

1.5V to 3.6V, 357ksps, 1-Channel True-Differential/ 2-Channel Single-Ended, 10-Bit, SAR ADCs

General Description

The MAX1392/MAX1395 micropower, serial-output, 10-bit, analog-to-digital converters (ADCs) operate with a single power supply from +1.5V to +3.6V. These ADCs feature automatic shutdown, fast wake-up, and a high-speed 3-wire interface. Power consumption is only 0.740mW ($V_{DD} = +1.5V$) at the maximum conversion rate of 357ksps. AutoShutdownTM between conversions reduces power consumption at slower throughput rates.

The MAX1392/MAX1395 require an external reference V_{REF} that has a wide range from 0.6V to V_{DD}. The MAX1392 provides one true-differential analog input that accepts signals ranging from 0 to V_{REF} (unipolar mode) or ±V_{REF}/2 (bipolar mode). The MAX1395 provides two single-ended inputs that accept signals ranging from 0 to V_{REF}. Analog conversion results are available through a 5MHz, 3-wire SPI™-/QSPI™-/MICROWIRE™-/digital signal processor (DSP)-compatible serial interface. Excellent dynamic performance, low voltage, low power, ease of use, and small package sizes make these converters ideal for portable battery-powered data-acquisition applications, and for other applications that demand low power consumption and minimal space.

The MAX1392/MAX1395 are available in a space-saving (3mm x 3mm) 10-pin TDFN package. The parts operate over the extended (-40°C to +85°C) temperature range.

Applications

Portable Datalogging Data Acquisition Medical Instruments Battery-Powered Instruments Process Control

_Features

- 357ksps 10-Bit Successive-Approximation Register (SAR) ADCs
- Single True-Differential Analog Input Channel with Unipolar-/Bipolar-Selected Input (MAX1392)
- Dual Single-Ended Input Channel with Channel-Selected Input (MAX1395)
- ♦ ±0.5 LSB INL, ±0.5 LSB DNL, No Missing Codes
- ♦ ±1 LSB Total Unadjusted Error
- 61dB SINAD at 85kHz Input Frequency
- Single-Supply Voltage (+1.5V to +3.6V)
- ♦ 0.945mW at 350ksps, 1.8V
- 0.27mW at 100ksps, 1.8V
- ♦ 3.1µW at 1ksps, 1.8V
- ♦ < 1µA Shutdown Current</p>
- External Reference (0.6V to VDD)
- AutoShutdown Between Conversions
- SPI-/QSPI-/MICROWIRE-/DSP-Compatible,
 or 4-Wire Serial Interface
- Small (3mm x 3mm), 10-Pin TDFN

Typical Operating Circuit and Pin Configurations appear at end of data sheet.

AutoShutdown is a trademark of Maxim Integrated Products, Inc. SPI/QSPI are trademarks of Motorola, Inc. MICROWIRE is a trademark of National Semiconductor Corp.

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	ANALOG INPUTS	TOP MARK
MAX1392ETB+	-40°C to +85°C	10 TDFN-EP*	1-CH DIFF	AOY
MAX1395ETB+	-40°C to +85°C	10 TDFN-EP*	2-CH S/E	APB

+Denotes a lead(Pb)-free/RoHS-compliant package. *EP = Exposed pad.

Maxim Integrated Products 1

AX7395

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

MAX1392/MAX1395

ABSOLUTE MAXIMUM RATINGS

10-Pin TDFN (derate 18.5mW/°C above +70°C)1481.5mW

Operating Temperature Ranges

MAX139_E	40°C to +85°C
Junction Temperature	+150°C
Storage Temperature Range	60°C to +150°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

 $(V_{DD} = +1.5V \text{ to } +3.6V, V_{REF} = V_{DD}, C_{REF} = 0.1 \mu\text{F}, f_{SCLK} = 5MHz, T_A = T_{MIN} \text{ to } T_{MAX}$, unless otherwise noted. Typical values are at $T_A = +25^{\circ}\text{C.}$ (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	ТҮР	MAX	UNITS		
DC ACCURACY (Note 2)									
Resolution				10			Bits		
Integral Nonlinearity	INL					±0.5	LSB		
Differential Nonlinearity	DNL	No missing code overtemp	perature			±0.5	LSB		
Offset Error					0.25	±0.5	LSB		
Gain Error		Offset nulled			0.25	±0.5	LSB		
Total Unadjusted Error	TUE					±1	LSB		
Offset-Error Temperature Coefficient					±0.001		LSB/°C		
Gain-Error Temperature Coefficient					±0.00025		LSB/°C		
Channel-to-Channel Offset Matching		MAX1395 only			±0.1		LSB		
Channel-to-Channel Gain Matching		MAX1395 only			±0.1		LSB		
Input Common-Mode Rejection	CMR	$V_{CM} = 0$ to V_{DD} , MAX1392 only			±0.1		mV/V		
DYNAMIC SPECIFICATIONS (Not	e 3)								
Signal-to-Noise Plus Distortion	SINAD	$V_{REF} = V_{DD} = 1.6 \text{ to } 3.6 \text{V}$		61			dB		
Signal-to-Noise Ratio	SNR	$V_{REF} = V_{DD} = 1.6 \text{ to } 3.6 \text{V}$		61			dB		
Total Harmonic Distortion	THD				-83	-73	dBc		
Spurious-Free Dynamic Range	SFDR				-84	-74	dBc		
Intermodulation Distortion	IMD	$f_{IN1} = 83$ kHz at -6.5dBFS, $f_{IN2} = 87$ kHz at -6.5dBFS			-75		dB		
Channel-to-Channel Crosstalk		MAX1395 only			-70		dB		
Full-Power Bandwidth		-3dB point			4		MHz		
Full Lipcor Pondwidth			MAX1392		200		kH=		
	211/4D > 290R		MAX1395	150			КПИ		

ELECTRICAL CHARACTERISTICS (continued)

 $(V_{DD} = +1.5V \text{ to } +3.6V, V_{REF} = V_{DD}, C_{REF} = 0.1 \mu\text{F}, f_{SCLK} = 5MHz, T_A = T_{MIN} \text{ to } T_{MAX}$, unless otherwise noted. Typical values are at $T_A = +25^{\circ}\text{C.}$) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	ТҮР	МАХ	UNITS		
CONVERSION RATE								
Conversion Time	tCONV	11 clock cycles	2.2			μs		
Throughput Rate		14 clocks per conversion; includes power- up, acquisition, and conversion time			357	ksps		
Power-Up and Acquisition Time	tacq	Three SCLK cycles	600			ns		
Aperture Delay	tad			8		ns		
Aperture Jitter	t _{AJ}			30		ps		
Serial Clock Frequency	fCLK		0.1		5.0	MHz		
ANALOG INPUTS (AIN+, AIN-, AI	N1, AIN2)							
Input Voltage Denge	Max	Unipolar	0		V _{REF}	N		
Input voltage Range	۷IN	Bipolar, MAX1392 only (AIN+ - AIN-)	-V _{REF} /2		+V _{REF} /2	v		
Common-Mode Input Voltage Range	V _{CM}	Bipolar, MAX1392 only [(AIN+) + (AIN-)] / 2	0		V _{DD}	V		
Input Leakage Current		Channel not selected, or conversion stopped, or in shutdown mode			±1.5	μA		
Input Capacitance				16		рF		
REFERENCE INPUT (REF)		•						
REF Input Voltage Range	VREF		0.6		V _{DD} + 0.05	V		
REF Input Capacitance				24		рF		
REF DC Leakage Current				0.025	±2.5	μA		
REF Input Dynamic Current		357ksps		20	60	μA		
DIGITAL INPUTS (SCLK, CS, OE,	, CH 1/CH2, U	NI/BIP)						
Input-Voltage Low	VIL				0.3 x V _{DD}	V		
Input-Voltage High	V _{IH}		0.7 x V _{DD}			V		
Input Hysteresis				0.06 x V _{DD}		V		
Input Leakage Current	١ _{IL}	Inputs at GND or V _{DD}			±1	μA		
	0	CS, OE	1 12.5			pF		
Input Capacitance	CIN	CH1/CH2, UNI/BIP						
DIGITAL OUTPUT (DOUT)								
Output-Voltage Low	Vol	I _{SINK} = 2mA			0.1 x V _{DD}	V		
Output-Voltage High	V _{OH}	ISOURCE = 2mA	0.9 x V _{DD}			V		

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +1.5V to +3.6V, V_{REF} = V_{DD}, C_{REF} = 0.1 μ F, f_{SCLK} = 5MHz, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS			ТҮР	MAX	UNITS
Tri-State Leakage Current	ILT	$\overline{OE} = V_{DD}$				±1	μΑ
Tri-State Output Capacitance	COUT	$\overline{OE} = V_{DD}$			10		pF
POWER SUPPLY							
Positive Supply Voltage	V _{DD}			1.5		3.6	V
	IDD	fSAMPLE = 100ksps	$V_{DD} = 1.6V$		150	170	μA
			$V_{DD} = 3V$		200	225	
Depitive Supply Current (Note 4)		fsample = 357ksps	$V_{DD} = 1.6V$		520	600	
Positive Supply Current (Note 4)			$V_{DD} = 3V$		710	800	
		Power-down mode (Note 5)			5	10	-
		Power-down mode (Note 6)			0.2	±2.5	
Power-Supply Rejection (Note 7)	PSR	V _{DD} = 1.5V to 3.6V, full-scale input			±150	±1000	μV/V

TIMING CHARACTERISTICS

 $(V_{DD} = +1.5V \text{ to } +3.6V, V_{REF} = V_{DD}, C_{REF} = 0.1 \mu\text{F}, \text{ fsclk} = 5\text{MHz}, \text{T}_{A} = T_{MIN} \text{ to } T_{MAX}, \text{ unless otherwise noted}. Typical values are at T_{A} = +25^{\circ}\text{C}.)$ (Figure 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	ТҮР	МАХ	UNITS
SCLK Clock Period	tCP		200		10000	ns
SCLK Pulse-Width High	tсн		90			ns
SCLK Pulse-Width Low	t _{CL}		90			ns
CS Fall to SCLK Rise Setup	tcss		80			ns
SCLK Rise to CS Fall Ignore	tcso		0			ns
SCLK Fall to DOUT Valid	tDOV	$C_{LOAD} = 0$ to $30pF$	10		80	ns
OE Rise to DOUT Disable	tdod			6	20	ns
OE Fall to DOUT Enable	tDOE			9	20	ns
CS Pulse-Width High or Low	tcsw		80			ns
OE Pulse-Width High or Low	toew		80			ns
CH1/CH2 Setup Time (to the First SCLK)	tCHS	MAX1395 only	10			ns
CH1/CH2 Hold Time (to the First SCLK)	tснн	MAX1395 only	0			ns
UNI/BIP Setup Time (to the First SCLK)	tubs	MAX1392 only	10			ns
UNI/BIP Hold Time (to the First SCLK)	tubh	MAX1392 only	0			ns

Note 1: Devices are production tested at $T_A = +25^{\circ}$ C and $T_A = +85^{\circ}$ C. Specifications to -40°C are guaranteed by design.

Note 2: $V_{DD} = 1.5V$, $V_{REF} = 1.5V$, and $V_{AIN} = 1.5V$.

Note 3: V_{DD} = 1.5V, V_{REF} = 1.5V, V_{AIN} = 1.5V_{P-P}, f_{SCLK} = 5MHz, f_{SAMPLE} = 357ksps, and f_{IN} (sine-wave) = 85kHz.

Note 4: All digital inputs swing between V_{DD} and GND. $V_{REF} = V_{DD}$, $f_{IN} = 85$ kHz sine-wave, $V_{AIN} = V_{REFP-P}$, $C_{LOAD} = 30$ pF on DOUT. **Note 5:** $\overline{CS} = V_{DD}$, $\overline{OE} = UNI/\overline{BIP} = \overline{CH1}/\overline{CH2} = V_{DD}$ or GND, SCLK is active.

Note 6: $\overline{CS} = V_{DD}$, $\overline{OE} = UNI/BIP = \overline{CH1}/CH2 = V_{DD}$ or GND, SCLK is inactive.

Note 7: Change in VAIN at code boundary 1022.5.



Figure 1. Detailed Serial-Interface Timing Diagram



Figure 2. Load Circuits for Enable/Disable Times

Typical Operating Characteristics

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MAX1392/MAX1395

 $(V_{DD} = +1.5V, V_{RFF} = +1.5V, C_{RFF} = 0.1\mu$ F, $C_{I} = 30$ pF, $f_{SCIK} = 5$ MHz. $T_{A} = +25^{\circ}$ C, unless otherwise noted.)

Typical Operating Characteristics (continued)



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Pin Description

PIN			FUNCTION		
MAX1392	MAX1395	NAME	FUNCTION		
1	1	V _{DD}	Positive Supply Voltage. Connect V_{DD} to a 1.5V to 3.6V power supply. Bypass V_{DD} to GND with a 0.1µF capacitor as close to the device as possible.		
2	_	AIN-	Negative Analog Input		
_	2	AIN2	Analog Input Channel 2		
3	_	AIN+	Positive Analog Input		
_	3	AIN1	Analog Input Channel 1		
4	4	GND	Ground		
5	5	REF	External Reference Voltage Input. $V_{REF} = 0.6V$ to ($V_{DD} + 0.05V$). Bypass REF to GND with a 0.1µF capacitor as close to the device as possible.		
6	_	UNI/BIP	Input-Mode Select. Drive UNI/BIP high to select unipolar input mode. Pull UNI/BIP low to select bipolar input mode. In unipolar mode, the output data is in straight binary format. In bipolar mode, the output data is in two's-complement format.		
	6	CH1/CH2	Channel-Select Input. Pull $\overline{CH1}/CH2$ low to select channel 1. Drive $\overline{CH1}/CH2$ high to select channel 2.		
7	7	ŌĒ	Active-Low Output Enable. Pull \overline{OE} low to enable DOUT. Drive \overline{OE} high to disable DOUT. Connect to \overline{CS} to interface with SPI, QSPI, and MICROWIRE devices or set low to interface with DSP devices.		
8	8	CS	Active-Low Chip-Select Input. A falling edge on $\overline{\text{CS}}$ initiates power-up and acquisition.		
9	9	DOUT	Serial-Data Output. DOUT changes state on the falling edge of SCLK. DOUT is high impedance when $\overline{\text{OE}}$ is high.		
10	10	SCLK	Serial-Clock Input. SCLK drives the conversion process and clocks data out. Acquisition ends on the 3rd falling edge after the \overline{CS} falling edge. The LSB is clocked out on the SCLK 13th falling edge and the device enters AutoShutdown mode (see Figures 8, 9, and 10).		
_	_	EP	Exposed Pad. Not internally connected. Connect the exposed pad to GND or leave unconnected.		

Detailed Description

The MAX1392/MAX1395 use an input track and hold (T/H) circuit along with a SAR to convert an analog input signal to a serial 10-bit digital output data stream. The serial interface provides easy interfacing to microprocessors and DSPs. Figure 3 shows the simplified functional diagram for the MAX1392 (1 channel, true differential) and the MAX1395 (2 channels, single ended).

True-Differential Analog Input T/H

The equivalent input circuit of Figure 4 shows the MAX1392/MAX1395 input architecture, which is composed of a T/H, a comparator, and a switched-capacitor DAC. The T/H enters its tracking mode on the falling edge of CS (while OE is held low). The positive input capacitor is connected to AIN+ (MAX1392), or to AIN1 or AIN2 (MAX1395). The negative input capacitor is connected to AIN- (MAX1392) or GND (MAX1395). The T/H enters its hold mode on the 3rd falling edge of SCLK



Figure 3. Simplified Functional Diagram

and the difference between the sampled positive and negative input voltages is converted. The time required for the T/H to acquire an input signal is determined by how quickly its input capacitance is charged. The required acquisition time lengthens as the input signal's source impedance increases. The acquisition time, tACQ, is the minimum time needed for the signal to be acquired. It is calculated by the following equation:

$$t_{ACQ} \ge 7.4 \times (R_{SOURCE} + R_{IN}) \times C_{IN} + t_{PU}$$

where:

RSOURCE is the source impedance of the input signal.

 R_{IN} = 500 Ω , which is the equivalent differential analog input resistance.

 C_{IN} = 16pF, which is the equivalent differential analog input capacitance.

tpu = 400ns.

Note: t_{ACQ} is never less than 600ns and any source impedance below 400Ω does not significantly affect the ADC's AC performance.



Figure 4. Equivalent Input Circuit

Analog Input Bandwidth

The ADC's input-tracking circuitry has a 4MHz fullpower bandwidth, making it possible to digitize highspeed transient events and measure periodic signals with bandwidths exceeding the ADC's sampling rate by using undersampling techniques.

Use anti-alias filtering to avoid high-frequency signals being aliased into the frequency band of interest.

Analog Input Range and Protection

The MAX1392/MAX1395 produce a digital output that corresponds to the analog input voltage as long as the analog inputs are within their specified range. When operating the MAX1392 in unipolar mode (UNI/BIP = 1), the specified differential analog input range is from 0 to VREF. When operating in bipolar mode (UNI/BIP = 0), the differential analog input range is from -V_{REF}/2 to +V_{REF}/2 with a common mode range of 0 to V_{DD}. The MAX1395 has an input range from 0 to V_{REF}.

Internal protection diodes confine the analog input voltage within the region of the analog power input rails (V_{DD}, GND) and allow the analog input voltage to swing from GND - 0.3V to V_{DD} + 0.3V without damage. Input voltages beyond GND - 0.3V and V_{DD} + 0.3V forward bias the internal protection diodes. In this situation, limit the forward diode current to less than 50mA to avoid damage to the MAX1392/MAX1395.

Output Data Format

Figures 8, 9, and 10 illustrate the conversion timing for the MAX1392/MAX1395. Fourteen SCLK cycles are required to read the conversion result and data on DOUT transitions on the falling edge of SCLK. The conversion result contains 4 zeros, followed by 10 data bits with the data in MSB-first format. For the MAX1392, data is straight binary for unipolar mode and two's complement for bipolar mode. For the MAX1395, data is always straight binary.

Transfer Function

Figure 5 shows the unipolar transfer function for the MAX1392/MAX1395. Figure 6 shows the bipolar transfer function for the MAX1392. Code transitions occur halfway between successive-integer LSB values.



Figure 5. Unipolar Transfer Function

Applications Information

Starting a Conversion

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A falling edge on \overline{CS} initiates the power-up sequence and begins acquiring the analog input as long as \overline{OE} is also asserted low. On the 3rd SCLK falling edge, the analog input is held for conversion. The most significant bit (MSB) decision is made and clocked onto DOUT on the 4th SCLK falling edge. Valid DOUT data is available to be clocked into the master (microcontroller (μ C)) on the following SCLK rising edge. The rest of the bits are decided and clocked out to DOUT on each successive SCLK falling edge. See Figures 8 and 9 for conversion timing diagrams.

Once a conversion has been initiated, \overline{CS} can go high at any time. Further falling edges of \overline{CS} do not reinitiate an acquisition cycle until the current conversion completes. Once a conversion completes, the first falling edge of \overline{CS} begins another acquisition/conversion cycle.



Figure 6. Bipolar Transfer Function

Selecting Unipolar or Bipolar Mode (MAX1392 Only)

Drive UNI/BIP high to select unipolar mode or pull UNI/BIP low to select bipolar mode. UNI/BIP can be connected to V_{DD} for logic high, to GND for logic low, or actively driven. UNI/BIP needs to be stable for t_{UBS} prior to the first rising edge of SCLK after the CS falling edge (see Figure 1) for a valid conversion result when being actively driven.

Selecting Analog Input AIN1 or AIN2 (MAX1395 Only)

Pull $\overline{CH1}/CH2$ low to select AIN1 or drive $\overline{CH1}/CH2$ high to select AIN2 for conversion. $\overline{CH1}/CH2$ can be connected to V_{DD} for logic high, to GND for logic low, or actively driven. $\overline{CH1}/CH2$ needs to be stable for t_{CHS} prior to the first rising edge of SCLK after the \overline{CS} falling edge (see Figure 1) for a valid conversion result when being actively driven.

MAX1392/MAX1395

1.5V to 3.6V, 357ksps, 1-Channel True-Differential/ 2-Channel Single-Ended, 10-Bit, SAR ADCs

AutoShutdown Mode

The ADC automatically powers down on the SCLK falling edge that clocks out the LSB. This is the falling edge after the 13th SCLK. DOUT goes low when the LSB has been clocked into the master (μ C) on the 16th rising SCLK edge.

Alternatively, drive \overline{OE} high to force the MAX1392/ MAX1395 into power-down. Whenever \overline{OE} goes high, the ADC powers down and disables DOUT regardless of \overline{CS} , SCLK, or the state of the ADC. DOUT enters a high-impedance state after t_{DOD}.

External Reference

The MAX1392/MAX1395 use an external reference between 0.6V and (V_DD + 50mV). Bypass REF with a



Figure 7. Common Serial-Interface Connections to the MAX1392/MAX1395



0.1µF capacitor to GND for best performance (see the *Typical Operating Circuit*).

Serial Interface

The MAX1392/MAX1395 serial interface is fully compatible with SPI, QSPI, and MICROWIRE (see Figure 7). If a serial interface is available, set the μ C's serial interface in master mode so the μ C generates the serial clock. Choose a clock frequency between 100kHz and 5MHz. CS and OE can be connected together and driven simultaneously. OE can also be connected to GND if the DOUT bus is not shared and driven independently.

SPI and MICROWIRE

When using SPI or MICROWIRE, make the µC the bus master and set CPOL = 0 and CPHA = 0 or CPOL = 1 and CPHA = 1. (These are the bits in the SPI or MICROWIRE control register.) Two consecutive 1-byte reads are required to get the entire 10-bit result from the ADC. The MAX1392/MAX1395 shut down after clocking the LSB and DOUT becomes high impedance. DOUT transitions on SCLK's falling edge and is clocked into the μ C on the SCLK's rising edge. See Figure 7 for connections and Figures 8 and 9 for timing diagrams. The conversion result contains 4 zeros. followed by the 10 data bits with the data in MSB-first format. When using CPOL = 0 and CPHA = 0 or CPOL = 1 and CPHA = 1. the MSB of the data is clocked into the µC on the SCLK's fifth rising edge. To be compatible with SPI and MICROWIRE, connect CS and OE together and drive simultaneously.

QSPI

Unlike SPI, which requires two 1-byte reads to acquire the 10 bits of data from the ADC, QSPI allows the minimum number of clock cycles necessary to clock in the data. The MAX1392/MAX1395 require a minimum of 14 clock cycles from the μ C to clock out the 10 bits of data. See Figure 7 for connections and Figures 8 and 9 for timing diagrams. The conversion result contains 4 zeros, followed by the 10 data bits with the data in MSB-first format. The MAX1392/MAX1395 shut down after clocking out the LSB. DOUT then becomes high impedance. When using CPOL = 0 and CPHA = 0 or CPOL = 1 and CPHA = 1, the MSB of the data is clocked into the μ C on the SCLK's fifth rising edge. To be compatible with QSPI, connect \overline{CS} and \overline{OE} together and drive simultaneously.

DSP Interface

Figure 10 shows the timing for DSP operation. Figure 11 shows the connections between the MAX1392/MAX1395 and several common DSPs.



Figure 8. Serial-Interface Timing for SPI/QSPI (CPOL = CPHA = 1) and MICROWIRE (G6 = 0, G5 = 1)



Figure 9. Serial-Interface Timing for SPI/QSPI (CPOL = CPHA = 0) and MICROWIRE (G6 = 0, G5 = 0)



Figure 10. DSP Serial-Timing Diagram

As shown in Figure 11, drive the MAX1392/MAX1395 chip-select input (\overline{CS}) with the DSP's frame-sync signal. \overline{OE} may be connected to GND or driven independently. For continuous conversion operation, keep \overline{OE} low and make the \overline{CS} falling edge coincident with the 14th falling edge of the SCLK. Fourteen-bit data transfers can also be performed with compatible DSPs.

Unregulated Two-Cell or Single Lithium LiMnO₂ Cell Operation

Low operating voltage (1.5V to 3.6V) and ultra-low-power consumption make the MAX1392/MAX1395 ideal for low cost, unregulated, battery-powered applications without the need for a DC-DC converter. Power the MAX1392/MAX1395 directly from two alkaline/NiMH/NiCd cells in series or a single lithium coin cell as shown in the *Typical Operating Circuit*.

Fresh alkaline cells have a voltage of approximately 1.5V per cell (3V with 2 cells in series) and approach end of life at 0.8V (1.6V with 2 cells in series). A typical 2xAA alkaline discharge curve is shown in Figure 12a. A typical CR2032 lithium (LiMnO₂) coin cell discharge curve is shown in Figure 12b.

Layout, Grounding, and Bypassing

For best performance, use PC boards. Board layout must ensure that digital and analog signal lines are separated from each other. Do not run analog and digital (especially clock) lines parallel to one another, or digital lines underneath the ADC package. Figure 13 shows the recommended system ground connections. Establish a single-point analog ground (star ground point) at the MAX1392/MAX1395s' GND pin or use the ground plane.

High-frequency noise in the power supply (V_{DD}) degrades the ADC's performance. Bypass V_{DD} to GND with a 0.1µF capacitor as close to the device as possible. Minimize capacitor lead lengths for best supply noise rejection. To reduce the effects of supply noise, a 10 Ω resistor can be connected as a lowpass filter to attenuate supply noise.

Exposed Pad

The MAX1392/MAX1395 TDFN package has an exposed pad on the bottom of the package. This pad is not internally connected. Connect the exposed pad to the GND pin on the MAX1392/MAX1395 or leave unconnected for proper electrical performance.

Definitions

Integral Nonlinearity (INL)

INL is the deviation of the values on an actual transfer function from a straight line. For the MAX1392/ MAX1395, this straight line is between the end points of the transfer function once offset and gain errors have been nullified. INL deviations are measured at every step and the worst-case deviation is reported in the *Electrical Characteristics* section.

MAX1392/MAX1395







Differential Nonlinearity (DNL)

DNL is the difference between an actual step width and the ideal value of 1 LSB. A DNL error specification of less than \pm 1 LSB guarantees no missing codes and a monotonic transfer function. For the MAX1392/ MAX1395, DNL deviations are measured at every step and the worst-case deviation is reported in the *Electrical Characteristics* section.



Figure 12a. Typical 2xAA Discharge Curve at 100ksps



Figure 12b. Typical CR2032 Discharge Curve at 100ksps

Signal-to-Noise Plus Distortion (SINAD)

SINAD is computed by taking the ratio of the RMS signal to the RMS noise plus the RMS distortion. RMS noise includes all spectral components to the Nyquist frequency excluding the fundamental, the first five harmonics (HD2–HD6), and the DC offset. RMS distortion includes the first five harmonics (HD2–HD6).





Figure 13. Power-Supply Grounding Connections

Signal-to-Noise Ratio (SNR)

SNR is a dynamic figure of merit that indicates the converter's noise performance. For a waveform perfectly reconstructed from digital samples, the theoretical maximum SNR is the ratio of the full-scale analog input (RMS value) to the RMS quantization error (residual error). The ideal, theoretical minimum analog-to-digital noise is caused by quantization error only and results directly from the ADC's resolution (N bits):

 $SNR_{dB[max]} = 6.02_{dB} \times N + 1.76_{dB}$

In reality, there are other noise sources such as thermal noise, reference noise, and clock jitter that also degrade SNR. SNR is computed by taking the ratio of the RMS signal to the RMS noise. RMS noise includes all spectral components to the Nyquist frequency excluding the fundamental, the first five harmonics, and the DC offset.

Total Harmonic Distortion (THD)

THD is a dynamic figure of merit that indicates how much harmonic distortion the converter adds to the signal.

THD is the ratio of the RMS sum of the first five harmonics of the fundamental signal to the fundamental itself. This is expressed as:

$$THD = 20 \times log \left(\frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2 + V_6^2}}{V_1} \right)$$

where V_1 is the fundamental amplitude, and V_2 through V_6 are the amplitudes of the 2nd- through 6th-order harmonics.

Spurious-Free Dynamic Range (SFDR) SFDR is a dynamic figure of merit that indicates the lowest usable input signal amplitude. SFDR is the ratio of the RMS amplitude of the fundamental (maximum signal component) to the RMS value of the next-largest spurious component, excluding DC offset. SFDR is specified in decibels relative to the carrier (dBc).

Intermodulation Distortion (IMD)

IMD is the ratio of the RMS sum of the intermodulation products to the RMS sum of the two fundamental input tones. This is expressed as:

$$\mathsf{IMD} = 20 \times \log \left(\frac{\sqrt{\mathsf{V_{IM1}}^2 + \mathsf{V_{IM2}}^2 + \dots + \mathsf{V_{IM3}}^2 + \mathsf{V_{IMN}}^2}}{\sqrt{\mathsf{V_1}^2 + \mathsf{V_2}^2}} \right)$$

The fundamental input tone amplitudes (V₁ and V₂) are at -6.5dBFS. Fourteen intermodulation products (V_{IM}) are used in the MAX1392/MAX1395 IMD calculation. The intermodulation products are the amplitudes of the output spectrum at the following frequencies, where f_{IN1} and f_{IN2} are the fundamental input tone frequencies:

- 2nd-order intermodulation products: fIN1 + fIN2, fIN2 - fIN1
- 3rd-order intermodulation products: 2 x fIN1 - fIN2, 2 x fIN2 - fIN1, 2 x fIN1 + fIN2, 2 x fIN2 + fIN1
- 4th-order intermodulation products: $3 \times f_{IN1} - f_{IN2}$, $3 \times f_{IN2} - f_{IN1}$, $3 \times f_{IN1} + f_{IN2}$, $3 \times f_{IN2} + f_{IN1}$
- 5th-order intermodulation products: 3 x f_{IN1} - 2 x f_{IN2}, 3 x f_{IN2} - 2 x f_{IN1}, 3 x f_{IN1} + 2 x f_{IN2}, 3 x f_{IN2} + 2 x f_{IN1}

Channel-to-Channel Crosstalk

Channel-to-channel crosstalk indicates how well each analog input is isolated from the others. The channel-tochannel crosstalk for the MAX1395 is measured by applying DC to channel 2 while an AC sine wave is applied to channel 1. An FFT is taken for channel 1 and channel 2 and the difference (in dB) is reported as the channel-to-channel crosstalk.

Aperture Delay

The MAX1392/MAX1395 sample data on the falling edge of its third SCLK cycle (Figure 14). In actuality, there is a small delay between the falling edge of the sampling clock and the actual sampling instant. Aperture delay (t_{AD}) is the time defined between the falling edge of the sampling clock and the instant when an actual sample is taken.

Aperture Jitter

Aperture jitter (t_{AJ}) is the sample-to-sample variation in the aperture delay (Figure 14).

DC Power-Supply Rejection Ratio (PSRR)

DC PSRR is defined as the change in the positive fullscale transfer function point caused by a full range variation in the analog power-supply voltage (V_{DD}).



TRANSISTOR COUNT: 9106 PROCESS: BICMOS



Figure 14. T/H Aperture Timing

Typical Operating Circuit



_Pin Configurations



Package Information

For the latest package outline information and land patterns, go to <u>www.maxim-ic.com/packages</u>. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
10 TDFN-EP	T1033+1	<u>21-0137</u>

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0 11/00		Removed the future status from the MAX1392 part number in the Ordering Information table.	1
2	11/00	In the <i>Electrical Characteristics</i> table, changed the Input Leakage Current parameter from $\pm 1\mu A$ (max) to $\pm 1.5\mu A$ (max).	3
3	10/09	Removed the military grade packages from the <i>General Description</i> section, <i>Ordering Information</i> table, and <i>Absolute Maximum Ratings</i> section.	1, 2

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Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600