

## FEATURES

- Improves SMBus Rise Time Transition
- Ensures Data Integrity with Multiple Devices on the SMBus
- Improves Low State Noise Margin
- Auto Detect Low Power Standby Mode
- Wide Supply Voltage Range: 2.7V to 6V
- Tiny 5-Pin SOT-23 Package

## APPLICATIONS

- Notebook and Palmtop Computers
- Portable Instruments
- Battery Chargers
- Industrial Control Application
- TV/Video Products
- ACPI SMBus Interface


## DESCRIPTION

The LTC<sup>®</sup>1694 is a dual SMBus active pull-up designed to enhance data transmission speed and reliability under all specified SMBus loading conditions. The LTC1694 is also compatible with the Philips I<sup>2</sup>C<sup>™</sup> Bus.

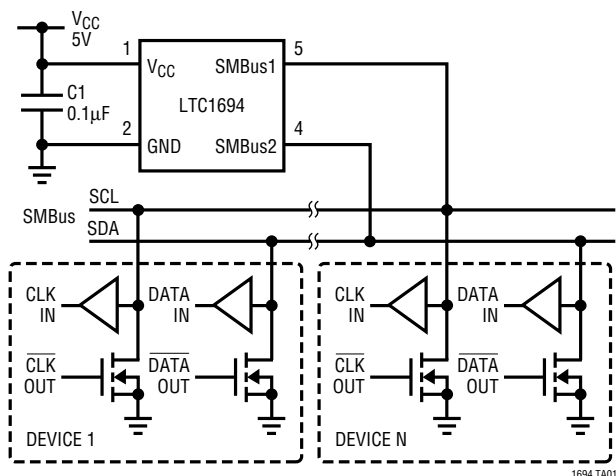
The LTC1694 allows multiple device connections or a longer, more capacitive interconnect, without compromising slew rates or bus performance, by using two bilevel hysteric current source pull-ups.

During positive bus transitions, the LTC1694 current sources provide 2.2mA to quickly slew the SMBus line. During negative transitions or steady DC levels, the current sources decrease to 275 $\mu$ A to improve negative slew rate and improve low state noise margins. An auto detect standby mode reduces supply current if both SCL and SDA are high.

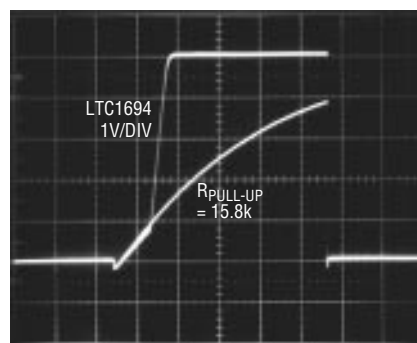
The LTC1694 is available in a 5-pin SOT-23 package, requiring virtually the same space as two surface mount resistors.

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 I<sup>2</sup>C is a trademark of Philips Electronics N.V.

## TYPICAL APPLICATION



**Comparison of SMBus Waveforms for the LTC1694 vs Resistor Pull-Up**



V<sub>CC</sub> = 5V  
 C<sub>LD</sub> = 200pF  
 f<sub>SMBus</sub> = 100kHz

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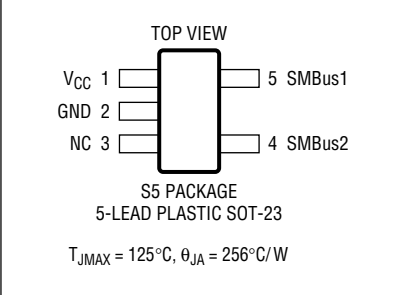
LTC1694: Patent Pending

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

Supply Voltage ( $V_{CC}$ )	7V
SMBus1, SMBus2 Inputs	–0.3V to ( $V_{CC} + 0.3V$ )
Operating Ambient Temperature Range	0°C to 70°C
Junction Temperature	125°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature (Soldering, 10 sec.)	300°C

## PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
	LTC1694CS5
	S5 PART MARKING
	LTCJ

Consult factory for Industrial and Military grade parts.

ELECTRICAL CHARACTERISTICS  $V_{CC} = 2.7V$  to  $6V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V <sub>CC</sub>	Supply Voltage Range			2.7		6	V
I <sub>CC</sub>	Supply Current	SMBus1 = SMBus2 = Open	●	20	60	100	μA
I <sub>PULL-UP</sub>	Pull-Up Current	SMBus1 = SMBus2 = 0V	●	125	275	350	μA
	Boosted Pull-Up Current	Positive Transition on SMBus ( Figure 1) Slew Rate = 0.5V/μs, SMBus > V <sub>THRES</sub>	●	1.0	2.2		mA
V <sub>THRES</sub>	Input Threshold Voltage	Slew Rate = 0.5V/μs (Figure 1)	●	0.4	0.65	0.9	V
SR <sub>THRES</sub>	Slew Rate Detector Threshold	SMBus > V <sub>THRES</sub>	●		0.2	0.5	V/μs
t <sub>r</sub>	SMBus Rise Time	Bus Capacitance = 200pF (Note 2)	●		0.25	1.0	μs
	Standard Mode I <sup>2</sup> C Bus Rise Time	Bus Capacitance = 400pF (Note 3)	●		0.30	1.0	μs
f <sub>MAX</sub>	SMBus Maximum Operating Frequency	(Note 4)	●			100	kHz

The ● denotes specifications that apply over the full operating temperature range.

**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** The rise time of an SMBus line is calculated from ( $V_{IL(MAX)} - 0.15V$ ) to ( $V_{IH(MIN)} + 0.15V$ ) or 0.45V to 1.55V. This parameter is guaranteed by design and not tested. With a minimum pull-up current of 125μA, a minimum boosted pull-up current of 1mA and a maximum input threshold voltage of 0.9V:

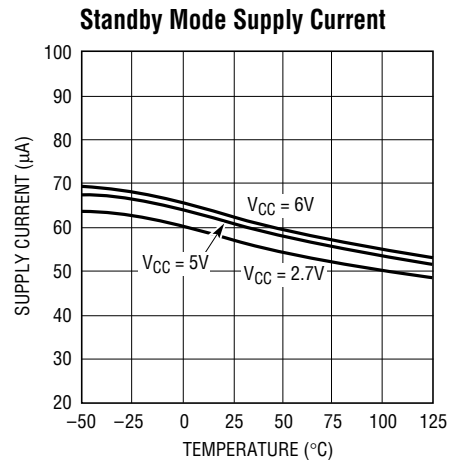
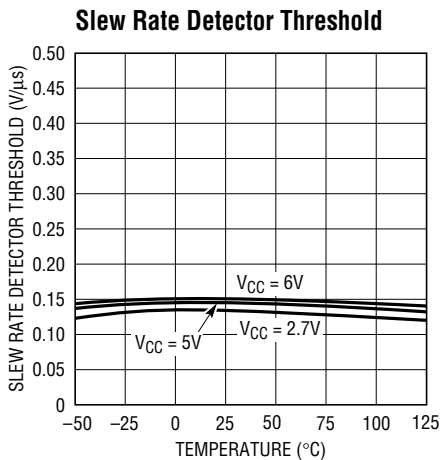
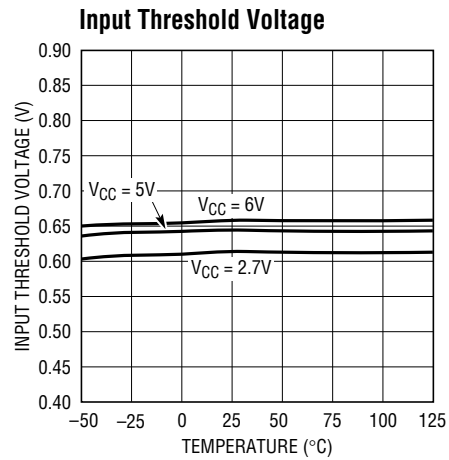
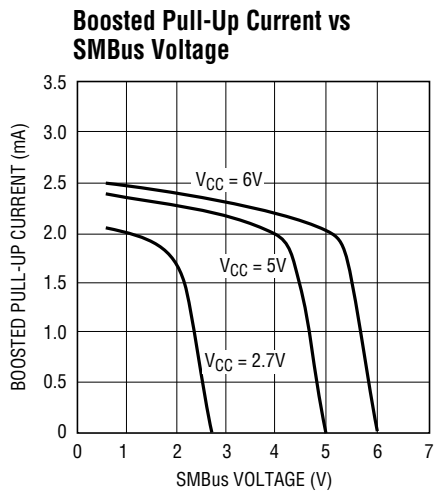
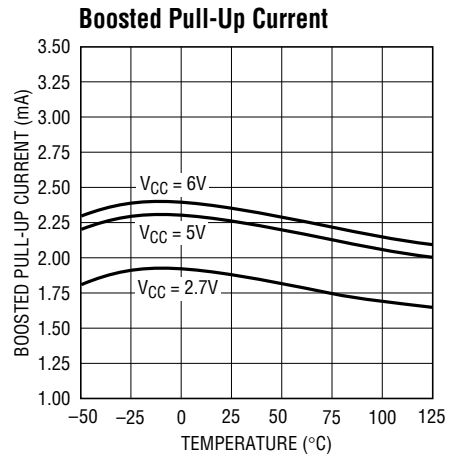
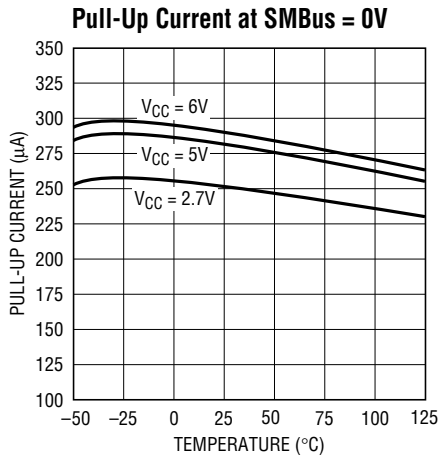
$$\text{Rise Time} = [(0.9V - 0.45V)/125\mu A + (1.55V - 0.9V)/1mA] \cdot 200pF = 0.85\mu s$$

**Note 3:** The rise time of an I<sup>2</sup>C bus line is calculated from  $V_{IL(MAX)}$  to  $V_{IH(MIN)}$  or 1.5V to 3V (with  $V_{CC} = 5V$ ). This parameter is guaranteed by design and not tested. With a minimum boosted pull-up current of 1mA:

$$\text{Rise Time} = (3V - 1.5V) \cdot 400pF/1mA = 0.6\mu s$$

**Note 4:** This parameter is guaranteed by design and not tested.

# TYPICAL PERFORMANCE CHARACTERISTICS



## PIN FUNCTIONS

**V<sub>CC</sub> (Pin 1):** Power Supply Input. V<sub>CC</sub> can range from 2.7V to 6V and requires a 0.1μF bypass capacitor to GND.

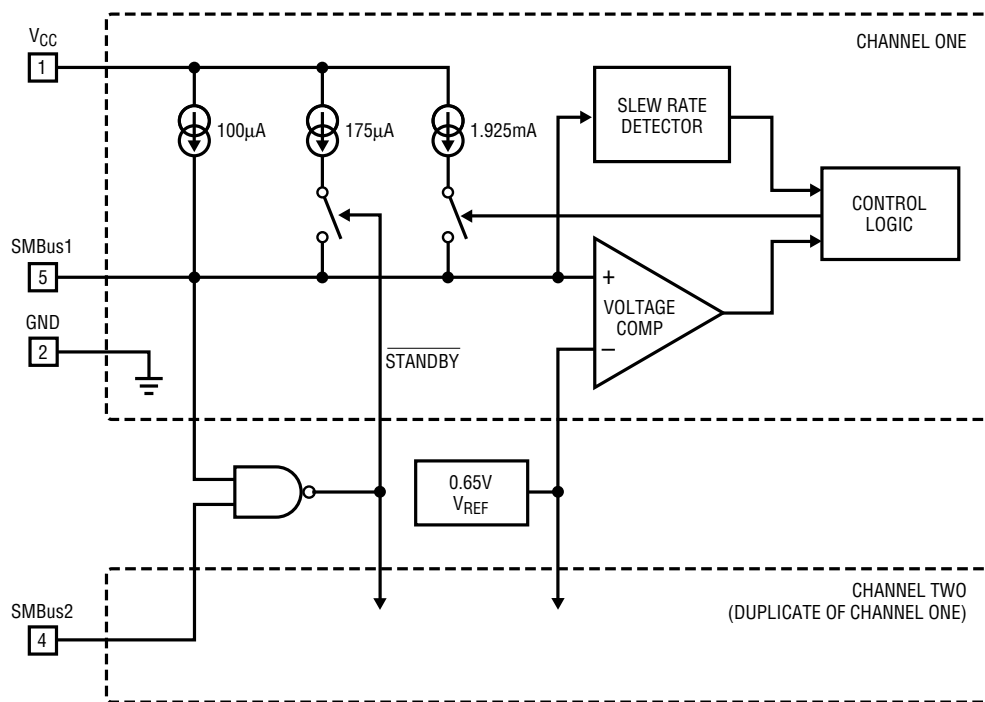
**GND (Pin 2):** Ground.

**NC (Pin 3):** No Connection.

**SMBus2 (Pin 4):** Active pull-up for SMBus.

**SMBus1 (Pin 5):** Active pull-up for SMBus.

## BLOCK DIAGRAM



1694 BD

## TEST CIRCUITS

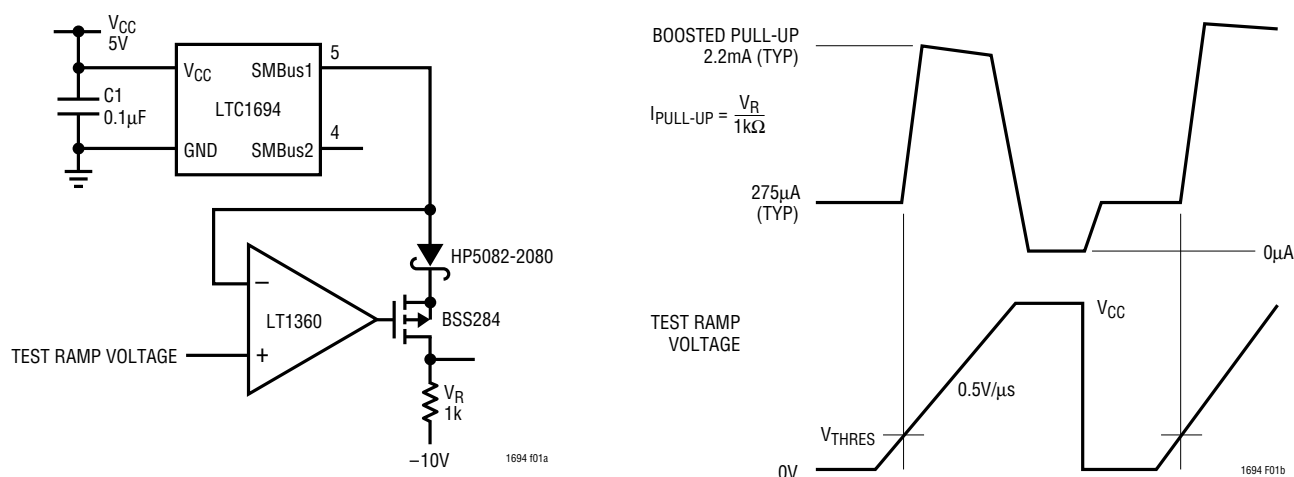


Figure 1

## APPLICATIONS INFORMATION

### SMBus Overview

SMBus communication protocol employs open-drain drives with resistive or current source pull-ups. This protocol allows multiple devices to drive and monitor the bus without bus contention. The simplicity of resistive or fixed current source pull-ups is offset by the slow rise times they afford when bus capacitance is high. Rise times can be improved by using lower pull-up resistor values or higher fixed current source values, but the additional current increases the low state bus voltage, decreasing noise margins. Slow rise times can seriously impact data reliability, enforcing a maximum practical bus speed well below the established SMBus maximum transmission rate.

### Theory of Operation

The LTC1694 overcomes these limitations by using bilevel hysteretic current sources as pull-ups. During positive SMBus line transitions, the pull-up current sources typically provide 2.2mA to quickly slew any parasitic bus

capacitance. Therefore, rise time is dramatically improved, especially with maximum SMBus loading conditions.

The LTC1694 has separate but identical circuitry for each SMBus output pin. The circuitry consists of a positive edge slew rate detector and a voltage comparator.

The LTC1694 nominally sources only 275µA of pull-up current to maintain good  $V_{OL}$  noise margin. The 2.2mA boosted pull-up current is only turned on if the voltage on the SMBus line voltage is greater than the 0.65V comparator threshold voltage and the positive slew rate of the SMBus line is greater than the 0.2V/µs threshold of the slew rate detector. The boosted pull-up current remains on until the voltage on the SMBus line is within 0.5V of  $V_{CC}$  and/or the slew rate drops below 0.2V/µs.

### Auto Detect Standby Mode

The LTC1694 enters standby mode if the voltage on both the SCL and SDA lines is high (idle state). In standby mode, the pull-up currents drop to 100µA, thereby lowering the system power consumption.

## APPLICATIONS INFORMATION

### Maximum $R_S$ Considerations

For ESD protection of the SMBus lines, a series resistor  $R_S$  (Figure 2) is sometimes added to the open-drain driver of the bus agents. This is especially common in SMBus-controlled smart batteries. The maximum value of  $R_S$  is limited by the low state noise margin and timing requirements of the SMBus specification. The maximum value for  $R_S$  is 700 $\Omega$  if resistive pull-ups or fixed value current sources are used.

In general, an  $R_S$  of 100 $\Omega$  to 200 $\Omega$  is sufficient for ESD protection while meeting both the low state noise margin and fall time requirement. If a larger value of  $R_S$  is required, take care to ensure that the low state noise margin and timing requirement of the SMBus specification is not violated. Also, the fall time of an SMBus line will also be increased by using a high value series resistor.

### Low State Noise Margin

An acceptable  $V_{OL}$  noise margin is easily achieved with the low pull-up current (350 $\mu$ A maximum) of the LTC1694. The maximum value of  $R_S$  is calculated from a desired low state noise margin ( $NM_L$ ):

$$R_{S(MAX)} = \frac{V_{OL(MAX)} - NM_L}{I_{PULL-UP(MAX)}} - R_{ON(MAX)}$$

$V_{OL(MAX)}$ : The maximum  $V_{OL}$  of the SMBus specification is 0.4V

$R_{ON(MAX)}$ : The maximum on resistance of the open-drain driver

$I_{PULL-UP(MAX)}$ : The maximum LTC1694 low pull-up current is 350 $\mu$ A

### Fall Time

Fall time is a function of the SMBus capacitance,  $R_S$ ,  $R_{ON}$  and the pull-up current. Figure 3 shows the maximum allowed ( $R_S + R_{ON}$ ) based on the Intel SMBus fall time requirement of 300ns with a 50ns safety margin.

### ACK Data Setup Time

The data setup time requirement for ACK (acknowledge) must be fulfilled if a higher  $R_S$  is used. An acknowledge is accomplished by the SMBus host releasing the SDA line (pulling high) at the end of the last bit sent and the SMBus slave device pulling the SDA line low before the rising edge of the ACK clock pulse.

The LTC1694 2.2mA boosted pull-up current is activated when the SMBus host releases the SDA line, allowing the voltage to rise above the LTC1694's comparator threshold

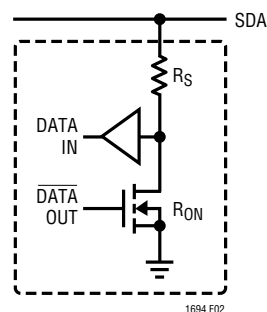


Figure 2

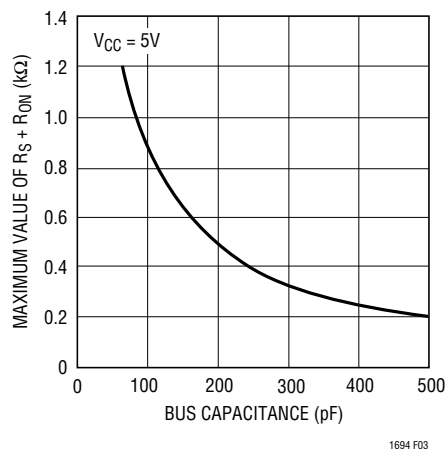
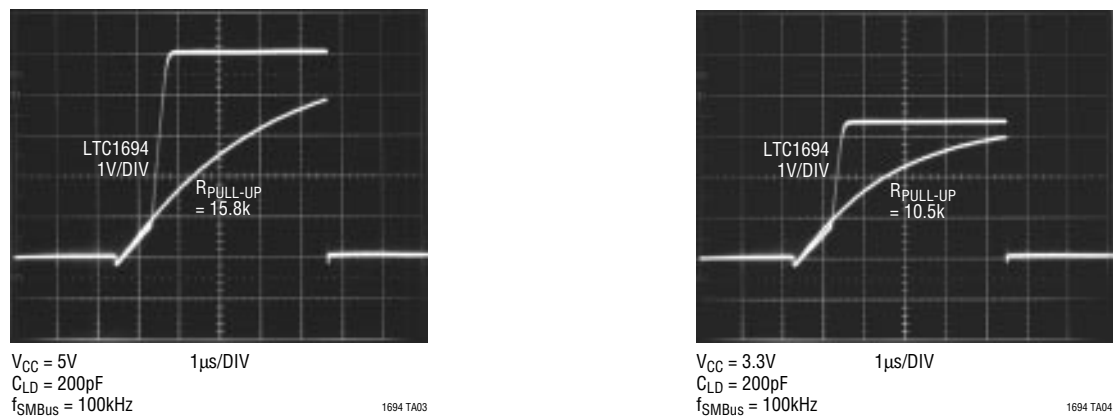


Figure 3. Maximum Value of  $R_S + R_{ON}$  as a Function of Bus Capacitance for Meeting the SMBus  $t_{f(MAX)}$  Requirement



APPLICATIONS INFORMATION

Comparison of SMBus Waveforms for the LTC1694 vs Resistor Pull-Up



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1380/LTC1393	8-Channel/4-Channel Analog Multiplexer with SMBus interface	Low $R_{ON}$ and Low Charge Injection
LTC1427	10-Bit Current DAC with SMBus Interface	50µA Full-Scale Current
LTC1623	Dual High Side Switch Controller with SMBus Interface	8 Selectable Addresses/16 Channel Capability
LT1786F	SMBus-Controlled CCFL Switching Regulator	1.25A, 200kHz, Floating or Grounded Lamp Configurations