



# Cold-Junction-Compensated K-Thermocouple-to-Digital Converter (0°C to +1024°C)

**MAX6675**

## General Description

The MAX6675 performs cold-junction compensation and digitizes the signal from a type-K thermocouple. The data is output in a 12-bit resolution, SPI™-compatible, read-only format.

This converter resolves temperatures to 0.25°C, allows readings as high as +1024°C, and exhibits thermocouple accuracy of 8LSBs for temperatures ranging from 0°C to +700°C.

The MAX6675 is available in a small, 8-pin SO package.

## Features

- ◆ Direct Digital Conversion of Type -K Thermocouple Output
- ◆ Cold-Junction Compensation
- ◆ Simple SPI-Compatible Serial Interface
- ◆ 12-Bit, 0.25°C Resolution
- ◆ Open Thermocouple Detection

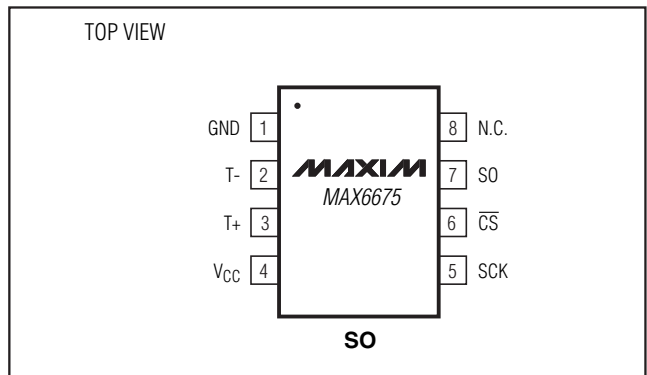
## Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX6675ISA	-20°C to +85°C	8 SO

## Applications

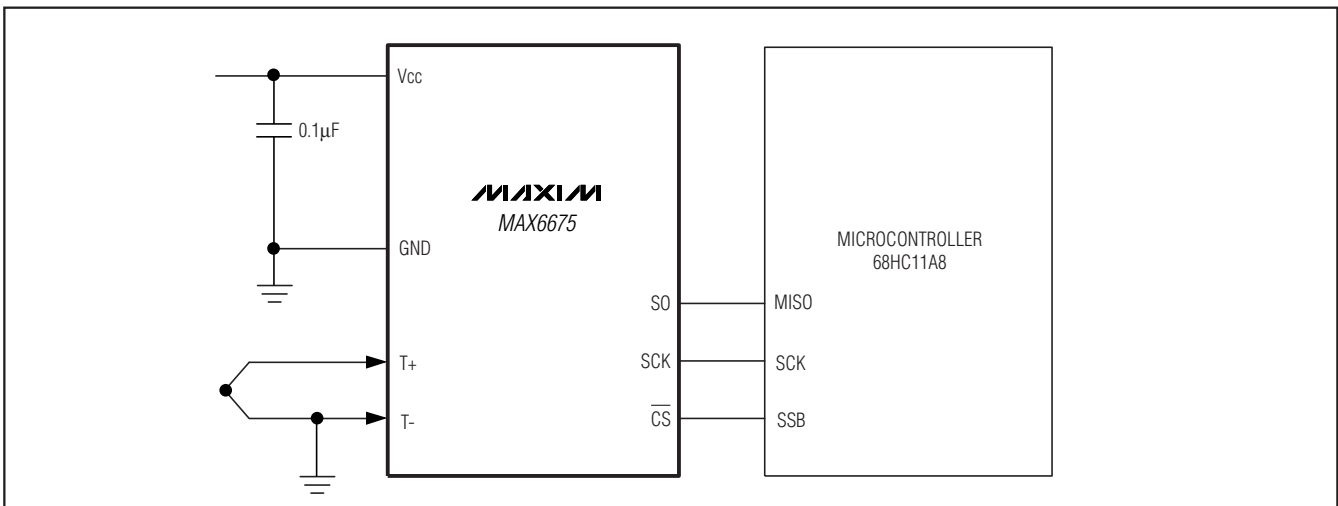
Industrial Appliances  
 HVAC  
 Automotive

## Pin Configuration



SPI is a trademark of Motorola, Inc.

## Typical Application Circuit



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## ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V<sub>CC</sub> to GND) ..... -0.3V to +6V  
 SO, SCK, CS, T-, T+ to GND ..... -0.3V to V<sub>CC</sub> + 0.3V  
 SO Current ..... 50mA  
 ESD Protection (Human Body Model) ..... ±2000V  
 Continuous Power Dissipation (T<sub>A</sub> = +70°C)  
 8-Pin SO (derate 5.88mW/°C above +70°C) ..... 471mW  
 Operating Temperature Range ..... -20°C to +85°C

Storage Temperature Range ..... -65°C to +150°C  
 Junction Temperature ..... +150°C  
 SO Package  
 Vapor Phase (60s) ..... +215°C  
 Infrared (15s) ..... +220°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<sub>CC</sub> = +3.0V to +5.5V, T<sub>A</sub> = -20°C to +85°C, unless otherwise noted. Typical values specified at +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Temperature Error		T <sub>THERMOCOUPLE</sub> = +700°C, T <sub>A</sub> = +25°C (Note 2)	V <sub>CC</sub> = +3.3V	-5		+5	LSB
			V <sub>CC</sub> = +5V	-6		+6	
		T <sub>THERMOCOUPLE</sub> = 0°C to +700°C, T <sub>A</sub> = +25°C (Note 2)	V <sub>CC</sub> = +3.3V	-8		+8	
			V <sub>CC</sub> = +5V	-9		+9	
		T <sub>THERMOCOUPLE</sub> = +700°C to +1000°C, T <sub>A</sub> = +25°C (Note 2)	V <sub>CC</sub> = +3.3V	-17		+17	
			V <sub>CC</sub> = +5V	-19		+19	
Thermocouple Conversion Constant					10.25		μV/LSB
Cold-Junction Compensation Error		T <sub>A</sub> = -20°C to +85°C (Note 2)	V <sub>CC</sub> = +3.3V	-3.0		+3.0	°C
			V <sub>CC</sub> = +5V	-3.0		+3.0	
Resolution					0.25		°C
Thermocouple Input Impedance					60		kΩ
Supply Voltage	V <sub>CC</sub>			3.0		5.5	V
Supply Current	I <sub>CC</sub>				0.7	1.5	mA
Power-On Reset Threshold		V <sub>CC</sub> rising		1	2	2.5	V
Power-On Reset Hysteresis					50		mV
Conversion Time		(Note 2)			0.17	0.22	s
<b>SERIAL INTERFACE</b>							
Input Low Voltage	V <sub>IL</sub>					0.3 x V <sub>CC</sub>	V
Input High Voltage	V <sub>IH</sub>			0.7 x V <sub>CC</sub>			V
Input Leakage Current	I <sub>LEAK</sub>	V <sub>IN</sub> = GND or V <sub>CC</sub>				±5	μA
Input Capacitance	C <sub>IN</sub>				5		pF

# Cold-Junction-Compensated K-Thermocouple-to-Digital Converter (0°C to +1024°C)

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +3.0V$  to  $+5.5V$ ,  $T_A = -20^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values specified at  $+25^\circ C$ .) (Note 1)

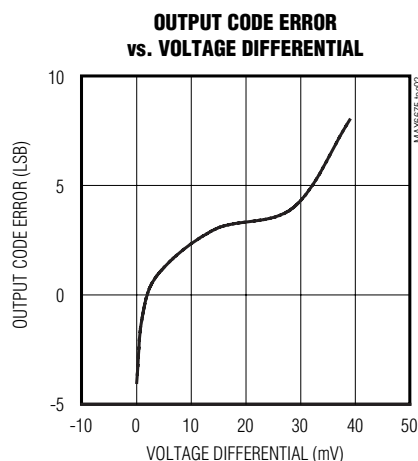
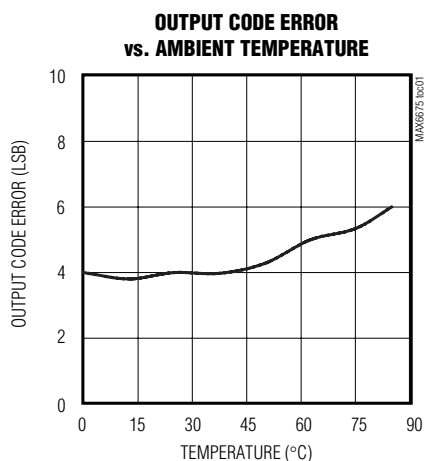
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output High Voltage	$V_{OH}$	$I_{SOURCE} = 1.6mA$	$V_{CC} - 0.4$			V
Output Low Voltage	$V_{OL}$	$I_{SINK} = 1.6mA$			0.4	V
<b>TIMING</b>						
Serial Clock Frequency	$f_{SCL}$				4.3	MHz
SCK Pulse High Width	$t_{CH}$		100			ns
SCK Pulse Low Width	$t_{CL}$		100			ns
CSB Fall to SCK Rise	$t_{CSS}$	$C_L = 10pF$	100			ns
CSB Fall to Output Enable	$t_{DV}$	$C_L = 10pF$			100	ns
CSB Rise to Output Disable	$t_{TR}$	$C_L = 10pF$			100	ns
SCK Fall to Output Data Valid	$t_{DO}$	$C_L = 10pF$			100	ns

**Note 1:** All specifications are 100% tested at  $T_A = +25^\circ C$ . Specification limits over temperature ( $T_A = T_{MIN}$  to  $T_{MAX}$ ) are guaranteed by design and characterization, not production tested.

**Note 2:** Guaranteed by design. Not production tested.

## Typical Operating Characteristics

( $V_{CC} = +3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# Cold-Junction-Compensated K-Thermocouple-to-Digital Converter (0°C to +1024°C)

## Pin Description

PIN	NAME	FUNCTION
1	GND	Ground
2	T-	Alumel Lead of Type-K Thermocouple. Should be connected to ground externally.
3	T+	Chromel Lead of Type-K Thermocouple
4	V <sub>CC</sub>	Positive Supply. Bypass with a 0.1μF capacitor to GND.
5	SCK	Serial Clock Input
6	$\overline{\text{CS}}$	Chip Select. Set $\overline{\text{CS}}$ low to enable the serial interface.
7	SO	Serial Data Output
8	N.C.	No Connection

## Detailed Description

The MAX6675 is a sophisticated thermocouple-to-digital converter with a built-in 12-bit analog-to-digital converter (ADC). The MAX6675 also contains cold-junction compensation sensing and correction, a digital controller, an SPI-compatible interface, and associated control logic.

The MAX6675 is designed to work in conjunction with an external microcontroller (μC) or other intelligence in thermostatic, process-control, or monitoring applications.

### Temperature Conversion

The MAX6675 includes signal-conditioning hardware to convert the thermocouple's signal into a voltage compatible with the input channels of the ADC. The T+ and T- inputs connect to internal circuitry that reduces the introduction of noise errors from the thermocouple wires.

Before converting the thermoelectric voltages into equivalent temperature values, it is necessary to compensate for the difference between the thermocouple cold-junction side (MAX6675 ambient temperature) and a 0°C virtual reference. For a type-K thermocouple, the voltage changes by 41μV/°C, which approximates the thermocouple characteristic with the following linear equation:

$$V_{\text{OUT}} = (41\mu\text{V} / ^\circ\text{C}) \times (T_{\text{R}} - T_{\text{AMB}})$$

Where:

V<sub>OUT</sub> is the thermocouple output voltage (μV).

T<sub>R</sub> is the temperature of the remote thermocouple junction (°C).

T<sub>AMB</sub> is the ambient temperature (°C).

### Cold-Junction Compensation

The function of the thermocouple is to sense a difference in temperature between two ends of the thermocouple wires. The thermocouple's hot junction can be read from 0°C to +1023.75°C. The cold end (ambient temperature of the board on which the MAX6675 is mounted) can only range from -20°C to +85°C. While the temperature at the cold end fluctuates, the MAX6675 continues to accurately sense the temperature difference at the opposite end.

The MAX6675 senses and corrects for the changes in the ambient temperature with cold-junction compensation. The device converts the ambient temperature reading into a voltage using a temperature-sensing diode. To make the actual thermocouple temperature measurement, the MAX6675 measures the voltage from the thermocouple's output and from the sensing diode. The device's internal circuitry passes the diode's voltage (sensing ambient temperature) and thermocouple voltage (sensing remote temperature minus ambient temperature) to the conversion function stored in the ADC to calculate the thermocouple's hot-junction temperature.

Optimal performance from the MAX6675 is achieved when the thermocouple cold junction and the MAX6675 are at the same temperature. Avoid placing heat-generating devices or components near the MAX6675 because this may produce cold-junction-related errors.

### Digitization

The ADC adds the cold-junction diode measurement with the amplified thermocouple voltage and reads out the 12-bit result onto the SO pin. A sequence of all zeros means the thermocouple reading is 0°C. A sequence of all ones means the thermocouple reading is +1023.75°C.

Типичная схема применения показывает MAX6675, сопряженный с микроконтроллером. В этом примере MAX6675 обрабатывает показания термопары и передает данные через последовательный интерфейс. Выключите CS и подайте тактовый сигнал в SCK, чтобы прочесть результаты в SO. Принудительное низкое значение CS немедленно останавливает любой процесс преобразования. Иницируйте новый процесс преобразования, форсируя высокий уровень CS. Принудительно низкое значение CS для вывода первого бита на вывод SO. Полное считывание последовательного интерфейса требует 16 тактов. Прочитайте 16 выходных битов на заднем фронте часов. Первый бит, D15, является фиктивным знаковым битом и всегда равен нулю. Биты D14 – D3 содержат преобразованную температуру в порядке от MSB до LSB. Бит D2 обычно имеет низкий уровень и повышается, когда вход термопары открыт. Значение D1 является низким для предоставления идентификатора устройства для MAX6675, а бит D0 имеет три состояния. Рисунок 1а - это протокол последовательного интерфейса, а рисунок 1b показывает синхронизацию последовательного интерфейса. Рисунок 2 - результат SO.

Бит D2 обычно низкий и становится высоким, если вход термопары открыт. Чтобы разрешить работу открытого датчика термопары, T- должен быть заземлен. Подключите заземление как можно ближе к выводу GND.

Точность MAX6675 чувствительна к шуму, связанному с питанием. Влияние шума источника питания можно минимизировать, поместив керамический перепускной конденсатор емкостью

#### **Thermal Considerations**

Self-heating degrades the temperature measurement accuracy of the MAX6675 in some applications. The magnitude of the temperature errors depends on the thermal conductivity of the MAX6675 package, the

## **Isolated K-Thermocouple-Converter (0°C to +1024°C)**

mounting technique, and the effects of airflow. Use a large ground plane to improve the temperature measurement accuracy of the MAX6675.

The accuracy of a thermocouple system can also be improved by following these precautions:

- Use the largest wire possible that does not shunt heat away from the measurement area.
- If small wire is required, use it only in the region of the measurement and use extension wire for the region with no temperature gradient.
- Avoid mechanical stress and vibration, which could strain the wires.
- When using long thermocouple wires, use a twisted-pair extension wire.
- Avoid steep temperature gradients.
- Try to use the thermocouple wire well within its temperature rating.
- Use the proper sheathing material in hostile environments to protect the thermocouple wire.
- Use extension wire only at low temperatures and only in regions of small gradients.
- Keep an event log and a continuous record of thermocouple resistance.

#### **Reducing Effects of Pick-Up Noise**

The input amplifier (A1) is a low-noise amplifier designed to enable high-precision input sensing. Keep the thermocouple and connecting wires away from electrical noise sources.

#### **Chip Information**

TRANSISTOR COUNT: 6720

PROCESS: BiCMOS

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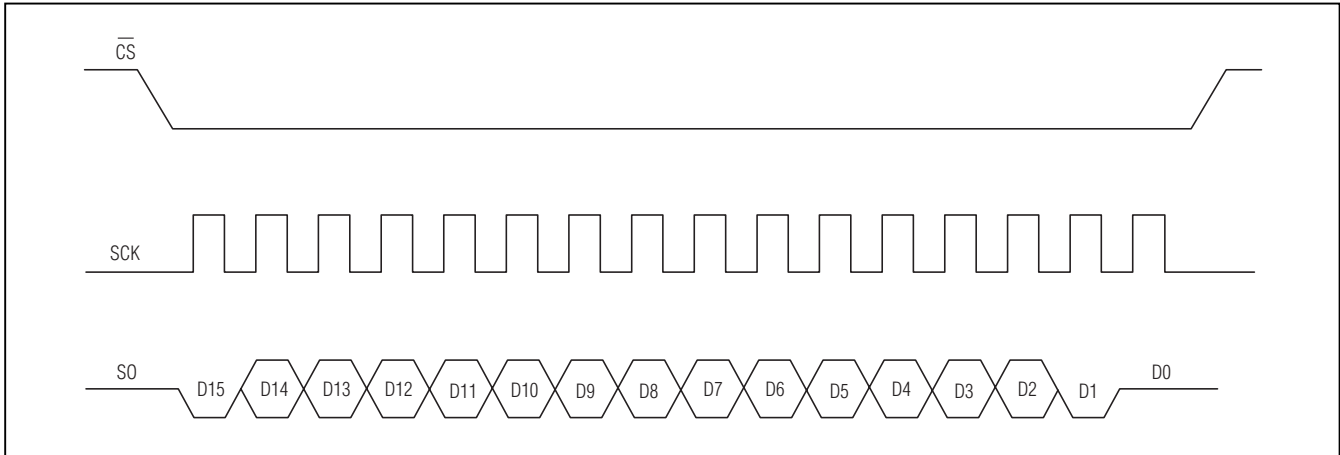


Figure 1a. Serial Interface Protocol

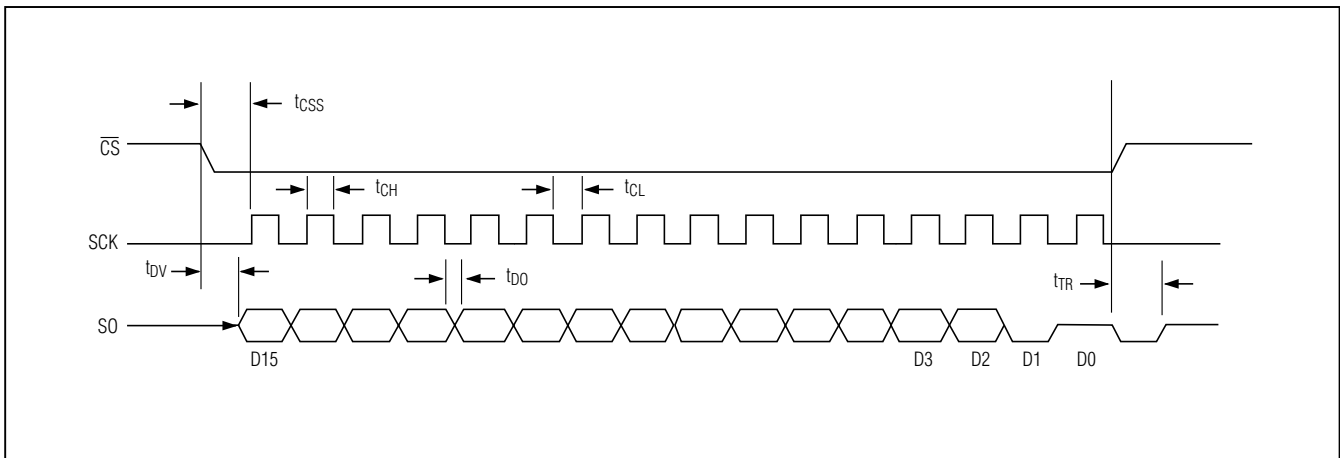


Figure 1b. Serial Interface Timing

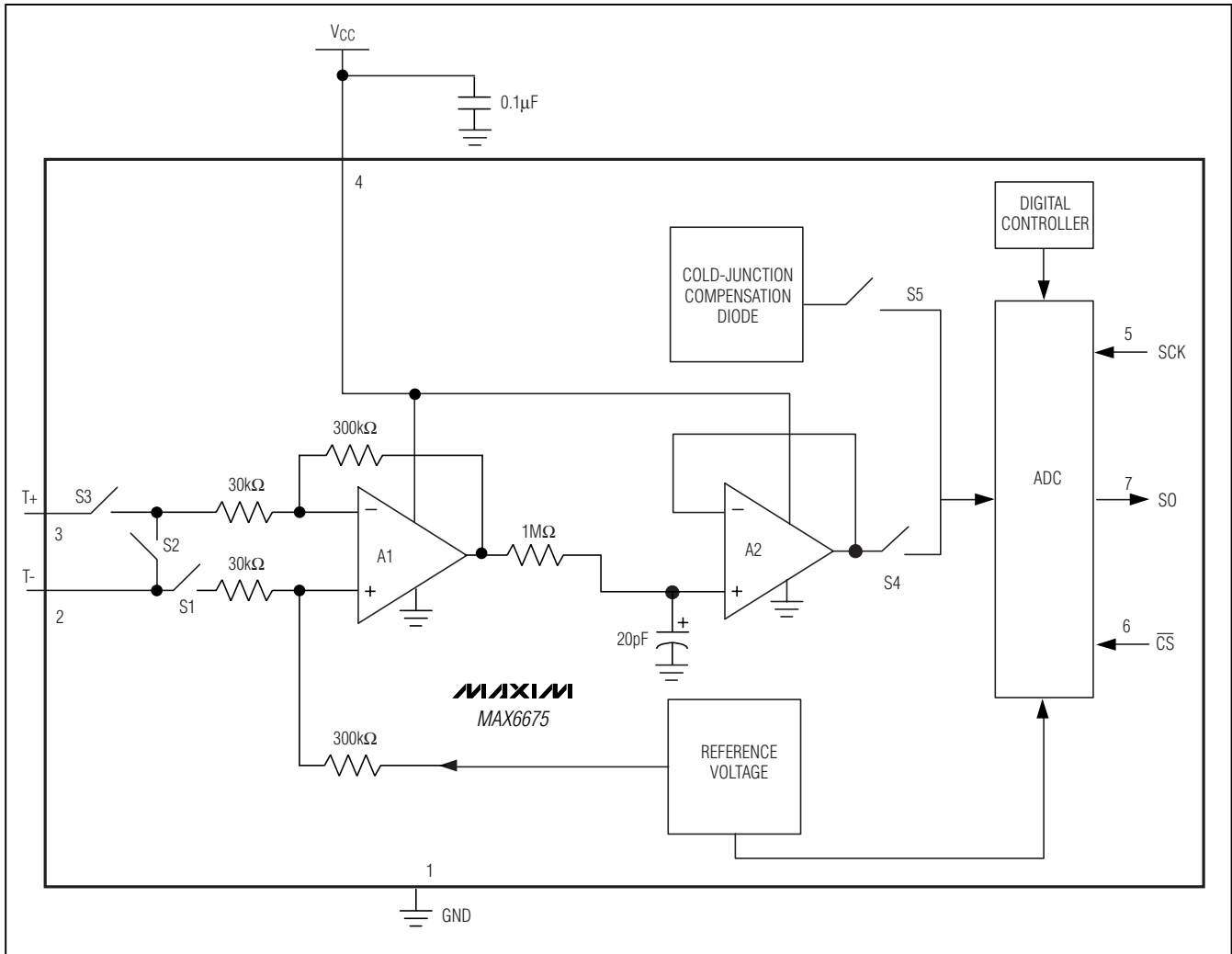
BIT	DUMMY SIGN BIT	12-BIT TEMPERATURE READING											THERMOCOUPLE INPUT	DEVICE ID	STATE	
		14	13	12	11	10	9	8	7	6	5	4				3
Bit	15													2	1	0
	0	MSB											LSB		0	Three-state

Figure 2. SO Output

# Cold-Junction-Compensated K-Thermocouple-to-Digital Converter (0°C to +1024°C)

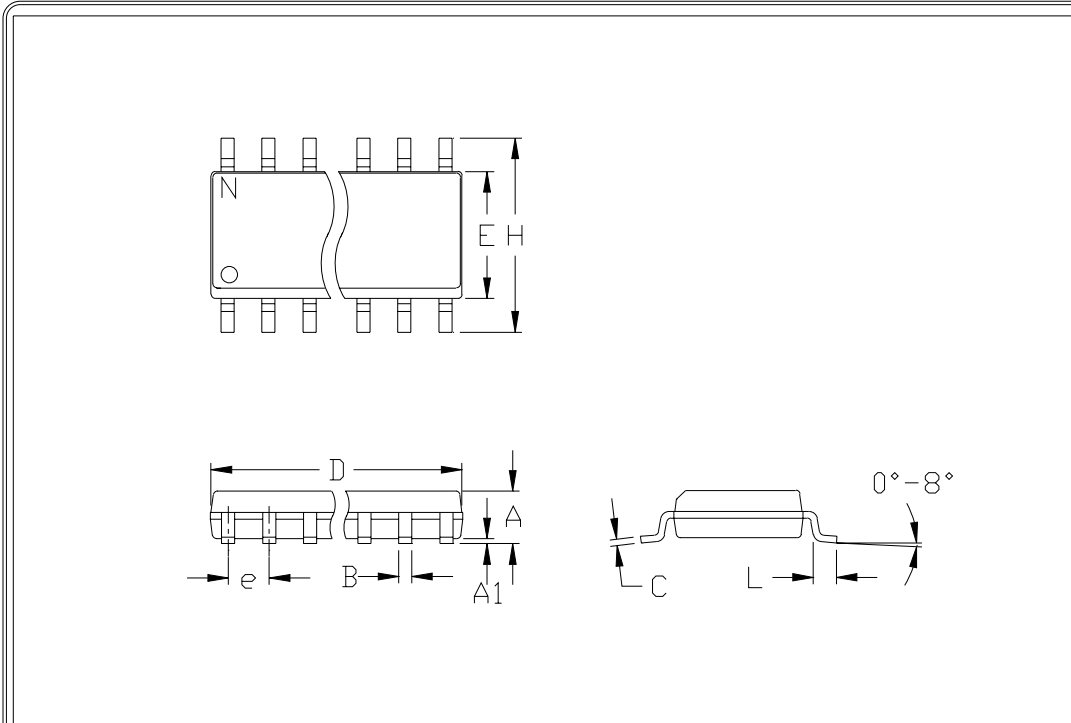
Block Diagram

MAX6675



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## Package Information



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
B	0.014	0.019	0.35	0.49
C	0.007	0.010	0.19	0.25
e	0.050		1.27	
E	0.150	0.157	3.80	4.00
H	0.228	0.244	5.80	6.20
h	0.010	0.020	0.25	0.50
L	0.016	0.050	0.40	1.27

	INCHES		MILLIMETERS		N	MS012
	MIN	MAX	MIN	MAX		
D	0.189	0.197	4.80	5.00	8	A
D	0.337	0.344	8.55	8.75	14	B
D	0.386	0.394	9.80	10.00	16	C

NOTES:

1. D&E DO NOT INCLUDE MOLD FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
3. LEADS TO BE COPLANAR WITHIN .102mm (.004")
4. CONTROLLING DIMENSION: MILLIMETER
5. MEETS JEDEC MS012-XX AS SHOWN IN ABOVE TABLE
6. N = NUMBER OF PINS

 <small>120 SAN GABRIEL DR. SUNNYVALE CA 94086 FAX (408) 737 7794</small> <small>PROPRIETARY INFORMATION</small>	PACKAGE FAMILY OUTLINE: SOIC .150" <small>TITLE</small>		21-0041 A <small>DOCUMENT CONTROL NUMBER REV</small>

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