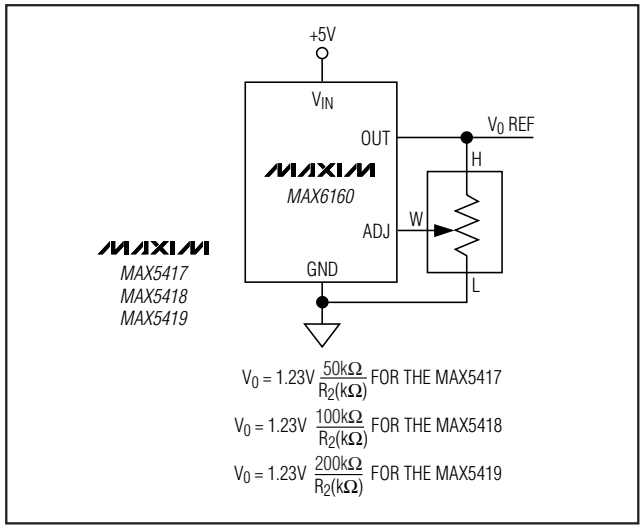


图 12. 可调电压基准

可调电压基准

图 12所示为使用 MAX5417/MAX5418/MAX5419作为多级可调电压基准应用中的反馈电阻。通过改变 MAX5417/MAX5418/MAX5419滑动端的位置，可在从 1.23V至V_{IN} - 0.2V的范围内独立调节 MAX6160的输出电压。

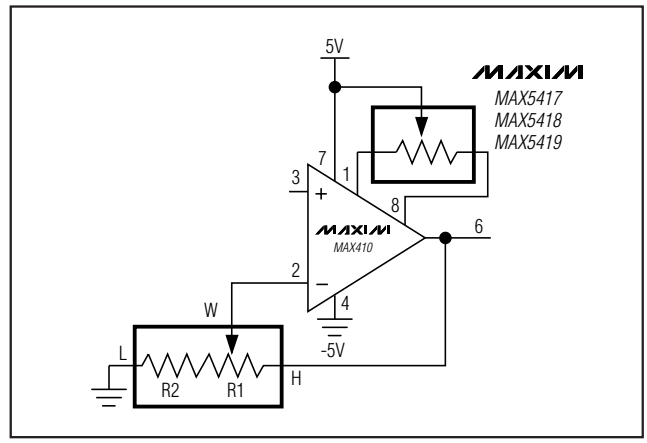
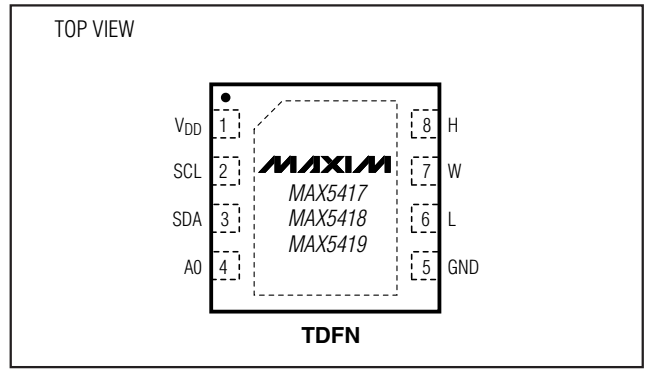


图 13. 失调电压与增益调节电路

引脚配置



失调电压和增益调节

将MAX5417中一个电位器的高端和低端分别接MAX410的NULL输入，滑动端接运放的正电源，可在整个工作温度范围内调节失调电压。另一个电位器用在MAX410的反馈回路上以调节其增益。

芯片信息

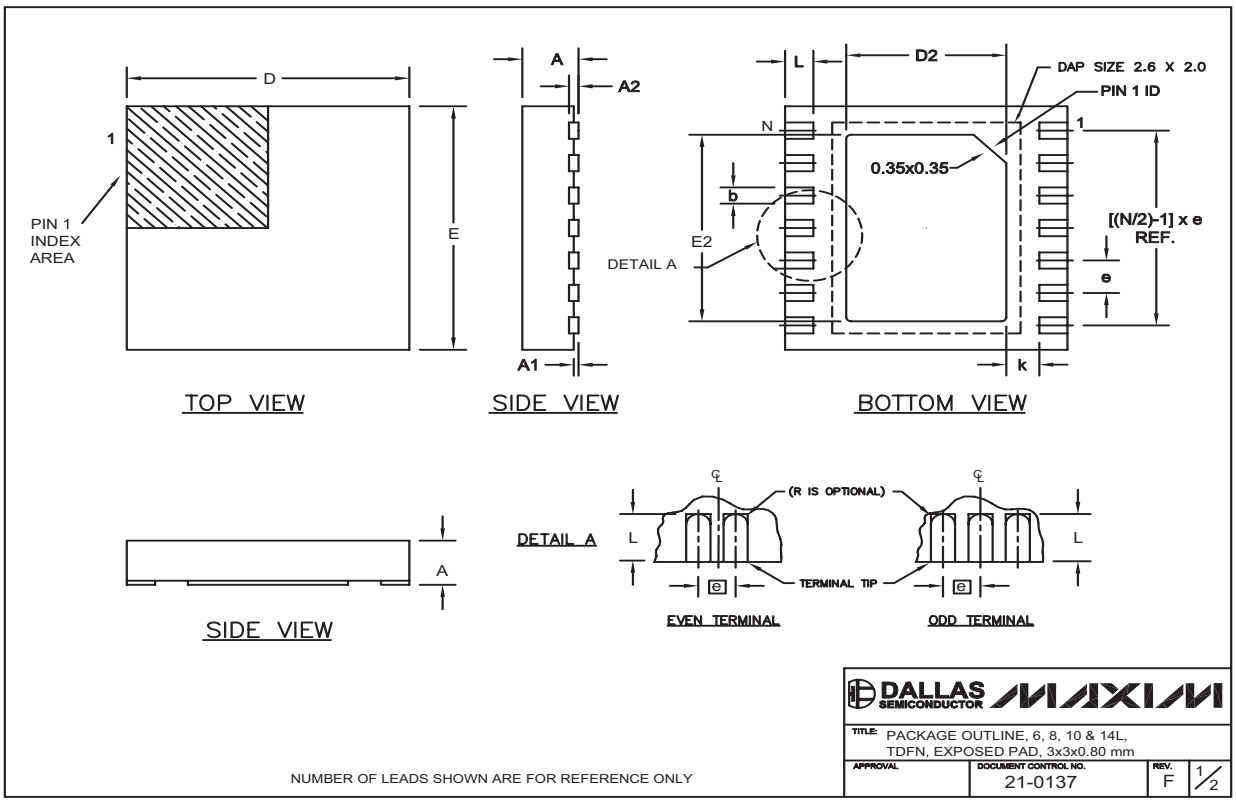
TRANSISTOR COUNT: 4637

PROCESS: BiCMOS

256抽头、非易失、I²C接口数字电位器

封装信息

(本数据资料提供的封装图可能不是最近的规格，如需最近的封装外型信息，请查询 www.maxim-ic.com.cn/packages。)



封装信息 (续)

(本数据资料提供的封装图可能不是最近的规格，如需最近的封装外型信息，请查询 www.maxim-ic.com.cn/packages。)

COMMON DIMENSIONS		
SYMBOL	MIN.	MAX.
A	0.70	0.80
D	2.90	3.10
E	2.90	3.10
A1	0.00	0.05
L	0.20	0.40
k	0.25 MIN.	
A2	0.20 REF.	

PACKAGE VARIATIONS							
PKG. CODE	N	D2	E2	e	JEDEC SPEC	b	[(N/2)-1] x e
T633-1	6	1.50±0.10	2.30±0.10	0.95 BSC	MO229 / WEEA	0.40±0.05	1.90 REF
T833-1	8	1.50±0.10	2.30±0.10	0.65 BSC	MO229 / WEEC	0.30±0.05	1.95 REF
T1033-1	10	1.50±0.10	2.30±0.10	0.50 BSC	MO229 / WEED-3	0.25±0.05	2.00 REF
T1433-1	14	1.70±0.10	2.30±0.10	0.40 BSC	- - - -	0.20±0.03	2.40 REF
T1433-2	14	1.70±0.10	2.30±0.10	0.40 BSC	- - - -	0.20±0.03	2.40 REF

NOTES:
1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY SHALL NOT EXCEED 0.08 mm.
3. WARPAGE SHALL NOT EXCEED 0.10 mm.
4. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
5. DRAWING CONFORMS TO JEDEC MO229, EXCEPT DIMENSIONS "D2" AND "E2", AND T1433-1 & T1433-2.
6. "N" IS THE TOTAL NUMBER OF LEADS.

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, 6, 8, 10 & 14L, TDFN, EXPOSED PAD, 3x3x0.80 mm

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0137	F	2/2

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北京8328信箱　邮政编码100083
免费电话：800 810 0310
电话：010-6201 0598
传真：010-6201 0298

MAX5417, MAX5417L, MAX5417M, MAX5417N, MAX5417P, MAX5418, MAX5419

256抽头、非易失、 I²C接口数字电位器

业内尺寸最小的256抽头电位器，3mm x 3mm TDFN封装

概述 | 技术文档 | 定购信息 | 用户说明 (0) | 所有内容

状况

状况：生产中。

概述

MAX5417/MAX5418/MAX5419为非易失性、线性变化的数字电位器，实现机械电位器的功能，采用简单的2线数字接口就取代了机械调节，且允许控制多个器件。每个器件具有分立电位器或可变电阻等相同功能，提供256级抽头。

这些器件内置非易失性EEPROM，用来存储中心抽头的位置，以便在上电期间进行初始化。快速模式的兼容I²C串行接口允许以400kbps的数据速率进行通讯，为多数应用尽可能减小了电路板尺寸，简化了布线。每个器件提供四个工厂预置地址之一(参阅完整数据资料中的选型指南)，和一个地址输入端，以实现总共8个唯一地址的组合。

完整的数据资料

提供更新的英文版数据资料

英文 下载 Rev. 3 (PDF, 288kB)

中文 下载 Rev. 2 (PDF, 536kB)

MAX5417/MAX5418/MAX5419提供三种标称电阻值：50kΩ (MAX5417)、100kΩ (MAX5418)及200kΩ (MAX5419)。标称端对端的电阻温度系数为50ppm/°C，比例系数仅5ppm/°C。以上特性使这些器件尤其适合于要求低温漂系数的可变电阻应用，如可编程增益放大器电路结构。

MAX5417/MAX5418/MAX5419采用3mm x 3mm、8引脚TDFN封装，工作在-40°C至+85°C的扩展级工作范围内。

现备有评估板：MAX5417LEVCMODU, MAX5417LEVKIT

关键特性

- 上电时由非失性存储器设定中心抽头位置
- 微型3mm x 3mm、8引脚TDFN封装
- 35ppm/°C端到端电阻温度系数
- 5ppm/°C比例温度系数
- 50kΩ/100kΩ/200kΩ电阻值
- 快速的兼容I²C串行接口
- 500nA (典型值)的静态电源电流
- 单电源工作：+2.7V至+5.25V
- 256抽头位置
- 在分压器模式下，达到±0.5 LSB的DNL
- 在分压器模式下，达到±0.5 LSB的INL
- 可提供评估板

应用/使用

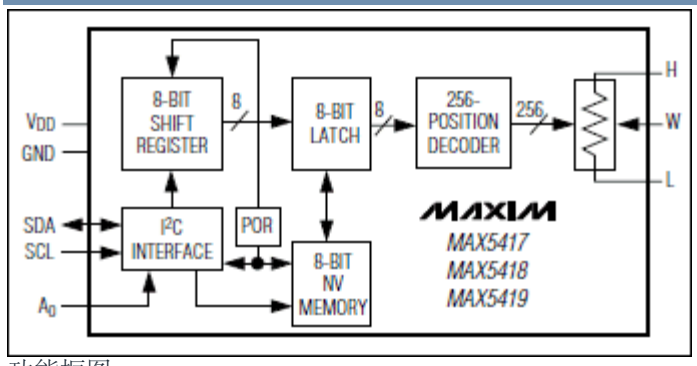
- 液晶显示器(LCD)对比度控制
- 低偏差可编程增益放大器
- 替代机械电位器
- 音量控制

Key Specifications: Digital Potentiometers

							Temp.				

Part Number	Taper	POTs	Control Interface	Wiper Memory	Steps	$R_{END-TO-END}$ (kΩ)	Coeff. (ppm/°C)	Wiper Resistance (Ω)	I_{CC} @5V (µA)	Smallest Available Pckg. (mm^2)	Price
							typ	typ	max	max w/pins	*See Notes*
MAX5418	Linear	1	2-Wire Serial	Non-Volatile	256	100	50	325	1	9.6	$1.25 @1k
MAX5419						200					$1.25 @1k
MAX5417						50					$1.16 @5k
查看所有Digital Potentiometers (128)											

图表



功能框图

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参考文献: 19-3185 Rev. 3; 2009-04-24
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19-3185; Rev 4; 4/10

256-Tap, Nonvolatile, I²C-Interface, Digital Potentiometers

General Description

The MAX5417/MAX5418/MAX5419 nonvolatile, linear-taper, digital potentiometers perform the function of a mechanical potentiometer by replacing the mechanics with a simple 2-wire digital interface, allowing communication with multiple devices. Each device performs the same function as a discrete potentiometer or variable resistor and has 256 tap points.

The devices feature an internal, nonvolatile EEPROM used to store the wiper position for initialization during power-up. The fast-mode I²C-compatible serial interface allows communication at data rates up to 400kbps, minimizing board space and reducing interconnection complexity in many applications. Each device is available with one of four factory-preset addresses (see the *Selector Guide*) and features an address input for a total of eight unique address combinations.

The MAX5417/MAX5418/MAX5419 provide three nominal resistance values: 50kΩ (MAX5417), 100kΩ (MAX5418), or 200kΩ (MAX5419). The nominal resistor temperature coefficient is 35ppm/°C end-to-end, and only 5ppm/°C ratiometric. This makes the devices ideal for applications requiring a low-temperature-coefficient variable resistor, such as low-drift, programmable gain-amplifier circuit configurations.

The MAX5417/MAX5418/MAX5419 are available in a 3mm x 3mm 8-pin TDFN package, and are specified over the extended -40°C to +85°C temperature range.

Applications

Mechanical Potentiometer Replacement

Low-Drift Programmable-Gain Amplifiers

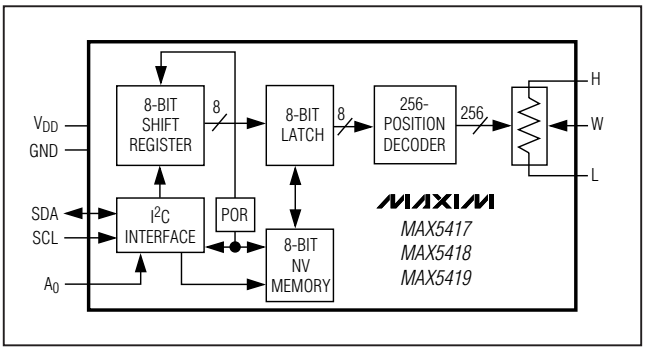
Volume Control

Liquid-Crystal Display (LCD) Contrast Control

Features

- **Power-On Recall of Wiper Position from Nonvolatile Memory**
- **Tiny 3mm x 3mm 8-Pin TDFN Package**
- **35ppm/°C End-to-End Resistance Temperature Coefficient**
- **5ppm/°C Ratiometric Temperature Coefficient**
- **50kΩ/100kΩ/200kΩ Resistor Values**
- **Fast I²C-Compatible Serial Interface**
- **500nA (typ) Static Supply Current**
- **Single-Supply Operation: +2.7V to +5.25V**
- **256 Tap Positions**
- **±0.5 LSB DNL in Voltage-Divider Mode**
- **±0.5 LSB INL in Voltage-Divider Mode**

Functional Diagram



Ordering Information/Selector Guide

PART	TEMP RANGE	I²C ADDRESS	R (kΩ)	PIN-PACKAGE	TOP MARK
MAX5417LETA+	-40°C to +85°C	010100A_0	50	8 TDFN-EP**	AIB
MAX5417META+	-40°C to +85°C	010101A_0	50	8 TDFN-EP**	ALS
MAX5417NETA+	-40°C to +85°C	010110A_0	50	8 TDFN-EP**	ALT
MAX5417PETA+	-40°C to +85°C	010111A_0	50	8 TDFN-EP**	ALU
MAX5418LETA+	-40°C to +85°C	010100A_0	100	8 TDFN-EP**	AIC
MAX5418META+	-40°C to +85°C	010101A_0	100	8 TDFN-EP**	ALV
MAX5418NETA+	-40°C to +85°C	010110A_0	100	8 TDFN-EP**	ALW
MAX5418PETA+	-40°C to +85°C	010111A_0	100	8 TDFN-EP**	ALX
MAX5419LETA+	-40°C to +85°C	010100A_0	200	8 TDFN-EP**	AID
MAX5419META+	-40°C to +85°C	010101A_0	200	8 TDFN-EP**	ALY
MAX5419NETA+	-40°C to +85°C	010110A_0	200	8 TDFN-EP**	ALZ
MAX5419PETA+	-40°C to +85°C	010111A_0	200	8 TDFN-EP**	AMA

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

***Exposed pad.*

Pin Configuration appears at end of data sheet.

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ABSOLUTE MAXIMUM RATINGS

V_{DD} to GND .....-0.3V to +6.0V
All Other Pins to GND.....-0.3V to (V_{DD} + 0.3V)
Maximum Continuous Current into H, L, and W
MAX5417.....±1.3mA
MAX5418.....±0.6mA
MAX5419.....±0.3mA

Continuous Power Dissipation (T_A = +70°C)
8-Pin TDFN (derate 24.4mW/°C above +70°C) 1951mW
Operating Temperature Range .....-40°C to +85°C
Junction Temperature.....+150°C
Storage Temperature Range .....-60°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} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DC PERFORMANCE (VOLTAGE-DIVIDER MODE)						
Resolution			256			Taps
Integral Nonlinearity	INL	(Note 1)			±0.5	LSB
Differential Nonlinearity	DNL	(Note 1)			±0.5	LSB
End-to-End Temperature Coefficient	TC_R			35		ppm/°C
Ratiometric Temperature Coefficient				5		ppm/°C
Full-Scale Error		MAX5417_, 50Ω		-0.6		LSB
		MAX5418_, 100kΩ		-0.3		
		MAX5419_, 200kΩ		-0.15		
Zero-Scale Error		MAX5417_, 50kΩ		0.6		LSB
		MAX5418_, 100kΩ		0.3		
		MAX5419_, 200kΩ		0.15		
DC PERFORMANCE (VARIABLE-RESISTOR MODE)						
Integral Nonlinearity (Note 2)	INL	V_{DD} = 3V			±3	LSB
		V_{DD} = 5V			±1.5	
Differential Nonlinearity (Note 2)	DNL	V_{DD} = 3V, MAX5417_, 50kΩ	-1		+2	LSB
		V_{DD} = 3V, MAX5418_, 100kΩ			±1	
		V_{DD} = 3V, MAX5419_, 200kΩ			±1	
		V_{DD} = 5V			±1	
DC PERFORMANCE (RESISTOR CHARACTERISTICS)						
Wiper Resistance	R_W	V_{DD} = 3V to 5.25V (Note 3)		325	675	Ω
Wiper Capacitance	C_W			10		pF
End-to-End Resistance	R_{HL}	MAX5417_	37.5	50	62.5	kΩ
		MAX5418_	75	100	125	
		MAX5419_	150	200	250	

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C.)

DIGITAL INPUTS						
Input High Voltage (Note 4)	V_{IH}	V_{DD} = 3.4V to 5.25V	2.4			V
		V_{DD} < 3.4V	0.7 x V_{DD}			
Input Low Voltage	V_{IL}	V_{DD} = 2.7V to 5.25V (Note 4)			0.8	V
Low-Level Output Voltage	V_{OL}	3mA sink current			0.4	V
Input Leakage Current	I_{LEAK}				±1	µA
Input Capacitance				5		pF
DYNAMIC CHARACTERISTICS						
Wiper -3dB Bandwidth (Note 5)		MAX5417_		100		kHz
		MAX5418_		50		
		MAX5419_		25		
NONVOLATILE MEMORY						
Data Retention		T_A = +85°C		50		Years
Endurance		T_A = +25°C		200,000		Stores
		T_A = +85°C		50,000		
POWER SUPPLY						
Power-Supply Voltage	V_{DD}		2.70		5.25	V
Standby Current	I_{DD}	Digital inputs = V_{DD} or GND, T_A = +25°C		0.5	1	µA
Programming Current		During nonvolatile write; digital inputs = V_{DD} or GND (Note 6)		200	400	µA

TIMING CHARACTERISTICS

(V_{DD} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C. See Figures 1 and 2.) (Note 7)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ANALOG SECTION						
Wiper Settling Time (Note 8)	t_{IL}	MAX5417_		500		ns
		MAX5418_		600		
		MAX5419_		1000		
DIGITAL SECTION						
SCL Clock Frequency	f_{SCL}				400	kHz
Setup Time for START Condition	t_{SU-STA}		0.6			µs
Hold Time for START Condition	t_{HD-STA}		0.6			µs
CLK High Time	t_{HIGH}		0.6			µs
CLK Low Time	t_{LOW}		1.3			µs

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TIMING CHARACTERISTICS (continued)

(V_{DD} = +2.7V to +5.25V, H = V_{DD}, L = GND, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD} = +5V, T_A = +25°C. See Figures 1 and 2.) (Note 7)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Data Setup Time	t_{SU-DAT}		100			ns
Data Hold Time	t_{HD-DAT}		0		0.9	µs
SDA, SCL Rise Time	t_R				300	ns
SDA, SCL Fall Time	t_F				300	ns
Setup Time for STOP Condition	t_{SU-STO}		0.6			µs
Bus Free Time Between STOP and START Condition	t_{BUF}	Minimum power-up rate = 0.2V/ms	1.3			µs
Pulse Width of Spike Suppressed	t_{SP}				50	ns
Maximum Capacitive Load for Each Bus Line	C_B	(Note 9)		400		pF
Write NV Register Busy Time	t_{BUSY}	(Note 10)			12	ms

Note 1: The DNL and INL are measured with the potentiometer configured as a voltage-divider with H = V_{DD} and L = GND. The wiper terminal is unloaded and measured with a high-input-impedance voltmeter.

Note 2: The DNL and INL are measured with the potentiometer configured as a variable resistor. H is unconnected and L = GND. For the 5V condition, the wiper terminal is driven with a source current of 80µA for the 50kΩ configuration, 40µA for the 100kΩ configuration, and 20µA for the 200kΩ configuration. For the 3V condition, the wiper terminal is driven with a source current of 40µA for the 50kΩ configuration, 20µA for the 100kΩ configuration, and 10µA for the 200kΩ configuration.

Note 3: The wiper resistance is measured using the source currents given in Note 2. For operation to V_{DD} = 2.7V, see Wiper Resistance vs. Temperature in the *Typical Operating Characteristics.*

Note 4: The device draws higher supply current when the digital inputs are driven with voltages between (V_{DD} - 0.5V) and (GND + 0.5V). See Supply Current vs. Digital Input Voltage in the *Typical Operating Characteristics.*

Note 5: Wiper at midscale with a 10pF load (DC measurement). L = GND; an AC source is applied to H; and the W output is measured. A 3dB bandwidth occurs when the AC W/H value is 3dB lower than the DC W/H value.

Note 6: The programming current operates only during power-up and NV writes.

Note 7: SCL clock period includes rise and fall times t_R and t_F. All digital input signals are specified with t_R = t_F = 2ns and timed from a voltage level of (V_{IL} + V_{IH}) / 2.

Note 8: Wiper settling time is the worst-case 0% to 50% rise time measured between consecutive wiper positions. H = V_{DD}, L = GND, and the wiper terminal is unloaded and measured with a 10pF oscilloscope probe (see the *Typical Operating Characteristics* for the tap-to-tap switching transient).

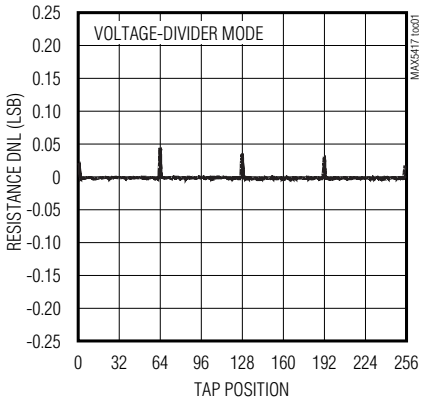
Note 9: An appropriate bus pullup resistance must be selected depending on board capacitance. Refer to the document linked to this web address: www.semiconductors.philips.com/acrobat/literature/9398/39340011.pdf.

Note 10: The idle time begins from the initiation of the stop pulse.

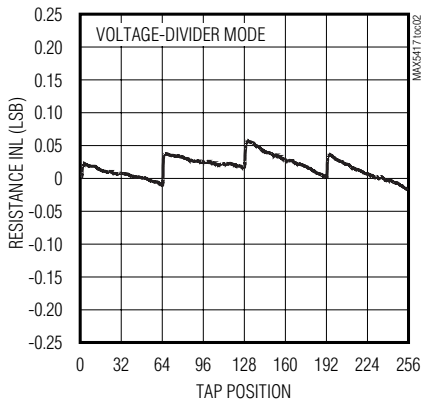
Typical Operating Characteristics

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

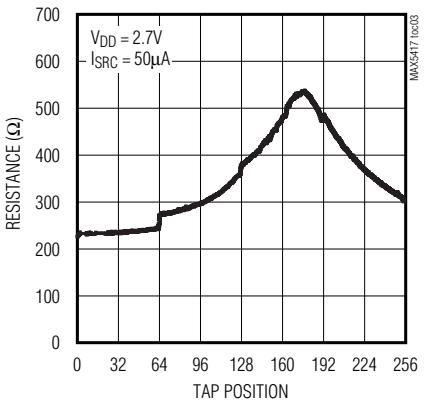
DNL vs. TAP POSITION



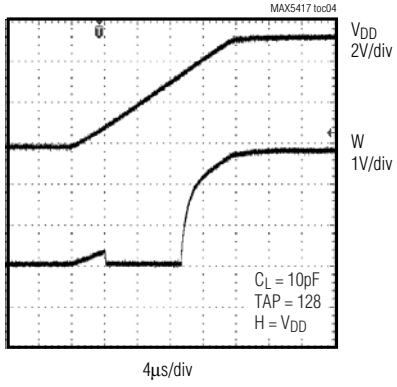
INL vs. TAP POSITION



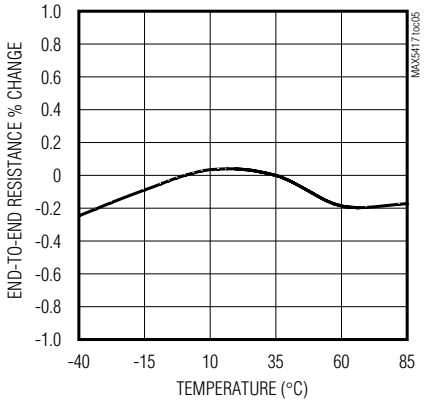
WIPER RESISTANCE vs. TAP POSITION



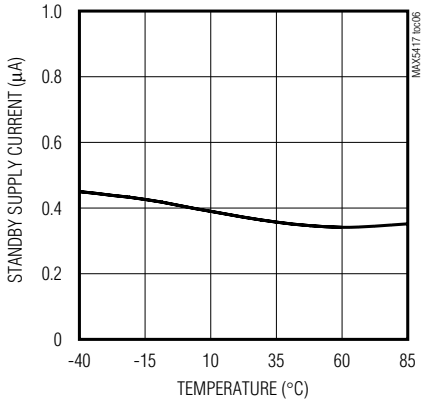
WIPER TRANSIENT AT POWER-ON



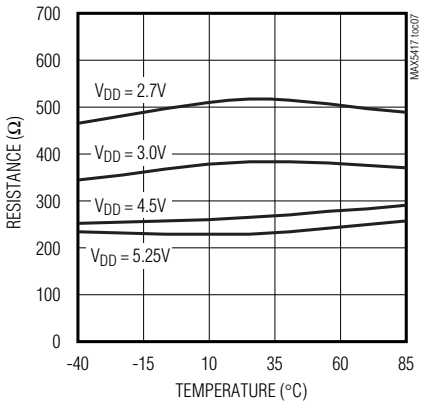
END-TO-END RESISTANCE % CHANGE vs. TEMPERATURE



STANDBY SUPPLY CURRENT vs. TEMPERATURE



WIPER RESISTANCE vs. TEMPERATURE

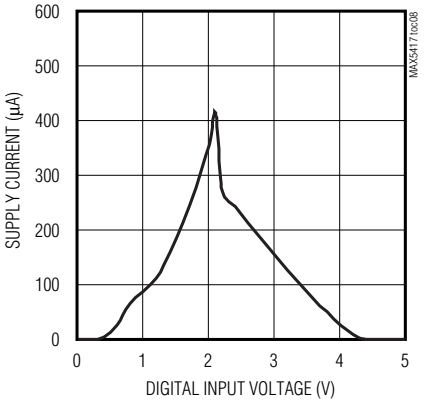


256-Tap, Nonvolatile, I²C-Interface, Digital Potentiometers

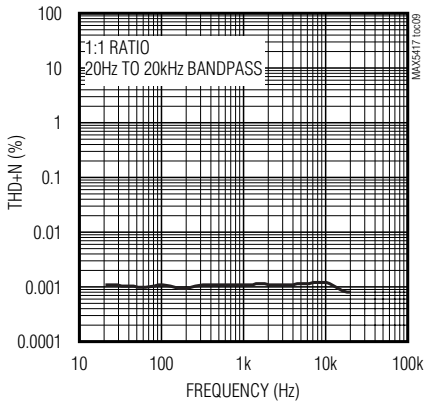
Typical Operating Characteristics (continued)

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

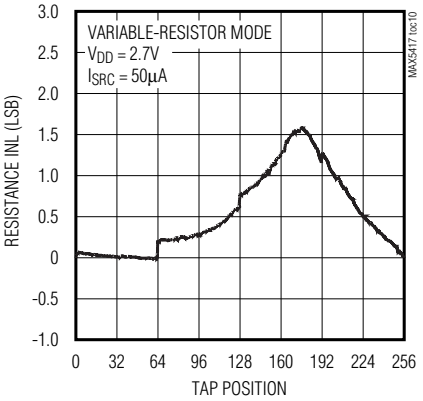
SUPPLY CURRENT vs. DIGITAL INPUT VOLTAGE



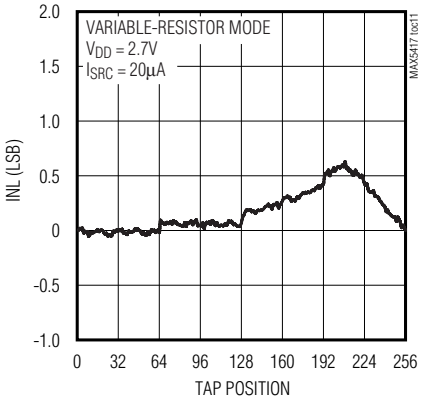
THD+N RESPONSE



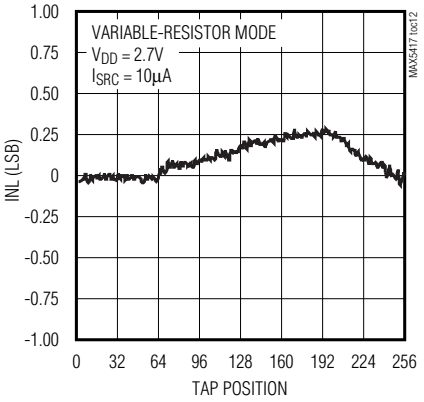
INL vs. TAP POSITION (MAX5417)



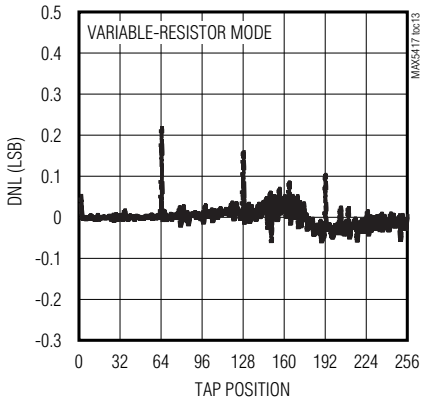
INL vs. TAP POSITION (MAX5418)



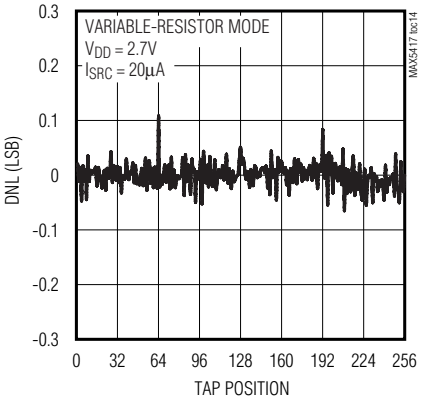
INL vs. TAP POSITION (MAX5419)



DNL vs. TAP POSITION (MAX5417)



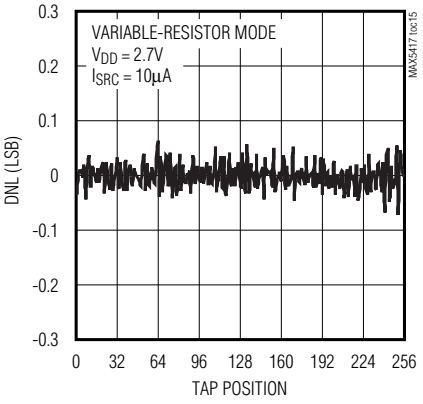
DNL vs. TAP POSITION (MAX5418)



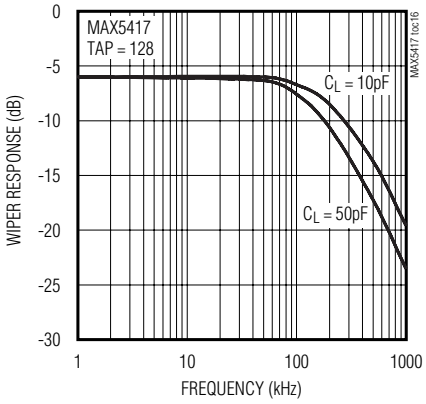
Typical Operating Characteristics (continued)

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

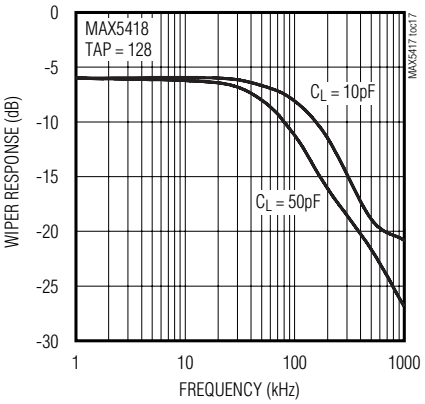
DNL vs. TAP POSITION (MAX5419)



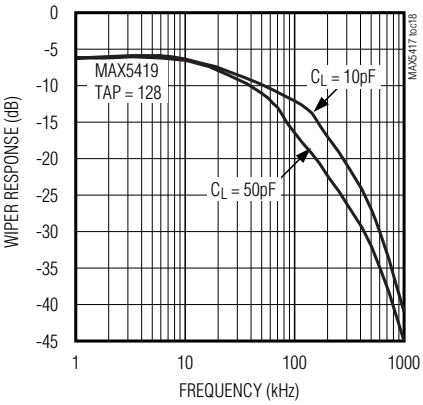
MIDSCALE WIPER RESPONSE vs. FREQUENCY (MAX5417)



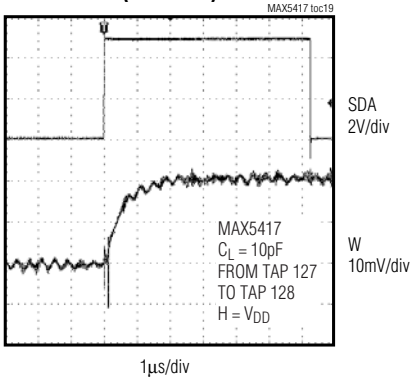
MIDSCALE WIPER RESPONSE vs. FREQUENCY (MAX5418)



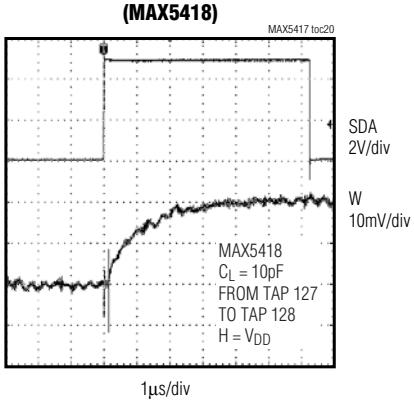
MIDSCALE WIPER RESPONSE vs. FREQUENCY (MAX5419)



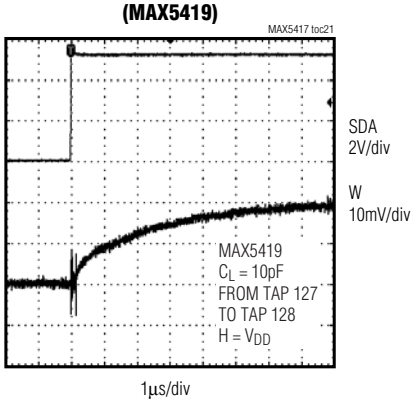
TAP-TO-TAP SWITCHING TRANSIENT (MAX5417)



TAP-TO-TAP SWITCHING TRANSIENT (MAX5418)



TAP-TO-TAP SWITCHING TRANSIENT (MAX5419)



256-Tap, Nonvolatile, I²C-Interface, Digital Potentiometers

Pin Description

PIN	NAME	FUNCTION
1	V_{DD}	Power-Supply Input. 2.7V to 5.25V voltage range. Bypass with a 0.1µF capacitor from V_{DD} to GND.
2	SCL	I²C-Interface Clock Input
3	SDA	I²C-Interface Data Input
4	A_0	Address Input. Sets the A0 bit in the device ID address.
5	GND	Ground
6	L	Low Terminal
7	W	Wiper Terminal
8	H	High Terminal
—	EP	Exposed Pad. Internally connected to GND. Connect to a large ground plane to maximize thermal performance. Not intended as an electrical point.

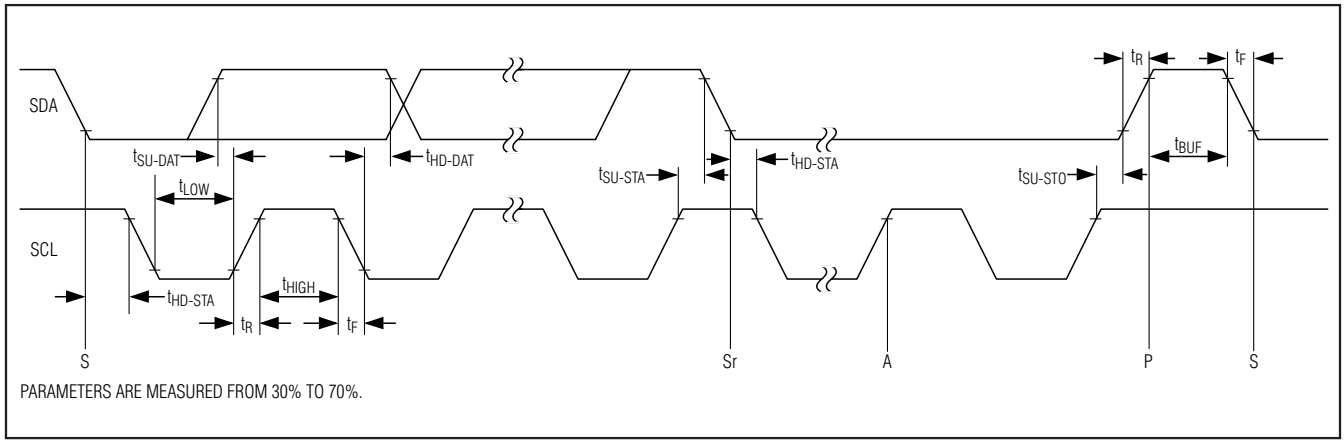


Figure 1. I²C Serial-Interface Timing Diagram

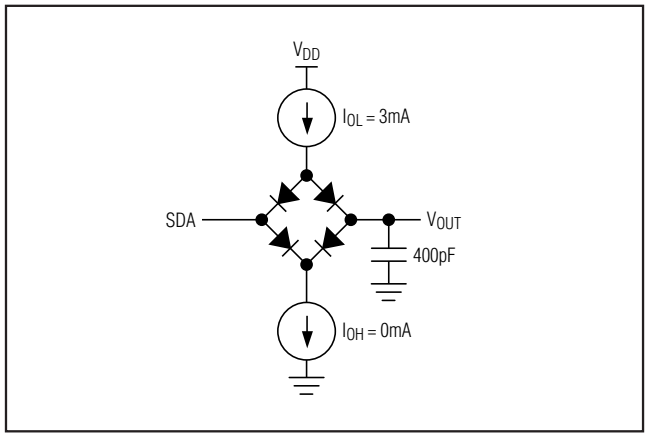


Figure 2. Load Circuit

Detailed Description

The MAX5417/MAX5418/MAX5419 contain a resistor array with 255 resistive elements. The MAX5417 has a total end-to-end resistance of 50kΩ, the MAX5418 has an end-to-end resistance of 100kΩ, and the MAX5419 has an end-to-end resistance of 200kΩ. The MAX5417/MAX5418/MAX5419 allow access to the high, low, and wiper terminals for a standard voltage-divider configuration. H, L, and W can be connected in any desired configuration as long as their voltages fall between GND and V_{DD}.

A simple 2-wire I²C-compatible serial interface moves the wiper among the 256 tap points. A nonvolatile memory stores the wiper position and recalls the stored wiper position in the nonvolatile memory upon power-up. The nonvolatile memory is guaranteed for 50 years for wiper data retention and up to 200,000 wiper store cycles.

Analog Circuitry

The MAX5417/MAX5418/MAX5419 consist of a resistor array with 255 resistive elements; 256 tap points are accessible to the wiper, W, along the resistor string between H and L. The wiper tap point is selected by programming the potentiometer through the 2-wire (I²C) interface. Eight data bits, an address byte, and a control byte program the wiper position. The H and L terminals of the MAX5417/MAX5418/MAX5419 are similar to the two end terminals of a mechanical potentiometer. The MAX5417/MAX5418/MAX5419 feature power-on reset circuitry that loads the wiper position from nonvolatile memory at power-up.

Digital Interface

The MAX5417/MAX5418/MAX5419 feature an internal, nonvolatile EEPROM that stores the wiper state for initialization during power-up. The shift register decodes the control and address bits, routing the data to the proper memory registers. Data can be written to a volatile memory register, immediately updating the wiper position, or data can be written to a nonvolatile register for storage.

The volatile register retains data as long as the device is powered. Once power is removed, the volatile register is cleared. The nonvolatile register retains data even after power is removed. Upon power-up, the power-on reset circuitry controls the transfer of data from the nonvolatile register to the volatile register.

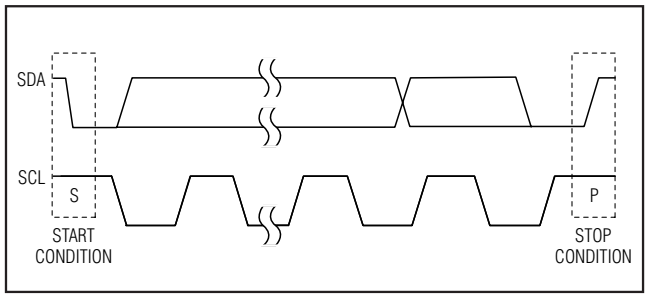


Figure 3. Start and Stop Conditions

Serial Addressing

The MAX5417/MAX5418/MAX5419 operate as a slave that receives data through an I²C- and SMBus™-compatible 2-wire interface. The interface uses a serial data access (SDA) line and a serial clock line (SCL) to achieve communication between master(s) and slave(s). A master, typically a microcontroller, initiates all data transfers to the MAX5417/MAX5418/MAX5419, and generates the SCL clock that synchronizes the data transfer (Figure 1).

The MAX5417/MAX5418/MAX5419 SDA line operates as both an input and an open-drain output. A pullup resistor, typically 4.7kΩ, is required on the SDA bus. The MAX5417/MAX5418/MAX5419 SCL operates only as an input. A pullup resistor, typically 4.7kΩ, is required on the SCL bus if there are multiple masters on the 2-wire interface, or if the master in a single-master system has an open-drain SCL output.

Each transmission consists of a START (S) condition (Figure 3) sent by a master, followed by the MAX5417/MAX5418/MAX5419 7-bit slave address plus the 8th bit (Figure 4), 1 command byte (Figure 7) and 1 data byte, and finally a STOP (P) condition (Figure 3).

Start and Stop Conditions

Both SCL and SDA remain high when the interface is not busy. A master signals the beginning of a transmission with a START condition by transitioning SDA from high to low while SCL is high. When the master has finished communicating with the slave, it issues a STOP condition by transitioning the SDA from low to high while SCL is high. The bus is then free for another transmission (Figure 3).

Bit Transfer

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable while SCL is high (Figure 5).

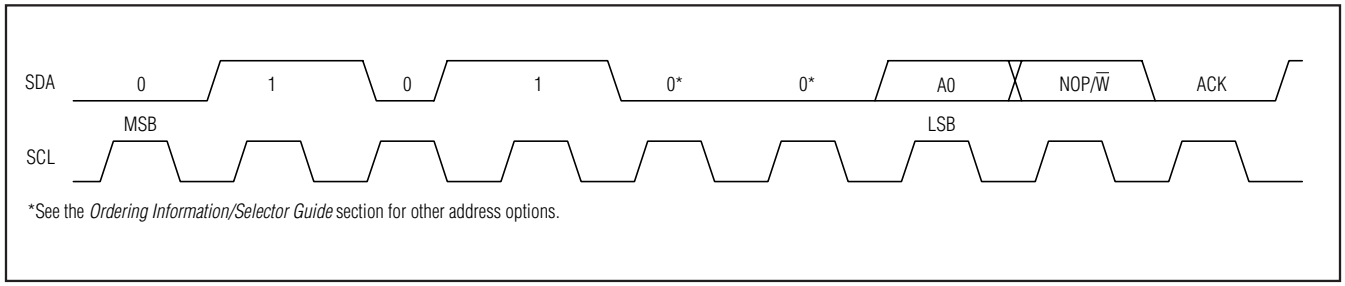


Figure 4. Slave Address

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Table 1. MAX5417/MAX5418/MAX5419 Address Codes

	ADDRESS BYTE							
PART SUFFIX	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**NOP/$\overline{W}$**
L	0	1	0	1	0	0	0	NOP/$\overline{W}$
L	0	1	0	1	0	0	1	NOP/$\overline{W}$
M	0	1	0	1	0	1	0	NOP/$\overline{W}$
M	0	1	0	1	0	1	1	NOP/$\overline{W}$
N	0	1	0	1	1	0	0	NOP/$\overline{W}$
N	0	1	0	1	1	0	1	NOP/$\overline{W}$
P	0	1	0	1	1	1	0	NOP/$\overline{W}$
P	0	1	0	1	1	1	1	NOP/$\overline{W}$

Acknowledge

The acknowledge bit is a clocked 9th bit that the recipient uses to handshake receipt of each byte of data (Figure 6). Thus, each byte transferred effectively requires 9 bits. The master generates the 9th clock pulse, and the recipient pulls down SDA during the acknowledge clock pulse, so the SDA line is stable low during the high period of the clock pulse. When the master transmits to the MAX5417/MAX5418/MAX5419, the devices generate the acknowledge bit because the MAX5417/MAX5418/MAX5419 are the recipients.

Slave Address

The MAX5417/MAX5418/MAX5419 have a 7-bit-long slave address (Figure 4). The 8th bit following the 7-bit slave address is the NOP/$\overline{W}$ bit. Set the NOP/$\overline{W}$ bit low for a write command and high for a no-operation command.

The MAX5417/MAX5418/MAX5419 are available in one of four possible slave addresses (Table 1). The first 4 bits (MSBs) of the MAX5417/MAX5418/MAX5419 slave addresses are always 0101. The next 2 bits are factory programmed (see Table 1). Connect the A0 input to either GND or V_{DD} to toggle between two unique device addresses for a part. Each device must have a unique address to share the bus. Therefore, a maximum of eight MAX5417/MAX5418/MAX5419 devices can share the same bus.

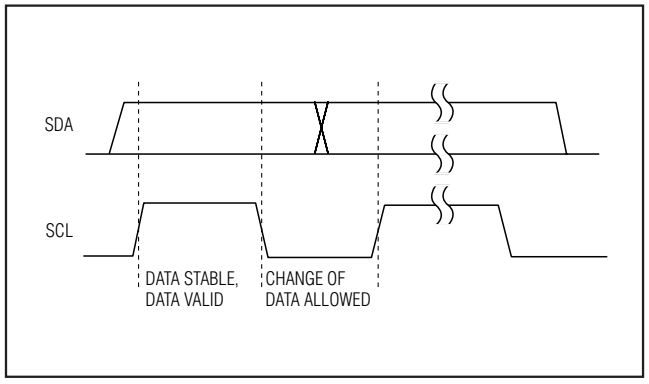

Figure 5. Bit Transfer

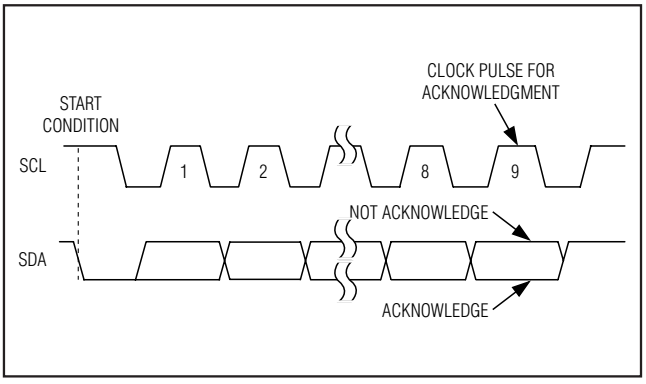

Figure 6. Acknowledge

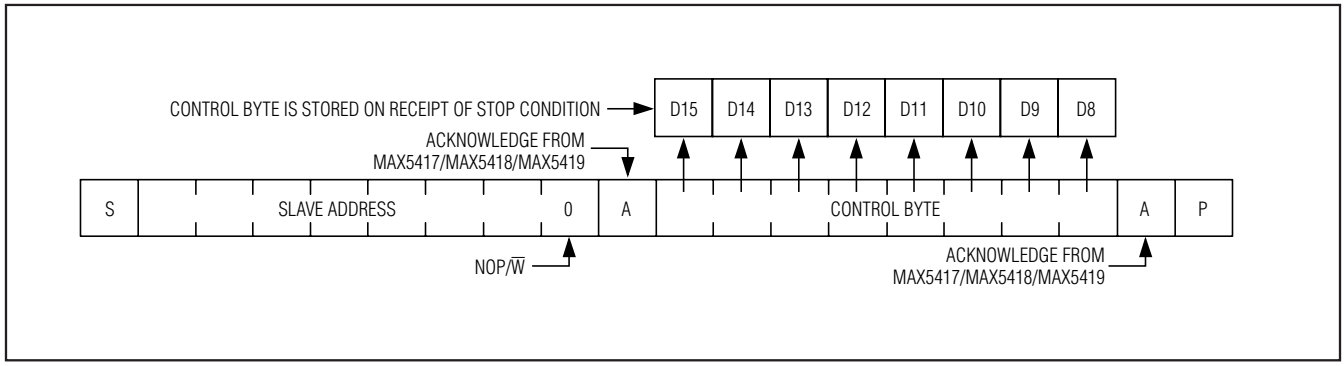

Figure 7. Command Byte Received

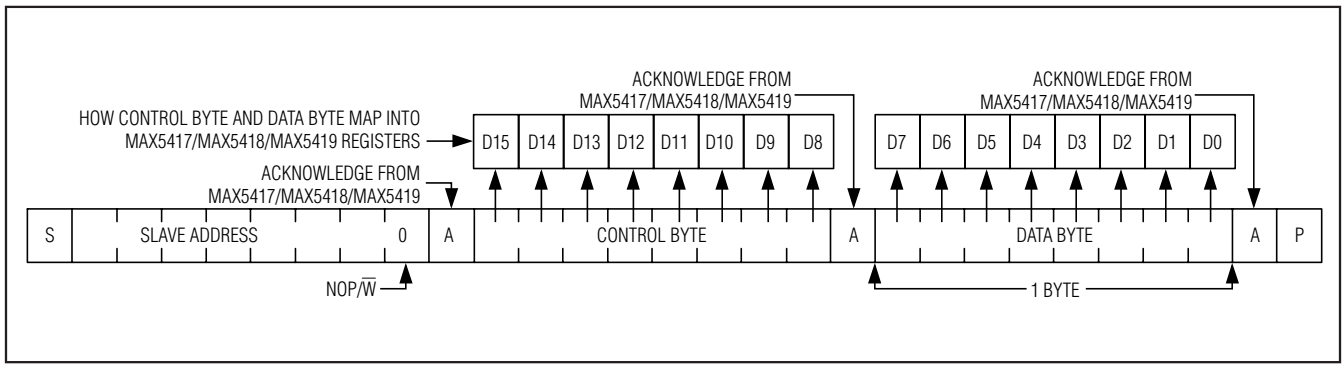

Figure 8. Command and Single Data Byte Received

Message Format for Writing

A write to the MAX5417/MAX5418/MAX5419 consists of the transmission of the device's slave address with the 8th bit set to zero, followed by at least 1 byte of information (Figure 7). The 1st byte of information is the command byte. The bytes received after the command byte are the data bytes. The 1st data byte goes into the internal register of the MAX5417/MAX5418/MAX5419 as selected by the command byte (Figure 8).

Command Byte

Use the command byte to select the source and destination of the wiper data (nonvolatile or volatile memory registers) and swap data between nonvolatile and volatile memory registers (see Table 2).

Command Descriptions

VREG: The data byte writes to the volatile memory register and the wiper position updates with the data in the volatile memory register.

NVREG: The data byte writes to the nonvolatile memory register. The wiper position is unchanged.

NVREGxVREG: Data transfers from the nonvolatile memory register to the volatile memory register (wiper position updates).

VREGxNVREG: Data transfers from the volatile memory register into the nonvolatile memory register.

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Table 2. Command Byte Summary

		ADDRESS BYTE									CONTROL BYTE									DATA BYTE									
SCL CYCLE NUMBER	S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	P
		A6	A5	A4	A3	A2	A1	A0		ACK		TX	NV	V	R3	R2	R1	R0	ACK	D7	D6	D5	D4	D3	D2	D1	D0	ACK	
VREG		0	1	0	1	A2	A1	A0	0		0	0	0	1	0	0	0	1		D7	D6	D5	D4	D3	D2	D1	D0		
NVREG		0	1	0	1	A2	A1	A0	0		0	0	1	0	0	0	0	1		D7	D6	D5	D4	D3	D2	D1	D0		
NVREGxVREG		0	1	0	1	A2	A1	A0	0		0	1	1	0	0	0	0	1		X	X	X	X	X	X	X	X		
VREGxNVREG		0	1	0	1	A2	A1	A0	0		0	1	0	1	0	0	0	1		X	X	X	X	X	X	X	X		

X = Don't care.

Nonvolatile Memory

The internal EEPROM consists of an 8-bit nonvolatile register that retains the value written to it before the device is powered down. The nonvolatile register is programmed with the midscale value at the factory.

Power-Up

Upon power-up, the MAX5417/MAX5418/MAX5419 load the data stored in the nonvolatile memory register into the volatile memory register, updating the wiper position with the data stored in the nonvolatile memory register. This initialization period takes 10µs.

Standby

The MAX5417/MAX5418/MAX5419 feature a low-power standby. When the device is not being programmed, it goes into standby mode and power consumption is typically 500nA.

Applications Information

The MAX5417/MAX5418/MAX5419 are intended for circuits requiring digitally controlled adjustable resistance, such as LCD contrast control (where voltage biasing adjusts the display contrast), or for programmable filters with adjustable gain and/or cutoff frequency.

Positive LCD Bias Control

Figures 9 and 10 show an application where the voltage-divider or variable resistor is used to make an adjustable, positive LCD bias voltage. The op amp provides buffering and gain to the resistor-divider network made by the potentiometer (Figure 9) or to a fixed resistor and a variable resistor (see Figure 10).

Programmable Filter

Figure 11 shows the configuration for a 1st-order programmable filter. The gain of the filter is adjusted by R2, and the cutoff frequency is adjusted by R3. Use the following equations to calculate the gain (G) and the 3dB cutoff frequency (f_C):

$$G = 1 + \frac{R1}{R2}$$

$$f_C = \frac{1}{2\pi \times R3 \times C}$$

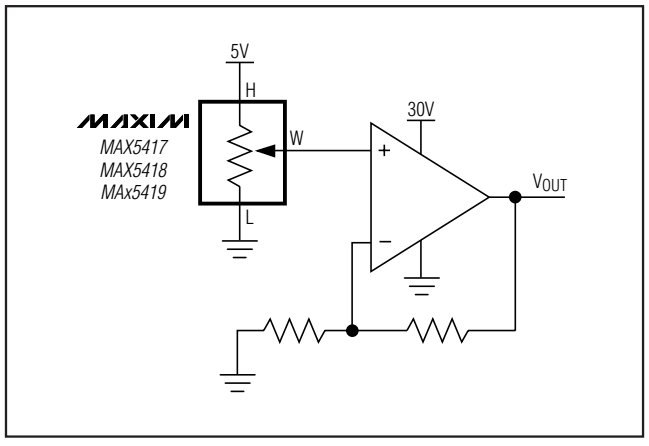


Figure 9. Positive LCD Bias Control Using a Voltage-Divider

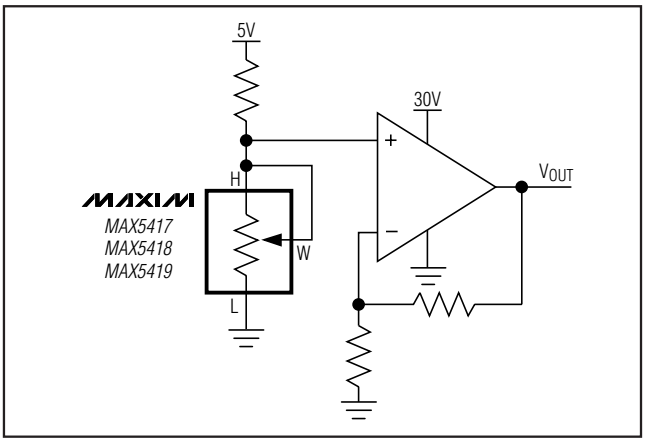


Figure 10. Positive LCD Bias Control Using a Variable Resistor

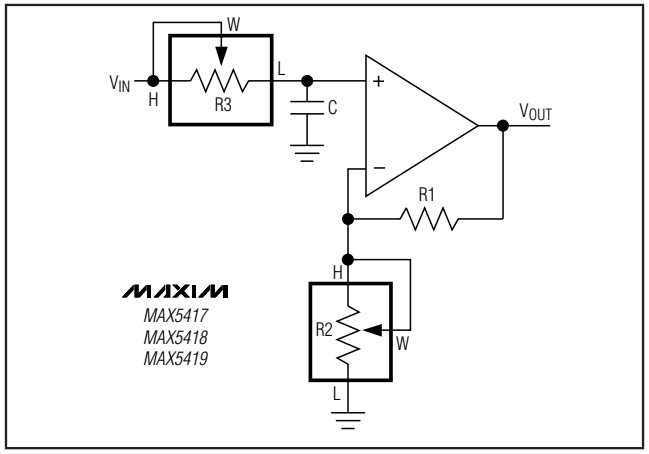


Figure 11. Programmable Filter

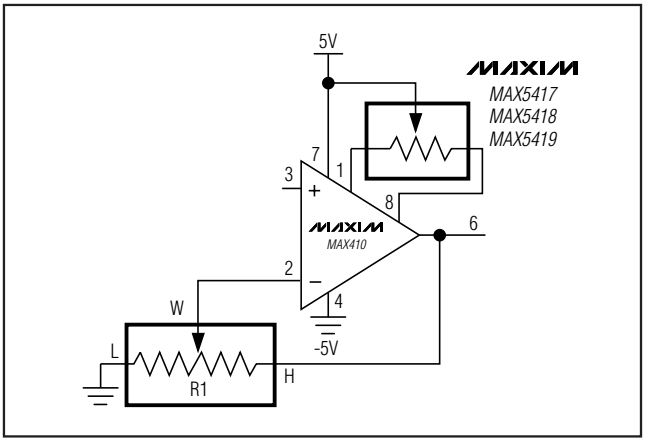


Figure 13. Offset Voltage and Gain Adjustment Circuit

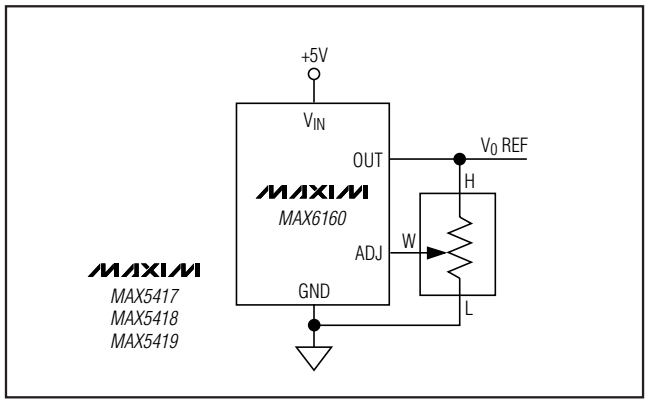
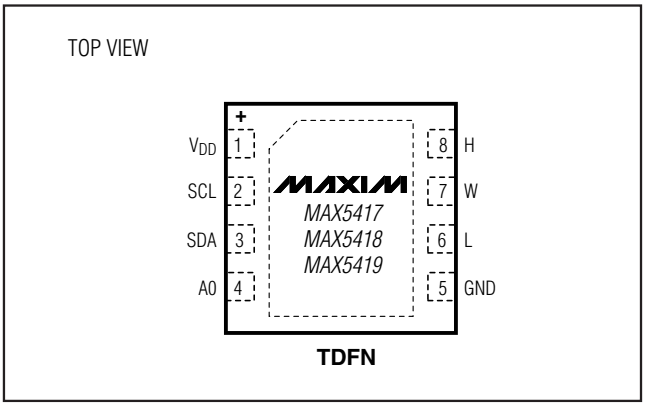


Figure 12. Adjustable Voltage Reference

Pin Configuration



Adjustable Voltage Reference

Figure 12 shows the MAX5417/MAX5418/MAX5419 used as the feedback resistors in multiple adjustable voltage-reference applications. Independently adjust the output voltage of the MAX6160 from 1.23V to V_{IN} - 0.2V by changing the wiper positions of the MAX5417/MAX5418/MAX5419.

Offset Voltage and Gain Adjustment

Connect the high and low terminals of one potentiometer of a MAX5417 between the NULL inputs of a MAX410 and the wiper to the op amp's positive supply to nullify the offset voltage over the operating temperature range. Install the other potentiometer in the feedback path to adjust the gain of the MAX410 (see Figure 13).

Chip 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.
8 TDFN-EP	T833-1	21-0137

256-Tap, Nonvolatile, I²C-Interface, Digital Potentiometers

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	2/04	Initial release	—
1	4/04	Adding future product	—
2	8/04	Adding new part	—
3	3/09	Changes to add details about exposed pad, corrections to Table 2, style edits	1, 8, 12–15
4	4/10	Added lead-free packages to *Ordering Information*, added Soldering Temperature to *Absolute Maximum Ratings*, corrected Conditions for Differential Linearity in *Electrical Characteristics*, corrected A_0 in *Pin Description*, corrected Figures 12 and 13	1, 2, 8, 13