



# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

MAX5166

## General Description

The MAX5166 contains four 1-to-8 multiplexers and 32 sample/hold amplifiers. The sample/hold amplifiers are organized into four octal sample/holds with separate inputs and independent TTL/CMOS-compatible hold enables for each octal set. Additional 3-bit TTL/CMOS-compatible address logic selects the 1-to-8 multiplexer channel. The MAX5166 is available with an output impedance of 50Ω, 500Ω, or 1kΩ, allowing output filtering.

The MAX5166 operates with +10V and -5V supplies, and a separate +5V digital logic supply. Manufactured with a proprietary BiCMOS process, it provides high accuracy, fast acquisition time, low droop rate, and a low hold step. The device acquires 8V step input signals to 0.01% accuracy in 2.5μs. Transitions from sample mode to hold mode result in only 0.5mV of error. While in hold mode, the output voltage slowly droops at a rate of 1mV/sec. The MAX5166 is available in a 48-pin TQFP package.

## Applications

- Automatic Test Systems (ATE)
- Industrial Process Controls
- Arbitrary Function Generators
- Avionics Equipment

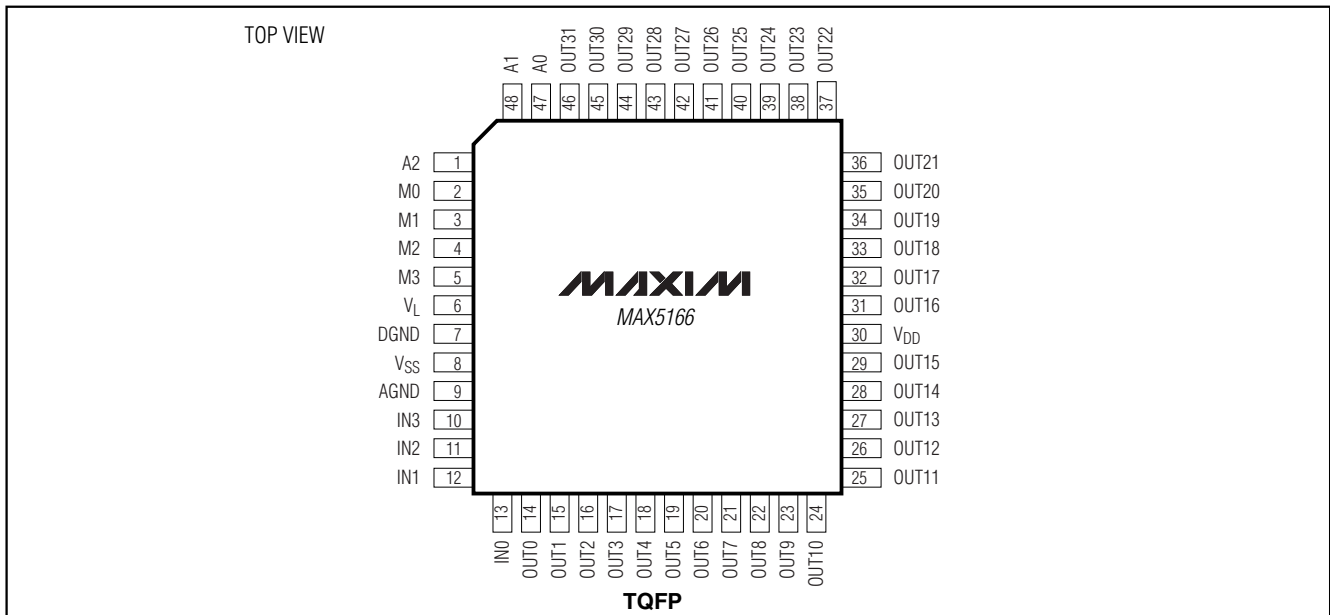
## Features

- ◆ Quad, 8-Channel Sample/Hold
- ◆ 0.01% Accuracy of Acquired Signal
- ◆ 0.01% Linearity Error
- ◆ Fast Acquisition Time: 2.5μs
- ◆ Low Droop Rate: 1mV/sec
- ◆ Low Hold Step: 0.25mV
- ◆ Wide Output Voltage Range: +7V to -4V

## Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	R <sub>OUT</sub> (Ω)
MAX5166LCCM	0°C to +70°C	48 TQFP	50
MAX5166MCCM	0°C to +70°C	48 TQFP	500
MAX5166NCCM	0°C to +70°C	48 TQFP	1k
MAX5166LECM	-40°C to +85°C	48 TQFP	50
MAX5166MECM	-40°C to +85°C	48 TQFP	500
MAX5166NECM	-40°C to +85°C	48 TQFP	1k

## Pin Configuration



# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

## ABSOLUTE MAXIMUM RATINGS

V <sub>DD</sub> to AGND	-0.3V to +11.0V	Maximum Current into A <sub>-</sub> , M <sub>-</sub>	±20mA
V <sub>SS</sub> to AGND	-6.0V to +0.3V	Continuous Power Dissipation (T <sub>A</sub> = +70°C)	
V <sub>DD</sub> to V <sub>SS</sub>	+15.75V	48-Pin TQFP (derate 12.5mW/°C above +70°C)	1W
V <sub>L</sub> to DGND	-0.3V to +6.0V	Operating Temperature Ranges	
V <sub>L</sub> to AGND	-0.3V to +6.0V	MAX5166_CCM	0°C to +70°C
DGND to AGND	-0.3V to +2.0V	MAX5166_ECM	-40°C to +85°C
IN <sub>-</sub> to AGND	V <sub>SS</sub> to V <sub>DD</sub>	Storage Temperature Range	-65°C to +150°C
A <sub>-</sub> , M <sub>-</sub> to DGND	-0.3V to +6.0V	Lead Temperature (soldering, 10sec)	+300°C
Maximum Current into Output Pin	±10mA		

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>DD</sub> = +10V, V<sub>SS</sub> = -5V, V<sub>L</sub> = +5V ±5%, AGND = DGND, R<sub>L</sub> = 5kΩ, C<sub>L</sub> = 50pF, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
<b>ANALOG SECTION</b>							
Linearity Error		-4V < V <sub>IN</sub> < +7V, R <sub>L</sub> = ∞		0.01	0.08	%	
Hold Step	V <sub>HS</sub>	IN <sub>-</sub> = AGND		0.25	1.00	mV	
Droop Rate	ΔV <sub>OUT</sub>	IN <sub>-</sub> = AGND, T <sub>A</sub> = +25°C		1	40	mV/sec	
Offset Voltage	V <sub>OS</sub>	IN <sub>-</sub> = AGND, T <sub>A</sub> = +25°C	-30	-5	+30	mV	
		+15°C ≤ T <sub>A</sub> ≤ +65°C (Note 1)		20	40	μV/°C	
Output Voltage Range	V <sub>OUT_</sub>	R <sub>L</sub> = ∞	V <sub>SS</sub> + 0.75		V <sub>DD</sub> - 2.4	V	
Analog Crosstalk		8V step with 500ns rising edge (Note 1)	MAX5165L, C <sub>L</sub> = 250pF	-72	-76	dB	
			MAX5165M, C <sub>L</sub> = 10nF				
			MAX5165N, C <sub>L</sub> = 10nF				
Input Capacitance	C <sub>IN_</sub>	(Note 1)		5	20	pF	
DC Output Impedance	R <sub>OUT_</sub>	R <sub>L</sub> = ∞, C <sub>L</sub> = 250pF	MAX5166L	35	50	65	Ω
			MAX5166M	350	500	650	
			MAX5166N	700	1000	1300	
Output Source Current	I <sub>SOURCE</sub>		2			mA	
Output Sink Current	I <sub>SINK</sub>		2			mA	
<b>TIMING PERFORMANCE</b>							
Acquisition Time	t <sub>AQ</sub>	8V step to 0.08%, R <sub>L</sub> = ∞, Figure 2 (Note 2)		2.5	4	μs	
		T <sub>A</sub> = +25°C, 100mV step to ±1mV, R <sub>L</sub> = ∞, Figure 2 (Note 2)		1			
Hold-Mode Settling Time	t <sub>H</sub>	To ±1mV of final value, Figure 2 (Note 1)		1	2	μs	
Aperture Delay	t <sub>AP</sub>	Figure 2 (Note 1)			200	ns	
Inhibit Pulse Width	t <sub>PW</sub>	Figure 2 (Note 1)	200			ns	
Data Hold Time	t <sub>DH</sub>	Figure 2 (Note 1)	150			ns	
Data Setup Time	t <sub>DS</sub>	Figure 2 (Note 1)	50			ns	

# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

**MAX5166**

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = +10V$ ,  $V_{SS} = -5V$ ,  $V_L = +5V \pm 5\%$ ,  $AGND = DGND$ ,  $R_L = 5k\Omega$ ,  $C_L = 50pF$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DIGITAL INPUTS</b>						
Input Voltage High	$V_{IH}$		2.0			V
Input Voltage Low	$V_{IL}$				0.8	V
Input Current	$I_I$	$A_- = DGND$ or $V_L$ ; $M_- = DGND$ or $V_L$	-1		+1	$\mu A$
<b>POWER SUPPLIES</b>						
Positive Analog Supply Voltage	$V_{DD}$	(Note 3)	9.5	10.0	10.5	V
Negative Analog Supply Voltage	$V_{SS}$	(Note 3)	-4.75	-5.0	-5.45	V
Digital Logic Supply Voltage	$V_L$		4.75	5.0	5.25	V
Positive Analog Supply Current	$I_{DD}$	$R_L = \infty$			36	mA
Negative Analog Supply Current	$I_{SS}$	$R_L = \infty$			36	mA
Digital Logic Supply Current	$I_L$	$A_- = DGND$ or $V_L$ ; $M_- = DGND$ or $V_L$			0.5	mA
		$V_{A0}-V_{A3} = 0.8V$ or $2V$ ; $V_{M0}, V_{M1}, V_{M2} = 0.8V$ or $2V$			5	
Power-Supply Rejection Ratio	PSRR	For both $V_{DD}$ and $V_{SS}$ in sample mode, $V_{IN} = 0$	-60	-75		dB

**Note 1:** Guaranteed by design.

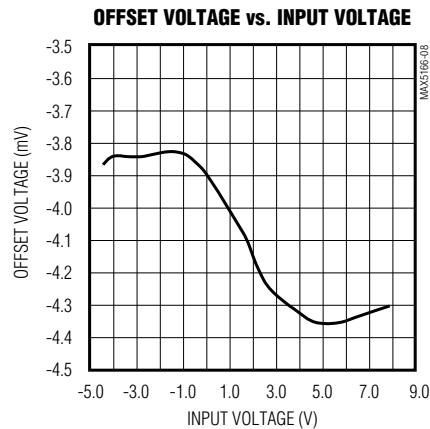
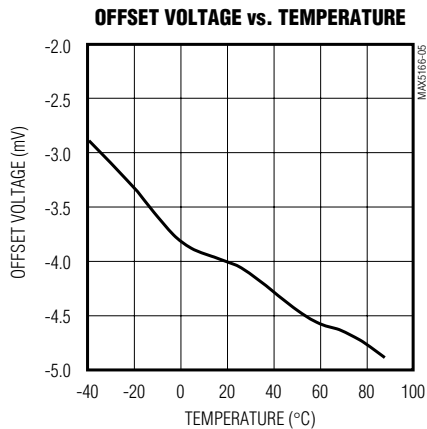
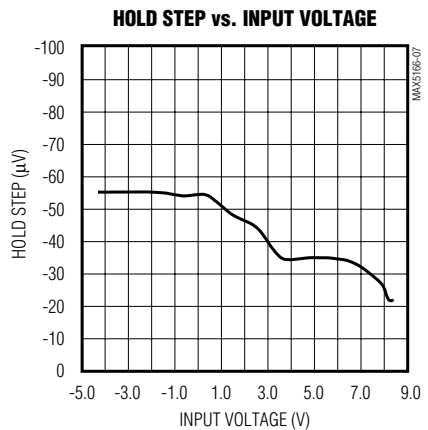
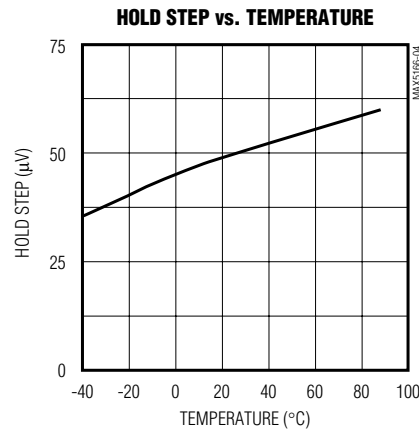
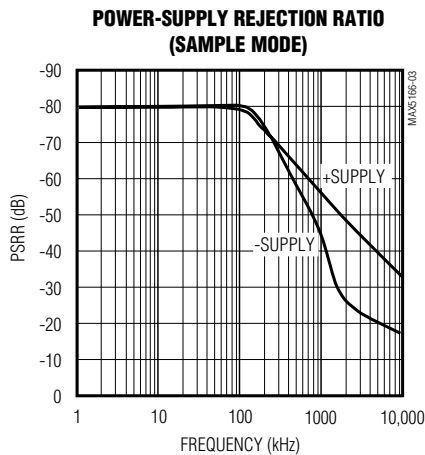
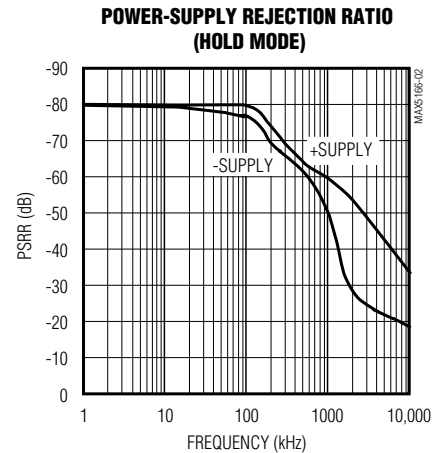
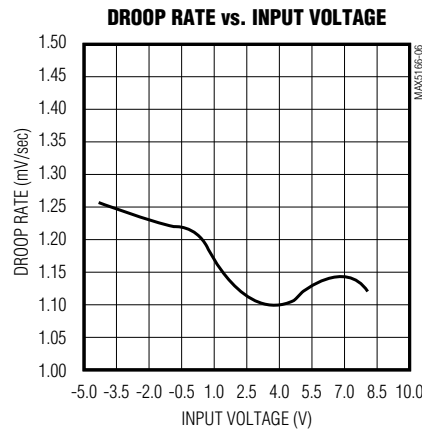
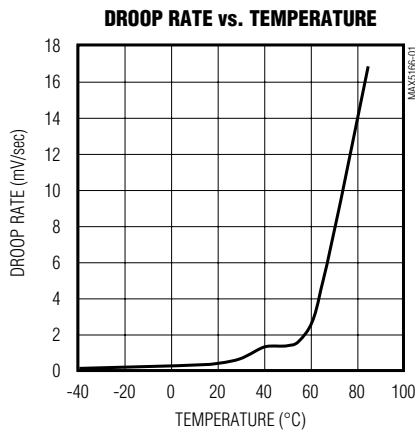
**Note 2:** Only one  $M_-$  input may be asserted low at a time, so only one channel is selected (see *Single vs. Simultaneous Sampling*).

**Note 3:** Do not exceed the absolute maximum rating for  $V_{DD}$  to  $V_{SS}$  of +15.75V (see *Absolute Maximum Ratings*).

# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

## Typical Operating Characteristics

( $V_{DD} = +10V$ ,  $V_{SS} = -5V$ ,  $V_L = +5V$ ,  $I_{N-} = +5V$ ,  $R_L = \infty$ ,  $C_L = 0$ ,  $AGND = DGND$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

MAX5166

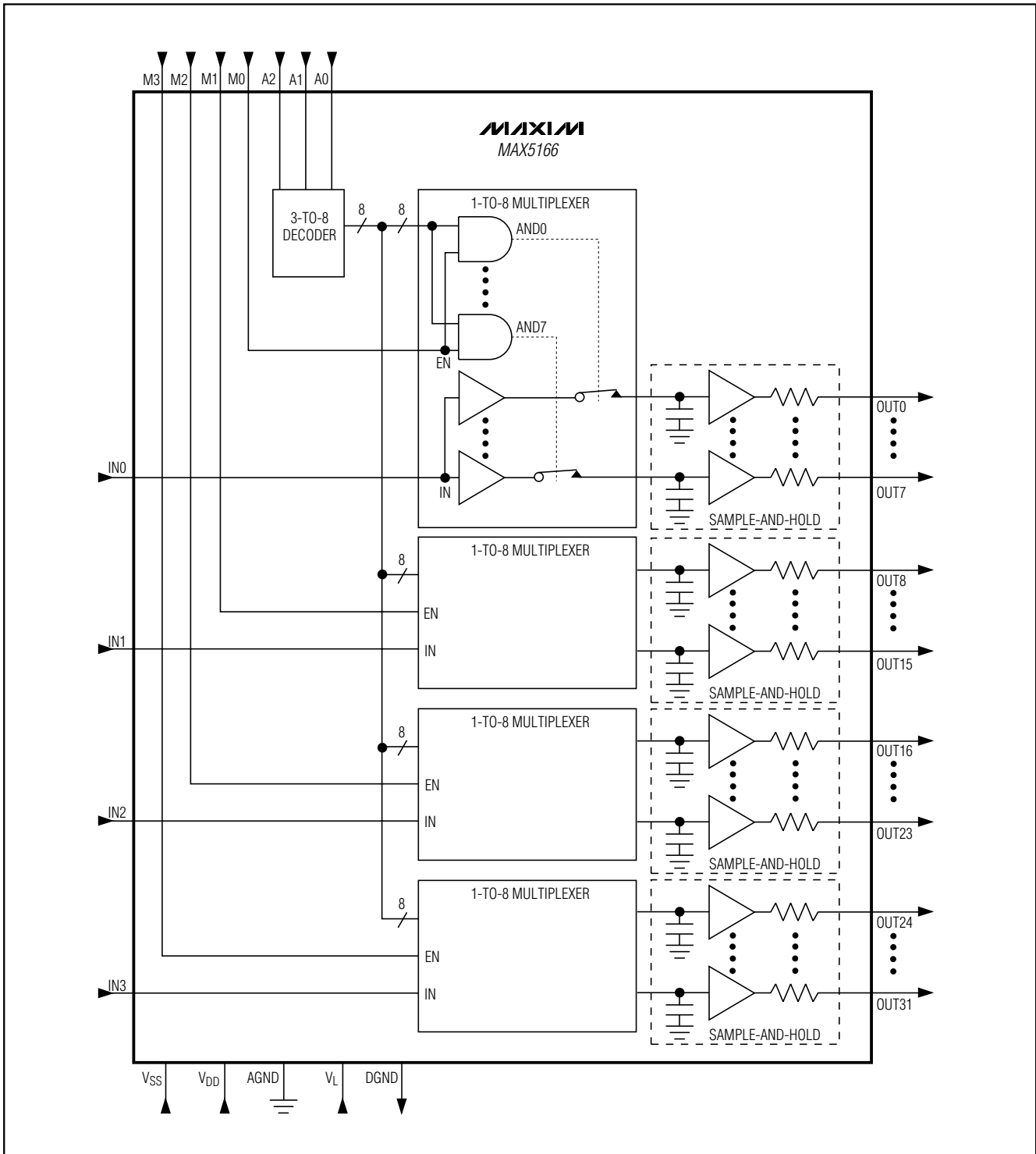


Figure 1. Functional Diagram

# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

## Pin Description

PIN	NAME	FUNCTION
1, 47, 48	A2, A0, A1	Address Inputs. The input of a 3-to-8 decoder that controls channel selection for all four 1-to-8 multiplexers. Selects which output channels are connected to the input during sample mode (Tables 1, 2).
2–5	M0–M3	Mode-Selection/Multiplexer-Enable Inputs 0 to 3. All four 1-to-8 multiplexers are independently controlled. A logic low enables sample mode by connecting the selected channel to IN_. A logic high enables hold mode (Tables 1, 2).
6	VL	Positive Digital Logic Power-Supply Input
7	DGND	Digital Ground
8	VSS	Negative Analog Power-Supply Input
9	AGND	Analog Ground
10–13	IN3–IN0	Analog Inputs 0 to 3
14–29	OUT0–OUT15	Outputs 0 to 15
30	VDD	Positive Analog Power-Supply Input
31–46	OUT16–OUT31	Outputs 16 to 31

### Detailed Description

The MAX5166 connects four separate analog inputs to four internal 1-to-8 analog multiplexers. Each multiplexer channel connects to a buffered sample/hold circuit and a series output resistor, creating a four-input device with 32 sample/hold output channels. Three multiplexer channel-address inputs and four mode-select inputs (one for each multiplexer) control channel selection and sample/hold functions (Figure 1 and Tables 1 and 2).

#### Digital Interface

Three address pins and 3-to-8 address decoder logic select the channel for all four internal analog multiplexers. The mode-select inputs (M3–M0) independently control the sample/hold functions for each multiplexer (Tables 1 and 2).

#### Sample/Hold

The MAX5166 contains 32 buffered sample/hold circuits with internal hold capacitors. Internal hold capacitors minimize leakage current, dielectric absorption, feedthrough, and required board space. The value of the hold capacitor affects acquisition time, hold step, and droop rate. Lower capacitance allows faster acquisition

times but increases the droop rate. Higher values increase hold time and acquisition time. The hold capacitor used in the MAX5166 provides fast 2.5 $\mu$ s (typ) acquisition time while maintaining a low 1mV/sec (typ) droop rate, making the sample/hold ideal for high-speed sampling.

#### Sample Mode

Driving M3–M0 low (one at a time) selects sample mode (Tables 1 and 2). During sample mode, the selected multiplexer channel connects to IN\_ allowing the hold capacitor to acquire the input signal. To guarantee an accurate sample, maintain sample mode for at least 4 $\mu$ s. Sampling for longer than 4 $\mu$ s results in tracking. Only the addressed channel on the selected multiplexer samples the input; all other channels remain in hold mode.

#### Hold Mode

Driving M3–M0 high selects hold mode. Hold mode disables the multiplexer, which disconnects all eight channels on the 1-to-8 multiplexer from the input. When a channel is disconnected, the hold capacitor maintains the sampled voltage at the output with a 1mV/sec droop rate (towards VDD).

# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

**Table 1. Output Selection**

ADDRESS			OUTPUT SELECTED			
A2	A1	A0	MUX0	MUX1	MUX2	MUX3
0	0	0	OUT0	OUT8	OUT16	OUT24
0	0	1	OUT1	OUT9	OUT17	OUT25
0	1	0	OUT2	OUT10	OUT18	OUT26
0	1	1	OUT3	OUT11	OUT19	OUT27
1	0	0	OUT4	OUT12	OUT20	OUT28
1	0	1	OUT5	OUT13	OUT21	OUT29
1	1	0	OUT6	OUT14	OUT22	OUT30
1	1	1	OUT7	OUT15	OUT23	OUT31

0 = Logic Low, 1 = Logic High

**Table 2. Mode Selection**

MODE-SELECT INPUTS* (M3–M0)	ACTION
0	Sample mode enabled on selected analog multiplexer and channel (Table 1).
1	Hold mode enabled on selected analog multiplexer and channel (Table 1).

0 = Logic Low, 1 = Logic High

\* Only one M<sub>n</sub> input asserted low; all others must be logic high to meet the timing specification (see Single vs. Simultaneous Sampling).

### Hold Step

When switching between sample mode and hold mode, the voltage of the hold capacitor changes due to charge injection from stray capacitance. This voltage change, called hold step, is minimized by limiting the amount of stray capacitance seen by the hold capacitor. The MAX5166 limits the hold step to 0.25mV (typ). An output capacitor to ground can be used to filter out this small hold-step error.

### Output

The MAX5166 contains an output buffer for each multiplexer channel (32 total), so the hold capacitor sees a high-impedance input, reducing the droop rate. While in hold mode, the hold capacitor discharges at a rate of 1mV/sec (typ). The buffer also provides a low output impedance; however, the device contains output resistors in series with the buffer output (Figure 1) for selected output filtering. To provide greater design flexibility, the MAX5166 is available with an R<sub>O</sub> of 50Ω, 500Ω, or 1kΩ.

**Note: Output loads increase the analog supply current (I<sub>DD</sub> and I<sub>SS</sub>).** Excessive loading of the output(s) damages the device by consuming more power than the device will dissipate (see *Absolute Maximum Ratings*). The resistor-divider formed by the output resistor (R<sub>OUT\_</sub>) and load impedance (R<sub>L</sub>) scales the sampled voltage (V<sub>SAMP</sub>). Determine the output voltage (V<sub>OUT\_</sub>) as follows:

$$\text{Voltage Gain} = A_v = R_L / (R_L + R_{OUT})$$

$$V_{OUT\_} = V_{SAMP} \cdot A_v$$

The maximum output voltage range depends on the analog supply voltages available and the scaling factor used:

$$(V_{SS} + 0.75V) \cdot A_v \leq V_{OUT\_} \leq (V_{DD} - 2.4V) \cdot A_v$$

when R<sub>L</sub> = ∞, then A<sub>v</sub> = 1, and this equation becomes (V<sub>SS</sub> + 0.75V) ≤ V<sub>OUT</sub> ≤ (V<sub>DD</sub> - 2.4V).

### Timing Definitions

Acquisition time (t<sub>AQ</sub>) is the amount of time the MAX5166 must remain in sample mode for the hold capacitor to acquire an accurate sample. The hold-mode settling time (t<sub>H</sub>) is the amount of time necessary for the output voltage to settle to its final value. Aperture delay (t<sub>AP</sub>) is the time interval required to disconnect the input from the hold capacitor. The inhibit pulse width (t<sub>PW</sub>) is the amount of time the MAX5166 must remain in hold mode while the address is changed. The data setup time (t<sub>DS</sub>) is the amount of time an address must be maintained before the address becomes valid. The data hold time (t<sub>DH</sub>) is the amount of time an address must be maintained after mode select has gone from low to high (Figure 2).

## 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

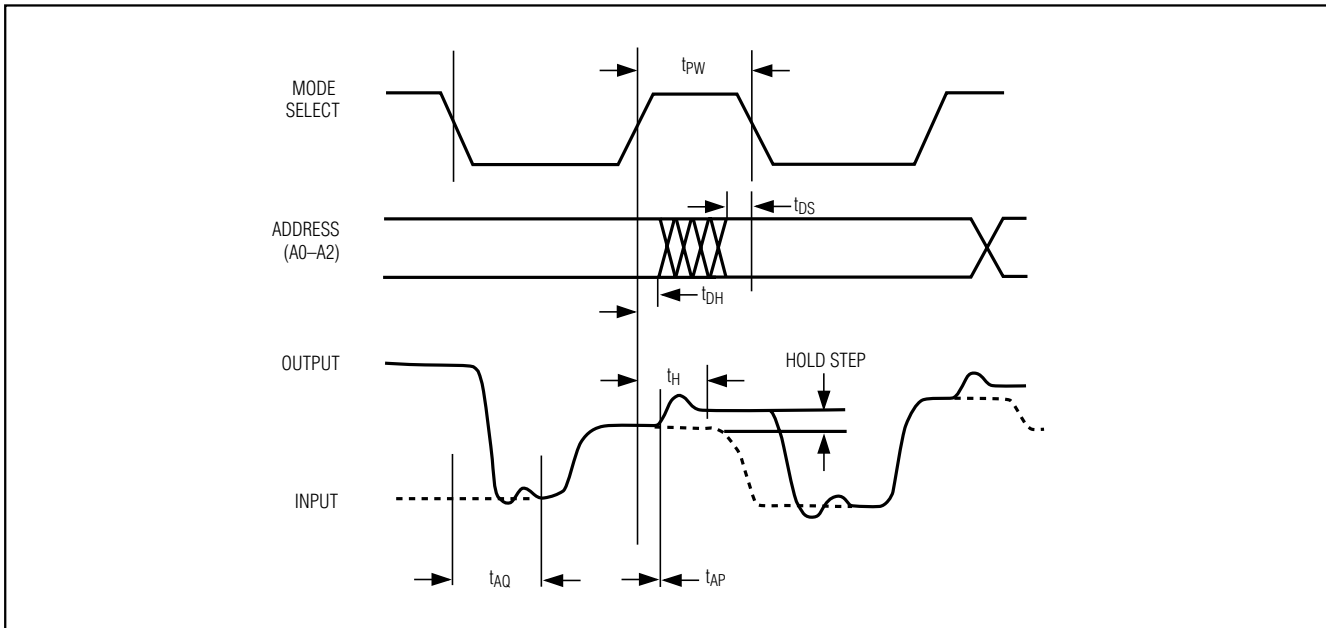


Figure 2. Timing Performance

### Applications Information

#### Combining Inputs

The MAX5166 contains a separate input for each 1-to-8 multiplexer. Externally connect the input pins to form larger multiplexers. When all four inputs are connected to the same source, the MAX5166 is functionally equivalent to the MAX5165, except the MAX5166 does not contain output clamping diodes.

#### Control-Line Reduction

The MAX5166 contains four separate 1-to-8 multiplexers and individual mode selectors for each multiplexer. When sampling one channel at a time, use an external 2-to-4 decoder (with active-low outputs) to reduce the number of digital control lines from seven to five (Figure 3).

#### Single vs. Simultaneous Sampling

Individually control the four mode/multiplexer-select pins to simultaneously sample on four channels, the same channel for each multiplexer (Figure 4). Each mode-select pin controls sampling on one of the 1-to-8 multiplexers, while the 3-bit address selects one of the eight channels on all the multiplexers (Tables 1 and 2). Setting any combination of the mode-select pin low enables sampling on the addressed channels for the selected multiplexers.

Simultaneously sampling two or more channels reduces offset voltage but increases acquisition time. Multiply the single-channel acquisition time by the number of channels sampling.

#### Multiplexed DAC

Figure 5 shows a typical demultiplexer application. Different digital codes are converted by the digital-to-analog converter (DAC) and then stored on eight different channels, or as many as 32 different channels when all four inputs are active. The 100mV/sec (max) droop rate requires refreshing the hold capacitors every 100ms before the voltage drops by 1/2LSB for an 8-bit DAC with a 5V full-scale voltage.

#### Powering the MAX5166

The MAX5166 does not require a special power-up sequence to avoid latchup. The device requires three separate supply voltages for operation; however, when one or two of the voltages are not available, DC-DC charge-pump (switched-capacitor) converters provide a simple, efficient solution. The MAX860 provides voltage doubling or inversion, ideal for conversions from +5V to +10V or from +5V to -5V. The MAX860 also functions as a voltage divider to provide conversion from +10V to +5V.



# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

**MAX5166**

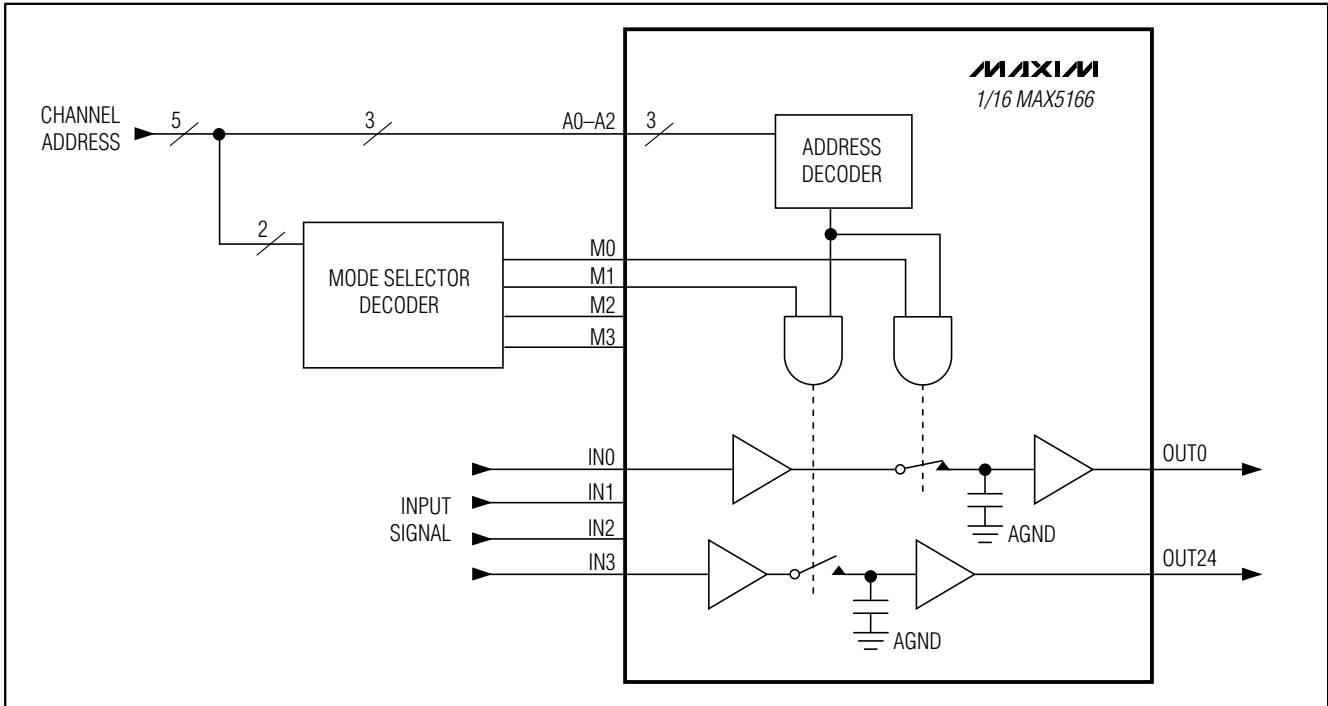


Figure 3. Control-Line Reduction

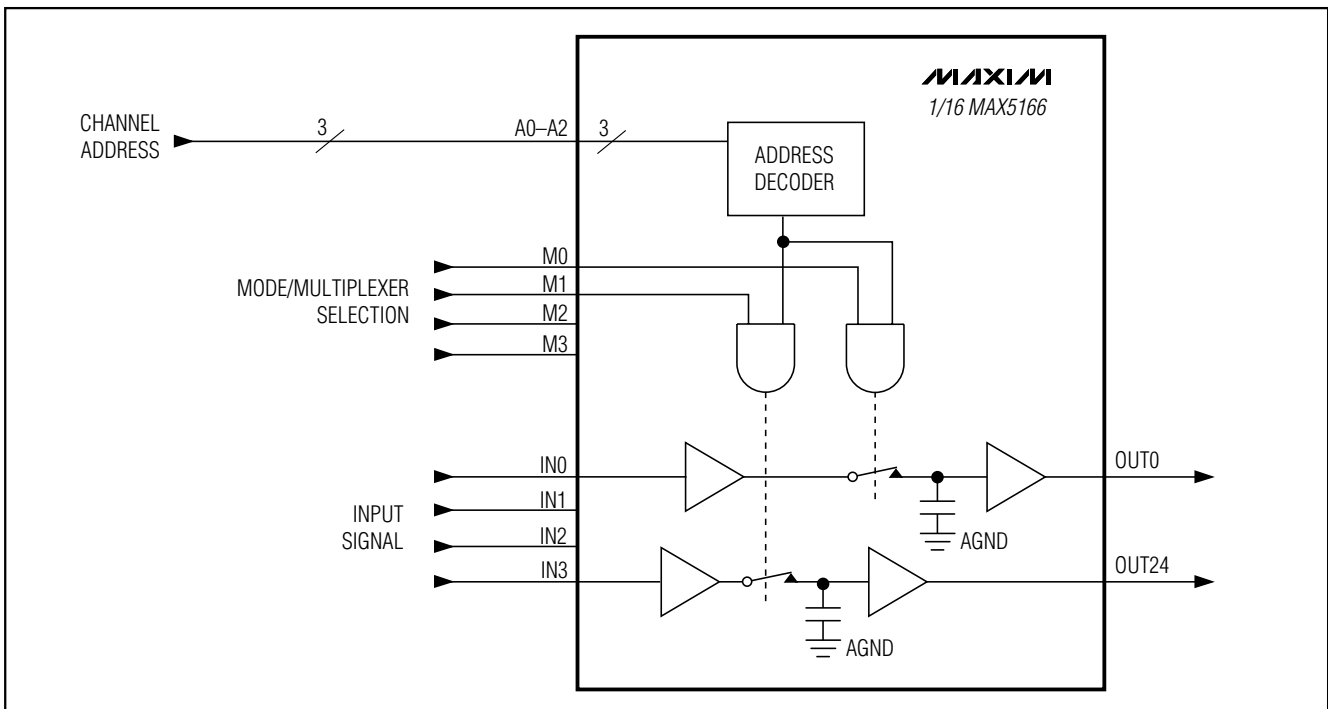


Figure 4. Simultaneous Sampling

# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

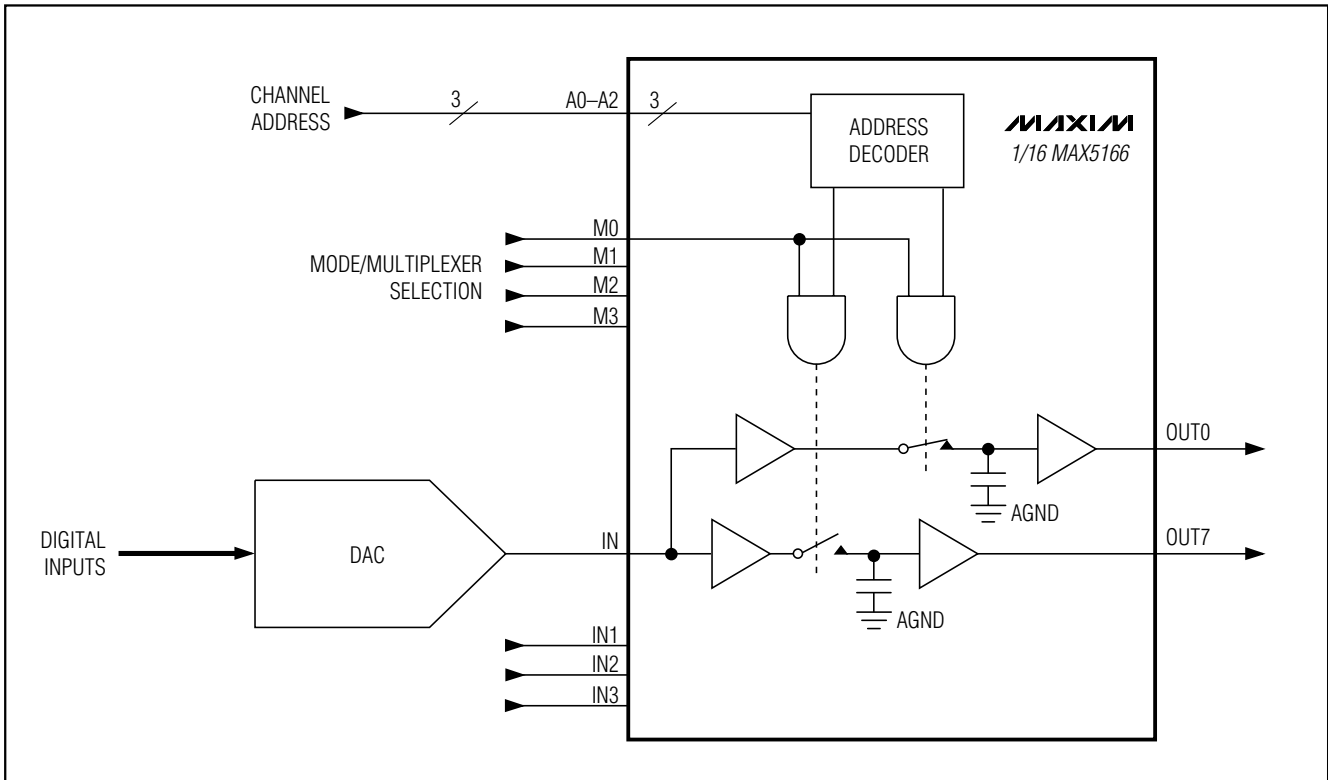


Figure 5. Multiplexing a DAC

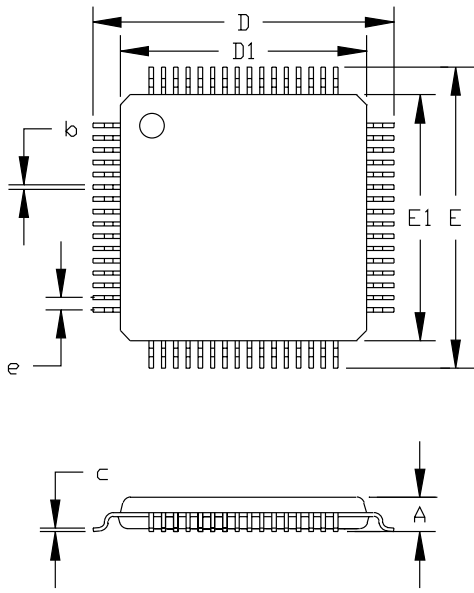
## Chip Information

TRANSISTOR COUNT: 5077

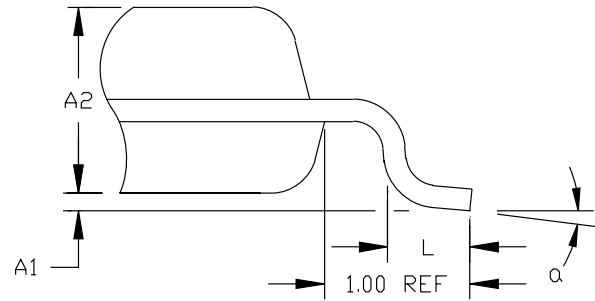
# 32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs

## Package Information

**MAX5166**



JEDEC VARIATION						
	BC		BE		BJ	
	32 LEAD		48 LEAD		64 LEAD	
	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
A	---	1.60	---	1.60	---	1.60
A <sub>1</sub>	0.05	0.15	0.05	0.15	0.05	0.15
A <sub>2</sub>	1.35	1.45	1.35	1.45	1.35	1.45
D	8.90	9.10	8.90	9.10	12.00	BSC.
D <sub>1</sub>	7.00	BSC.	7.00	BSC.	10.00	BSC.
E	8.90	9.10	8.90	9.10	12.00	BSC.
E <sub>1</sub>	7.00	BSC.	7.00	BSC.	10.00	BSC.
e	0.8	BSC.	0.5	BSC.	0.5	BSC.
L	0.45	0.75	0.45	0.75	0.45	0.75
b	0.30	0.45	0.17	0.27	0.17	0.27
c	0.09	0.20	0.09	0.20	0.09	0.20
α	0°	7°	0°	7°	0°	7°



**NOTES:**

1. ALL DIMENSIONING AND TOLERANCING CONFORM TO ANSI Y14.5-1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. THIS OUTLINE CONFORMS TO JEDEC PUBLICATION 95 REGISTRATION MO-136, VARIATIONS BC, BE AND BJ.

<b>MAXIM</b>			
<small>PROPRIETARY INFORMATION</small>			
<small>TITLE:</small>			
PACKAGE OUTLINE, TQFP			
<small>APPROVAL</small>	<small>DOCUMENT CONTROL NO.</small>	<small>REV</small>	<small>1/1</small>
	21-0054	C	

# **32-Channel Sample/Hold Amplifier with Four Multiplexed Inputs**

## **NOTES**

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