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Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

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EVALUATION KIT AVAILABLE

12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

General Description

The MAX1221/MAX1223/MAX1343 integrate a multichannel, 12-bit, analog-to-digital converter (ADC) and a 12-bit, digital-to-analog converter (DAC) in a single IC. The devices also include a temperature sensor and configurable general-purpose I/O ports (GPIOs) with a 25MHz SPI™-/QSPI™-/MICROWIRE™-compatible serial interface. The ADC is available in a 12 or an eight input-channel version. The DAC outputs settle within 2.0µs, and the ADC has a 225ksps conversion rate.

All devices include an internal reference (2.5V) providing a well-regulated, low-noise reference for both the ADC and DAC. Programmable reference modes for the ADC and DAC allow the use of an internal reference, an external reference, or a combination of both. Features such as an internal ±1°C accurate temperature sensor, FIFO, scan modes, programmable internal or external clock modes, data averaging, and AutoShutdown™ allow users to minimize both power consumption and processor requirements. The low glitch energy (4nV•s) and low digital feedthrough (0.5nV•s) of the integrated DACs make these devices ideal for digital control of fast-response closed-loop systems.

The devices are guaranteed to operate with a supply voltage from +2.7V to +5.25V. The devices consume 2.5mA at 225ksps throughput, only 22µA at 1ksps throughput, and under 0.2µA in the shutdown mode. The MAX1221/MAX1343 offer four GPIOs that can be configured as inputs or outputs.

The MAX1221/MAX1223/MAX1343 are available in 36-pin thin QFN packages. All devices are specified over the -40°C to +85°C temperature range.

Applications

Closed-Loop Controls for Optical Components and Base Stations

System Supervision and Control

Data-Acquisition Systems

Features

- **12-Bit, 225ksps ADC**
  - **Analog Multiplexer with True-Differential Track/Hold (T/H)**
  - **12 Single-Ended Channels or Six Differential Channels (Unipolar or Bipolar) (MAX1223)**
  - **Eight Single-Ended Channels or Four Differential Channels (Unipolar or Bipolar) (MAX1221/MAX1343)**
  - **Excellent Accuracy: ±0.5 LSB INL, ±0.5 LSB DNL**
- **12-Bit, Octal, 2µs Settling DAC (MAX1221/MAX1223)**
  - **Ultra-Low Glitch Energy (4nV•s)**
  - **Power-Up Options from Zero Scale or Full Scale**
  - **Excellent Accuracy: ±0.5 LSB INL**
- **Internal Reference or External Single-Ended/Differential Reference**
  - **Internal Reference Voltage 2.5V**
- **Internal ±1°C Accurate Temperature Sensor**
- **On-Chip FIFO Capable of Storing 16 ADC Conversion Results and One Temperature Result**
- **On-Chip Channel-Scan Mode and Internal Data-Averaging Features**
- **Analog Single-Supply Operation**
  - **+2.7V to +5.25V**
- **2.7V to AV_{DD} Digital Supply**
- **25MHz, SPI/QSPI/MICROWIRE Serial Interface**
- **AutoShutdown Between Conversions**
- **Low-Power ADC**
  - **2.5mA at 225ksps**
  - **22µA at 1ksps**
  - **0.2µA at Shutdown**
- **Low-Power DAC: 1.5mA**
- **Evaluation Kit Available (Order MAX1258EVKIT)**

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

Pin Configurations appear at end of data sheet.

Ordering Information/Selector Guide

PART	PIN-PACKAGE	REF VOLTAGE (V)	ANALOG SUPPLY VOLTAGE (V)	RESOLUTION BITS**	ADC CHANNELS	DAC CHANNELS	GPIOs	PKG CODE
MAX1221BETX	36 Thin QFN-EP*	2.5	2.7 to 5.25	12	8	8	4	T3666-3
MAX1223BETX	36 Thin QFN-EP*	2.5	2.7 to 5.25	12	12	8	0	T3666-3
MAX1343BETX	36 Thin QFN-EP*	2.5	2.7 to 5.25	12	8	4	4	T3666-3

Note: *All devices are specified over the -40°C to +85°C operating temperature range.*
**EP = Exposed pad.*
***Number of resolution bits refers to both DAC and ADC.*

12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

ABSOLUTE MAXIMUM RATINGS

AV_{DD} to AGND ....-0.3V to +6V
DGND to AGND...-0.3V to +0.3V
DV_{DD} to AV_{DD} ....-3.0V to +0.3V
Digital Inputs to DGND..-0.3V to +6V
Digital Outputs to DGND.........................-0.3V to (DV_{DD} + 0.3V)
Analog Inputs, Analog Outputs and REF_
to AGND...-0.3V to (AV_{DD} + 0.3V)
Maximum Current into Any Pin (except AGND, DGND, AV_{DD}, DV_{DD}, and OUT_)...50mA
Maximum Current into OUT_...100mA
Continuous Power Dissipation (T_A = +70°C)
36-Pin Thin QFN (6mm x 6mm)
(derate 26.3mW/°C above +70°C).....................2105.3mW
Operating Temperature Range ....-40°C to +85°C
Storage Temperature Range ....-60°C to +150°C
Junction Temperature...+150°C
Lead Temperature (soldering, 10s) ....+300°C

Note: If the package power dissipation is not exceeded, one output at a time may be shorted to AV_{DD}, DV_{DD}, AGND, or DGND indefinitely.

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

(AV_{DD} = DV_{DD} = 2.7V to 5.25V, external reference V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at AV_{DD} = DV_{DD} = 3V. T_A = +25°C. Outputs are unloaded, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ADC						
DC ACCURACY (Note 1)						
Resolution			12			Bits
Integral Nonlinearity	INL			±0.5	±1.0	LSB
Differential Nonlinearity	DNL			±0.5	±1.0	LSB
Offset Error				±0.5	±4.0	LSB
Gain Error		(Note 2)		±0.5	±4.0	LSB
Gain Temperature Coefficient				±0.8		ppm/°C
Channel-to-Channel Offset				±0.1		LSB
DYNAMIC SPECIFICATIONS (10kHz sine-wave input, V_{IN} = 2.5V_{P-P}, 225ksps, f_{CLK} = 3.6MHz)						
Signal-to-Noise Plus Distortion	SINAD			70		dB
Total Harmonic Distortion (Up to the Fifth Harmonic)	THD			-76		dBc
Spurious-Free Dynamic Range	SFDR			72		dBc
Intermodulation Distortion	IMD	f_{IN1} = 9.9kHz, f_{IN2} = 10.2kHz		76		dBc
Full-Linear Bandwidth		SINAD > 70dB		100		kHz
Full-Power Bandwidth		-3dB point		1		MHz
CONVERSION RATE (Note 3)						
Power-Up Time	t_{PU}	External reference		0.8		µs
		Internal reference (Note 4)		218		Conversion clock cycles

ELECTRICAL CHARACTERISTICS (continued)

(AV_{DD} = DV_{DD} = 2.7V to 5.25V, external reference V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at AV_{DD} = DV_{DD} = 3V. T_A = +25°C. Outputs are unloaded, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Acquisition Time	t_{ACQ}	(Note 5)	0.6			µs
Conversion Time	t_{CONV}	Internally clocked		5.5		µs
		Externally clocked	3.6			
External-Clock Frequency	f_{CLK}	Externally clocked conversion (Note 5)	0.1		3.6	MHz
Duty Cycle			40		60	%
Aperture Delay				30		ns
Aperture Jitter				< 50		ps
ANALOG INPUTS						
Input Voltage Range (Note 6)		Unipolar	0		V_{REF}	V
		Bipolar	$-V_{REF}$ / 2		V_{REF} / 2	
Input Leakage Current				±0.01	±1	µA
Input Capacitance				24		pF
INTERNAL TEMPERATURE SENSOR						
Measurement Error (Notes 5, 7)		T_A = +25°C		±0.7		°C
		T_A = T_{MIN} to T_{MAX}		±1.0	±2.0	
Temperature Resolution				1/8		°C/LSB
INTERNAL REFERENCE						
REF1 Output Voltage		(Note 8)	2.482	2.50	2.518	V
REF1 Voltage Temperature Coefficient	TC_{REF}			±30		ppm/°C
REF1 Output Impedance				6.5		kΩ
REF1 Short-Circuit Current		V_{REF} = 2.5V		0.39		mA
EXTERNAL REFERENCE						
REF1 Input Voltage Range	V_{REF1}	REF mode 11 (Note 4)	1		AV_{DD} + 0.05	V
REF2 Input Voltage Range (Note 4)	V_{REF2}	REF mode 01	1		AV_{DD} + 0.05	V
		REF mode 11	0		1	

12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

ELECTRICAL CHARACTERISTICS (continued)

(AV_{DD} = DV_{DD} = 2.7V to 5.25V, external reference V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at AV_{DD} = DV_{DD} = 3V. T_A = +25°C. Outputs are unloaded, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
REF1 Input Current (Note 9)	I_{REF1}	V_{REF} = 2.5V, f_{SAMPLE} = 225ksps		25	80	µA
		Acquisition between conversions		±0.01	±1	
REF2 Input Current	I_{REF2}	V_{REF} = 2.5V, f_{SAMPLE} = 225ksps		25	80	µA
		Acquisition between conversions		±0.01	±1	
DAC						
DC ACCURACY (Note 10)						
Resolution			12			Bits
Integral Nonlinearity	INL			±0.5	±4	LSB
Differential Nonlinearity	DNL	Guaranteed monotonic			±1.0	LSB
Offset Error	V_{OS}	(Note 8)		±3	±10	mV
Offset-Error Drift				±10		ppm of FS/°C
Gain Error	GE	(Note 8)		±5	±10	LSB
Gain Temperature Coefficient				±8		ppm of FS/°C
DAC OUTPUT						
Output Voltage Range		No load	0.02		AV_{DD} - 0.02	V
		10kΩ load to either rail	0.1		AV_{DD} - 0.1	
DC Output Impedance				0.5		Ω
Capacitive Load		(Note 11)			1	nF
Resistive Load to AGND	R_L	AV_{DD} = 2.7V, V_{REF} = 2.5V, gain error < 1%	2000			Ω

ELECTRICAL CHARACTERISTICS (continued)

($AV_{DD} = DV_{DD}$ = 2.7V to 5.25V, external reference V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at $AV_{DD} = DV_{DD}$ = 3V. T_A = +25°C. Outputs are unloaded, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Wake-Up Time (Note 12)		From power-down mode, AV_{DD} = 5V		25		µs
		From power-down mode, AV_{DD} = 2.7V		21		
1kΩ Output Termination		Programmed in power-down mode		1		kΩ
100kΩ Output Termination		At wake-up or programmed in power-down mode		100		kΩ
DYNAMIC PERFORMANCE (Notes 5, 13)						
Output-Voltage Slew Rate	SR	Positive and negative	3			V/µs
Output-Voltage Settling Time	t_S	To 1 LSB, 400 - C00 hex (Note 7)		2	5	µs
Digital Feedthrough		Code 0, all digital inputs from 0 to DV_{DD}		0.5		nV•s
Major Code Transition Glitch Impulse		Between codes 2047 and 2048		4		nV•s
Output Noise (0.1Hz to 50MHz)		From V_{REF}		660		μV_{P-P}
		Using internal reference		720		
Output Noise (0.1Hz to 500kHz)		From V_{REF}		260		μV_{P-P}
		Using internal reference		320		
DAC-to-DAC Transition Crosstalk				0.5		nV•s
INTERNAL REFERENCE						
REF1 Output Voltage			2.482	2.50	2.518	V
REF1 Temperature Coefficient	TC_{REF}			±30		ppm/°C
REF1 Short-Circuit Current		V_{REF} = 2.5V		0.39		mA
EXTERNAL-REFERENCE INPUT						
REF1 Input Voltage Range	V_{REF1}	REF modes 01, 10, and 11 (Note 4)	0.7		AV_{DD}	V
REF1 Input Impedance	R_{REF1}		70	100	130	kΩ
DIGITAL INTERFACE						
DIGITAL INPUTS (SCLK, DIN, $\overline{CS}$, $\overline{CNVST}$, $\overline{LDAC}$)						
Input-Voltage High	V_{IH}	DV_{DD} = 2.7V to 5.25V	2.4			V
Input-Voltage Low	V_{IL}	DV_{DD} = 3.6V to 5.25V			0.8	V
		DV_{DD} = 2.7V to 3.6V			0.6	
Input Leakage Current	I_L			±0.01	±10	µA
Input Capacitance	C_{IN}			15		pF
DIGITAL OUTPUT (DOUT) (Note 14)						
Output-Voltage Low	V_{OL}	I_{SINK} = 2mA			0.4	V

ELECTRICAL CHARACTERISTICS (continued)

(AV_{DD} = DV_{DD} = 2.7V to 5.25V, external reference V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at AV_{DD} = DV_{DD} = 3V. T_A = +25°C. Outputs are unloaded, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output-Voltage High	V_{OH}	I_{SOURCE} = 2mA		DV_{DD} - 0.5			V
Tri-State Leakage Current						±10	µA
Tri-State Output Capacitance	C_{OUT}				15		pF
DIGITAL OUTPUT ($\overline{EOC}$) (Note 14)							
Output-Voltage Low	V_{OL}	I_{SINK} = 2mA				0.4	V
Output-Voltage High	V_{OH}	I_{SOURCE} = 2mA		DV_{DD} - 0.5			V
Tri-State Leakage Current						±10	µA
Tri-State Output Capacitance	C_{OUT}				15		pF
DIGITAL OUTPUTS (GPIO_) (Note 14)							
GPIOC_ Output-Voltage Low		I_{SINK} = 2mA				0.4	V
		I_{SINK} = 4mA				0.8	
GPIOC_ Output-Voltage High		I_{SOURCE} = 2mA		DV_{DD} - 0.5			V
GPIOA_ Output-Voltage Low		I_{SINK} = 15mA				0.8	V
GPIOA_ Output-Voltage High		I_{SOURCE} = 15mA		DV_{DD} - 0.8			V
Tri-State Leakage Current						±10	µA
Tri-State Output Capacitance	C_{OUT}				15		pF
POWER REQUIREMENTS (Note 15)							
Digital Positive-Supply Voltage	DV_{DD}			2.7		AV_{DD}	V
Digital Positive-Supply Current	DI_{DD}	Idle, all blocks shut down			0.2	4	µA
		Only ADC on, external reference			1		mA
Analog Positive-Supply Voltage	AV_{DD}			2.70		5.25	V
Analog Positive-Supply Current	AI_{DD}	Idle, all blocks shut down			0.2	2	µA
		Only ADC on, external reference	f_{SAMPLE} = 225ksps		2.8	4.2	mA
			f_{SAMPLE} = 100ksps		2.6		
		All DACs on, no load, internal reference			1.5	4.0	
REF1 Positive-Supply Rejection	PSRR	AV_{DD} = 2.7V			-77		dB
DAC Positive-Supply Rejection	PSRD	Output code = FFFhex, AV_{DD} = 2.7V to 5.25V			±0.1	±0.5	mV

ELECTRICAL CHARACTERISTICS (continued)

(AV_{DD} = DV_{DD} = 2.7V to 5.25V, external reference V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at AV_{DD} = DV_{DD} = 3V. T_A = +25°C. Outputs are unloaded, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ADC Positive-Supply Rejection	PSRA	Full-scale input, AV_{DD} = 2.7V to 5.25V		±0.06	±0.5	mV
TIMING CHARACTERISTICS (Figures 6–13)						
SCLK Clock Period	t_{CP}		40			ns
SCLK Pulse-Width High	t_{CH}	40/60 duty cycle	16			ns
SCLK Pulse-Width Low	t_{CL}	60/40 duty cycle	16			ns
GPIO Output Rise/Fall After $\overline{CS}$ Rise	t_{GOD}	C_{LOAD} = 20pF			100	ns
GPIO Input Setup Before $\overline{CS}$ Fall	t_{GSU}		0			ns
$\overline{LDAC}$ Pulse Width	$t_{LDACPWL}$		20			ns
SCLK Fall to DOUT Transition (Note 16)	t_{DOT}	C_{LOAD} = 20pF, SLOW = 0	1.8		12.0	ns
		C_{LOAD} = 20pF, SLOW = 1	10		40	
SCLK Rise to DOUT Transition (Notes 16, 17)	t_{DOT}	C_{LOAD} = 20pF, SLOW = 0	1.8		12.0	ns
		C_{LOAD} = 20pF, SLOW = 1	10		40	
$\overline{CS}$ Fall to SCLK Fall Setup Time	t_{CSS}		10			ns
SCLK Fall to $\overline{CS}$ Rise Setup Time	t_{CSH}		0		2000	ns
DIN to SCLK Fall Setup Time	t_{DS}		10			ns
DIN to SCLK Fall Hold Time	t_{DH}		0			ns
$\overline{CS}$ Pulse-Width High	t_{CSPWH}		50			ns
$\overline{CS}$ Rise to DOUT Disable	t_{DOD}	C_{LOAD} = 20pF			25	ns
$\overline{CS}$ Fall to DOUT Enable	t_{DOE}	C_{LOAD} = 20pF	1.5		25.0	ns
$\overline{EOC}$ Fall to $\overline{CS}$ Fall	t_{RDS}		30			ns
$\overline{CS}$ or $\overline{CNVST}$ Rise to $\overline{EOC}$ Fall—Internally Clocked Conversion Time	t_{DOV}	CKSEL = 01 (temp sense) or CKSEL = 10 (temp sense), internal reference on			65	µs
		CKSEL = 01 (temp sense) or CKSEL = 10 (temp sense), internal reference initially off			140	
		CKSEL = 01 (voltage conversion)			9	
		CKSEL = 10 (voltage conversion), internal reference on			9	
		CKSEL = 10 (voltage conversion), internal reference initially off			80	
$\overline{CNVST}$ Pulse Width	t_{CSW}	CKSEL = 00, CKSEL = 01 (temp sense)	40			ns
		CKSEL = 01 (voltage conversion)	1.4			µs

12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

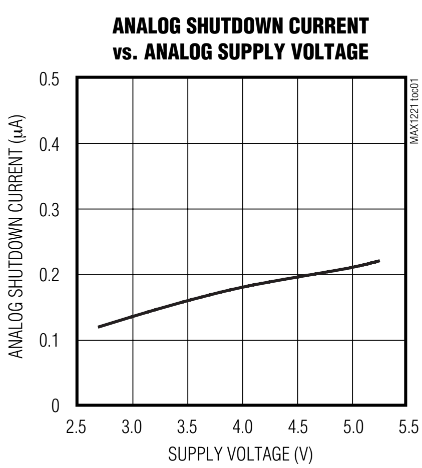
ELECTRICAL CHARACTERISTICS (continued)

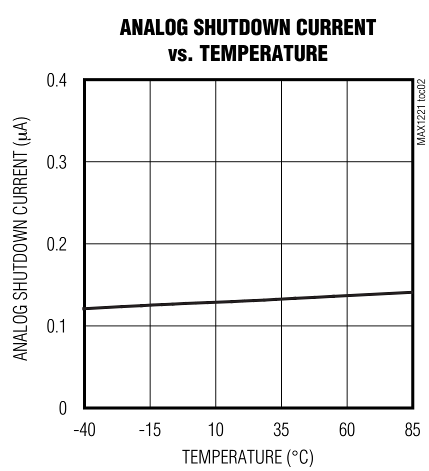
(AV_{DD} = DV_{DD} = 2.7V to 5.25V, external reference V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), T_A = -40°C to +85°C, unless otherwise noted. Typical values are at AV_{DD} = DV_{DD} = 3V. T_A = +25°C. Outputs are unloaded, unless otherwise noted.)

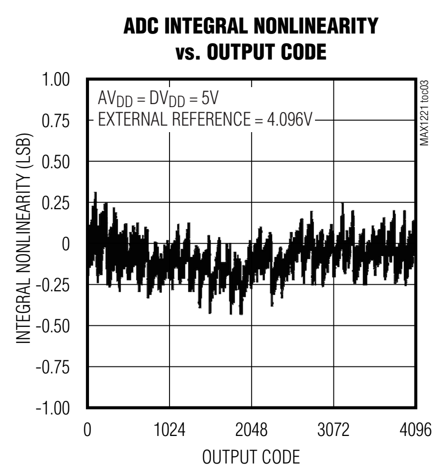
Note 1: Tested at DV_{DD} = AV_{DD} = +2.7V.
Note 2: Offset nulled.
Note 3: No bus activity during conversion. Conversion time is defined as the number of conversion clock cycles, multiplied by the clock period.
Note 4: See Table 5 for reference-mode details.
Note 5: Not production tested. Guaranteed by design.
Note 6: See the *ADC/DAC References* section.
Note 7: Fast automated test, excludes self-heating effects.
Note 8: Specified over the -40°C to +85°C temperature range.
Note 9: REFSEL[1:0] = 00 or when DACs are not powered up.
Note 10: DAC linearity, gain, and offset measurements are made between codes 115 and 3981.
Note 11: The DAC buffers are guaranteed by design to be stable with a 1nF load.
Note 12: Time required by the DAC output to power up and settle within 1 LSB in the external reference mode.
Note 13: All DAC dynamic specifications are valid for a load of 100pF and 10kΩ.
Note 14: Only one digital output (either DOUT, $\overline{EOC}$, or the GPIOs) can be indefinitely shorted to either supply at one time.
Note 15: All digital inputs at either DV_{DD} or DGND. DV_{DD} should not exceed AV_{DD}.
Note 16: See the *Reset Register* section and Table 9 for details on programming the SLOW bit.
Note 17: Clock mode 11 only.

Typical Operating Characteristics

(AV_{DD} = DV_{DD} = 3V external V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), f_{SAMPLE} = 225ksps, C_{LOAD} = 50pF, 0.1µF capacitor at REF, T_A = +25°C, unless otherwise noted.)



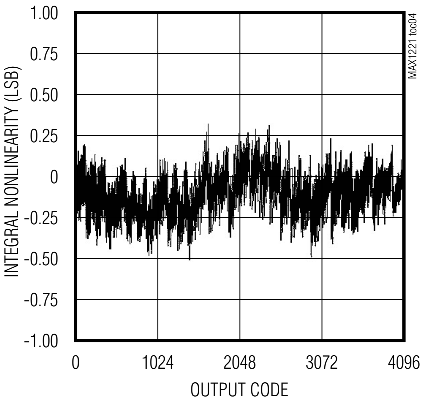




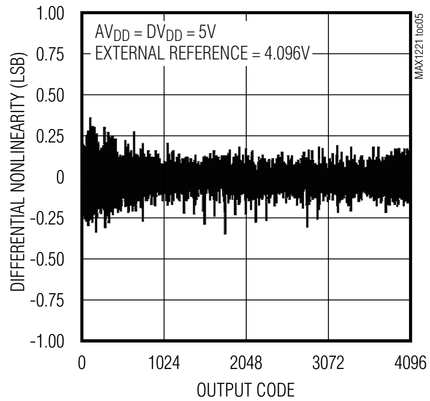
Typical Operating Characteristics (continued)

($AV_{DD} = DV_{DD}$ = 3V external V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), f_{SAMPLE} = 225ksps, C_{LOAD} = 50pF, 0.1µF capacitor at REF, T_A = +25°C, unless otherwise noted.)

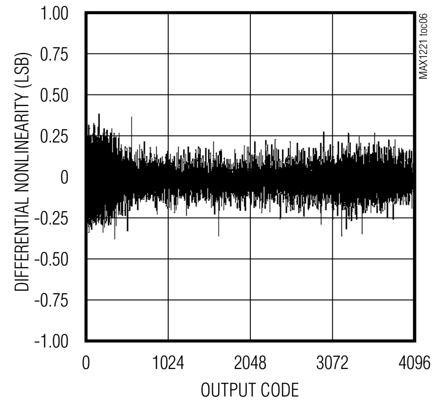
ADC INTEGRAL NONLINEARITY vs. OUTPUT CODE



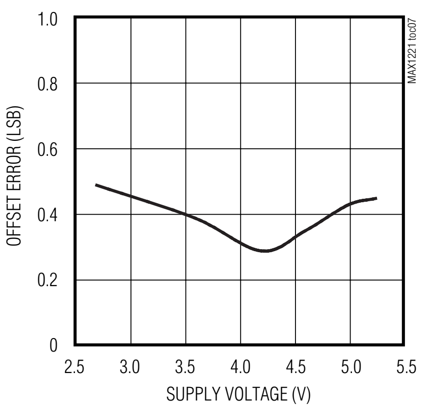
ADC DIFFERENTIAL NONLINEARITY vs. OUTPUT CODE



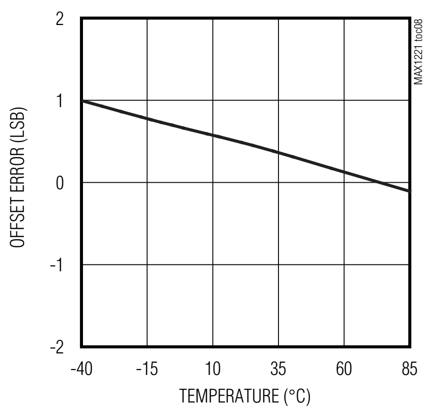
ADC DIFFERENTIAL NONLINEARITY vs. OUTPUT CODE



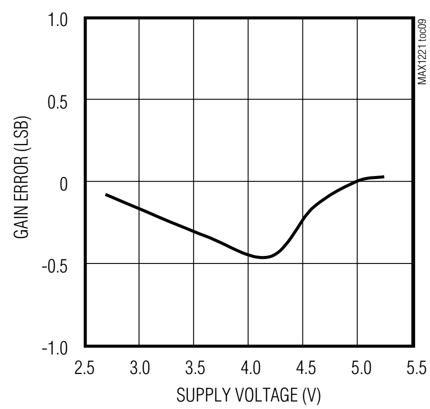
ADC OFFSET ERROR vs. ANALOG SUPPLY VOLTAGE



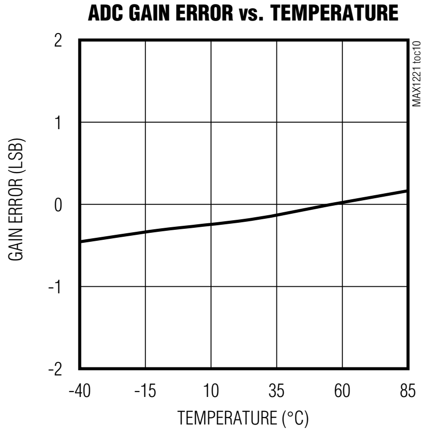
ADC OFFSET ERROR vs. TEMPERATURE



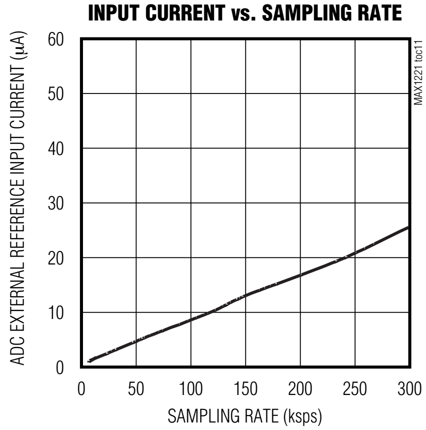
ADC GAIN ERROR vs. ANALOG SUPPLY VOLTAGE



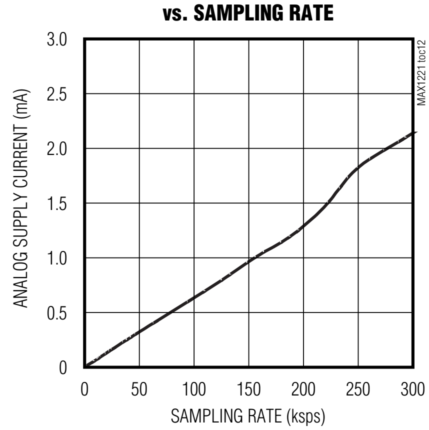
ADC GAIN ERROR vs. TEMPERATURE



ADC EXTERNAL REFERENCE INPUT CURRENT vs. SAMPLING RATE



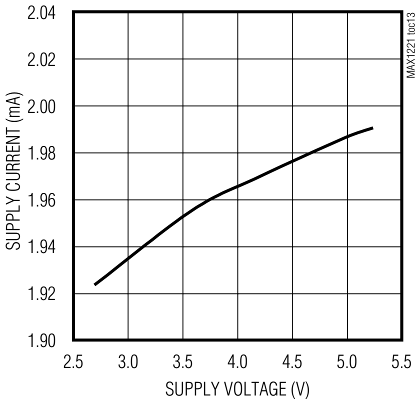
ANALOG SUPPLY CURRENT vs. SAMPLING RATE



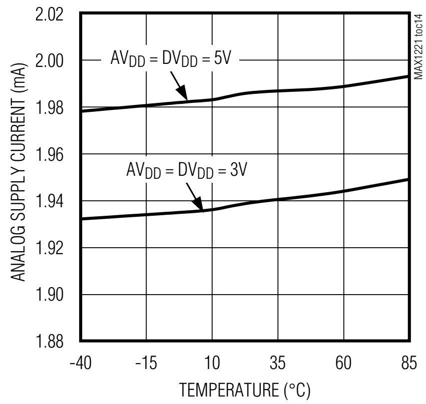
Typical Operating Characteristics (continued)

($AV_{DD} = DV_{DD} = 3V$ external $V_{REF} = 2.5V$, $f_{CLK} = 3.6MHz$ (50% duty cycle), $f_{SAMPLE} = 225ksps$, $C_{LOAD} = 50pF$, 0.1µF capacitor at REF, $T_A = +25°C$, unless otherwise noted.)

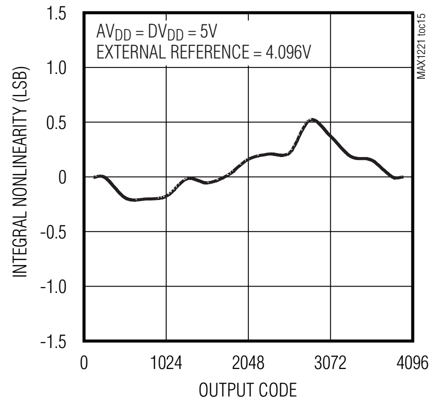
ANALOG SUPPLY CURRENT vs. ANALOG SUPPLY VOLTAGE



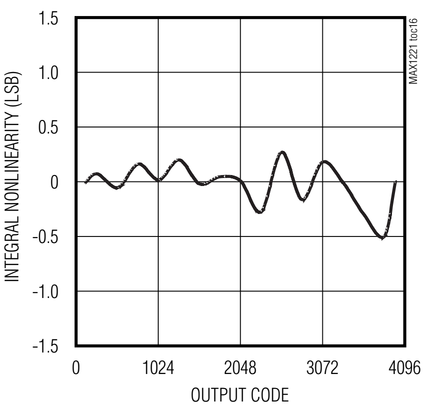
ANALOG SUPPLY CURRENT vs. TEMPERATURE



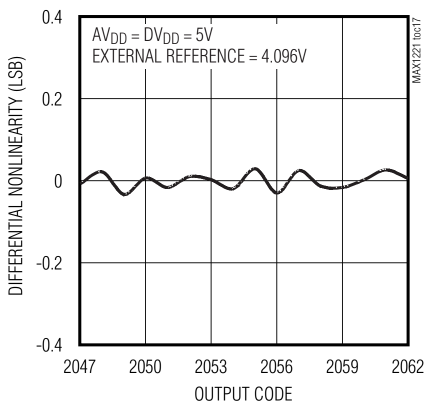
DAC INTEGRAL NONLINEARITY vs. OUTPUT CODE



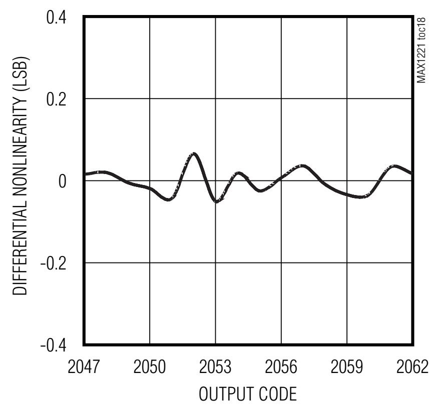
DAC INTEGRAL NONLINEARITY vs. OUTPUT CODE



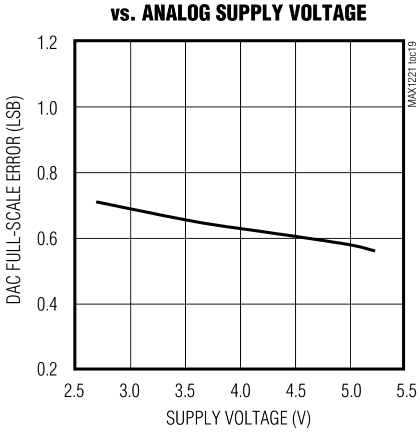
DAC DIFFERENTIAL NONLINEARITY vs. OUTPUT CODE



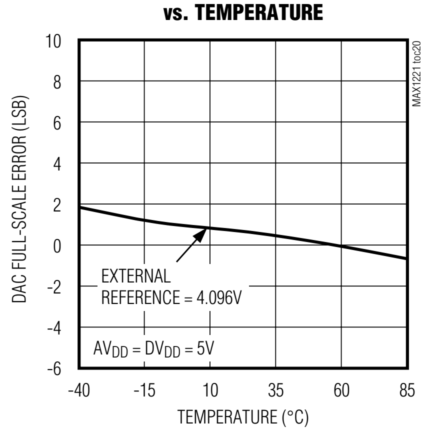
DAC DIFFERENTIAL NONLINEARITY vs. OUTPUT CODE



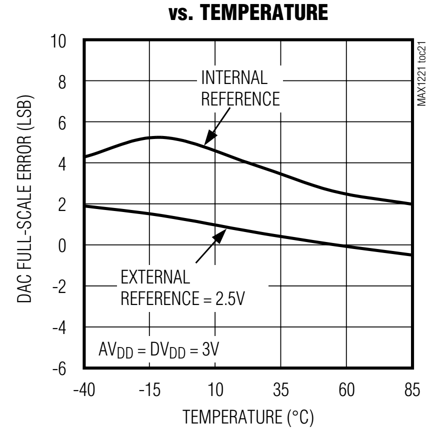
DAC FULL-SCALE ERROR vs. ANALOG SUPPLY VOLTAGE



DAC FULL-SCALE ERROR vs. TEMPERATURE



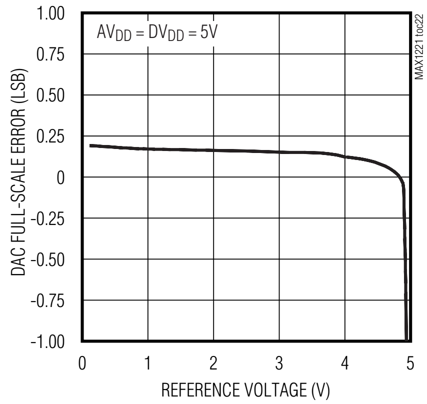
DAC FULL-SCALE ERROR vs. TEMPERATURE



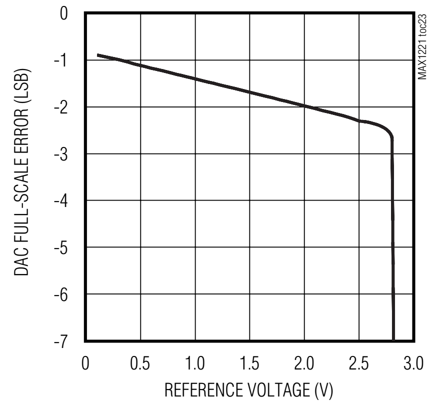
Typical Operating Characteristics (continued)

(AV_{DD} = DV_{DD} = 3V external V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), f_{SAMPLE} = 225ksps, C_{LOAD} = 50pF, 0.1µF capacitor at REF, T_A = +25°C, unless otherwise noted.)

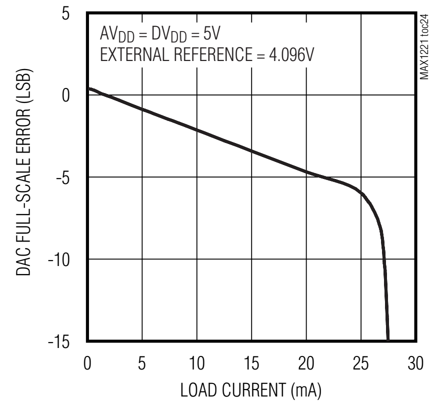
DAC FULL-SCALE ERROR vs. REFERENCE VOLTAGE



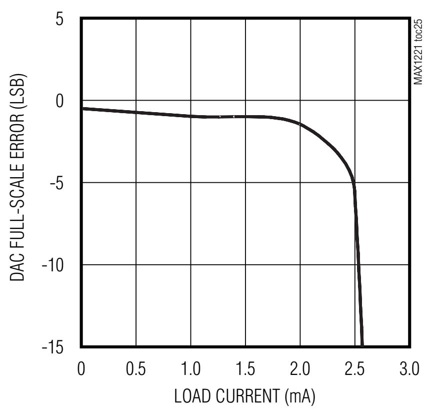
DAC FULL-SCALE ERROR vs. REFERENCE VOLTAGE



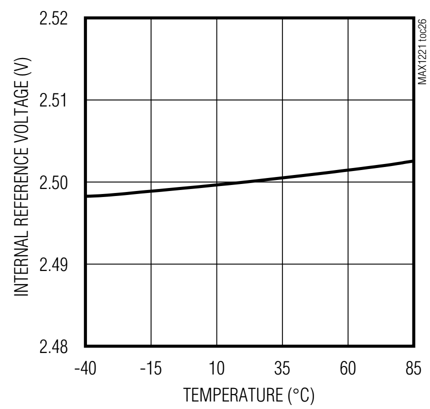
DAC FULL-SCALE ERROR vs. LOAD CURRENT



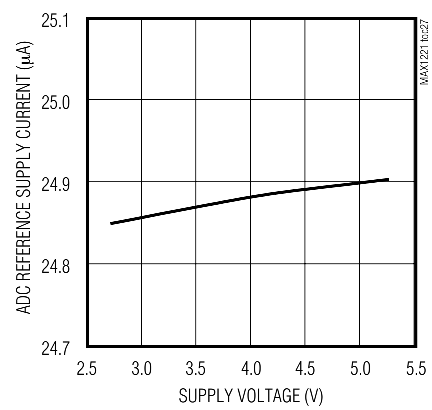
DAC FULL-SCALE ERROR vs. LOAD CURRENT



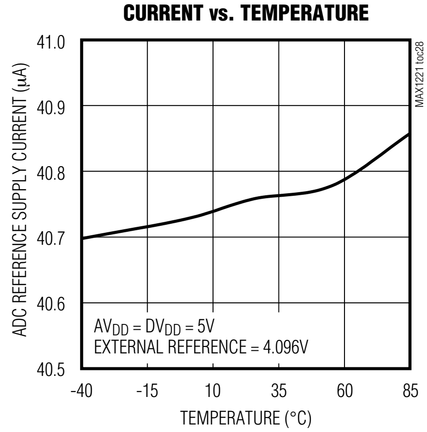
INTERNAL REFERENCE VOLTAGE vs. TEMPERATURE



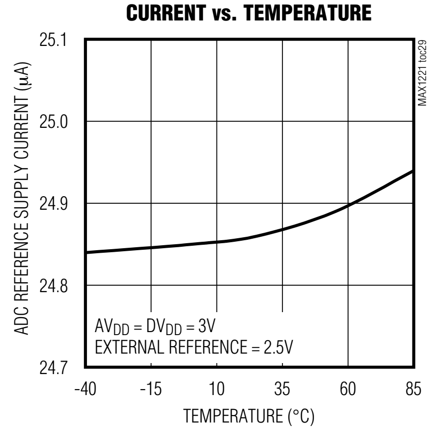
ADC REFERENCE SUPPLY CURRENT vs. ANALOG SUPPLY VOLTAGE



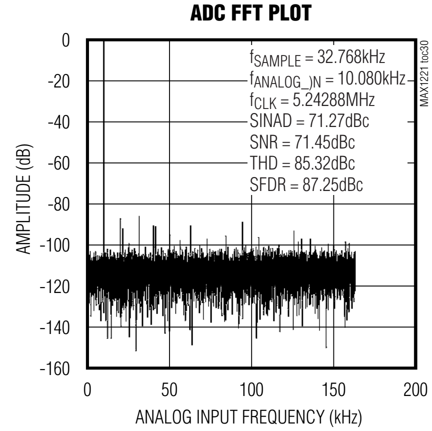
ADC REFERENCE SUPPLY CURRENT vs. TEMPERATURE



ADC REFERENCE SUPPLY CURRENT vs. TEMPERATURE



ADC FFT PLOT

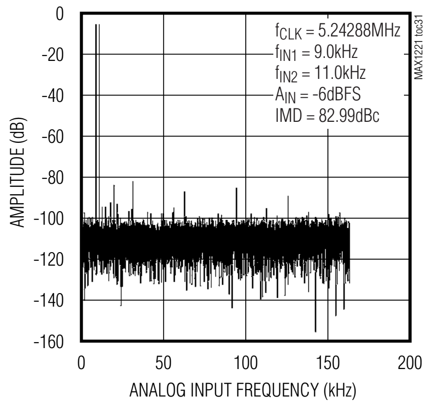


12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

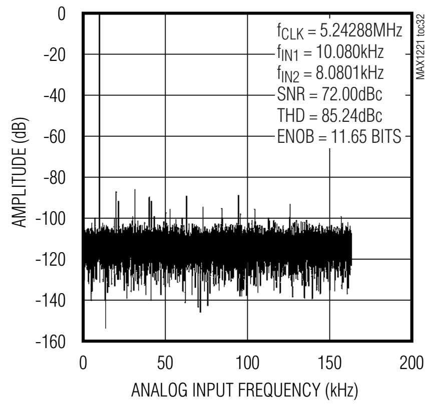
Typical Operating Characteristics (continued)

($AV_{DD} = DV_{DD} = 3V$ external $V_{REF} = 2.5V$, $f_{CLK} = 3.6MHz$ (50% duty cycle), $f_{SAMPLE} = 225ksps$, $C_{LOAD} = 50pF$, 0.1µF capacitor at REF, $T_A = +25°C$, unless otherwise noted.)

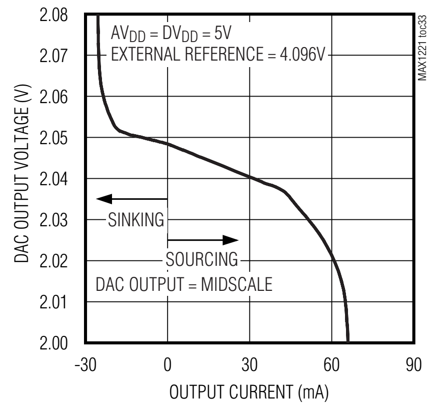
ADC IMD PLOT



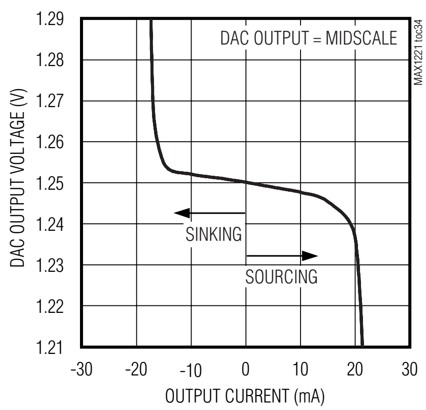
ADC CROSSTALK PLOT



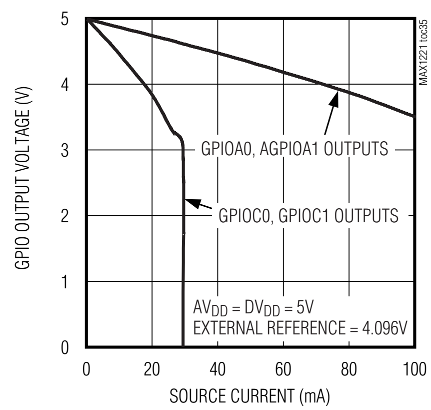
DAC OUTPUT LOAD REGULATION vs. OUTPUT CURRENT



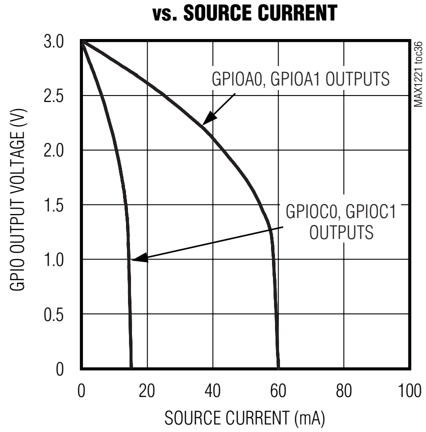
DAC OUTPUT LOAD REGULATION vs. OUTPUT CURRENT



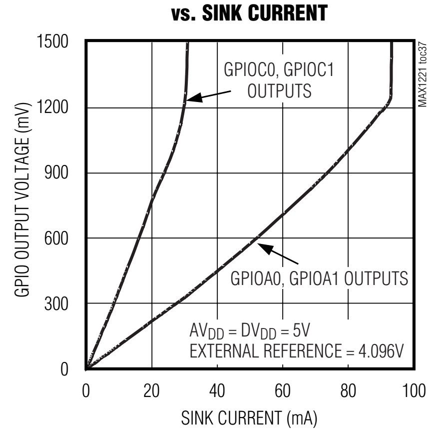
GPIO OUTPUT VOLTAGE vs. SOURCE CURRENT



GPIO OUTPUT VOLTAGE vs. SOURCE CURRENT



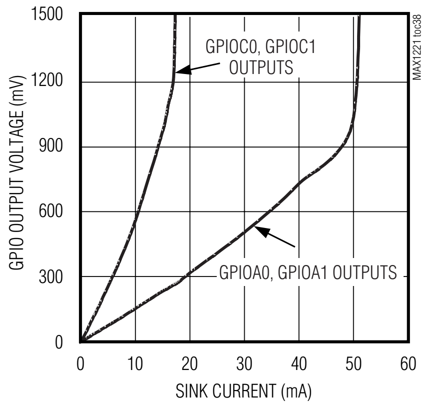
GPIO OUTPUT VOLTAGE vs. SINK CURRENT



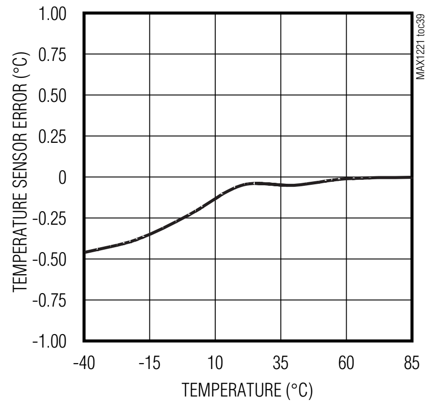
Typical Operating Characteristics (continued)

($AV_{DD} = DV_{DD}$ = 3V external V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), f_{SAMPLE} = 225ksps, C_{LOAD} = 50pF, 0.1µF capacitor at REF, T_A = +25°C, unless otherwise noted.)

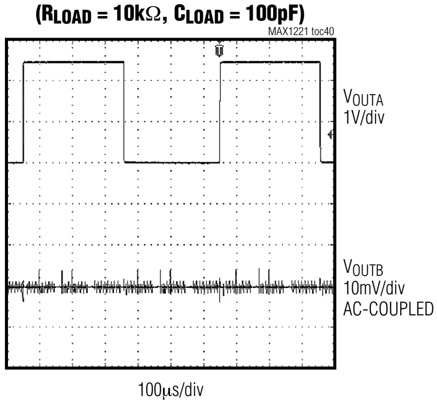
GPIO OUTPUT VOLTAGE vs. SINK CURRENT



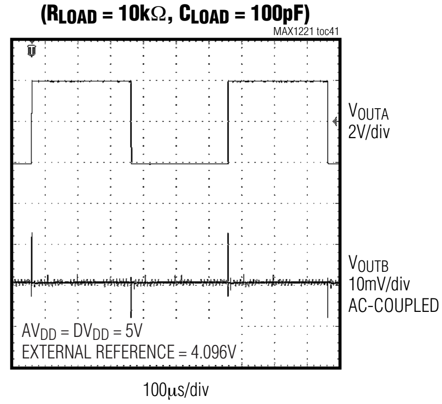
TEMPERATURE SENSOR ERROR vs. TEMPERATURE



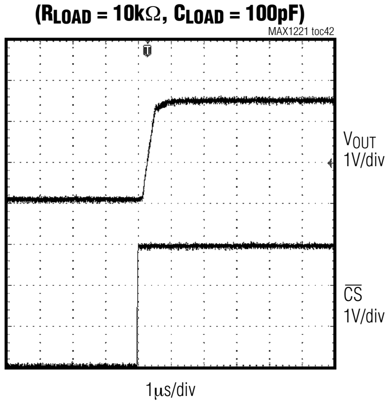
DAC-TO-DAC CROSSTALK (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



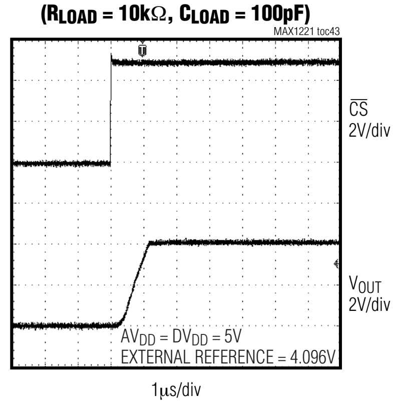
DAC-TO-DAC CROSSTALK (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



DYNAMIC RESPONSE RISE TIME (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



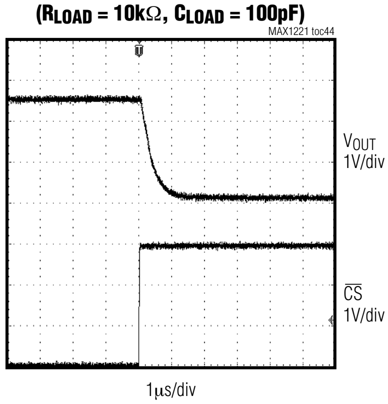
DYNAMIC RESPONSE RISE TIME (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



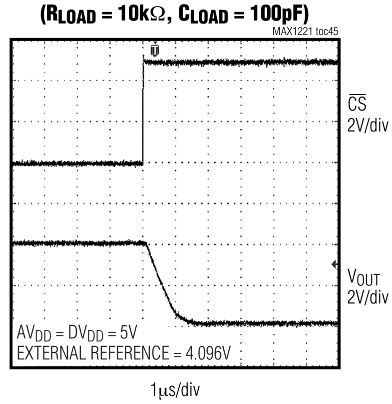
Typical Operating Characteristics (continued)

($AV_{DD} = DV_{DD} = 3V$ external $V_{REF} = 2.5V$, $f_{CLK} = 3.6MHz$ (50% duty cycle), $f_{SAMPLE} = 225ksps$, $C_{LOAD} = 50pF$, 0.1µF capacitor at REF, $T_A = +25°C$, unless otherwise noted.)

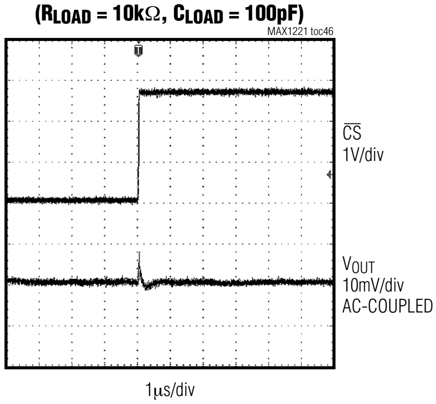
DYNAMIC RESPONSE FALL TIME ($R_{LOAD} = 10k\Omega$, $C_{LOAD} = 100pF$)



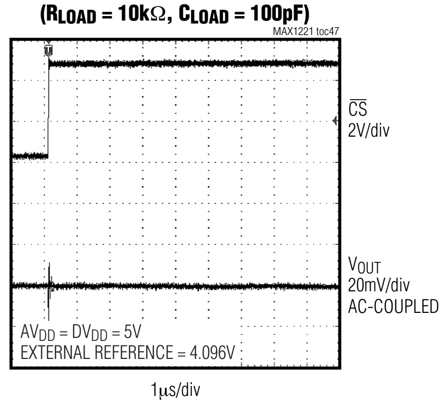
DYNAMIC RESPONSE FALL TIME ($R_{LOAD} = 10k\Omega$, $C_{LOAD} = 100pF$)



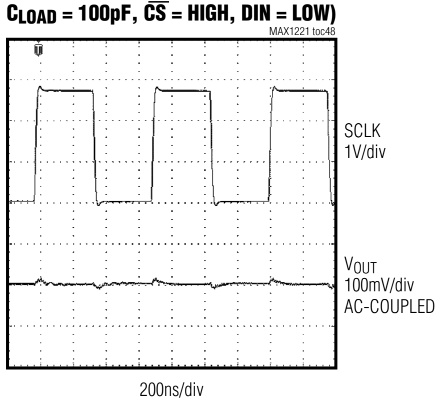
MAJOR CARRY TRANSITION ($R_{LOAD} = 10k\Omega$, $C_{LOAD} = 100pF$)



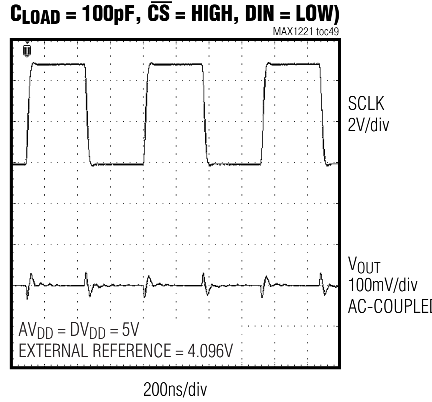
MAJOR CARRY TRANSITION ($R_{LOAD} = 10k\Omega$, $C_{LOAD} = 100pF$)



DAC DIGITAL FEEDTHROUGH ($R_{LOAD} = 10k\Omega$, $C_{LOAD} = 100pF$, $\overline{CS}$ = HIGH, DIN = LOW)



DAC DIGITAL FEEDTHROUGH ($R_{LOAD} = 10k\Omega$, $C_{LOAD} = 100pF$, $\overline{CS}$ = HIGH, DIN = LOW)

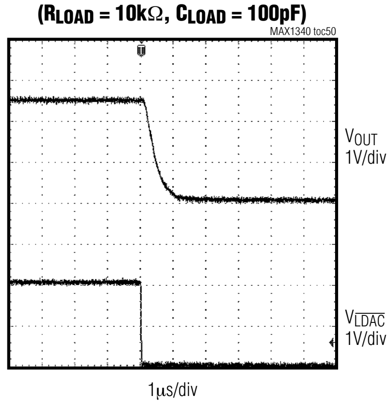


12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

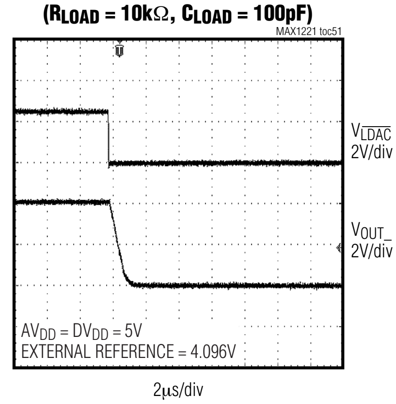
Typical Operating Characteristics (continued)

($AV_{DD} = DV_{DD}$ = 3V external V_{REF} = 2.5V, f_{CLK} = 3.6MHz (50% duty cycle), f_{SAMPLE} = 225ksps, C_{LOAD} = 50pF, 0.1µF capacitor at REF, T_A = +25°C, unless otherwise noted.)

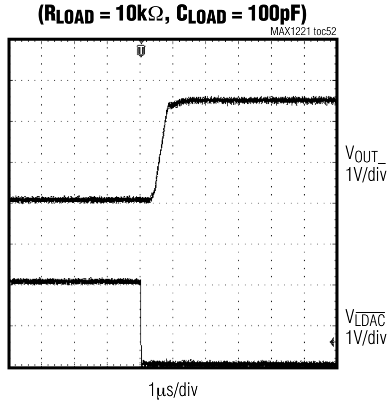
NEGATIVE FULL-SCALE SETTLING TIME (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



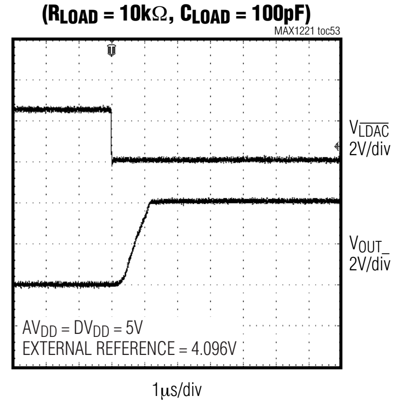
NEGATIVE FULL-SCALE SETTLING TIME (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



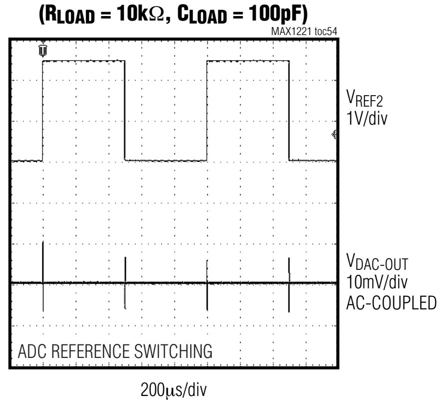
POSITIVE FULL-SCALE SETTLING TIME (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



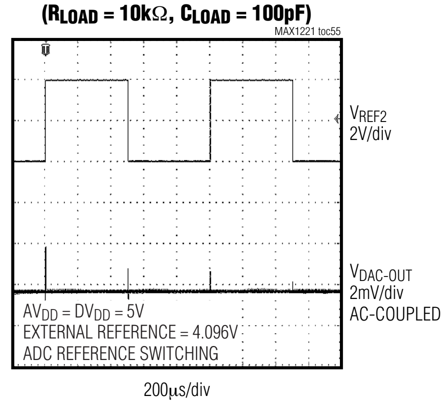
POSITIVE FULL-SCALE SETTLING TIME (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



ADC REFERENCE FEEDTHROUGH (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



ADC REFERENCE FEEDTHROUGH (R_{LOAD} = 10kΩ, C_{LOAD} = 100pF)



Pin Description

PIN			NAME	FUNCTION
MAX1221	MAX1223	MAX1343		
1, 2	—	1, 2	GPIOA0, GPIOA1	General-Purpose I/O A0, A1. GPIOA0, A1 can sink and source 15mA.
—	1	—	$\overline{CNVST}$/AIN11	Active-Low Conversion-Start Input/Analog Input 11. See Table 5 for details on programming the setup register.
3	3	3	$\overline{EOC}$	Active-Low End-of-Conversion Output. Data is valid after the falling edge of $\overline{EOC}$.
4	4	4	DV_{DD}	Digital Positive-Power Input. Bypass DV_{DD} to DGND with a 0.1µF capacitor.
5	5	5	DGND	Digital Ground. Connect DGND to AGND.
6	6	6	DOUT	Serial-Data Output. Data is clocked out on the falling edge of the SCLK clock in modes 00, 01, and 10. Data is clocked out on the rising edge of the SCLK clock in mode 11. It is high impedance when $\overline{CS}$ is high.
7	7	7	SCLK	Serial-Clock Input. Clocks data in and out of the serial interface. (Duty cycle must be 40% to 60%). See Table 5 for details on programming the clock mode.
8	8	8	DIN	Serial-Data Input. DIN data is latched into the serial interface on the falling edge of SCLK.
—	—	9–12	OUT0–OUT3	DAC Outputs
9–12, 16–19	9–12, 16–19	—	OUT0–OUT7	DAC Outputs
13	13	13	AV_{DD}	Positive Analog Power Input. Bypass AV_{DD} to AGND with a 0.1µF capacitor.
14	14	14	AGND	Analog Ground
15, 23, 32, 33	2, 15, 24, 32	15, 23, 32, 33	N.C.	No Connection. Not internally connected.
—	—	16–19	D.C.	Do Not Connect. Do not connect to this pin.
20	20	20	$\overline{LDAC}$	Active-Low Load DAC. $\overline{LDAC}$ is an asynchronous active-low input that updates the DAC outputs. Drive $\overline{LDAC}$ low to make the DAC registers transparent.
21	21	21	$\overline{CS}$	Active-Low Chip-Select Input. When $\overline{CS}$ is low, the serial interface is enabled. When $\overline{CS}$ is high, DOUT is high impedance.
22	22	22	RES_SEL	Reset Select. Select DAC wake-up mode. Set RES_SEL low to wake up the DAC outputs with a 100kΩ resistor to GND or set RES_SEL high to wake up the DAC outputs with a 100kΩ resistor to V_{REF}. The default is the external V_{REF}.
24, 25	—	24, 25	GPIOC0, GPIOC1	General-Purpose I/O C0, C1. GPIOC0, C1 can sink 4mA and source 2mA.

Pin Description (continued)

PIN			NAME	FUNCTION
MAX1221	MAX1223	MAX1343		
—	23, 25, 27–31, 33, 34, 35	—	AIN0–AIN9	Analog Inputs
26	26	26	REF1	Reference 1 Input. Reference voltage; leave unconnected to use the internal reference (2.5V). REF1 is the positive reference in ADC differential mode. Bypass REF1 to AGND with a 0.1µF capacitor in external reference mode only. See the *ADC/DAC References* section.
27–31, 34	—	27–31, 34	AIN0–AIN5	Analog Inputs
35	—	35	REF2/AIN6	Reference 2 Input/Analog Input Channel 6. See Table 5 for details on programming the setup register.
36	—	36	$\overline{\text{CNVST}}$/AIN7	Active-Low Conversion-Start Input/Analog Input 7. See Table 5 for details on programming the setup register.
—	36	—	REF2/AIN10	Reference 2 Input/Analog Input Channel 10. See Table 5 for details on programming the setup register.
—	—	—	EP	Exposed Pad. Must be externally connected to AGND. Do not use as a ground connect.

12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

Detailed Description

The MAX1221/MAX1223/MAX1343 integrate a multichannel 12-bit ADC, and an octal/quad 12-bit DAC in a single IC. The devices also include a temperature sensor and configurable GPIOs with a 25MHz SPI-/QSPI-/MICROWIRE-compatible serial interface. The ADC is available in a 12 or an eight input-channel version. The DAC outputs settle within 2.0µs, and the ADC has a 225ksps conversion rate.

All devices include an internal reference (2.5V) providing a well-regulated, low-noise reference for both the ADC and DAC. Programmable reference modes for the ADC and DAC allow the use of an internal reference, an external reference, or a combination of both. Features such as an internal ±1°C accurate temperature sensor, FIFO, scan modes, programmable internal or external clock modes, data averaging, and AutoShutdown allow users to minimize both power consumption and processor requirements. The low glitch energy (4nV•s) and low digital feedthrough (0.5nV•s) of the integrated DACs make these devices ideal for digital control of fast-response closed-loop systems.

The devices are guaranteed to operate with a supply voltage from +2.7V to +5.25V. The devices consume 2.5mA at 225ksps throughput, only 22µA at 1ksps throughput, and under 0.2µA in the shutdown mode. The MAX1221/MAX1343 offer four GPIOs that can be configured as inputs or outputs.

Figure 1 shows the MAX1221 functional diagram. The MAX1221/MAX1343 only include the GPIOA0, GPIOA1 and GPIOC0, GPIOC1 blocks. The MAX1223 excludes the GPIOs. The output-conditioning circuitry takes the internal parallel data bus and converts it to a serial data format at DOUT, with the appropriate wake-up timing. The arithmetic logic unit (ALU) performs the averaging function.

SPI-Compatible Serial Interface

The MAX1221/MAX1223/MAX1343 feature a serial interface that is compatible with SPI and MICROWIRE devices. For SPI, ensure the SPI bus master (typically a microcontroller (µC)) runs in master mode so that it generates the serial clock signal. Select the SCLK frequency of 25MHz or less, and set the clock polarity (CPOL) and phase (CPHA) in the µC control registers to the same value. The MAX1221/MAX1223/MAX1343 operate with SCLK idling high or low, and thus operate with CPOL = CPHA = 0 or CPOL = CPHA = 1. Set $\overline{CS}$ low to latch any input data at DIN on the falling edge of SCLK. Output data at DOUT is updated on the falling edge of SCLK in clock modes 00, 01, and 10. Output data at DOUT is updated on the rising edge of SCLK in clock mode 11. See Figures 6–11. Bipolar true-differential results and temperature-sensor results are available in two's complement format, while all other results are in binary.

A high-to-low transition on $\overline{CS}$ initiates the data-input operation. Serial communications to the ADC always begin with an 8-bit command byte (MSB first) loaded from DIN. The command byte and the subsequent data bytes are clocked from DIN into the serial interface on the falling edge of SCLK. The serial-interface and fast-interface circuitry is common to the ADC, DAC, and GPIO sections. The content of the command byte determines whether the SPI port should expect 8, 16, or 24 bits and whether the data is intended for the ADC, DAC, or GPIOs (if applicable). See Table 1. Driving $\overline{CS}$ high resets the serial interface.

The conversion register controls ADC channel selection, ADC scan mode, and temperature-measurement requests. See Table 4 for information on writing to the conversion register. The setup register controls the clock mode, reference, and unipolar/bipolar ADC configuration. Use a second byte, following the first, to write to the unipolar-mode or bipolar-mode registers. See Table 5 for details of the setup register and see Tables 6, 7, and 8 for setting the unipolar- and bipolar-mode registers. Hold $\overline{CS}$ low between the command byte and the second and third byte. The ADC averaging register is specific to the ADC. See Table 9 to address that register. Table 11 shows the details of the reset register.

Begin a write to the DAC by writing 0001XXXX as a command byte. The last 4 bits of this command byte are don't-care bits. Write another 2 bytes (holding $\overline{CS}$ low) to the DAC interface register following the command byte to select the appropriate DAC and the data to be written to it. See the *DAC Serial Interface* section and Tables 10, 17, and 18.

Write to the GPIOs (if applicable) by issuing a command byte to the appropriate register. Writing to the MAX1221/MAX1343 GPIOs requires 1 additional byte following the command byte. See Tables 12–16 for details on GPIO configuration, writes, and reads. See the *GPIO Command* section. Command bytes written to the GPIOs on devices without GPIOs are ignored.

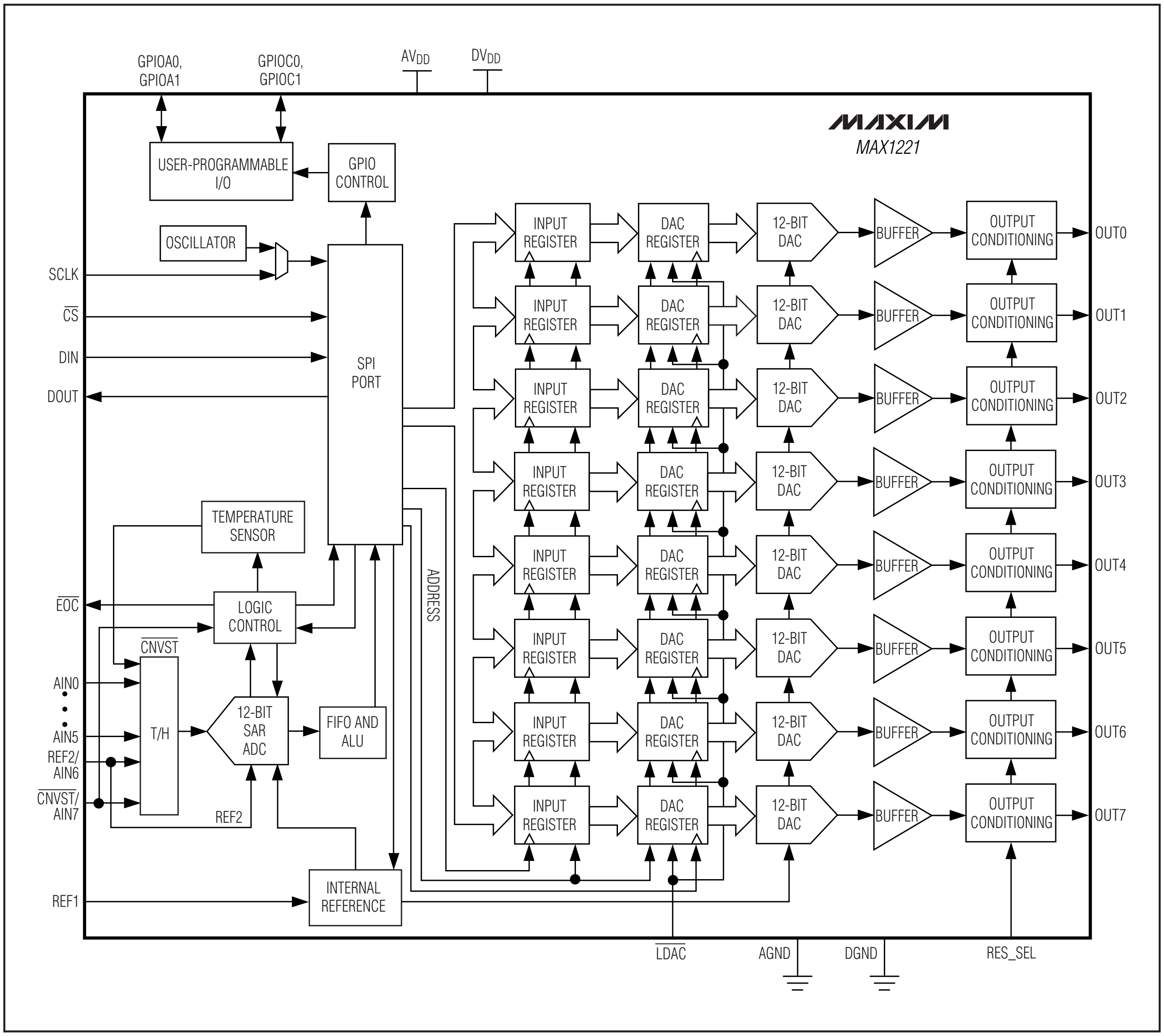


Figure 1. MAX1221 Functional Diagram

12-Bit, Multichannel ADCs/DACs with FIFO, Temperature Sensing, and GPIO Ports

Table 1. Command Byte (MSB First)

REGISTER NAME	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Conversion	1	CHSEL3	CHSEL2	CHSEL1	CHSEL0	SCAN1	SCAN0	TEMP
Setup	0	1	CKSEL1	CKSEL0	REFSEL1	REFSEL0	DIFFSEL1	DIFFSEL0
ADC Averaging	0	0	1	AVGON	NAVG1	NAVG0	NSCAN1	NSCAN0
DAC Select	0	0	0	1	X	X	X	X
Reset	0	0	0	0	1	RESET	SLOW	FBGON
GPIO Configure*	0	0	0	0	0	0	1	1
GPIO Write*	0	0	0	0	0	0	1	0
GPIO Read*	0	0	0	0	0	0	0	1
No Operation	0	0	0	0	0	0	0	0

X = Don't care.
**Only applicable on the MAX1221/MAX1343.*

Power-Up Default State

The MAX1221/MAX1223/MAX1343 power up with all blocks in shutdown (including the reference). All registers power up in state 00000000, except for the setup register and the DAC input register. The setup register powers up at 0010 1000 with CKSEL1 = 1 and REFSEL1 = 1. The DAC input register powers up to FFFh when RES_SEL is high and powers up to 000h when RES_SEL is low.

12-Bit ADC

The MAX1221/MAX1223/MAX1343 ADCs use a fully differential successive-approximation register (SAR) conversion technique and on-chip track-and-hold (T/H) circuitry to convert temperature and voltage signals into 12-bit digital results. The analog inputs accept both single-ended and differential input signals. Single-ended signals are converted using a unipolar transfer function, and differential signals are converted using a selectable bipolar or unipolar transfer function. See the *ADC Transfer Functions* section for more data.

ADC Clock Modes

When addressing the setup, register bits 5 and 4 of the command byte (CKSEL1 and CKSEL0, respectively) control the ADC clock modes. See Table 5. Choose between four different clock modes for various ways to start a conversion and determine whether the acquisitions are internally or externally timed. Select clock mode 00 to configure $\overline{\text{CNVST}}$/AIN_ to act as a conversion start and use it to request internally timed conversions, without tying up the serial bus. In clock mode 01, use $\overline{\text{CNVST}}$ to request conversions one channel at a time, thereby controlling the sampling speed without tying up the serial bus. Request and start internally timed conversions through the serial interface by writing to the conversion register in the default clock mode, 10. Use clock mode 11 with SCLK up to 3.6MHz for externally timed acquisitions to achieve sampling rates up to 225ksps. Clock mode 11 disables scanning and averaging. See Figures 6–9 for timing specifications on how to begin a conversion.

These devices feature an active-low, end-of-conversion output. $\overline{\text{EOC}}$ goes low when the ADC completes the last requested operation and is waiting for the next command byte. $\overline{\text{EOC}}$ goes high when $\overline{\text{CS}}$ or $\overline{\text{CNVST}}$ go low. $\overline{\text{EOC}}$ is always high in clock mode 11.

Single-Ended or Differential Conversions

The MAX1221/MAX1223/MAX1343 use a fully differential ADC for all conversions. When a pair of inputs are connected as a differential pair, each input is connected to the ADC. When configured in single-ended mode, the positive input is the single-ended channel and the negative input is referred to AGND. See Figure 2.

In differential mode, the T/H samples the difference between two analog inputs, eliminating common-mode DC offsets and noise. IN+ and IN- are selected from the following pairs: AIN0/AIN1, AIN2/AIN3, AIN4/AIN5, AIN6/AIN7, AIN8/AIN9, AIN10/AIN11. AIN0–AIN7 are available on all devices. AIN0–AIN11 are available on the MAX1223. See Tables 5–8 for more details on configuring the inputs. For the inputs that are configurable as $\overline{\text{CNVST}}$, REF2, and an analog input, only one function can be used at a time.

Unipolar or Bipolar Conversions

Address the unipolar- and bipolar-mode registers through the setup register (bits 1 and 0). See Table 5 for the setup register. See Figures 3 and 4 for the transfer-function graphs. Program a pair of analog inputs for differential operation by writing a one to the appropriate bit of the bipolar- or unipolar-mode register. Unipolar mode sets the differential input range from 0 to V_{REF1}. A negative differential analog input in unipolar mode causes the digital output code to be zero. Selecting bipolar mode sets the differential input range to $\pm V_{REF1}$ / 2. The digital output code is binary in unipolar mode and two's complement in bipolar mode.

In single-ended mode, the MAX1221/MAX1223/MAX1343 always operate in unipolar mode. The analog inputs are internally referenced to AGND with a full-scale input range from 0 to the selected reference voltage.

Analog Input (T/H)

The equivalent circuit of Figure 2 shows the ADC input architecture of the MAX1223. In track mode, a positive input capacitor is connected to AIN0–AIN11 in single-ended mode and AIN0, AIN2, AIN4–AIN10 in differential mode. A negative input capacitor is connected to AGND in single-ended mode or AIN1, AIN3, AIN5–AIN11 in differential mode. The MAX1221/MAX1343 feature eight analog input channels (AIN0–AIN7). In track mode, a positive input capacitor is connected to AIN0–AIN7 in single-ended mode and to AIN0, AIN2, AIN4, and AIN6 in differential mode. A negative input capacitor is connected to AGND in single-ended mode or to AIN1, AIN3, AIN5, and AIN7 in differential mode. For external T/H timing, use clock mode 01. After the T/H enters hold mode, the difference between the sampled positive and negative input voltages is converted. The input capacitance charging rate determines the time required for the T/H to acquire an input signal. If the input signal's source impedance is high, the required acquisition time lengthens.

Any source impedance below 300Ω does not significantly affect the ADC's AC performance. A high-impedance source can be accommodated either by lengthening t_{ACQ} (only in clock mode 01) or by placing a 1µF capacitor between the positive and negative analog inputs. The combination of the analog-input source impedance and the capacitance at the analog input creates an RC filter that limits the analog input bandwidth.

Input Bandwidth

The ADC's input-tracking circuitry has a 1MHz small-signal bandwidth, making it possible to digitize high-speed transient events and measure periodic signals with bandwidths exceeding the ADC's sampling rate by using undersampling techniques. Anti-alias prefiltering of the input signals is necessary to avoid high-frequency signals aliasing into the frequency band of interest.

Analog Input Protection

Internal electrostatic-discharge (ESD) protection diodes clamp all analog inputs to AV_{DD} and AGND, allowing the inputs to swing from (AGND - 0.3V) to (AV_{DD} + 0.3V) without damage. However, for accurate conversions near full scale, the inputs must not exceed AV_{DD} by more than 50mV or be lower than AGND by 50mV. If an analog input voltage exceeds the supplies, limit the input current to 2mA.

Internal FIFO

The MAX1221/MAX1223/MAX1343 contain a first-in/first-out (FIFO) buffer that holds up to 16 ADC results plus one temperature result. The internal FIFO allows the ADC to process and store multiple internally clocked conversions and a temperature measurement without being serviced by the serial bus.

If the FIFO is filled and further conversions are requested without reading from the FIFO, the oldest ADC results are overwritten by the new ADC results. Each result contains 2 bytes, with the MSB preceded by four leading zeros. After each falling edge of $\overline{CS}$, the oldest available pair of bytes of data is available at DOUT, MSB first. When the FIFO is empty, DOUT is zero.

The first 2 bytes of data read out after a temperature measurement always contain the 12-bit temperature result, preceded by four leading zeros, MSB first. If another temperature measurement is performed before the first temperature result is read out, the old measurement is overwritten by the new result. Temperature results are in degrees Celsius (two's complement), at a resolution of 8

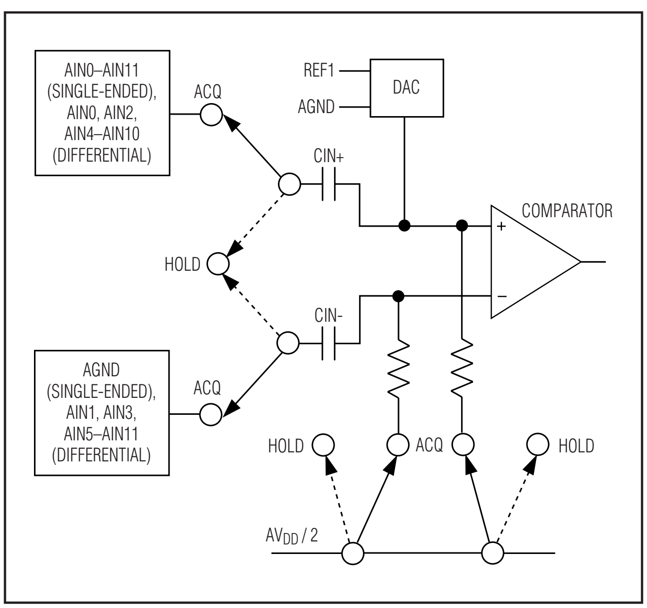


Figure 2. MAX1223 Equivalent Input Circuit

LSB per degree. See the *Temperature Measurements* section for details on converting the digital code to a temperature.

12-Bit DAC

In addition to the 12-bit ADC, the MAX1221/MAX1223/MAX1343 also include eight (MAX1221/MAX1223) or four (MAX1343) voltage-output, 12-bit, monotonic DACs with less than 4 LSB integral nonlinearity error and less than 1 LSB differential nonlinearity error. Each DAC has a 2µs settling time and ultra-low glitch energy (4nV•s). The 12-bit DAC code is unipolar binary with 1 LSB = V_{REF} / 4096.

DAC Digital Interface

Figure 1 shows the functional diagram of the MAX1221. The shift register converts a serial 16-bit word to parallel data for each input register operating with a clock rate up to 25MHz. The SPI-compatible digital interface to the shift register consists of $\overline{CS}$, SCLK, DIN, and DOUT. Serial data at DIN is loaded on the falling edge of SCLK. Pull $\overline{CS}$ low to begin a write sequence. Begin a write to the DAC by writing 0001XXXX as a command byte. The last 4 bits of the DAC select register are don't-care bits. See Table 10. Write another 2 bytes to the DAC interface register following the command byte to select the appropriate DAC and the data to be written to it. See Tables 17 and 18.

The double-buffered DACs include an input and a DAC register. The input registers are directly connected to the shift register and hold the result of the most recent write operation. The 12-bit DAC registers hold the current output code for the respective DAC. Data can be transferred from the input registers to the DAC registers by pulling $\overline{LDAC}$ low or by writing the appropriate DAC command sequence at DIN. See Table 17. The outputs of the DACs are buffered through eight (MAX1221/MAX1223) or four (MAX1343) rail-to-rail op amps.

The MAX1221/MAX1223/MAX1343 DAC output-voltage range is based on the internal reference or an external reference. Write to the setup register (see Table 5) to program the reference. If using an external voltage reference, bypass REF1 with a 0.1µF capacitor to AGND. The internal reference is 2.5V. When using an external reference on any of these devices, the voltage range is 0.7V to AV_{DD}.

DAC Transfer Function

See Table 2 for various analog outputs from the DAC.

DAC Power-On Wake-Up Modes

The state of the RES_SEL input determines the wake-up state of the DAC outputs. Connect RES_SEL to AV_{DD} or AGND upon power-up to be sure the DAC outputs wake up to a known state. Connect RES_SEL to AGND to wake up all DAC outputs at 000h. While RES_SEL is low, the 100kΩ internal resistor pulls the DAC outputs to AGND and the output buffers are powered down. Connect RES_SEL to AV_{DD} to wake up all DAC outputs at FFFh. While RES_SEL is high, the 100kΩ pullup resistor pulls the DAC outputs to V_{REF1} and the output buffers are powered down.

DAC Power-Up Modes

See Table 18 for a description of the DAC power-up and power-down modes.

GPIOs

In addition to the internal ADC and DAC, the MAX1221/MAX1343 also provide four GPIO channels, GPIOA0, GPIOA1, GPIOC0, GPIOC1. Read and write to the GPIOs as detailed in Table 1 and Tables 12–16. Also, see the *GPIO Command* section. See Figures 11 and 12 for GPIO timing.

Write to the GPIOs by writing a command byte to the GPIO command register. Write a single data byte to the MAX1221/MAX1343 following the command byte.

The GPIOs can sink and source current. GPIOA0 and GPIOA1 can sink and source up to 15mA. GPIOC0 and GPIOC1 can sink 4mA and source 2mA. See Table 3.

Table 2. DAC Output Code Table

DAC CONTENTS			ANALOG OUTPUT
MSB		LSB	
1111	1111	1111	$+V_{REF}\left(\frac{4095}{4096}\right)$
1000	0000	0001	$+V_{REF}\left(\frac{2049}{4096}\right)$
1000	0000	0000	$+V_{REF}\left(\frac{2048}{4096}\right) = \left(\frac{+V_{REF}}{2}\right)$
0111	0111	0111	$+V_{REF}\left(\frac{2047}{4096}\right)$
0000	0000	0001	$+V_{REF}\left(\frac{1}{4096}\right)$
0000	0000	0000	0

Clock Modes

Internal Clock

The MAX1221/MAX1223/MAX1343 can operate from an internal oscillator. The internal oscillator is active in clock modes 00, 01, and 10. Figures 6, 7, and 8 show how to start an ADC conversion in the three internally timed conversion modes.

Read out the data at clock speeds up to 25MHz through the SPI interface.

External Clock

Set CKSEL1 and CKSEL0 in the setup register to 11 to set up the interface for external clock mode 11. See Table 5. Pulse SCLK at speeds from 0.1MHz to 3.6MHz. Write to SCLK with a 40% to 60% duty cycle. The SCLK frequency controls the conversion timing. See Figure 9 for clock mode 11 timing. See the *ADC Conversions in Clock Mode 11* section.

ADC/DAC References

Address the reference through the setup register, bits 3 and 2. See Table 5. Following a wake-up delay, set REFSEL[1:0] = 00 to program both the ADC and DAC for internal reference use. Set REFSEL[1:0] = 10 to program the ADC for internal reference use without a wake-up delay. Set REFSEL[1:0] = 10 to program the DAC for external reference, REF1. When using REF1 or REF2/AIN_ in external-reference mode, connect a 0.1µF capacitor to AGND. Set REFSEL[1:0] = 01 to program the ADC and DAC for external-reference mode. The DAC uses REF1 as its external reference, while the ADC uses REF2 as its external reference. Set REFSEL[1:0] = 11 to program the ADC for external differential reference mode. REF1 is the positive reference and REF2 is the negative reference in the ADC external differential mode.

When REFSEL[1:0] = 00 or 10, REF2/AIN_ functions as an analog input channel. When REFSEL[1:0] = 01 or 11, REF2/AIN_ functions as the device's negative reference.

Temperature Measurements

Issue a command byte setting bit 0 of the conversion register to one to take a temperature measurement. See Table 4. The MAX1221/MAX1223/MAX1343 perform temperature measurements with an internal diode-connected transistor. The diode bias current changes from 68µA to 4µA to produce a temperature-dependent bias voltage difference. The second conversion result at 4µA is subtracted from the first at 68µA to calculate a digital value that is proportional to absolute temperature. The output data appearing at DOUT is the digital code above, minus an offset to adjust from Kelvin to Celsius.

The reference voltage used for the temperature measurements is always derived from the internal reference source to ensure that 1 LSB corresponds to 1/8 of a degree Celsius. On every scan where a temperature measurement is requested, the temperature conversion is carried out first. The first 2 bytes of data read from the FIFO contain the result of the temperature measurement. If another temperature measurement is performed before the first temperature result is read out, the old measurement is overwritten by the new result. Temperature results are in degrees Celsius (two's complement). See the *Applications Information* section for information on how to perform temperature measurements in each clock mode.

Table 3. GPIO Maximum Sink/Source Current

CURRENT	MAX1221/MAX1343	
	GPIOA0, GPIOA1 (mA)	GPIOC0, GPIOC1 (mA)
Sink	15	4
Source	15	2

Register Descriptions

The MAX1221/MAX1223/MAX1343 communicate between the internal registers and the external circuitry through the SPI-compatible serial interface. Table 1 details the command byte, the registers, and the bit names. Tables 4–12 show the various functions within the conversion register, setup register, unipolar-mode register, bipolar-mode register, ADC averaging register, DAC select register, reset register, and GPIO command register, respectively.

Conversion Register

Select active analog input channels, scan modes, and a single temperature measurement per scan by issuing a command byte to the conversion register. Table 4 details channel selection, the four scan modes, and how to request a temperature measurement. Start a scan by writing to the conversion register when in clock mode 10 or 11, or by applying a low pulse to the $\overline{\text{CNVST}}$ pin when in clock mode 00 or 01. See Figures 6 and 7 for timing specifications for starting a scan with $\overline{\text{CNVST}}$.

A conversion is not performed if it is requested on a channel or one of the channel pairs that has been configured as $\overline{\text{CNVST}}$ or REF2. For channels configured as differential pairs, the CHSEL0 bit is ignored and the two pins are treated as a single differential channel. For the MAX1221/MAX1343, the CHSEL3 bit must be zero.

Channels 8–11 are invalid. Any scans or averages on these channles can cause corrupt data.

Select scan mode 00 or 01 to return one result per single-ended channel and one result per differential pair within the selected scanning range (set by bits 2 and 1, SCAN1 and SCAN0), plus one temperature result if selected. Select scan mode 10 to scan a single input channel numerous times, depending on NSCAN1 and NSCAN0 in the ADC averaging register (Table 9). Select scan mode 11 to return only one result from a single channel.

Setup Register

Issue a command byte to the setup register to configure the clock, reference, power-down modes, and ADC single-ended/differential modes. Table 5 details the bits in the setup-register command byte. Bits 5 and 4 (CKSEL1 and CKSEL0) control the clock mode, acquisition and sampling, and the conversion start. Bits 3 and 2 (REFSEL1 and REFSEL0) set the device for either internal or external reference. Bits 1 and 0 (DIFFSEL1 and DIFFSEL0) address the ADC unipolar-mode and bipolar-mode registers and configure the analog input channels for differential operation.

The ADC reference is always on if any of the following conditions are true:

1) The FBGON bit is set to one in the reset register.
2) At least one DAC output is powered up and REFSEL[1:0] (in the setup register) = 00.
3) At least one DAC is powered down through the 100kΩ to V_{REF} and REFSEL[1:0] = 00.

If any of the above conditions exist, the ADC reference is always on, but there is a 188 clock-cycle delay before temperature-sensor measurements begin, if requested.

Table 4. Conversion Register*

BIT NAME	BIT	FUNCTION
—	7 (MSB)	Set to one to select conversion register.
CHSEL3	6	Analog input channel select (MAX1223). Set to 0 on the MAX1221/MAX1343.
CHSEL2	5	Analog input channel select.
CHSEL1	4	Analog input channel select.
CHSEL0	3	Analog input channel select.
SCAN1	2	Scan mode select.
SCAN0	1	Scan mode select.
TEMP	0 (LSB)	Set to one to take a single temperature measurement. The first conversion result of a scan contains temperature information.

**See below for bit details.*

CHSEL3	CHSEL2	CHSEL1	CHSEL0	SELECTED CHANNEL (N)
0	0	0	0	AIN0
0	0	0	1	AIN1
0	0	1	0	AIN2
0	0	1	1	AIN3
0	1	0	0	AIN4
0	1	0	1	AIN5
0	1	1	0	AIN6
0	1	1	1	AIN7
1	0	0	0	AIN8
1	0	0	1	AIN9
1	0	1	0	AIN10
1	0	1	1	AIN11

SCAN1	SCAN0	SCAN MODE (CHANNEL N IS SELECTED BY BITS CHSEL3–CHSEL0)
0	0	Scans channels 0 through N.
0	1	Scans channels N through the highest numbered channel.
1	0	Scans channel N repeatedly. The ADC averaging register sets the number of results.
1	1	No scan. Converts channel N once only.

Table 5. Setup Register*

BIT NAME	BIT	FUNCTION
—	7 (MSB)	Set to zero to select setup register.
—	6	Set to one to select setup register.
CKSEL1	5	Clock mode and $\overline{\text{CNVST}}$ configuration; resets to one at power-up.
CKSEL0	4	Clock mode and $\overline{\text{CNVST}}$ configuration.
REFSEL1	3	Reference-mode configuration.
REFSEL0	2	Reference-mode configuration.
DIFFSEL1	1	Unipolar-/bipolar-mode register configuration for differential mode.
DIFFSEL0	0 (LSB)	Unipolar-/bipolar-mode register configuration for differential mode.

**See below for bit details.*

Table 5a. Clock Modes (see *Clock Modes* section)

CKSEL1	CKSEL0	CONVERSION CLOCK	ACQUISITION/SAMPLING	$\overline{\text{CNVST}}$ CONFIGURATION
0	0	Internal	Internally timed.	$\overline{\text{CNVST}}$
0	1	Internal	Externally timed by $\overline{\text{CNVST}}$.	$\overline{\text{CNVST}}$
1	0	Internal	Internally timed.	AIN11/AIN7
1	1	External (3.6MHz max)	Externally timed by SCLK.	AIN11/AIN7

Table 5b. Clock Modes 00, 01, and 10

REFSEL1	REFSEL0	VOLTAGE REFERENCE	OVERRIDE CONDITIONS	AUTOSHUTDOWN	REF2 CONFIGURATION
0	0	Internal (DAC and ADC)	AIN	Internal reference turns off after scan is complete. If internal reference is turned off, there is a programmed delay of 218 internal-conversion clock cycles.	AIN10/AIN6
			Temperature	Internal reference required. There is a programmed delay of 244 internal-conversion clock cycles for the internal reference to settle after wake-up.	
0	1	External single-ended (REF1 for DAC and REF2 for ADC)	AIN	Internal reference not used.	REF2
			Temperature	Internal reference required. There is a programmed delay of 244 internal-conversion clock cycles for the internal reference to settle after wake-up.	
1	0	Internal (ADC) and external REF1 (DAC)	AIN	Default reference mode. Internal reference turns off after scan is complete. If internal reference is turned off, there is a programmed delay of 218 internal-conversion clock cycles.	AIN10/AIN6
			Temperature	Internal reference required. There is a programmed delay of 244 internal-conversion clock cycles for the internal reference to settle after wake-up.	
1	1	External differential (ADC), external REF1 (DAC)	AIN	Internal reference not used.	REF2
			Temperature	Internal reference required. There is a programmed delay of 244 internal-conversion clock cycles for the internal reference to settle after wake-up.	