



High-Speed 12-Bit A/D Converters With External Reference Input

General Description

The MAX183/184/185 are 12-bit, high-speed, BiCMOS, analog-to-digital converters (ADCs) that consume only 90mW of power while performing conversions in as little as 3 μ s. All three ADCs perform identically, except for conversion time: MAX183 - 3 μ s, MAX184 - 5 μ s, MAX185 - 10 μ s.

The MAX183/184/185 require an external -5V reference. A buffered reference input minimizes reference-current requirements and allows a single reference to drive several ADCs. External reference specs can be chosen to suit the accuracy of the application. The ADC clock can be driven from either a crystal or an external clock source, such as a microprocessor (μ P) clock.

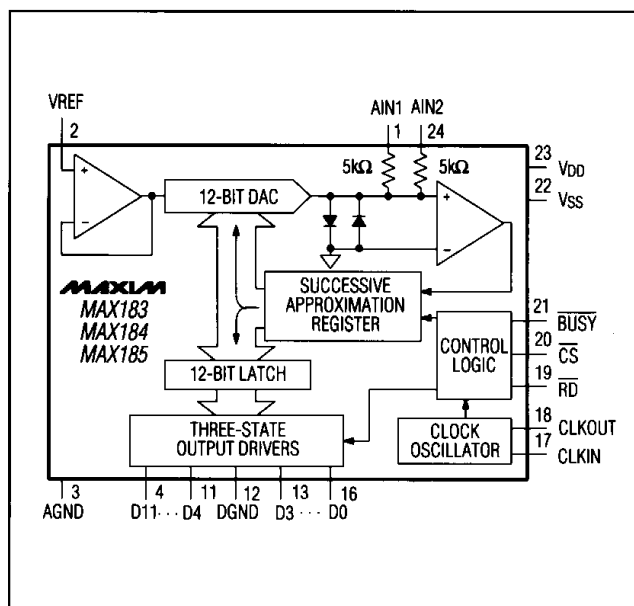
Analog input range is pin-selectable for 0 to +5V, 0 to +10V, or $\pm$ 5V, making the ADCs ideal for data acquisition and analog input/output cards. A high-speed digital interface (100ns data access time) with three-state data outputs is compatible with most μ Ps.

The MAX183/184/185 are available in space-saving, 24-pin narrow plastic DIP, CERDIP, and wide SO packages.

Applications

Telecommunications
Sonar and Radar Signal Processing
High-Speed Data Acquisition Systems
Personal Computer I/O Boards

Functional Diagram



Features

- ◆ 12-Bit Resolution and Accuracy
- ◆ Fast Conversion Times:
MAX183 - 3 μ s
MAX184 - 5 μ s
MAX185 - 10 μ s
- ◆ Low 90mW Power Consumption
- ◆ Choice of +5V, +10V or $\pm$ 5V Input Ranges
- ◆ Buffered Reference Input
- ◆ Fast 100ns Bus Access Time
- ◆ Operate with +5V, and -12V to -15V Supplies
- ◆ Available in 0.3" DIP or Wide SO Packages

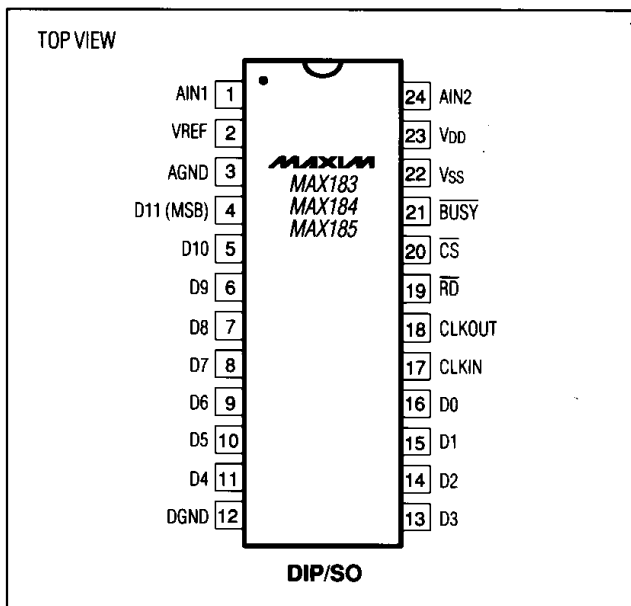
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	LINEARITY (LSBs)
3μs Maximum Conversion Time			
MAX183ACNG	0°C to +70°C	24 Plastic DIP	$\pm 1/2$
MAX183BCNG	0°C to +70°C	24 Plastic DIP	± 1
MAX183ACWG	0°C to +70°C	24 Wide SO	$\pm 1/2$
MAX183BCWG	0°C to +70°C	24 Wide SO	± 1
MAX183BC/D	0°C to +70°C	Dice*	± 1

Ordering information continued on last page.

*Consult factory for dice specifications.

Pin Configuration



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ABSOLUTE MAXIMUM RATINGS

V _{DD} to DGND	-0.3V to +7V
V _{SS} to DGND	+0.3V to -17V
AGND to DGND	-0.3V to V _{DD} +0.3V
AIN1, AIN2 to AGND	-15V to +15V
VREF to AGND	V _{SS} -0.3V to V _{DD} +0.3V
Digital Input Voltage to DGND (CLKIN, CS, RD)	-0.3V to V _{DD} +0.3V
Digital Output Voltage to DGND (D11-D0, BUSY, CLKOUT)	-0.3V to V _{DD} +0.3V

Power Dissipation to +75°C (any package)	1000mW
Derate above +75°C by	10mW/°C
Operating Temperature Ranges:	
MAX18_AC/BC	0°C to +70°C
MAX18_AE/BE	-40°C to +85°C
MAX18_AM/BM	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+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} = +5V ±5%, V_{SS} = -10.8V to -16.5V; VREF = -5V; Slow Memory Mode; f_{CLK} = 4MHz for MAX183, f_{CLK} = 2.5MHz for MAX184, f_{CLK} = 1.25MHz for MAX185; T_A = T_{MIN} to T_{MAX}, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
ACCURACY (Note 2)							
Resolution	N			12			Bits
Integral Nonlinearity	INL	Tested range ±5V	MAX18_AC/AE	±1/2			LSB
			MAX18_AM T _A = +25°C	±1/2			
			MAX18_AM	±3/4			
			MAX18_B	±1			
Differential Nonlinearity	DNL	12-Bits, no missing codes over temp.		±0.9			LSB
Unipolar/Bipolar Offset Error			T _A = +25°C	±3			LSB
			T _A = T _{MIN} to T _{MAX}	±4			
				±2			ppm/°C
Unipolar/Bipolar Gain Error			T _A = +25°C	±4			LSB
			T _A = T _{MIN} to T _{MAX}	±6			
				±2			ppm/°C
Conversion Time	t _{CONV}	Synchronous Clk (12.5 Clks)	MAX183	3.125			μs
			MAX184	5			
			MAX185	10			
		Asynchronous Clk (12 to 13 Clks)	MAX183	3.0	3.25		
			MAX184	4.8	5.2		
			MAX185	9.6	10.4		
ANALOG AND REFERENCE INPUTS							
Analog Input Current, AIN1 or AIN2		Unipolar input ranges 0V to +5V, 0V to +10V			3.5		mA
		Bipolar range ±5V			±1.75		
VREF Input Range (Note 3)					-5.1	-4.9	V
VREF Input Current					±3		μA
LOGIC INPUTS							
Input Low Voltage	V _{INL}	CS, RD, CLKIN			0.8		V
Input High Voltage	V _{INH}	CS, RD, CLKIN			2.4		V
Input Current	I _{IN}	CS, RD; V _{IN} = 0 to V _{DD}			±10		μA
		CLKIN; V _{IN} = 0 to V _{DD}			±20		
Input Capacitance (Note 3)	C _{IN}				10		pF

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MAX183/184/185

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +5V ±5%, V_{SS} = -10.8V to -16.5V; V_{REF} = -5V; Slow Memory Mode; f_{CLK} = 4MHz for MAX183, f_{CLK} = 2.5MHz for MAX184, f_{CLK} = 1.25MHz for MAX185; T_A = T_{MIN} to T_{MAX}, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
LOGIC OUTPUTS						
Output Low Voltage	V _{OL}	D11-D0, $\overline{\text{BUSY}}$, CLK OUT; I _{SINK} = 1.6mA			0.4	V
Output High Voltage	V _{OH}	D11-D0, $\overline{\text{BUSY}}$, CLK OUT; I _{SOURCE} = 200μA	4.0			V
Floating State Leakage Current	I _{LKG}	D11-D0; V _{OUT} = 0V to V _{DD}			±10	μA
Floating State Output Capacitance (Note 3)	C _{OUT}				15	pF
POWER REQUIREMENTS						
Supply Voltage (Note 1)	V _{DD}		4.75	5	5.25	V
	V _{SS}		-16.5	-12	-10.8	
Supply Current	I _{DD}	$\overline{\text{CS}} = \overline{\text{RD}} = \text{V}_{\text{DD}}$, AIN1 = AIN2 = 5V BUSY = HIGH			7	mA
	I _{SS}				10	
Power Dissipation	PD	V _{DD} = +5V, V _{SS} = -12V		90	155	mW
Power-Supply Rejection, V _{DD} Only		FS Change, V _{SS} = -12V, V _{DD} = 4.75V to 5.25V		±1/4	±1	LSB
Power-Supply Rejection, V _{SS} Only		FS Change, V _{DD} = +5V, V _{SS} = -10.8V to -16.5V		±1/2	±1	LSB

TIMING CHARACTERISTICS

(V_{DD} = +5V, V_{SS} = -10.8V to -16.5V; 100% production tested, T_A = T_{MIN} to T_{MAX}, unless otherwise indicated.) (Note 4, Figures 7, 9, 10)

PARAMETER	SYMBOL	CONDITIONS	T _A = +25°C			MAX18_C/E			MAX18_M			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$\overline{\text{CS}}$ to $\overline{\text{RD}}$ Setup Time (Note 3)	t ₁		0			0			0			ns
$\overline{\text{RD}}$ to $\overline{\text{BUSY}}$ Delay	t ₂	CL = 50pF		70	120			150			180	ns
Data Access Time (Note 5)	t ₃	CL = 100pF		50	100			130			150	ns
$\overline{\text{RD}}$ Pulse Width (Note 3)	t ₄		t ₃			t ₃			t ₃			ns
$\overline{\text{CS}}$ to $\overline{\text{RD}}$ Hold Time (Note 3)	t ₅		0			0			0			ns
Data Setup Time After $\overline{\text{BUSY}}$ (Note 5)	t ₆	CL = 100pF		40	70			90			100	ns
Bus Relinquish Time (Note 6)	t ₇			30	60			75			90	ns
Delay Between Read Operations	t ₈		200			200			200			ns
CLKIN to $\overline{\text{BUSY}}$ Delay (Note 3)	t ₉				120			150			180	ns
$\overline{\text{RD}}$ to CLKIN Setup/Hold Time (Notes 3, 7)	t ₁₀		25		100	25		100	25		100	ns

Note 1: Performance guaranteed over supply range by testing end-point errors (power-supply rejection) at the supply extremes.

Note 2: V_{DD} = +5V, V_{SS} = -12V, V_{REF} = -5V

Note 3: Guaranteed by design.

Note 4: All inputs are 0V to +5V swing with t_r = t_f = 5ns (10% to 90% of +5V) and timed from a voltage level of +1.6V.

Note 5: t₃ and t₆ are measured with the load circuits of Figure 1 and defined as the time required for an output to cross +0.8V or +2.4V.

Note 6: t₇ is defined as the time required for the data lines to change 0.5V when loaded with the circuit of Figure 2.

Note 7: For predictable conversion times, $\overline{\text{RD}}$ to CLKIN falling edge must be outside this window.

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Pin Description

PIN	NAME	FUNCTION
1	AIN1	Analog Input
2	VREF	Voltage-Reference Input
3	AGND	Analog Ground
4-11	D11-D4	Three-State Data Outputs. They are active when CS and RD are low. DB11 is the most significant bit.
12	DGND	Digital Ground
13-16	D3-D0	Three-State Data Outputs
17	CLKIN	Clock Input. Connect an external TTL-compatible clock to CLKIN. Alternatively, insert a crystal or ceramic resonator between CLKIN and CLKOUT.
18	CLKOUT	Clock Output. When using an external clock, an inverted CLKIN signal appears on CLKOUT. See CLKIN description.
19	$\overline{RD}$	READ Input. Along with $\overline{CS}$, this active low signal enables the three-state drivers and starts a conversion.
20	$\overline{CS}$	CHIP SELECT. Along with $\overline{RD}$, this active low signal enables the three-state drivers and starts a conversion.
21	$\overline{BUSY}$	$\overline{BUSY}$. Low while a conversion is in progress. $\overline{BUSY}$ indicates converter status.
22	VSS	Negative Supply, -12V to -15V
23	VDD	Positive Supply, +5V
24	AIN2	Analog Input

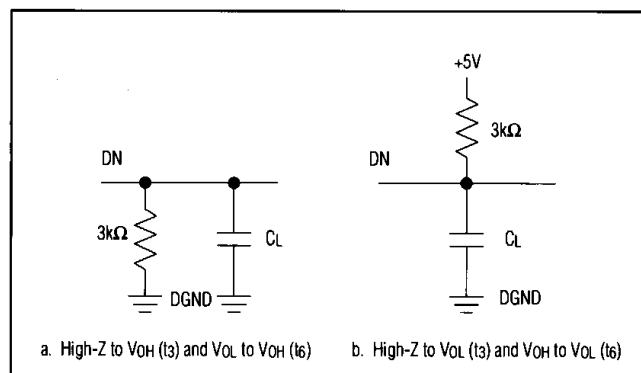


Figure 1. Load Circuits for Access Time

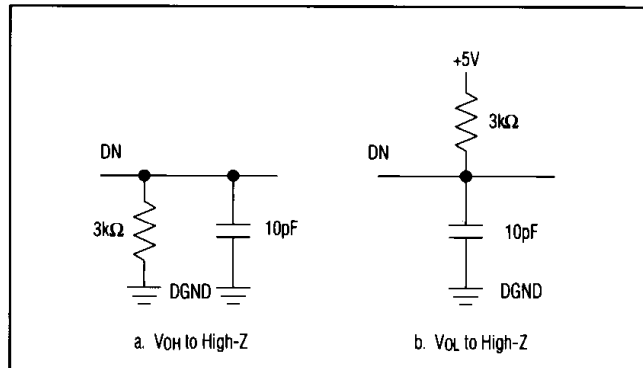


Figure 2. Load Circuits for Bus-Relinquish Time

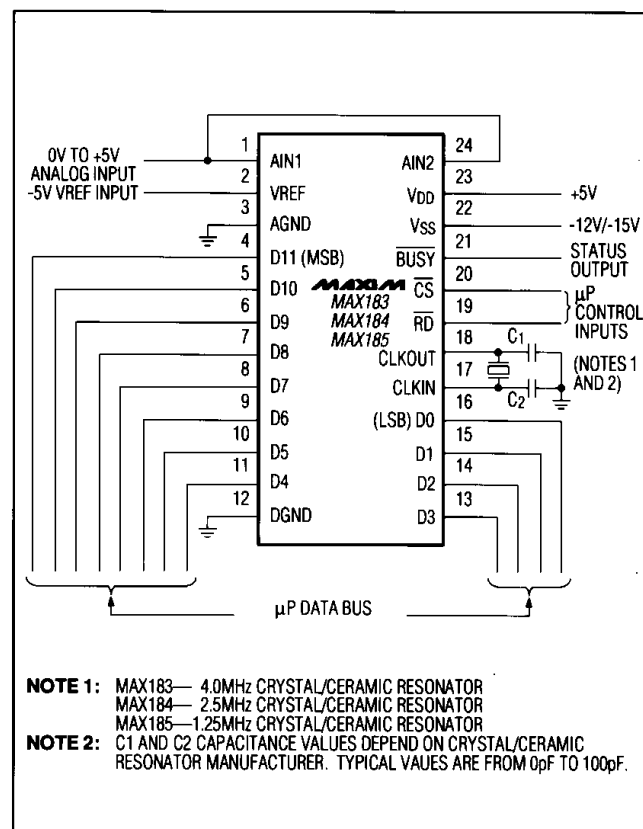


Figure 3. MAX183/184/185 Operational Diagram

MAX183/184/185

High-Speed 12-Bit A/D Converters With External Reference Input

The MAX183/184/185 $\overline{RD}$ input should go low at the rising edge of CLKIN. In this case, the conversion lasts 12.5 clock cycles, and the conversion time is $3.125\mu\text{s}$ when $f_{\text{CLK}} = 4\text{MHz}$, $5\mu\text{s}$ when $f_{\text{CLK}} = 2.5\text{MHz}$, and $10\mu\text{s}$ when $f_{\text{CLK}} = 1.25\text{MHz}$. The delay from the falling edge of $\overline{RD}$ to the falling edge of CLKIN must not be less than 100ns to ensure the 12.5 clock cycle conversion time (Figure 7). This gives the external sample-and-hold 1.5 clock cycles to settle from hold transients. An additional 1/2 clock cycle of settling can be allowed for the sample-and-hold by having $\overline{RD}$ go low at the falling edge of CLKIN. This results in a 13 cycle conversion time ($3.25\mu\text{s}$, $5.2\mu\text{s}$ and $10.4\mu\text{s}$).

Digital Interface

Timing and Control

$\overline{CS}$ and $\overline{RD}$ control conversion start and data-read operations. Figure 8 shows the logic equivalent for the conversion and the data-output control circuitry. A logic low at both inputs starts a conversion. Once a conversion is in progress, it cannot be restarted. The BUSY output remains low during the entire conversion cycle.

Figures 9 and 10 outline the two interface modes (slow memory and ROM). Slow memory mode is for μPs that can be forced into a wait state for periods as long as the MAX183/184/185 conversion time. ROM mode is for μPs that cannot be forced into a wait state. In both interface modes, a processor read operation to the ADC address starts the conversion. In the ROM mode, a second read operation accesses the conversion result.

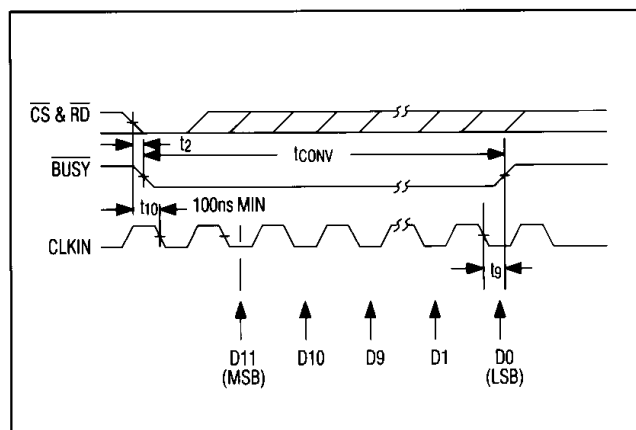


Figure 7. MAX183/184/185 $\overline{RD}$ and CLKIN for Synchronous Operation and Conversion Time of 12.5 Clock Cycles

Slow Memory Mode

The timing diagram in Figure 9 illustrates slow memory mode, which is designed for μPs with a wait state. $\overline{CS}$ and $\overline{RD}$ go low, triggering a conversion, and are kept low until the conversion is complete. BUSY responds by going low, and data from the previous conversion remains on the three-state data outputs. At conversion end, BUSY returns high, and the output latches transfer the new conversion results to the three-state data outputs. The μP completes the read operation by taking $\overline{CS}$ and $\overline{RD}$ high.

ROM Mode

The ROM mode avoids placing the μP into a wait state. A conversion begins with a read operation. While $\overline{CS}$ and $\overline{RD}$ are low, data from the last conversion is available on the data outputs. A second read operation reads the new data and begins the conversion process again. A delay at least as long as the MAX183/184/185 conversion times must be allowed between read operations. The data on the output bus is in a parallel format in either mode.

Application Hints

Digital Bus Noise

If the data bus connected to the ADC is active during a conversion, coupling from the data pins to the ADC comparator may cause LSBs of error. Using slow memory mode avoids this problem by placing the μP in a wait state during the conversion. In ROM mode, if the data bus is active during the conversion, use three-state drivers to isolate the bus from the ADC.

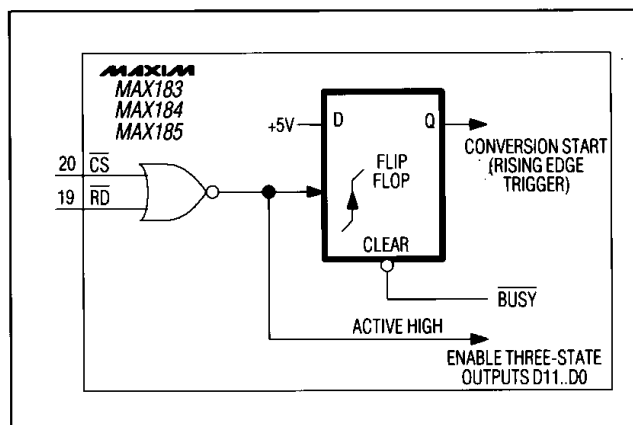


Figure 8. Logic for Control Inputs $\overline{CS}$ and $\overline{RD}$ Internal

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MAX183/184/185

ROM Mode

Digital noise is generated in the ADC when $\overline{RD}$ or $\overline{CS}$ go high, and the output data drivers are disabled after a conversion is started. This noise will feed into the ADC comparator and cause large errors if it coincides with the time the SAR is latching a bit decision. To avoid this problem, $\overline{RD}$ and $\overline{CS}$ should be active for less than 1 clock cycle. In other words, the $\overline{RD}$ and $\overline{CS}$ low pulse should be less than 250ns for the MAX183, 400ns for the MAX184, and 1 μ s for the MAX185. If this cannot be done, the $\overline{RD}$ or $\overline{CS}$ signal must go high at a rising edge of CLKIN since the comparator output is always latched at falling edges of CLKIN.

Physical Layout

For best system performance, printed circuit boards should be used for the MAX183/184/185; wire-wrap boards are not recommended. Separate the digital- and analog-signal lines as much as possible in the board layout. Do not run analog and digital lines parallel to each other or digital lines underneath the MAX183/184/185 package.

Grounding

Figure 11 shows the recommended system ground connections. Establish a single-point analog ground (star ground), separate from the logic ground, at AGND of the MAX183/184/185. Connect all other analog grounds and DGND of the MAX183/184/185 to this star ground (no other digital grounds should be connected to this point). For noise-free operation of the ADC, use a low-impedance ground return to the power supply from this star ground.

Power-Supply Bypassing

The ADC's high-speed comparator is sensitive to high-frequency noise in the V_{DD} and V_{SS} power supplies. These supplies should be bypassed to the analog star ground with 0.1 μ F and 10 μ F bypass capacitors with minimum lead length for supply noise rejection. If the +5V power supply is very noisy, a small (10 Ω -20 Ω) resistor can be connected (Figure 11) to filter external noise.

Driving The Analog Input

The input signal leads to AIN and the input return leads to AGND should be as short as possible to minimize input noise coupling. Use shielded cables if the leads must be long.

The input impedance at each AIN is typically 5k Ω . The amplifier driving AIN must have low enough DC output impedance for low gain error. Furthermore, low AC output impedance is needed since the analog input current is modulated at the clock rate during a conversion (up to 4MHz for MAX183, 2.5MHz for MAX184, or 1.25MHz for the MAX185). The output impedance of the driving am-

plifier is equal to its open-loop output impedance divided by the loop gain at the frequency of interest.

MAX184/185 – The MAX184/185 maximum clock rate of 2.5MHz makes it possible to drive AIN with amplifiers like the OP42, AD711 or a Maxim OP27. A MAX400 or a Maxim OP07 can also be used up to 1.25MHz clock rate.

MAX183 – The MAX183, with a maximum 4MHz clock rate, might exhibit settling problems with the above amplifiers. An LF356, LF400 or LT1056 can be used to drive the input. Alternatively, an emitter follower buffer inside the feedback loop of a Maxim OP27, an OP42, or an AD711 improves high-frequency output impedance.

Reference Input

VREF connects to an external -5V source. This may be either a precision negative reference, a positive reference (such as the MX584) connected as a two-terminal device to provide -5V (Figure 16), or an existing system reference. The allowed input range at REFIN is -5.1V to -4.9V. VREF (and AIN2 in bipolar input operation) should be bypassed to ground with a 10 μ F electrolytic capacitor in parallel with a 0.1 μ F ceramic capacitor.

If the external reference is biased from a power supply other than V_{SS} , then care must be taken to ensure that V_{SS} is applied to the ADC before VREF. If supply sequencing is in doubt, then connect a diode between V_{SS} and VREF, as shown in Figure 12. If the reference source is powered from the same supply as V_{SS} , then no diode is needed.

MAX183/184/185 to Sample-and-Hold Interface

The analog input to the ADC must be stable to within 1/2LSB during the entire conversion for specified 12-bit accuracy. This limits the input-signal bandwidth to less than 6Hz for sinusoidal inputs, even when using the faster MAX183. A sample-and-hold should be used for higher bandwidth signals.

The $\overline{BUSY}$ output from the MAX183/184/185 may be used to provide the TRACK/HOLD signal to the sample-and-hold amplifier. However, since the ADC's DAC is switched at approximately the same time as the $\overline{BUSY}$ signal goes low, sample-and-hold transients caused by DAC switching may result in code-dependent errors due to sample-and-hold aperture delay. Adding a NAND (inverted AND) gate ensures that the sample-and-hold is switched to the hold mode BEFORE any disturbances (Figures 13 and 14). The NAND gate solution works only if the width of the $\overline{RD}$ pulse is wider than the $\overline{RD}$ to $\overline{BUSY}$ delay in the MAX183/184/185. If this is not the case, use a flip-flop, which is set by the falling edge of $\overline{RD}$ and reset by the rising edge of $\overline{BUSY}$.

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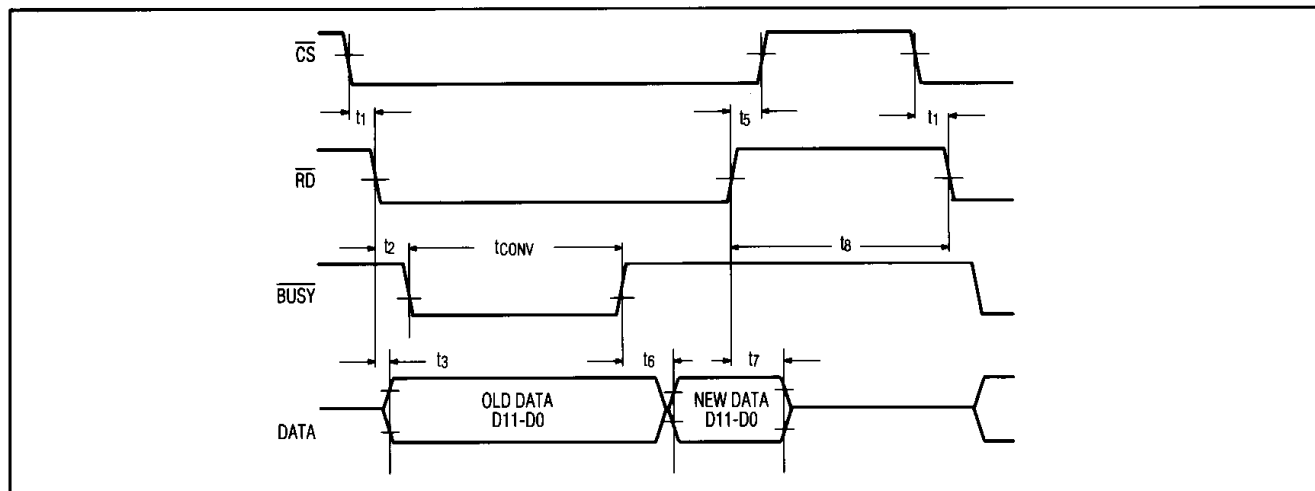


Figure 9. Slow Memory Mode Timing Diagram

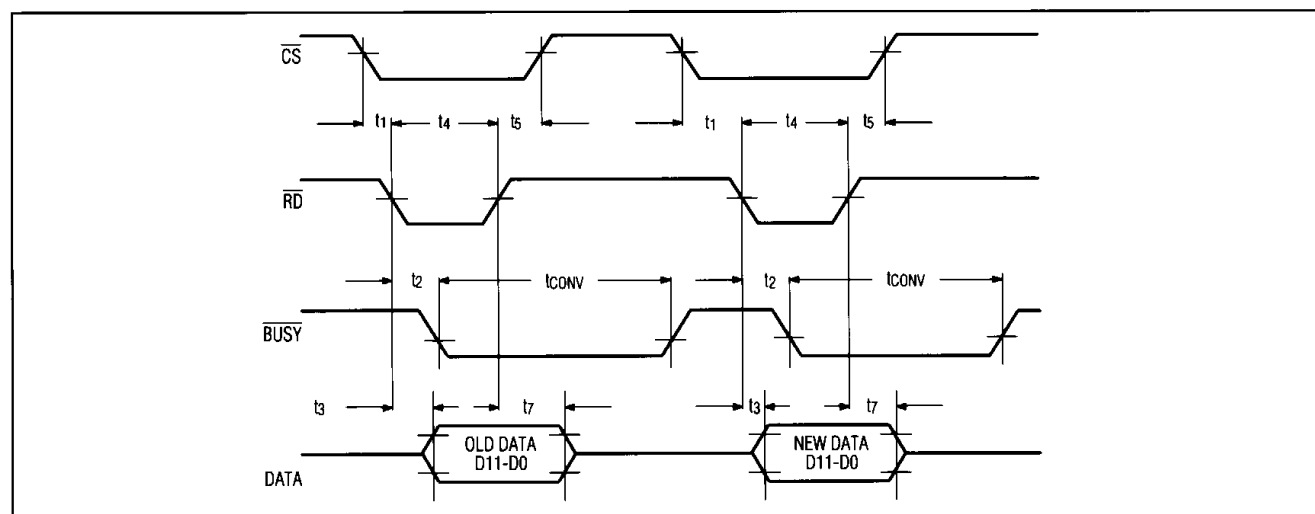


Figure 10. ROM Mode Timing Diagram

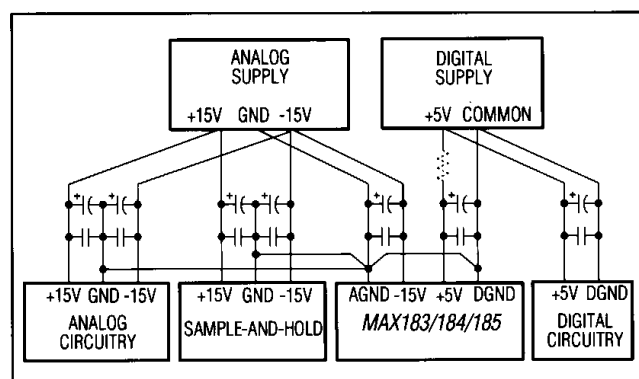


Figure 11. Power-Supply Grounding Practice

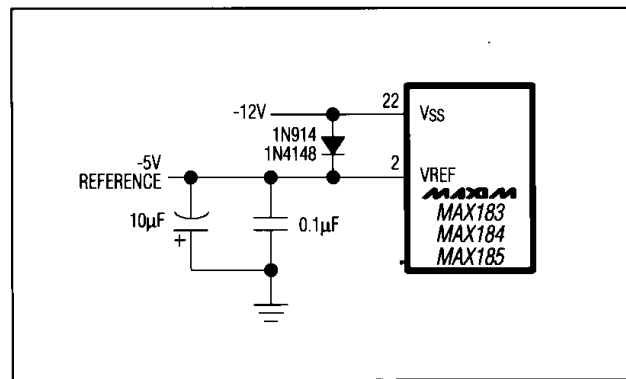


Figure 12. VREF/VSS Diode Clamp (See "Reference Input" Text).

High-Speed 12-Bit A/D Converters With External Reference Input

MAX183/184/185

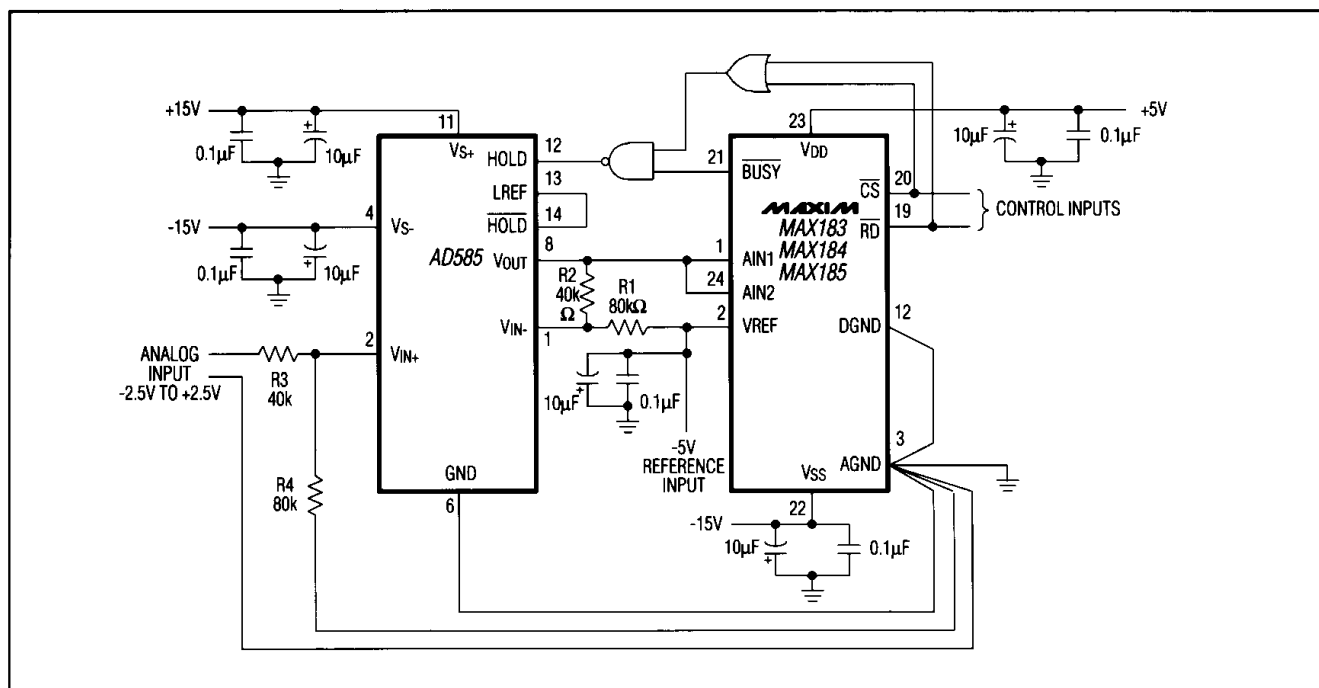


Figure 13. MAX183/184/185—AD585 Sample-and-Hold Interface

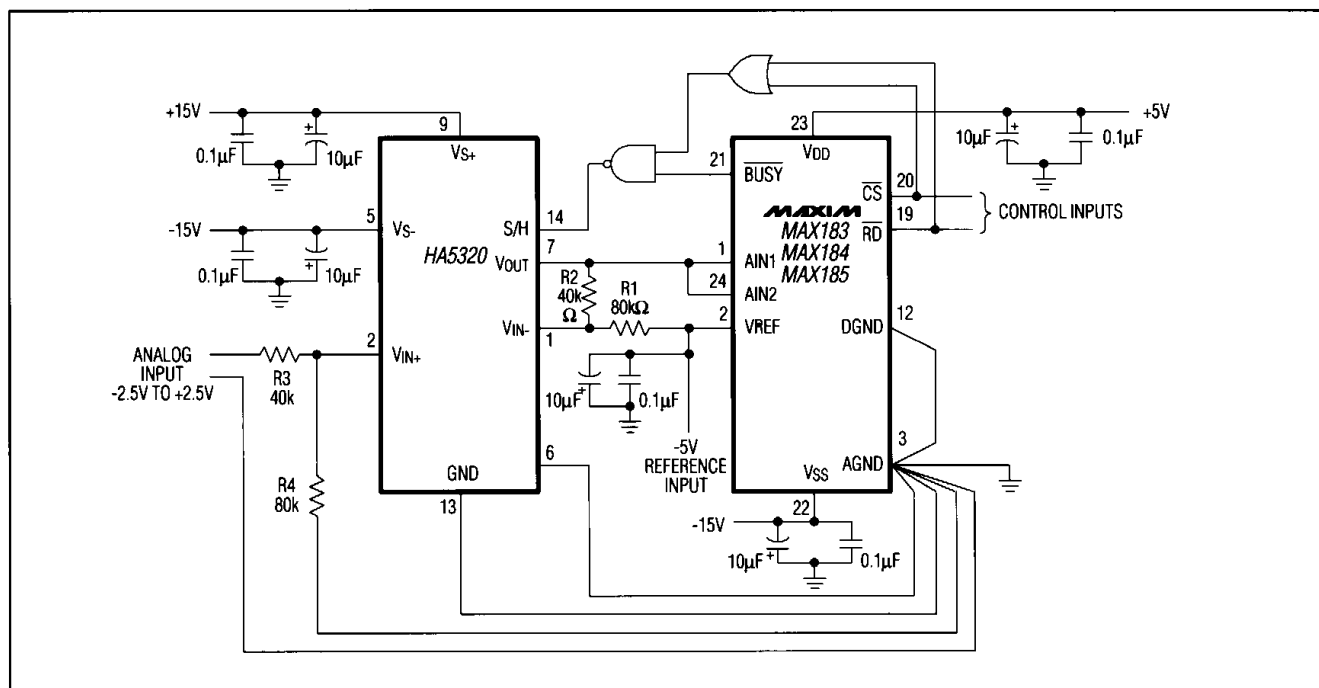


Figure 14. MAX183/184/185—HA5320 Sample-and-Hold Interface

High-Speed 12-Bit A/D Converters With External Reference Input

For synchronous $\overline{RD}$ and CLKIN, the hold settling time allowed for the sample-and-hold is 375ns (MAX183), 600ns (MAX184), and 1.5 μ s (MAX185).

The maximum sampling rate is 125kHz with a 2.5MHz clock and 64.5kHz with a 1MHz clock, allowing for a 3 μ s sample-and-hold acquisition time.

Although this circuit works well for the 1MHz clock rate, a faster sample-and-hold amplifier, such as the HA5320, is recommended at a 2.5MHz clock rate.

MAX183 – Figure 14 is the MAX183 to HA5320 interface. The maximum sampling rate is 210kHz with a 4MHz clock, which allows a 1.5 μ s acquisition time. The HA5320 can also be replaced by a HA5330 for higher throughput.

Analog Input Ranges

The MAX183/184/185 provides three selectable analog input ranges: 0V to +5V, 0V to +10V, and $\pm$ 5V. Figure 15

shows the configuration for the two analog inputs (AIN1 and AIN2) for these ranges.

Unipolar Operation

Figure 16 shows unipolar operation using a MX584 voltage reference configured for -5V.

Figure 17 shows the nominal input/output transfer function of the MAX183/184/185. Code transitions occur half way between successive integer LSB values. The output coding is binary with 1LSB = Full Scale (FS)/4096. FS is either +5V or +10V, based on the analog input configurations.

Offset and Full-Scale Adjustment

In applications requiring offset and FS range adjustment, use the circuit in Figure 19. Note: The amplifier shown could also be a sample-and-hold. Offset should be adjusted first. Apply 1/2LSB (0.61mV) at the analog input (AIN1 or AIN2) and adjust the offset of the amplifier until

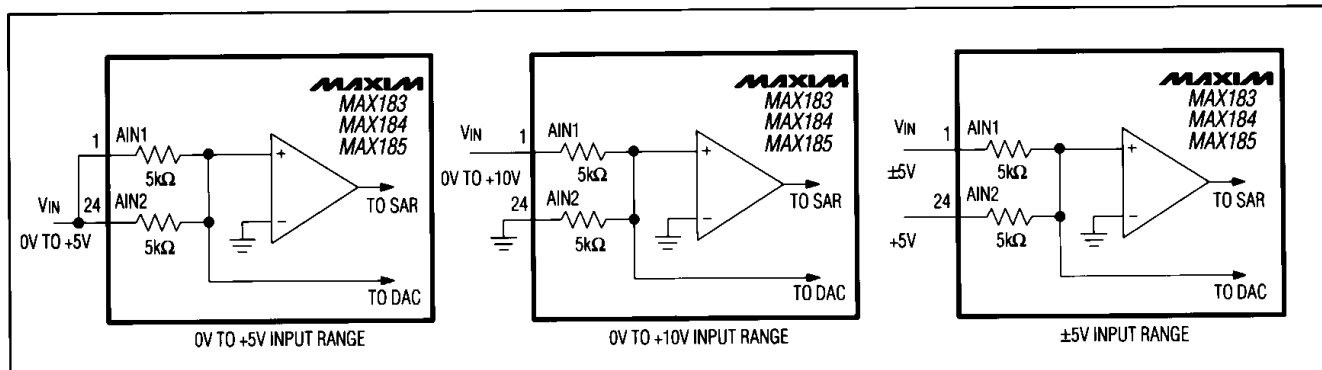


Figure 15. Analog Input Range Configurations

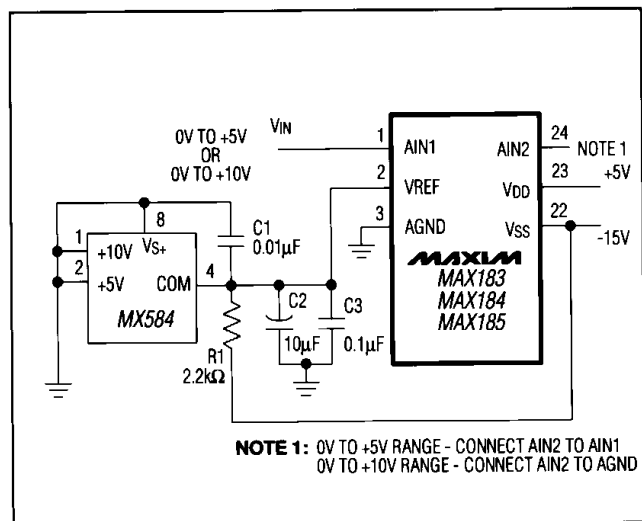


Figure 16. Unipolar Operation Using a MX584 Reference

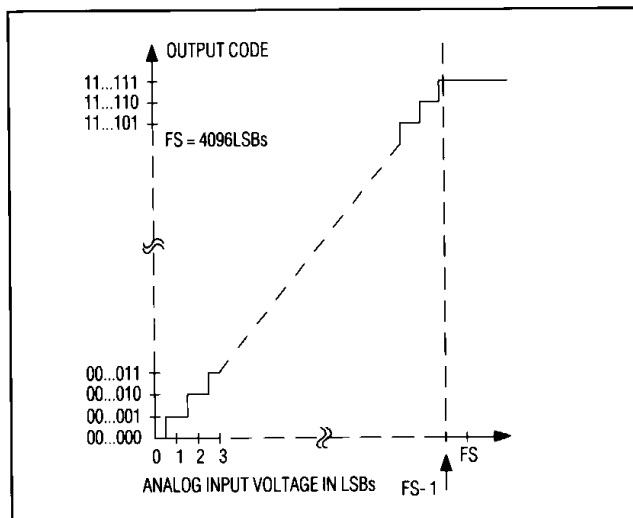


Figure 17. MAX183/184/185 Ideal Unipolar Transfer Function

MAX183/184/185

High-Speed 12-Bit A/D Converters With External Reference Input

Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE	LINEARITY (LSBs)
MAX183AENG	-40°C to +85°C	24 Plastic DIP	±1/2
MAX183BENG	-40°C to +85°C	24 Plastic DIP	±1
MAX183AEWG	-40°C to +85°C	24 Wide SO	±1/2
MAX183BEWG	-40°C to +85°C	24 Wide SO	±1
5µs Maximum Conversion Time			
MAX184ACNG	0°C to +70°C	24 Plastic DIP	±1/2
MAX184BCNG	0°C to +70°C	24 Plastic DIP	±1
MAX184ACWG	0°C to +70°C	24 Wide SO	±1/2
MAX184BCWG	0°C to +70°C	24 Wide SO	±1
MAX184BC/D	0°C to +70°C	Dice*	±1
MAX184AENG	-40°C to +85°C	24 Plastic DIP	±1/2
MAX184BENG	-40°C to +85°C	24 Plastic DIP	±1
MAX184AEWG	-40°C to +85°C	24 Wide SO	±1/2
MAX184BEWG	-40°C to +85°C	24 Wide SO	±1
MAX184AMRG	-55°C to +125°C	24 CERDIP**	±3/4
MAX184BMRG	-55°C to +125°C	24 CERDIP**	±1
10µs Maximum Conversion Time			
MAX185ACNG	0°C to +70°C	24 Plastic DIP	±1/2
MAX185BCNG	0°C to +70°C	24 Plastic DIP	±1
MAX185ACWG	0°C to +70°C	24 Wide SO	±1/2
MAX185BCWG	0°C to +70°C	24 Wide SO	±1
MAX185BC/D	0°C to +70°C	Dice*	±1
MAX185AENG	-40°C to +85°C	24 Plastic DIP	±1/2
MAX185BENG	-40°C to +85°C	24 Plastic DIP	±1
MAX185AEWG	-40°C to +85°C	24 Wide SO	±1/2
MAX185BEWG	-40°C to +85°C	24 Wide SO	±1
MAX185AMRG	-55°C to +125°C	24 CERDIP**	±3/4
MAX185BMRG	-55°C to +125°C	24 CERDIP**	±1

* Consult factory for dice specifications.

** Contact factory for processing to MIL-STD-883.

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