



LTC1391

## 8-Channel Analog Multiplexer with Cascadable Serial Interface

### FEATURES

- Low  $R_{ON}$ : 45 $\Omega$
- Single 2.7V to  $\pm 5V$  Supply Operation
- Analog Inputs May Extend to Supply Rails
- Low Charge Injection
- Serial Digital Interface
- Low Leakage:  $\pm 5nA$  Max
- Guaranteed Break-Before-Make
- TTL/CMOS Compatible for All Digital Inputs
- Cascadable to Allow Additional Channels
- Can Be Used as a Demultiplexer

### APPLICATIONS

- Data Acquisition Systems
- Communication Systems
- Signal Multiplexing/Demultiplexing

### DESCRIPTION

The LTC<sup>®</sup>1391 is a high performance CMOS 8-to-1 analog multiplexer. It features a serial digital interface that allows several LTC1391s to be daisy-chained together, increasing the number of MUX channels available using a single digital port.

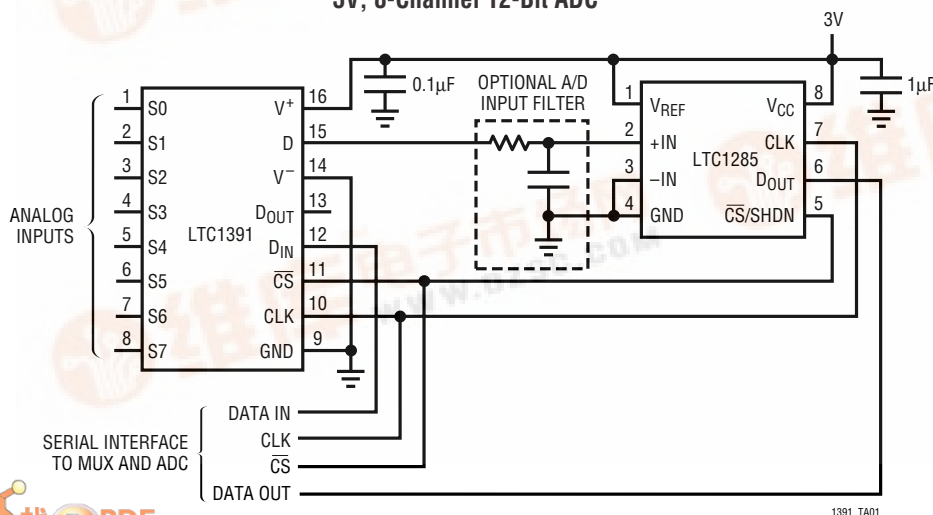
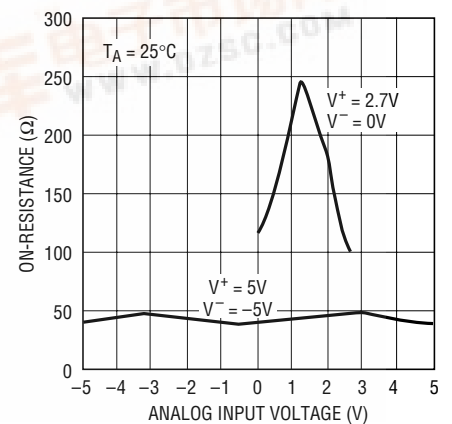
The LTC1391 features a typical  $R_{ON}$  of 45 $\Omega$ , a typical switch leakage of 50pA and guaranteed break-before-make operation. Charge injection is  $\pm 10pC$  maximum. All digital inputs are TTL and CMOS compatible when operated from single or dual supplies. The inputs can withstand 100mA fault current.

The LTC1391 is available in 16-pin PDIP, SSOP and narrow SO packages. For applications requiring 2-way serial data transmission, see the LTC1390 data sheet.

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### TYPICAL APPLICATION

3V, 8-Channel 12-Bit ADC

On-Resistance vs  
Analog Input Voltage

1391 TA02

1391 TA01

# LTC1391

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

Total Supply Voltage ( $V^+$ to $V^-$ )	15V
Input Voltage	
Analog Inputs ( $V^- - 0.3V$ ) to ( $V^+ + 0.3V$ )	
Digital Inputs $-0.3V$ to 15V	
Digital Outputs $-0.3V$ to ( $V^+ + 0.3V$ )	
Power Dissipation	500mW
Operating Temperature Range	
LTC1391C	$0^\circ\text{C}$ to $70^\circ\text{C}$
LTC1391I	$-40^\circ\text{C}$ to $85^\circ\text{C}$
Storage Temperature Range	$-65^\circ\text{C}$ to $150^\circ\text{C}$
Lead Temperature (Soldering, 10 sec)	$300^\circ\text{C}$

## PACKAGE/ORDER INFORMATION

<p>GN PACKAGE 16-LEAD PLASTIC SSOP</p> <p>N PACKAGE 16-LEAD PDIP</p> <p>S PACKAGE 16-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 125^\circ\text{C}</math>, <math>\theta_{JA} = 110^\circ\text{C/W}</math> (GN)  <math>T_{JMAX} = 125^\circ\text{C}</math>, <math>\theta_{JA} = 70^\circ\text{C/W}</math> (N)  <math>T_{JMAX} = 125^\circ\text{C}</math>, <math>\theta_{JA} = 100^\circ\text{C/W}</math> (S)</p>	ORDER PART NUMBER	
	LTC1391CGN LTC1391CN LTC1391CS LTC1391IGN LTC1391IN LTC1391IS	
	GN PART MARKING	
	1391 1391I	

Consult factory for Military grade parts.

## ELECTRICAL CHARACTERISTICS

$V^+ = 5V$ ,  $V^- = -5V$ ,  $GND = 0V$ ,  $T_A$  = operating temperature range, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Switch</b>						
$V_{ANALOG}$	Analog Signal Range	(Note 2)	●	-5	5	V
$R_{ON}$	On-Resistance	$V_S = \pm 3.5V$			75	$\Omega$
		$I_D = 1mA$			45	$\Omega$
		$T_{MIN}$			120	$\Omega$
	$\Delta R_{ON}$ vs $V_S$			20		%
	$\Delta R_{ON}$ vs Temperature			0.5		%/ $^\circ\text{C}$
$I_{S(OFF)}$	Off Input Leakage	$V_S = 4V$ , $V_D = -4V$ , $V_S = -4V$ , $V_D = 4V$ Channel Off	●	$\pm 0.05$	$\pm 5$	nA
$I_{D(OFF)}$	Off Output Leakage	$V_S = 4V$ , $V_D = -4V$ , $V_S = -4V$ , $V_D = 4V$ Channel Off	●	$\pm 0.05$	$\pm 5$	nA
$I_{D(ON)}$	On Channel Leakage	$V_S = V_D = \pm 4V$ Channel On	●	$\pm 0.05$	$\pm 5$	nA
<b>Digital</b>						
$V_{INH}$	High Level Input Voltage	$V^+ = 5.25V$	●	2.4		V
$V_{INL}$	Low Level Input Voltage	$V^+ = 4.75V$	●		0.8	V
$I_{INL}$ , $I_{INH}$	Input Current	$V_{IN} = 5V, 0V$	●		$\pm 5$	$\mu A$
$V_{OH}$	High Level Output Voltage	$V^+ = 4.75V$ , $I_O = -10\mu A$ $I_O = -360\mu A$	●	4.74		V
$V_{OL}$	Low Level Output Voltage	$V^+ = 4.75V$ , $I_O = 1.6mA$	●	2.4	4.50	V
<b>Dynamic</b>						
$f_{CLK}$	Clock Frequency	(Note 2)			5	MHz
$t_{ON}$	Enable Turn-On Time	$V_S = 2.5V$ , $R_L = 1k$ , $C_L = 35pF$		260	400	ns
$t_{OFF}$	Enable Turn-Off Time	$V_S = 2.5V$ , $R_L = 1k$ , $C_L = 35pF$		100	200	ns
$t_{OPEN}$	Break-Before-Make Interval			35	155	ns
OIRR	Off Isolation	$V_S = 2V_{P-P}$ , $R_L = 1k$ , $f = 100kHz$		70		dB
$Q_{INJ}$	Charge Injection	$R_S = 0$ , $C_L = 1000pF$ , $V_S = 1V$ (Note 2)		$\pm 2$	$\pm 10$	pC

## ELECTRICAL CHARACTERISTICS

$V^+ = 5V$ ,  $V^- = -5V$ ,  $GND = 0V$ ,  $T_A$  = operating temperature range, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Dynamic</b>						
$C_{S(OFF)}$	Input Off Capacitance			5		pF
$C_{D(OFF)}$	Output Off Capacitance			10		pF
<b>Supply</b>						
$I^+$	Positive Supply Current	All Logic Inputs Tied Together, $V_{IN} = 0V$ or $5V$	●	15	40	$\mu A$
$I^-$	Negative Supply Current	All Logic Inputs Tied Together, $V_{IN} = 0V$ or $5V$	●	-15	-40	$\mu A$

$V^+ = 2.7V$ ,  $V^- = GND = 0V$ ,  $T_A$  = operating temperature range, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Switch</b>						
$V_{ANALOG}$	Analog Signal Range	(Note 2)	●	0	2.7	V
$R_{ON}$	On-Resistance	$V_S = 1.2V$ $I_O = 1mA$ $T_{MIN}$			300	$\Omega$
		$25^\circ C$		250	300	$\Omega$
		$T_{MAX}$			350	$\Omega$
	$\Delta R_{ON}$ vs $V_S$			20		%
	$\Delta R_{ON}$ vs Temperature			0.5		%/ $^\circ C$
$I_{S(OFF)}$	Off Input Leakage	$V_S = 2.5V$ , $V_D = 0.5V$ ; $V_S = 0.5V$ , $V_D = 2.5V$ (Note 3) Channel Off	●	$\pm 0.05$	$\pm 5$ $\pm 20$	nA nA
$I_{D(OFF)}$	Off Output Leakage	$V_S = 2.5V$ , $V_D = 0.5V$ ; $V_S = 0.5V$ , $V_D = 2.5V$ (Note 3) Channel Off	●	$\pm 0.05$	$\pm 5$ $\pm 20$	nA nA
$I_{D(ON)}$	On Channel Leakage	$V_S = V_D = 0.5V$ , $2.5V$ (Note 3) Channel On	●	$\pm 0.05$	$\pm 5$ $\pm 20$	nA nA
<b>Digital</b>						
$V_{INH}$	High Level Input Voltage	$V^+ = 3.0V$	●	2.0		V
$V_{INL}$	Low Level Input Voltage	$V^+ = 2.4V$	●		0.8	V
$I_{INL}$ , $I_{INH}$	Input Current	$V_{IN} = 2.7V$ , $0V$	●		$\pm 5$	$\mu A$
$V_{OH}$	High Level Output Voltage	$V^+ = 2.7V$ , $I_O = -20\mu A$ $I_O = -400\mu A$	●	2.68 2.30		V V
$V_{OL}$	Low Level Output Voltage	$V^+ = 2.7V$ , $I_O = 20\mu A$ $I_O = 400\mu A$	●	0.01 0.20	0.8	V V

<b>Dynamic</b>						
$f_{CLK}$	Clock Frequency	(Note 2)			5	MHz
$t_{ON}$	Enable Turn-On Time	$V_S = 1.5V$ , $R_L = 1k$ , $C_L = 35pF$ (Note 4)		490	800	ns
$t_{OFF}$	Enable Turn-Off Time	$V_S = 1.5V$ , $R_L = 1k$ , $C_L = 35pF$ (Note 4)		190	400	ns
$t_{OPEN}$	Break-Before-Make Interval	(Note 4)	125	290		ns
$Q_{IRR}$	Off Isolation	$V_S = 2V_{P-P}$ , $R_L = 1k$ , $f = 100kHz$		70		dB
$Q_{INJ}$	Charge Injection	$R_S = 0$ , $C_L = 1000pF$ , $V_S = 1V$ (Note 2)		$\pm 1$	$\pm 5$	pC
$C_{S(OFF)}$	Input Off Capacitance			5		pF
$C_{D(OFF)}$	Output Off Capacitance			10		pF
<b>Supply</b>						
$I^+$	Positive Supply Current	All Logic Inputs Tied Together, $V_{IN} = 0V$ or $2.7V$	●	0.2	2	$\mu A$

The ● denotes specifications which 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.

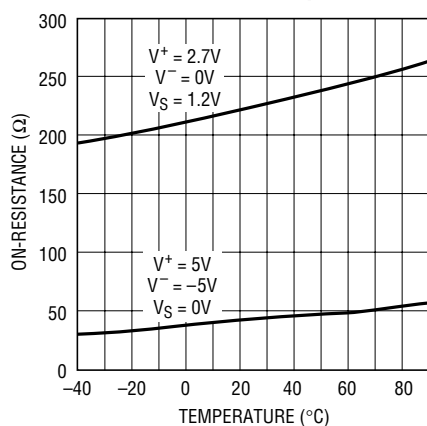
**Note 2:** Guaranteed by Design.

**Note 3:** Leakage current with a single 2.7V supply is guaranteed by correlation with the  $\pm 5V$  leakage current specifications.

**Note 4:** Timing specifications with a single 2.7V supply are guaranteed by correlation with the  $\pm 5V$  timing specifications.

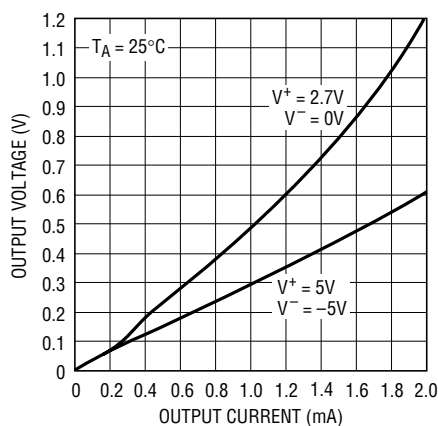
## TYPICAL PERFORMANCE CHARACTERISTICS

On-Resistance vs Temperature



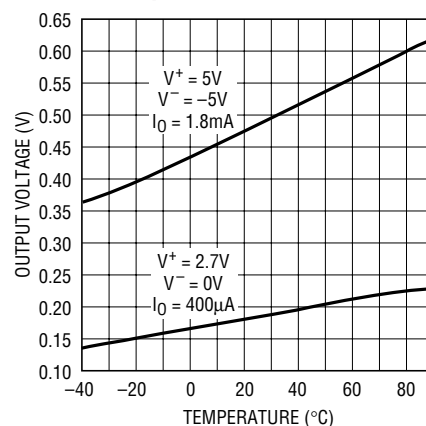
1391 G01

Driver Output Low Voltage vs Output Current



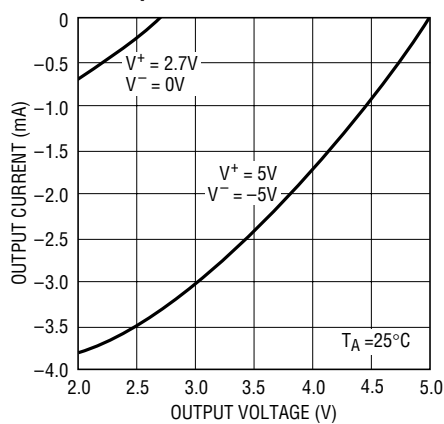
1391 G02

Driver Output Low Voltage vs Temperature



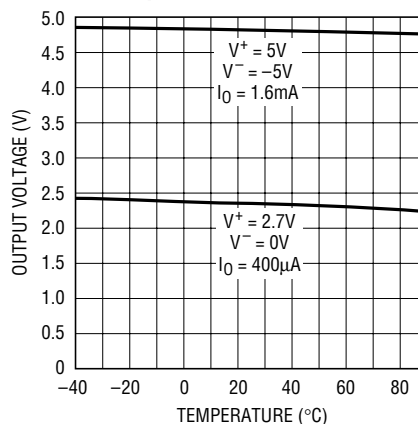
1391 G03

Driver Output High Voltage vs Output Current



1391 G04

Driver Output High Voltage vs Temperature



1391 G05

## PIN FUNCTIONS

**S0, S1, S2, S3, S4, S5, S6, S7 (Pins 1, 2, 3, 4, 5, 6, 7, 8):** Analog Multiplexer Inputs.

**GND (Pin 9):** Digital Ground. Connect to system ground.

**CLK (Pin 10):** System Clock (TTL/CMOS Compatible). The clock synchronizes the channel selection bits and the serial data transfer from  $D_{IN}$  to  $D_{OUT}$ .

**$\overline{CS}$  (Pin 11):** Channel Select Input (TTL/CMOS Compatible). A logic high on this input enables the LTC1391 to read in the channel selection bits and allows digital data transfer from  $D_{IN}$  to  $D_{OUT}$ . A logic low on this input puts

$D_{OUT}$  into three-state and enables the selected channel for analog signal transmission.

**$D_{IN}$  (Pin 12):** Digital Input (TTL/CMOS Compatible). Input for the channel selection bits.

**$D_{OUT}$  (Pin 13):** Digital Output (TTL/CMOS Compatible). Output from the internal shift register.

**$V^-$  (Pin 14):** Negative Supply.

**D (Pin 15):** Analog Multiplexer Output.

**$V^+$  (Pin 16):** Positive Supply.

## APPLICATIONS INFORMATION

### Multiplexer Operation

Figure 1 shows the block diagram of the components within the LTC1391 required for MUX operation. The LTC1391 uses  $D_{IN}$  to select the active channel and the chip select input,  $\overline{CS}$ , to switch on the selected channel as shown in Figure 2.

When  $\overline{CS}$  is high, the input data on the  $D_{IN}$  pin is latched into the 4-bit shift register on the rising clock edge. The input data consists of the “EN” bit and a string of three bits for channel selection. If “EN” bit is logic high as illustrated in the first input data sequence, it enables the selected channel. After the clocking in of the last channel selection bit B0, the  $\overline{CS}$  pin must be pulled low before the next rising clock edge to ensure correct operation. Once  $\overline{CS}$  is pulled low, the previously selected channel is switched off to ensure a break-before-make interval. After a delay of  $t_{ON}$ , the selected channel is switched on allowing signal transmission. The selected channel remains on until the next falling edge of  $\overline{CS}$ . After a delay of  $t_{OFF}$ , the LTC1391 terminates the analog signal transmission and allows the

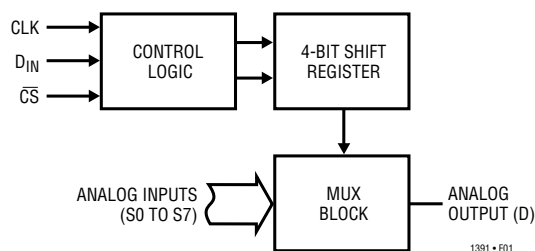


Figure 1. Simplified Block Diagram of the MUX Operation

selection of next channel. If the “EN” bit is logic low, as illustrated in the second data sequence, it disables all channels and there will be no analog signal transmission. Table 1 shows the various bit combinations for channel selection.

Table 1. Logic Table for Channel Selection

ACTIVE CHANNEL	EN	B2	B1	B0
All Off	0	X	X	X
S0	1	0	0	0
S1	1	0	0	1
S2	1	0	1	0
S3	1	0	1	1
S4	1	1	0	0
S5	1	1	0	1
S6	1	1	1	0
S7	1	1	1	1

### Digital Data Transfer Operation

The block diagram of Figure 3 shows the components within the LTC1391 required for serial data transfer. When  $\overline{CS}$  is held high, data is fed into the 4-bit shift register and then shifted to  $D_{OUT}$ . Data appears at  $D_{OUT}$  after the fourth rising edge of the clock as shown in Figure 4. The last four

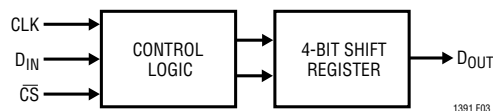


Figure 3. Simplified Block Diagram of the Digital Data Transfer Operation

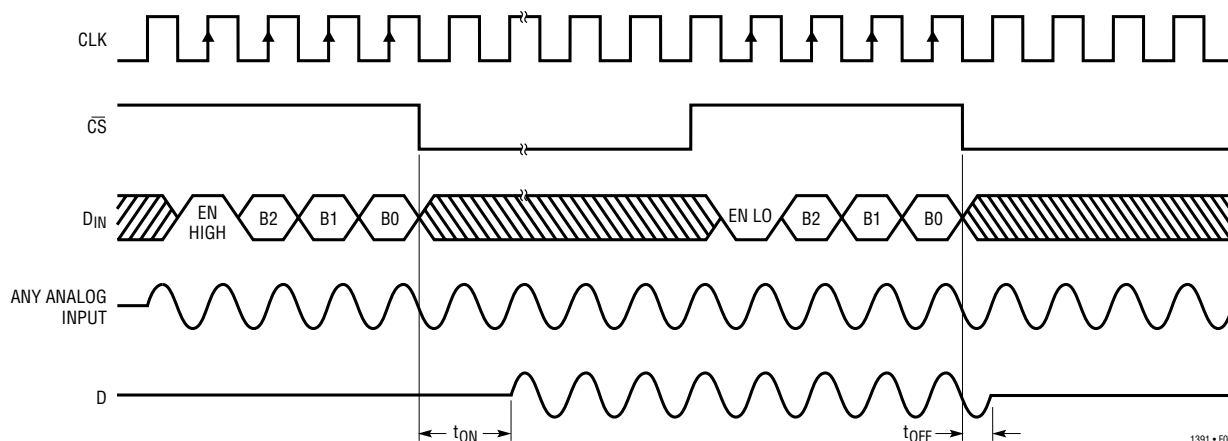


Figure 2. Multiplexer Operation

## APPLICATIONS INFORMATION

bits clocked into the LTC1391 shift register before  $\overline{\text{CS}}$  is taken low select the MUX channel that is turned on. This allows a series of devices, with the  $\text{D}_{\text{OUT}}$  of one device connected to the  $\text{D}_{\text{IN}}$  of the next device, to be programmed with a single data stream.

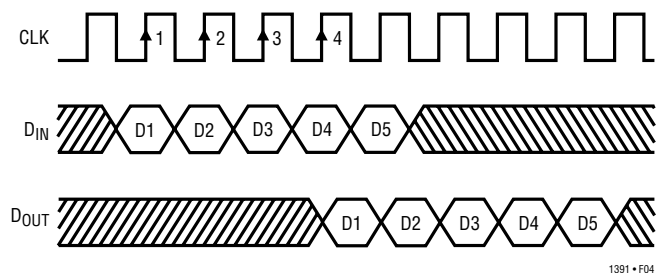


Figure 4. Digital Data Transfer Operation

### Multiplexer Expansion

Several LTC1391s can be daisy-chained to expand the number of multiplexer inputs. No additional interface ports are required for the expansion. Figure 5 shows two LTC1391s connected at their analog outputs to form a 16-to-1 multiplexer at the input to an LTC1400 A/D converter.

To ensure that only one channel is switched on at any one time, two sets of channel selection bits are needed for DATA as shown in Figure 6. The first data sequence is used to switch off one MUX and the second data sequence is used to select one channel from the other MUX or vice versa. In other words, if bit "ENA" is high and bit "ENB" is low, one channel of MUX A is switched on and all channels of MUX B are switched off. If bit "ENA" is low and bit "ENB" is high, all channels at MUX A are switched off and one channel of MUX B is switched on. Care should be taken to ensure that only one LTC1391 is enabled at any one time to prevent two channels from being enabled simultaneously.

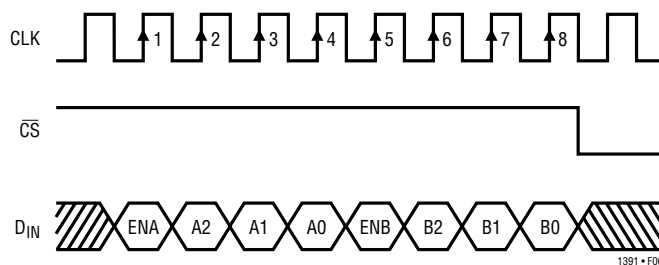


Figure 6. Data Sequence for MUX Expansion

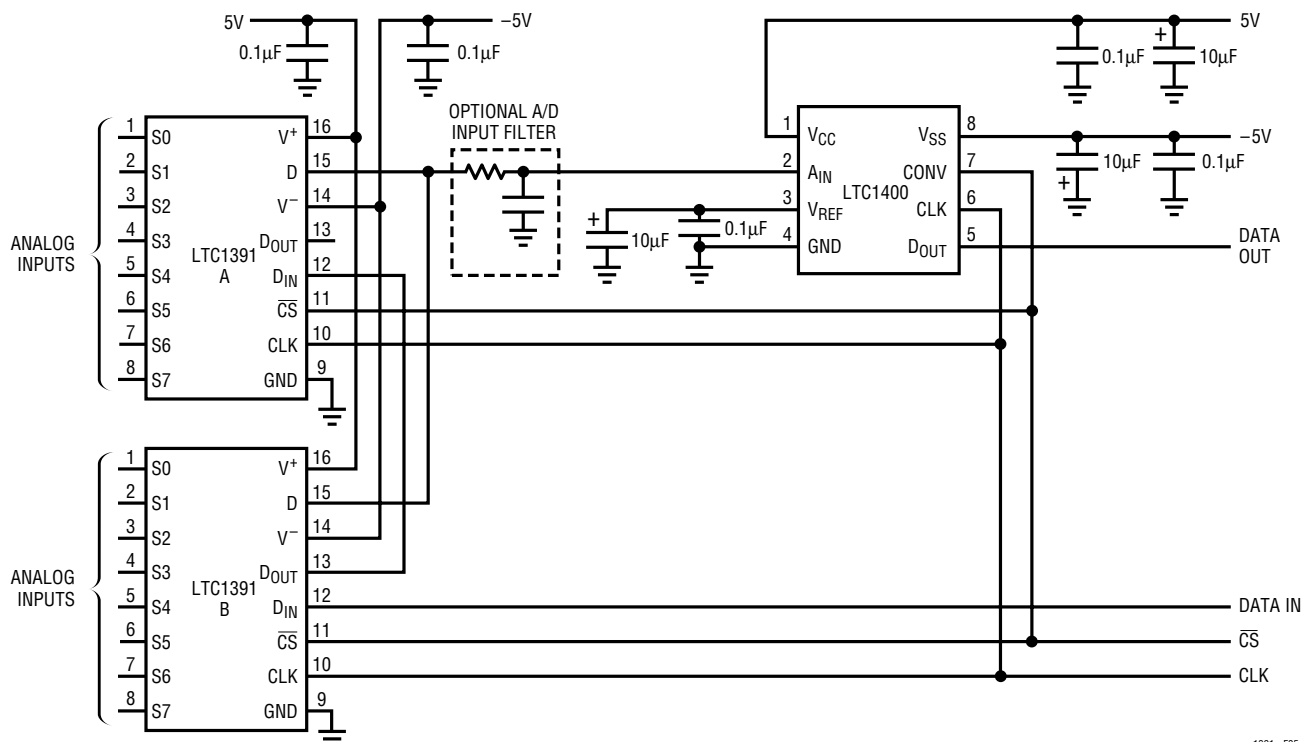
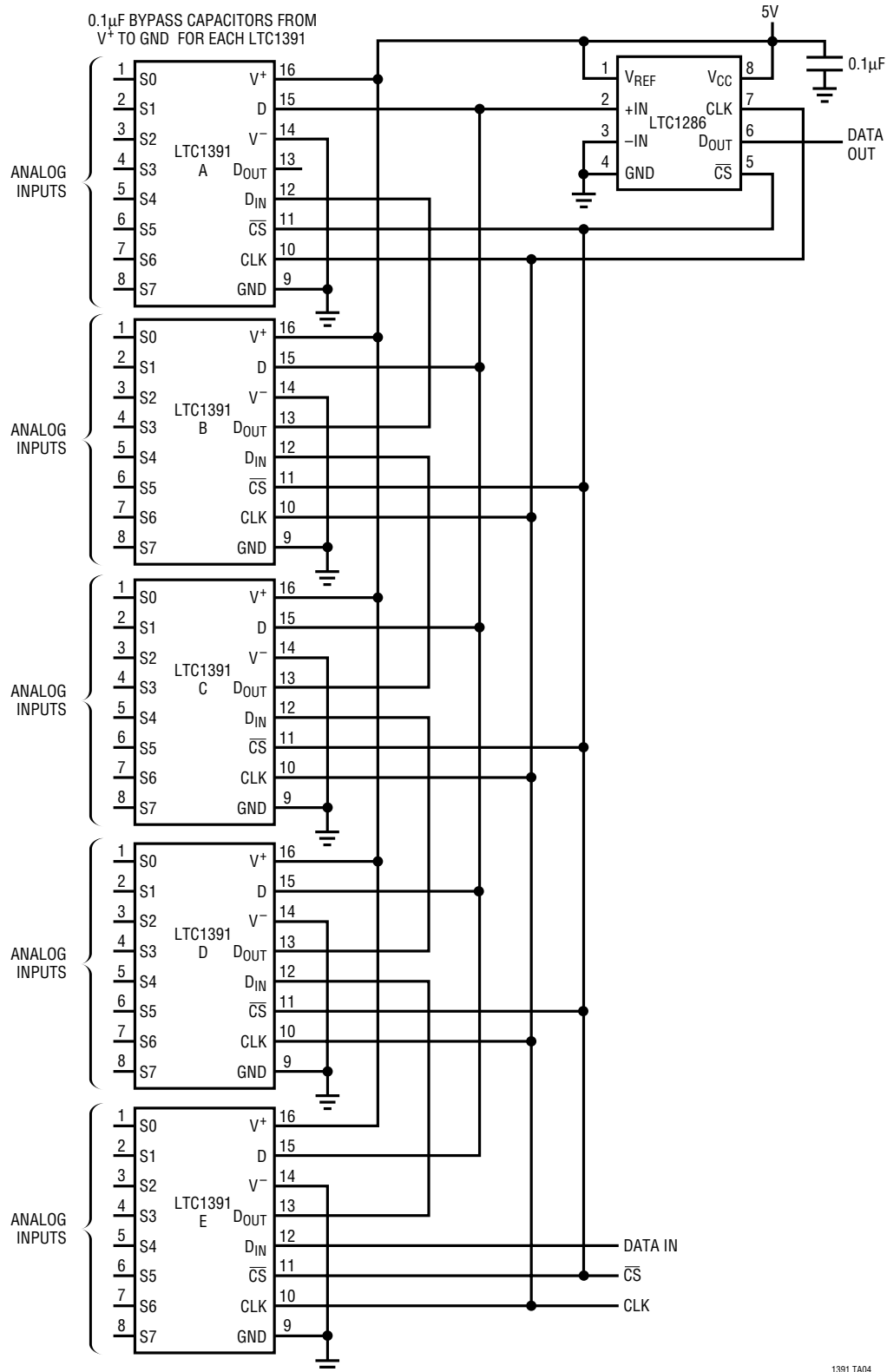


Figure 5. Daisy-Chaining Two LTC1391s for Expansion

## TYPICAL APPLICATIONS

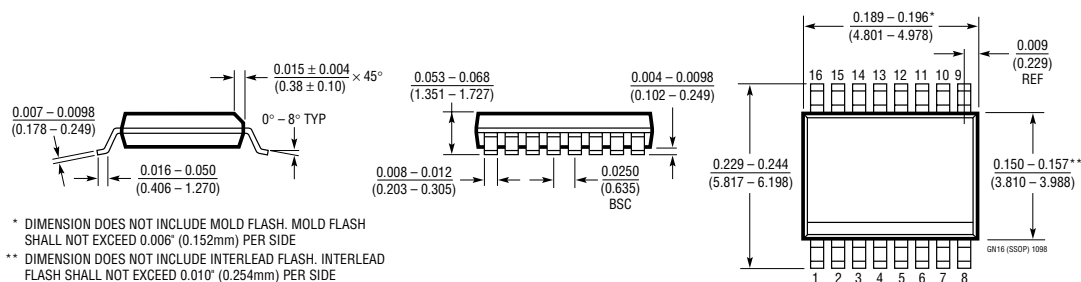
Daisy-Chaining Five LTC1391s



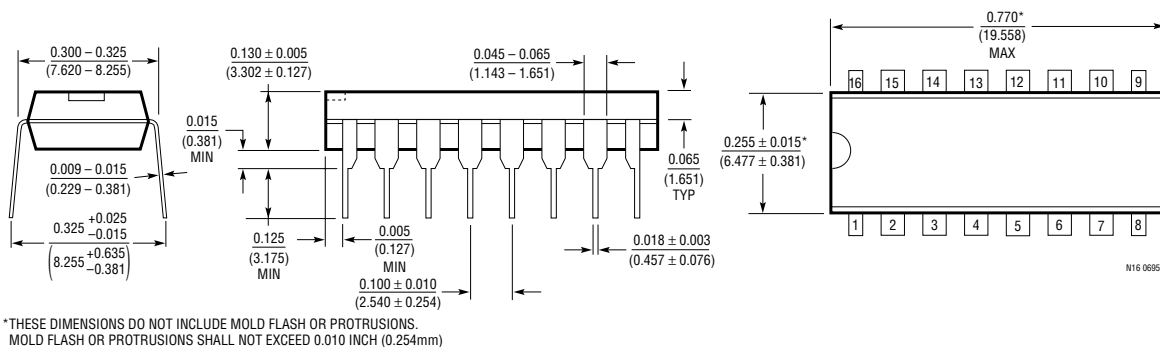
# LTC1391

## PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

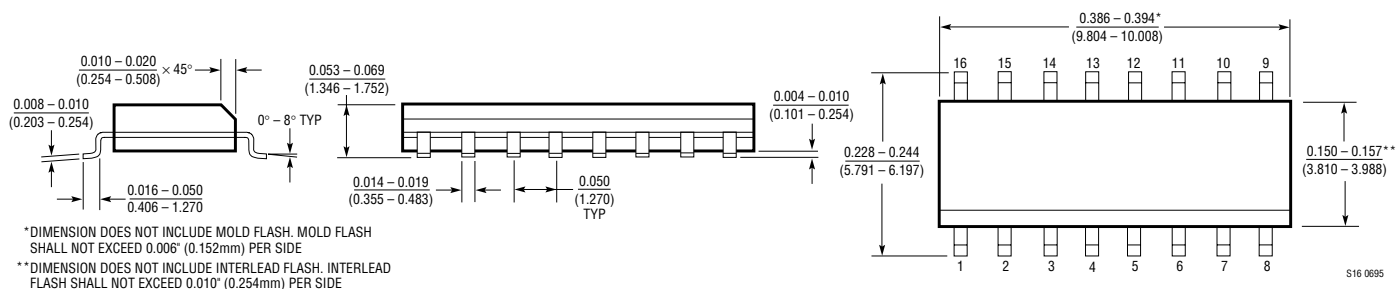
### GN Package 16-Lead Plastic SSOP (Narrow 0.150) (LTC DWG # 05-08-1641)



### N Package 16-Lead PDIP (Narrow 0.300) (LTC DWG # 05-08-1510)



### S Package 16-Lead Plastic Small Outline (Narrow 0.150) (LTC DWG # 05-08-1610)





## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1285	3V 12-Bit ADC	Micropower, Auto Shutdown, SO-8 Package, SPI, QSPI + MICROWIRE™ Compatible
LTC1286	5V 12-Bit ADC	Micropower, Auto Shutdown, SO-8 Package, SPI, QSPI + MICROWIRE Compatible
LTC1390	Serial-Controlled 8-to-1 Analog Multiplexer	Low R <sub>ON</sub> , Bidirectional Serial Interface, Low Power, 16-Pin SO
LTC1451	5V 12-Bit DAC	Complete V <sub>OUT</sub> DAC, SO-8 Package, Daisy-Chainable, Low Power
LTC1452	5V and 3V 12-Bit DAC	Multiplying V <sub>OUT</sub> DAC, SO-8 Package, Rail-to-Rail Output, Low Power
LTC1453	3V 12-Bit DAC	Complete V <sub>OUT</sub> DAC, SO-8 Package, Daisy-Chainable, Low Power

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