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4.8 kHz Ultralow Noise 24-Bit Sigma-Delta ADC with PGA

Data Sheet **AD7190**

FEATURES

- RMS noise: 8.5 nV @ 4.7 Hz (gain = 128)
- 16 noise free bits @ 2.4 kHz (gain = 128)
- Up to 22.5 noise free bits (gain = 1)
- Offset drift: 5 nV/°C
- Gain drift: 1 ppm/°C
- Specified drift over time
- 2 differential/4 pseudo differential input channels
- Automatic channel sequencer
- Programmable gain (1 to 128)
- Output data rate: 4.7 Hz to 4.8 kHz
- Internal or external clock
- Simultaneous 50 Hz/60 Hz rejection
- 4 general-purpose digital outputs
- Power supply
  - AV_{DD}: 4.75 V to 5.25 V
  - DV_{DD}: 2.7 V to 5.25 V
- Current: 6 mA
- Temperature range: −40°C to +105°C
- Interface
  - 3-wire serial
  - SPI, QSPI™, MICROWIRE™, and DSP compatible
  - Schmitt trigger on SCLK
- Qualified for automotive applications

APPLICATIONS

- Weigh scales
- Strain gauge transducers
- Pressure measurement
- Temperature measurement
- Chromatography
- PLC/DCS analog input modules
- Data acquisition
- Medical and scientific instrumentation

GENERAL DESCRIPTION

The AD7190 is a low noise, complete analog front end for high precision measurement applications. It contains a low noise, 24-bit sigma-delta (Σ-Δ) analog-to-digital converter (ADC). The on-chip low noise gain stage means that signals of small amplitude can be interfaced directly to the ADC.

The device can be configured to have two differential inputs or four pseudo differential inputs. The on-chip channel sequencer allows several channels to be enabled, and the AD7190 sequentially converts on each enabled channel. This simplifies communication with the part. The on-chip 4.92 MHz clock can be used as the clock source to the ADC or, alternatively, an external clock or crystal can be used. The output data rate from the part can be varied from 4.7 Hz to 4.8 kHz.

The device has two digital filter options. The choice of filter affects the rms noise/noise-free resolution at the programmed output data rate, the settling time, and the 50 Hz/60 Hz rejection. For applications that require all conversions to be settled, the AD7190 includes a zero latency feature.

The part operates with 5 V analog power supply and a digital power supply from 2.7 V to 5.25 V. It consumes a current of 6 mA. It is housed in a 24-lead TSSOP package.

FUNCTIONAL BLOCK DIAGRAM

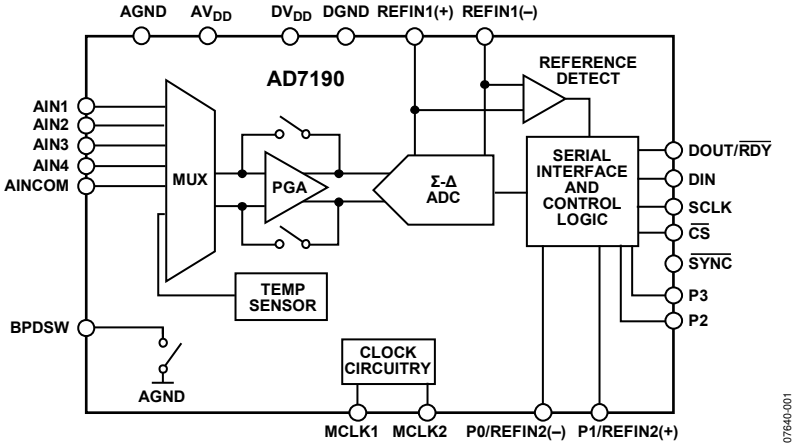

Figure 1.

Rev. C

Document Feedback

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700
Technical Support www.analog.com

AD7190* PRODUCT PAGE QUICK LINKS

Last Content Update: 02/23/2017

COMPARABLE PARTS

View a parametric search of comparable parts.

EVALUATION KITS

- AD7190 Evaluation Board

DOCUMENTATION

Application Notes

- AN-0979: Digital Filtering Options: AD7190, AD7192
- AN-1069: Zero Latency for the AD7190, AD7192, AD7193, AD7194, and AD7195
- AN-1084: Channel Switching: AD7190, AD7192, AD7193, AD7194, AD7195
- AN-1131: Chopping on the AD7190, AD7192, AD7193, AD7194, and AD7195

Data Sheet

- AD7190: 4.8 kHz Ultralow Noise 24-Bit Sigma-Delta ADC with PGA Data Sheet

User Guides

- UG-222: Evaluation Board for the AD7190/AD7192 4.8 kHz Ultralow Noise 24-Bit Sigma-Delta ADCs

SOFTWARE AND SYSTEMS REQUIREMENTS

- AD7190 - Microcontroller No-OS Driver
- AD7192 IIO High Precision ADC Linux Driver

TOOLS AND SIMULATIONS

- AD7190/AD7192 Digital Filter Models
- Download the Active Functional Model to evaluate and debug AD719x

REFERENCE DESIGNS

- CN0102

REFERENCE MATERIALS

Solutions Bulletins & Brochures

- Test & Instrumentation Solutions Bulletin, Volume 10, Issue 3

Tutorials

- Tutorial on Technical and Performance Benefits of AD719x Family

DESIGN RESOURCES

- AD7190 Material Declaration
- PCN-PDN Information
- Quality And Reliability
- Symbols and Footprints

DISCUSSIONS

View all AD7190 EngineerZone Discussions.

SAMPLE AND BUY

Visit the product page to see pricing options.

TECHNICAL SUPPORT

Submit a technical question or find your regional support number.

DOCUMENT FEEDBACK

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10/08—Revision 0—Initial Version

SPECIFICATIONS

AV_{DD} = 4.75 V to 5.25 V, DV_{DD} = 2.7 V to 5.25 V, AGND = DGND = 0 V, REFINx(+) = AV_{DD} , REFINx(−) = AGND, MCLK = 4.92 MHz, $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.

Table 1.

Parameter	AD7190B	Unit	Test Conditions/Comments[1]
ADC			
Output Data Rate	4.7 to 4800	Hz nom	Chop disabled.
	1.17 to 1200	Hz nom	Chop enabled, sinc[4] filter.
	1.56 to 1600	Hz nom	Chop enabled, sinc[3] filter.
No Missing Codes[2]	24	Bits min	FS > 1, sinc[4] filter[3].
	24	Bits min	FS > 4, sinc[3] filter[3].
Resolution	See the RMS Noise and Resolution section		
RMS Noise and Output Data Rates	See the RMS Noise and Resolution section		
Integral Nonlinearity			
B Grade	±5	ppm of FSR max	±1 ppm typical, gain = 1.
	±15	ppm of FSR max	±5 ppm typical, gain > 1.
WB Grade	±7	ppm of FSR max	±1 ppm typical, gain = 1.
	±30	ppm of FSR max	±5 ppm typical, gain > 1.
Offset Error[4, 5]	±75/gain	µV typ	Chop disabled.
	±0.5	µV typ	Chop enabled.
Offset Error Drift vs. Temperature[5]	±100/gain	nV/°C typ	Gain = 1 to 16. chop disabled.
	±5	nV/°C typ	Gain = 32 to 128. chop disabled.
	±5	nV/°C typ	Chop enabled.
Offset Error Drift vs. Time	25	nV/1000 hours typ	Gain ≥ 32.
Gain Error[4]			
B Grade	±0.005	% max	±0.001 % typical, gain = 1, T_A = 25°C, AV_{DD} = 5 V[6].
WB Grade	±0.0075	% max	±0.001 % typical, gain = 1, T_A = 25°C, AV_{DD} = 5 V[6].
	±0.0075	% typ	Gain > 1, post internal full-scale calibration.
Gain Drift vs. Temperature	±1	ppm/°C typ	
Gain Drift vs. Time	10	ppm/1000 hours typ	Gain = 1.
Power Supply Rejection	95	dB typ	Gain = 1, V_{IN} = 1 V.
B Grade	100	dB min	Gain > 1, V_{IN} = 1 V/gain. 110 dB typical.
WB Grade	95	dB min	Gain > 1, V_{IN} = 1 V/gain. 110 dB typical.
Common-Mode Rejection			
@ DC	100	dB min	Gain = 1, V_{IN} = 1 V[2].
	110	dB min	Gain > 1, V_{IN} = 1 V/gain.
@ 50 Hz, 60 Hz[2]	120	dB min	10 Hz output data rate, 50 ± 1 Hz, 60 ± 1 Hz.
@ 50 Hz, 60 Hz[2]	120	dB min	50 ± 1 Hz (50 Hz output data rate), 60 ± 1 Hz (60 Hz output data rate).
Normal Mode Rejection[2]			
Sinc[4] Filter			
Internal Clock			
@ 50 Hz, 60 Hz	100	dB min	10 Hz output data rate, 50 ± 1 Hz, 60 ± 1 Hz.
	74	dB min	50 Hz output data rate, REJ60[7] = 1, 50 ± 1 Hz, 60 ± 1 Hz.
@ 50 Hz	96	dB min	50 Hz output data rate, 50 ± 1 Hz.
@ 60 Hz	97	dB min	60 Hz output data rate, 60 ± 1 Hz.

Parameter	AD7190B	Unit	Test Conditions/Comments[1]
External Clock			
@ 50 Hz, 60 Hz	120	dB min	10 Hz output data rate, 50 ± 1 Hz, 60 ± 1 Hz.
	82	dB min	50 Hz output data rate, REJ60[7] = 1, 50 ± 1 Hz, 60 ± 1 Hz.
@ 50 Hz	120	dB min	50 Hz output data rate, 50 ± 1 Hz.
@ 60 Hz	120	dB min	60 Hz output data rate, 60 ± 1 Hz.
Sinc[3] Filter			
Internal Clock			
@ 50 Hz, 60 Hz	75	dB min	10 Hz output data rate, 50 ± 1 Hz, 60 ± 1 Hz.
	60	dB min	50 Hz output data rate, REJ60 = 1, 50 ± 1 Hz, 60 ± 1 Hz.
@ 50 Hz	70	dB min	50 Hz output data rate, 50 ± 1 Hz.
@ 60 Hz	70	dB min	60 Hz output data rate, 60 ± 1 Hz.
External Clock			
@ 50 Hz, 60 Hz	100	dB min	10 Hz output data rate, 50 ± 1 Hz, 60 ± 1 Hz.
	67	dB min	50 Hz output data rate, REJ60[7] = 1, 50 ± 1 Hz, 60 ± 1 Hz.
@ 50 Hz	95	dB min	50 Hz output data rate, 50 ± 1 Hz.
@ 60 Hz	95	dB min	60 Hz output data rate, 60 ± 1 Hz.
ANALOG INPUTS			
Differential Input Voltage Ranges	$\pm V_{REF}$/gain	V nom	V_{REF} = REFINx(+) − REFINx(−), gain = 1 to 128.
	$\pm(AV_{DD} - 1.25\ V)$/gain	V min/max	Gain > 1.
Absolute AIN Voltage Limits[2]			
Unbuffered Mode	AGND − 50 mV	V min	
	AV_{DD} + 50 mV	V max	
Buffered Mode	AGND + 250 mV	V min	
	AV_{DD} − 250 mV	V max	
Analog Input Current			
Buffered Mode			
Input Current[2]	±2	nA max	Gain = 1.
	±3	nA max	Gain > 1.
Input Current Drift	±5	pA/°C typ	
Unbuffered Mode			
Input Current	±5	µA/V typ	Gain = 1, input current varies with input voltage.
	±1	µA/V typ	Gain > 1.
Input Current Drift	±0.05	nA/V/°C typ	External clock.
	±1.6	nA/V/°C typ	Internal clock.
REFERENCE INPUT			
REFIN Voltage	AV_{DD}	V nom	REFIN = REFINx(+) − REFINx(−).
Reference Voltage Range[2]	1	V min	
	AV_{DD}	V max	The differential input must be limited to ± (AV_{DD} − 1.25 V)/gain when gain > 1.
Absolute REFIN Voltage Limits[2]	AGND − 50 mV	V min	
	AV_{DD} + 50 mV	V max	
Average Reference Input Current	7	µA/V typ	
Average Reference Input Current Drift	±0.03	nA/V/°C typ	External clock.
	1.3	nA/V/°C typ	Internal clock.

Parameter	AD7190B	Unit	Test Conditions/Comments[1]
Normal Mode Rejection[2]	Same as for analog inputs		
Common-Mode Rejection	95	dB typ	
Reference Detect Levels	0.3	V min	
	0.6	V max	
TEMPERATURE SENSOR			
Accuracy	±2	°C typ	Applies after user calibration at 25°C.
Sensitivity	2815	Codes/°C typ	Bipolar mode.
BRIDGE POWER-DOWN SWITCH			
R_{ON}	10	Ω max	
Allowable Current[2]	30	mA max	Continuous current.
BURNOUT CURRENTS			
AIN Current	500	nA nom	Analog inputs must be buffered and chop disabled.
DIGITAL OUTPUTS (P0 to P3)			
Output High Voltage, V_{OH}[2]	4	V min	AV_{DD} = 5V, I_{SOURCE} = 200 µA.
Output Low Voltage, V_{OL}[2]	0.4	V max	AV_{DD} = 5V, I_{SINK} = 800 µA.
Floating-State Leakage Current	±100	nA max	
Floating-State Output Capacitance	10	pF typ	
INTERNAL/EXTERNAL CLOCK			
Internal Clock			
Frequency	4.92 ± 4%	MHz min/max	
Duty Cycle	50:50	% typ	
External Clock/Crystal[2]			
Frequency	4.9152	MHz nom	
	2.4576/5.12	MHz min/max	
Input Low Voltage, V_{INL}	0.8	V max	DV_{DD} = 5 V.
	0.4	V max	DV_{DD} = 3 V.
Input High Voltage, V_{INH}	2.5	V min	DV_{DD} = 3 V.
	3.5	V min	DV_{DD} = 5 V.
Input Current	±10	µA max	
LOGIC INPUTS			
Input High Voltage, V_{INH}[2]	2	V min	
Input Low Voltage, V_{INL}[2]	0.8	V max	
Hysteresis[2]	0.1/0.25	V min/V max	
Input Currents	±10	µA max	
LOGIC OUTPUT (DOUT/$\overline{RDY}$)			
Output High Voltage, V_{OH}[2]	DV_{DD} − 0.6	V min	DV_{DD} = 3 V, I_{SOURCE} = 100 µA.
Output Low Voltage, V_{OL}[2]	0.4	V max	DV_{DD} = 3 V, I_{SINK} = 100 µA.
Output High Voltage, V_{OH}[2]	4	V min	DV_{DD} = 5 V, I_{SOURCE} = 200 µA.
Output Low Voltage, V_{OL}[2]	0.4	V max	DV_{DD} = 5 V, I_{SINK} = 1.6 mA.
Floating-State Leakage Current	±10	µA max	
Floating-State Output Capacitance	10	pF typ	
Data Output Coding	Offset binary		
SYSTEM CALIBRATION[2]			
Full-Scale Calibration Limit	1.05 × FS	V max	
Zero-Scale Calibration Limit	−1.05 × FS	V min	
Input Span	0.8 × FS	V min	
	2.1 × FS	V max	

Parameter	AD7190B	Unit	Test Conditions/Comments[1]
POWER REQUIREMENTS[8]			
Power Supply Voltage			
AV_{DD} − AGND	4.75/5.25	V min/max	
DV_{DD} − DGND	2.7/5.25	V min/max	
Power Supply Currents			
AI_{DD} Current	1	mA max	0.85 mA typical, gain = 1, buffer off.
	1.3	mA max	1.1 mA typical, gain = 1, buffer on.
B Grade	4.5	mA max	3.5 mA typical, gain = 8, buffer off.
	4.75	mA max	4 mA typical, gain = 8, buffer on.
	6.2	mA max	5 mA typical, gain = 16 to 128, buffer off.
	6.75	mA max	5.5 mA typical, gain = 16 to 128, buffer on.
WB Grade	5	mA max	3.5 mA typical, gain = 8, buffer off.
	5.3	mA max	4 mA typical, gain = 8, buffer on.
	6.8	mA max	5 mA typical, gain = 16 to 128, buffer off.
	7.4	mA max	5.5 mA typical, gain = 16 to 128, buffer on.
DI_{DD} Current	0.4	mA max	0.35 mA typical, DV_{DD} = 3 V.
	0.6	mA max	0.5 mA typical, DV_{DD} = 5 V.
	1.5	mA typ	External crystal used.
I_{DD} (Power-Down Mode)			
B Grade	2	μA max	
WB Grade	5	μA max	

[1] Temperature range: T_{MIN} = −40°C, T_{MAX} = +105°C.
[2] Specification is not production tested but is supported by characterization data at initial product release.
[3] FS = decimal equivalent of Bit FS9 to Bit FS0 in the mode register.
[4] Following a system or internal zero-scale calibration, the offset error is in the order of the noise for the programmed gain and output data rate selected. A system full-scale calibration reduces the gain error to the order of the noise for the programmed gain and output data rate.
[5] The analog inputs are configured for differential mode.
[6] Applies at the factory calibration conditions (AV_{DD} = 5 V, gain = 1, T_A = 25°C).
[7] REJ60 is a bit in the mode register. When the output data rate is set to 50 Hz, setting REJ60 to 1 places a notch at 60 Hz, allowing simultaneous 50 Hz/60 Hz rejection.
[8] Digital inputs equal to DV_{DD} or DGND.

TIMING CHARACTERISTICS

AV_{DD} = 4.75 V to 5.25 V, DV_{DD} = 2.7 V to 5.25 V, AGND = DGND = 0 V, Input Logic 0 = 0 V, Input Logic 1 = DV_{DD}, unless otherwise noted.

Table 2.

Parameter	Limit at T_{MIN}, T_{MAX} (B Version)	Unit	Conditions/Comments[1, 2]
t_3	100	ns min	SCLK high pulse width
t_4	100	ns min	SCLK low pulse width
READ OPERATION			
t_1	0	ns min	$\overline{CS}$ falling edge to DOUT/$\overline{RDY}$ active time
	60	ns max	DV_{DD} = 4.75 V to 5.25 V
	80	ns max	DV_{DD} = 2.7 V to 3.6 V
t_2[3]	0	ns min	SCLK active edge to data valid delay[4]
	60	ns max	DV_{DD} = 4.75 V to 5.25 V
	80	ns max	DV_{DD} = 2.7 V to 3.6 V
t_5[5, 6]	10	ns min	Bus relinquish time after $\overline{CS}$ inactive edge
	80	ns max	
t_6	0	ns min	SCLK inactive edge to $\overline{CS}$ inactive edge
t_7	10	ns min	SCLK inactive edge to DOUT/$\overline{RDY}$ high
WRITE OPERATION			
t_8	0	ns min	$\overline{CS}$ falling edge to SCLK active edge setup time[4]
t_9	30	ns min	Data valid to SCLK edge setup time
t_{10}	25	ns min	Data valid to SCLK edge hold time
t_{11}	0	ns min	$\overline{CS}$ rising edge to SCLK edge hold time

[1] Sample tested during initial release to ensure compliance. All input signals are specified with $t_R = t_F$ = 5 ns (10% to 90% of DV_{DD}) and timed from a voltage level of 1.6 V.
[2] See Figure 3 and Figure 4.
[3] These numbers are measured with the load circuit shown in Figure 2 and defined as the time required for the output to cross the V_{OL} or V_{OH} limits.
[4] The SCLK active edge is the falling edge of SCLK.
[5] These numbers are derived from the measured time taken by the data output to change 0.5 V when loaded with the circuit shown in Figure 2. The measured number is then extrapolated back to remove the effects of charging or discharging the 50 pF capacitor. This means that the times quoted in the timing characteristics are the true bus relinquish times of the part and, as such, are independent of external bus loading capacitances.
[6] $\overline{RDY}$ returns high after a read of the data register. In single conversion mode and continuous conversion mode, the same data can be read again, if required, while $\overline{RDY}$ is high, although care should be taken to ensure that subsequent reads do not occur close to the next output update. If the continuous read feature is enabled, the digital word can be read only once.

CIRCUIT AND TIMING DIAGRAMS

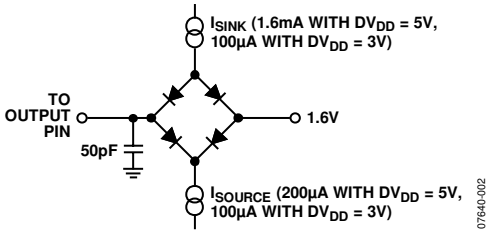

Figure 2. Load Circuit for Timing Characterization

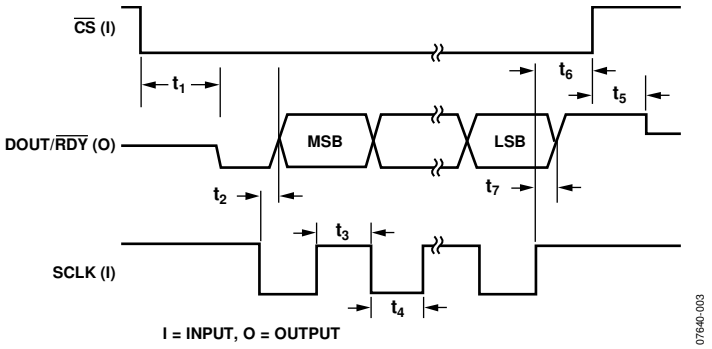

Figure 3. Read Cycle Timing Diagram

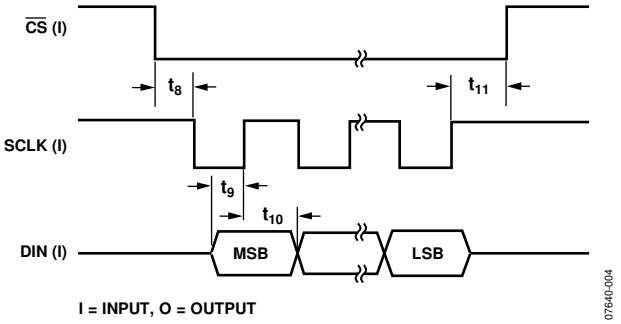

Figure 4. Write Cycle Timing Diagram

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C, unless otherwise noted.

Table 3.

Parameter	Rating
AV_{DD} to AGND	−0.3 V to +6.5 V
DV_{DD} to AGND	−0.3 V to +6.5 V
AGND to DGND	−0.3 V to +0.3 V
Analog Input Voltage to AGND	−0.3 V to AV_{DD} + 0.3 V
Reference Input Voltage to AGND	−0.3 V to AV_{DD} + 0.3 V
Digital Input Voltage to DGND	−0.3 V to DV_{DD} + 0.3 V
Digital Output Voltage to DGND	−0.3 V to DV_{DD} + 0.3 V
AIN/Digital Input Current	10 mA
Operating Temperature Range	−40°C to +105°C
Storage Temperature Range	−65°C to +150°C
Maximum Junction Temperature	150°C
Lead Temperature, Soldering Reflow	260°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

THERMAL RESISTANCE

θ_{JA} is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

Table 4. Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Unit
24-Lead TSSOP	128	42	°C/W

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

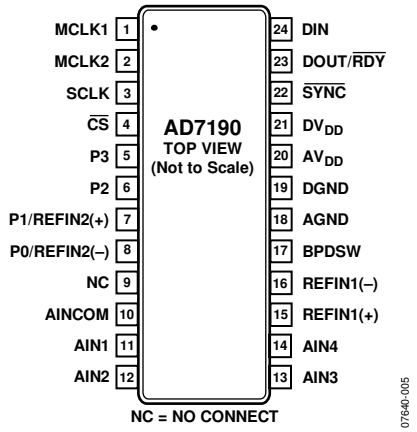

Figure 5. Pin Configuration

Table 5. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	MCLK1	When the master clock for the device is provided externally by a crystal, the crystal is connected between MCLK1 and MCLK2.
2	MCLK2	Master Clock Signal for the Device. The AD7190 has an internal 4.92 MHz clock. This internal clock can be made available on the MCLK2 pin. The clock for the AD7190 can be provided externally also in the form of a crystal or external clock. A crystal can be tied across the MCLK1 and MCLK2 pins. Alternatively, the MCLK2 pin can be driven with a CMOS-compatible clock and the MCLK1 pin left unconnected.
3	SCLK	Serial Clock Input. This serial clock input is for data transfers to and from the ADC. The SCLK has a Schmitt-triggered input, making the interface suitable for opto-isolated applications. The serial clock can be continuous with all data transmitted in a continuous train of pulses. Alternatively, it can be a noncontinuous clock with the information transmitted to or from the ADC in smaller batches of data.
4	$\overline{CS}$	Chip Select Input. This is an active low logic input used to select the ADC. $\overline{CS}$ can be used to select the ADC in systems with more than one device on the serial bus or as a frame synchronization signal in communicating with the device. $\overline{CS}$ can be hardwired low, allowing the ADC to operate in 3-wire mode with SCLK, DIN, and DOUT used to interface with the device.
5	P3	Digital Output Pin. This pin can function as a general-purpose output bit referenced between AV_{DD} and AGND.
6	P2	Digital Output Pin. This pin can function as a general-purpose output bit referenced between AV_{DD} and AGND.
7	P1/REFIN2(+)	Digital Output Pin/Positive Reference Input. This pin functions as a general-purpose output bit referenced between AV_{DD} and AGND. When REFSEL = 1, this pin functions as REFIN2(+). An external reference can be applied between REFIN2(+) and REFIN2(−). REFIN2(+) can lie anywhere between AV_{DD} and AGND + 1 V. The nominal reference voltage, (REFIN2(+) − REFIN2(−)), is AV_{DD}, but the part functions with a reference from 1 V to AV_{DD}.
8	P0/REFIN2(−)	Digital Output Pin/Negative Reference Input. This pin functions as a general-purpose output bit referenced between AV_{DD} and AGND. When REFSEL = 1, this pin functions as REFIN2(−). This reference input can lie anywhere between AGND and AV_{DD} − 1 V.
9	NC	No Connect. This pin should be tied to AGND.
10	AINCOM	Analog Input AIN1 to Analog Input AIN4 are referenced to this input when configured for pseudo differential operation.
11	AIN1	Analog Input. It can be configured as the positive input of a fully differential input pair when used with AIN2 or as a pseudo differential input when used with AINCOM.
12	AIN2	Analog Input. It can be configured as the negative input of a fully differential input pair when used with AIN1 or as a pseudo differential input when used with AINCOM.

Pin No.	Mnemonic	Description
13	AIN3	Analog Input. It can be configured as the positive input of a fully differential input pair when used with AIN4 or as a pseudo differential input when used with AINCOM.
14	AIN4	Analog Input. It can be configured as the negative input of a fully differential input pair when used with AIN3 or as a pseudo differential input when used with AINCOM.
15	REFIN1(+)	Positive Reference Input. An external reference can be applied between REFIN1(+) and REFIN1(−). REFIN1(+) can lie anywhere between AV_{DD} and AGND + 1 V. The nominal reference voltage, (REFIN1(+) − REFIN1(−)), is AV_{DD}, but the part functions with a reference from 1 V to AV_{DD}.
16	REFIN1(−)	Negative Reference Input. This reference input can lie anywhere between AGND and AV_{DD} − 1 V.
17	BPDSW	Bridge Power-Down Switch to AGND.
18	AGND	Analog Ground Reference Point.
19	DGND	Digital Ground Reference Point.
20	AV_{DD}	Analog Supply Voltage, 4.75 V to 5.25 V. AV_{DD} is independent of DV_{DD}.
21	DV_{DD}	Digital Supply Voltage, 2.7 V to 5.25 V. DV_{DD} is independent of AV_{DD}.
22	$\overline{SYNC}$	Logic input that allows for synchronization of the digital filters and analog modulators when using multiple AD7190 devices. While $\overline{SYNC}$ is low, the nodes of the digital filter, the filter control logic, and the calibration control logic are reset and the analog modulator is held in its reset state. $\overline{SYNC}$ does not affect the digital interface but does reset $\overline{RDY}$ to a high state if it is low. $\overline{SYNC}$ has a pull-up resistor internally to DV_{DD}.
23	DOUT/$\overline{RDY}$	Serial Data Output/Data Ready Output. DOUT/$\overline{RDY}$serves a dual purpose. It functions as a serial data output pin to access the output shift register of the ADC. The output shift register can contain data from any of the on-chip data or control registers. In addition, DOUT/$\overline{RDY}$ operates as a data ready pin, going low to indicate the completion of a conversion. If the data is not read after the conversion, the pin goes high before the next update occurs. The DOUT/$\overline{RDY}$ falling edge can be used as an interrupt to a processor, indicating that valid data is available. With an external serial clock, the data can be read using the DOUT/$\overline{RDY}$ pin. With $\overline{CS}$ low, the data/control word information is placed on the DOUT/$\overline{RDY}$ pin on the SCLK falling edge and is valid on the SCLK rising edge.
24	DIN	Serial Data Input to the Input Shift Register on the ADC. Data in this shift register is transferred to the control registers in the ADC, with the register selection bits of the communications register identifying the appropriate register.

TYPICAL PERFORMANCE CHARACTERISTICS

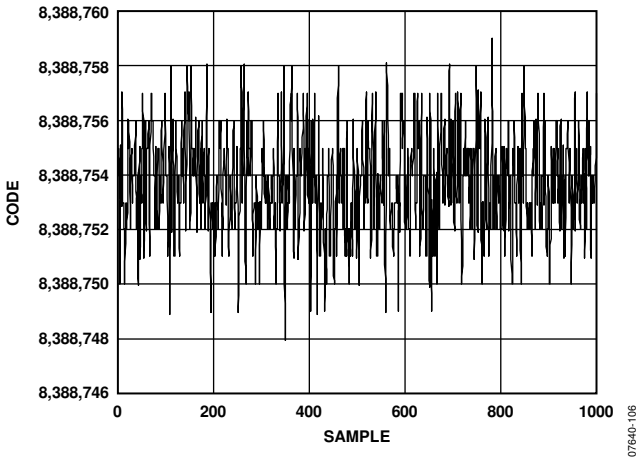

Figure 6. Noise (V_{REF} = 5 V, Output Data Rate = 4.7 Hz, Gain = 128, Chop Disabled, Sinc^4 Filter)

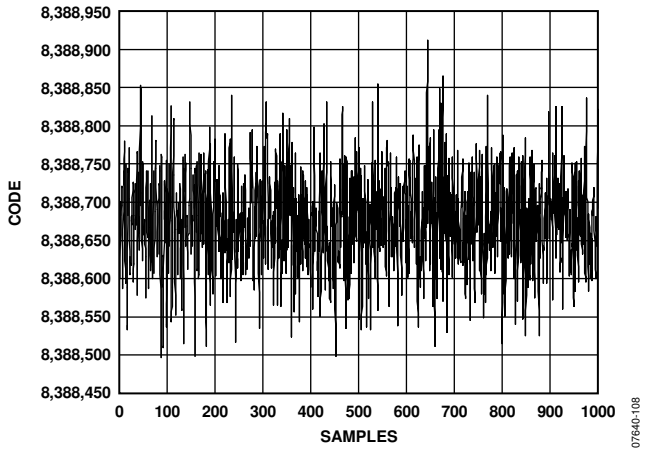

Figure 8. Noise (V_{REF} = 5 V, Output Data Rate = 4800 Hz, Gain = 128, Chop Disabled, Sinc^4 Filter)

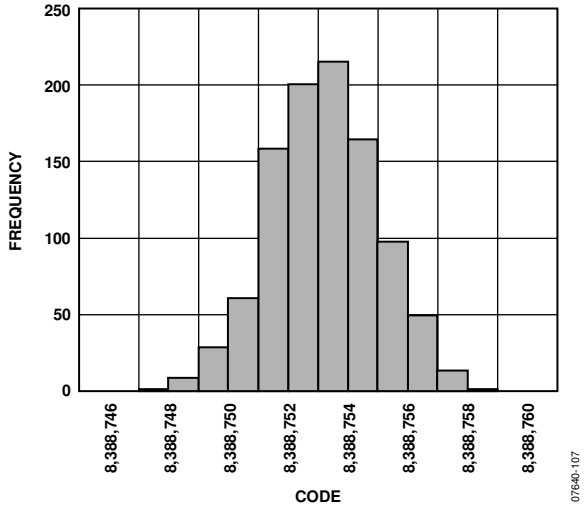

Figure 7. Noise Distribution Histogram (V_{REF} = 5 V, Output Data Rate = 4.7 Hz, Gain = 128, Chop Disabled, Sinc^4 Filter)

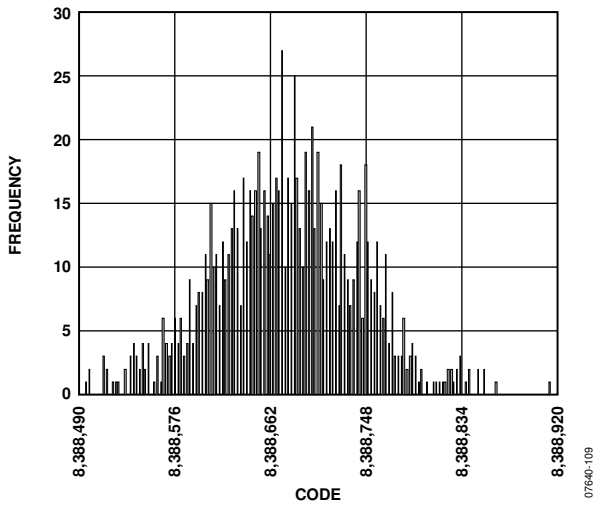

Figure 9. Noise Distribution Histogram (V_{REF} = 5 V, Output Data Rate = 4800 Hz, Gain = 128, Chop Disabled, Sinc^4 Filter)

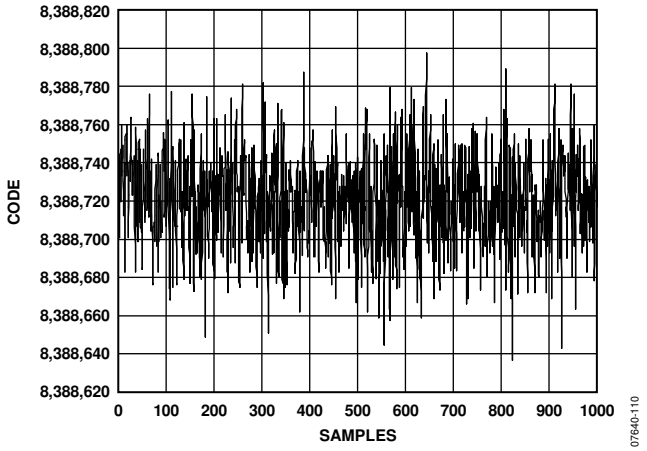

Figure 10. Noise (V_{REF} = 5 V, Output Data Rate = 4800 Hz, Gain = 1, Chop Disabled, Sinc^4 Filter)

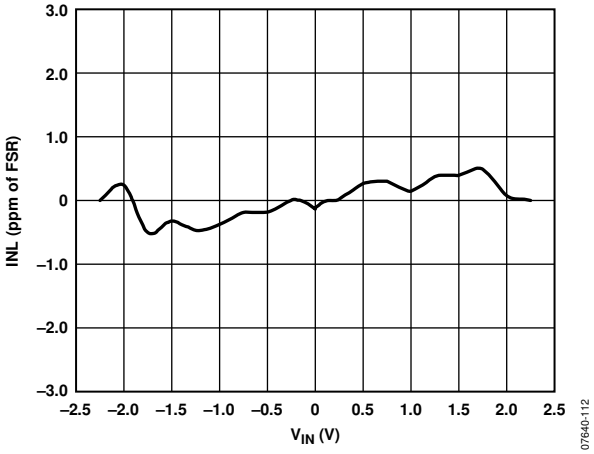

Figure 12. INL (Gain = 1)

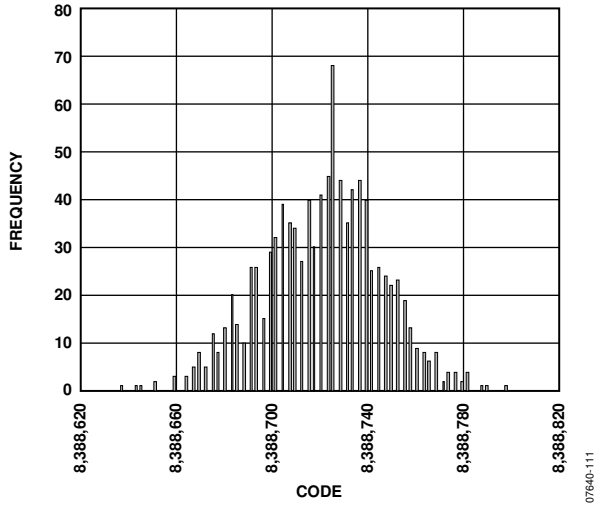

Figure 11. Noise Distribution Histogram (V_{REF} = 5 V, Output Data Rate = 4800 Hz, Gain = 1, Chop Disabled, Sinc^4 Filter)

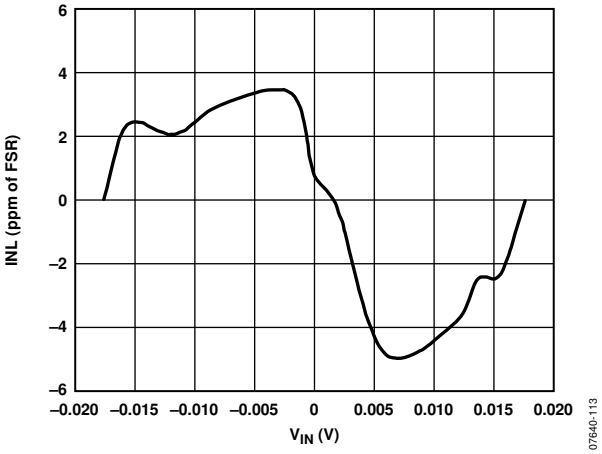

Figure 13. INL (Gain = 128)

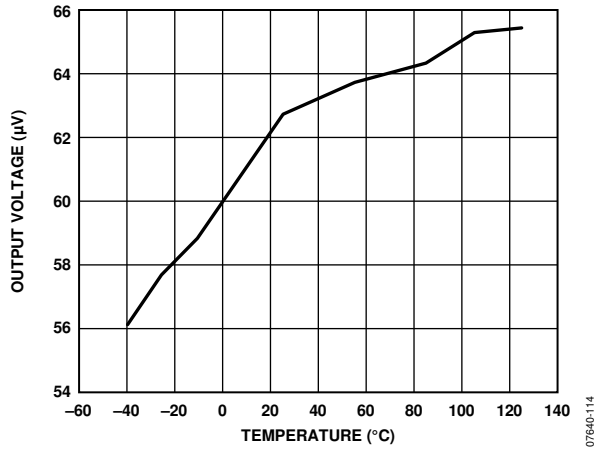

Figure 14. Offset Error (Gain = 1, Chop Disabled)

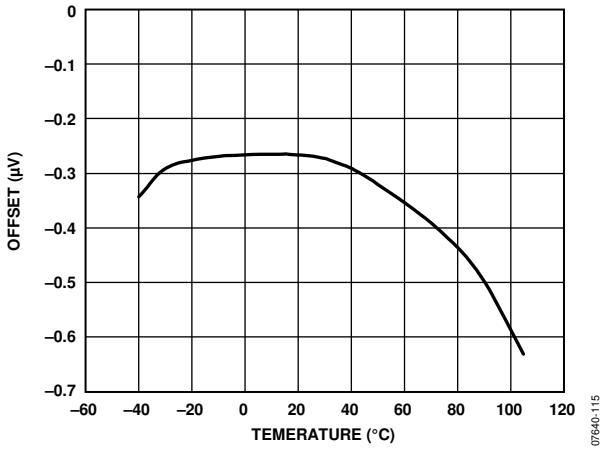

Figure 15. Offset Error (Gain = 128, Chop Disabled)

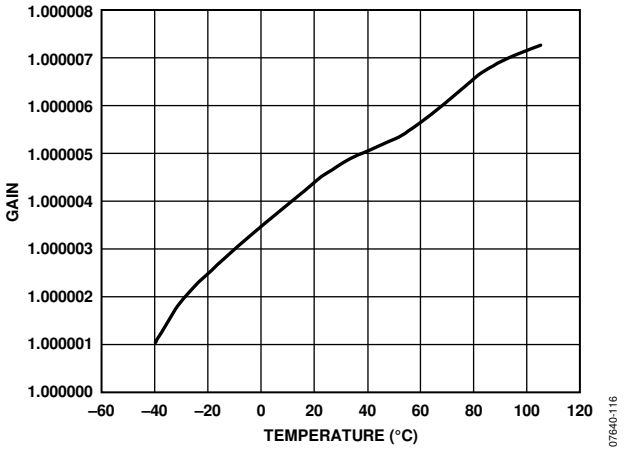

Figure 16. Gain Error (Gain = 1, Chop Disabled)

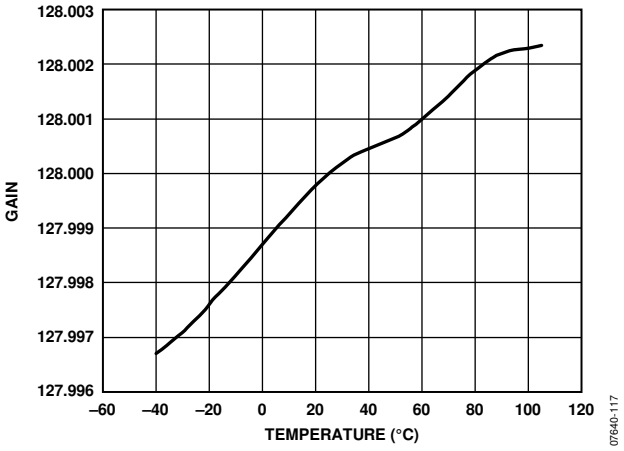

Figure 17. Gain Error (Gain = 128, Chop Disabled)

RMS NOISE AND RESOLUTION

The AD7190 has a choice of two filter types: sinc^4 and sinc^3. In addition, the AD7190 can be operated with chop enabled or chop disabled.

The following tables show the rms noise of the AD7190 for some of the output data rates and gain settings with chop disabled and enabled for the sinc^4 and sinc^3 filters. The numbers given are for the bipolar input range with the external 5 V reference. These numbers are typical and are generated with a differential input voltage of 0 V when the ADC is continuously converting on a single channel. The effective resolution is also shown, and the output peak-to-peak (p-p) resolution, or noise-free resolution, is listed in parentheses. It is important to note that the effective resolution is calculated using the rms noise, wheras the p-p resolution is calculated based on peak-to-peak noise. The p-p resolution represents the resolution for which there is no code flicker. These numbers are typical and are rounded to the nearest ½ LSB.

SINC^4 CHOP DISABLED

Table 6. RMS Noise (nV) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1	Gain of 8	Gain of 16	Gain of 32	Gain of 64	Gain of 128
1023	4.7	852.5	250	38	21	12	10	8.5
640	7.5	533	310	45	25	16	12	10.5
480	10	400	330	50	30	18	14	11.5
96	50	80	900	125	78	45	33	28
80	60	66.7	970	140	88	52	36	31
32	150	26.7	1460	215	125	75	55	48
16	300	13.3	1900	285	170	100	75	67
5	960	4.17	3000	480	280	175	140	121
2	2400	1.67	5000	780	440	280	220	198
1	4800	0.83	14,300	1920	1000	550	380	295

Table 7. Effective Resolution (Peak-to-Peak Resolution) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1[1]	Gain of 8[1]	Gain of 16[1]	Gain of 32[1]	Gain of 64[1]	Gain of 128[1]
1023	4.7	852.5	24 (22.5)	24 (22)	24 (22)	24 (22)	24 (21)	23 (20.5)
640	7.5	533	24 (22)	24 (22)	24 (22)	24 (21.5)	23.5 (21)	23 (20)
480	10	400	24 (22)	24 (22)	24 (21.5)	24 (21.5)	23.5 (20.5)	22.5 (20)
96	50	80	23.5 (20.5)	23.5 (20.5)	23 (20)	22.5 (20)	22 (19.5)	21.5 (18.5)
80	60	66.7	23.5 (20.5)	23 (20.5)	22.5 (20)	22.5 (20)	22 (19.5)	21.5 (18.5)
32	150	26.7	22.5 (20)	22.5 (19.5)	22.5 (19.5)	22 (19.5)	21.5 (18.5)	20.5 (18)
16	300	13.3	22.5 (19.5)	22 (19.5)	22 (19)	21.5 (19)	21 (18.5)	20 (17.5)
5	960	4.17	21.5 (19)	21.5 (18.5)	21 (18.5)	21 (18)	20 (17.5)	19.5 (16.5)
2	2400	1.67	21 (18)	20.5 (18)	20.5 (17.5)	20 (17.5)	19.5 (16.5)	18.5 (16)
1	4800	0.83	19.5 (16.5)	19.5 (16.5)	19.5 (16.5)	19 (16.5)	18.5 (16)	18 (15.5)

[1] The output peak-to-peak (p-p) resolution is listed in parentheses.

SINC³ CHOP DISABLED

Table 8. RMS Noise (nV) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1	Gain of 8	Gain of 16	Gain of 32	Gain of 64	Gain of 128
1023	4.7	639.4	270	42	23	13.5	10.5	9
640	7.5	400	320	50	27	17	13	11.5
480	10	300	350	60	35	19	15	12.5
96	50	60	1000	134	86	50	35	29
80	60	50	1050	145	95	55	40	32
32	150	20	1500	225	130	80	58	50
16	300	10	1950	308	175	110	83	73
5	960	3.125	4000	590	330	200	150	133
2	2400	1.25	56,600	7000	3500	1800	900	490
1	4800	0.625	442,000	55,000	28,000	14,000	7000	3450

Table 9. Effective Resolution (Peak-to-Peak Resolution) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1[1]	Gain of 8[1]	Gain of 16[1]	Gain of 32[1]	Gain of 64[1]	Gain of 128[1]
1023	4.7	639.4	24 (22.5)	24 (22)	24 (22)	24 (21.5)	24 (21)	23 (20.5)
640	7.5	400	24 (22)	24 (22)	24 (21.5)	24 (21.5)	23.5 (21)	22.5 (20)
480	10	300	24 (22)	24 (21.5)	24 (21.5)	24 (21)	23.5 (20.5)	22.5 (20)
96	50	60	23.5 (20.5)	23 (20.5)	23 (20)	22.5 (20)	22 (19.5)	21.5 (18.5)
80	60	50	23 (20.5)	23 (20.5)	22.5 (20)	22.5 (19.5)	22 (19)	21 (18.5)
32	150	20	22.5 (20)	22.5 (19.5)	22 (19.5)	22 (19)	21.5 (18.5)	20.5 (18)
16	300	10	22.5 (19.5)	22 (19)	22 (19)	21.5 (18.5)	21 (18)	20 (17.5)
5	960	3.125	21.5 (18.5)	21 (18.5)	21 (18)	20.5 (18)	20 (17.5)	19 (16.5)
2	2400	1.25	17.5 (14.5)	17.5 (14.5)	17.5 (14.5)	17.5 (14.5)	17.5 (14.5)	17.5 (14.5)
1	4800	0.625	14.5 (11.5)	14.5 (11.5)	14.5 (11.5)	14.5 (11.5)	14.5 (11.5)	14.5 (11.5)

[1] The output peak-to-peak (p-p) resolution is listed in parentheses.

SINC^4 CHOP ENABLED

Table 10. RMS Noise (nV) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1	Gain of 8	Gain of 16	Gain of 32	Gain of 64	Gain of 128
1023	1.175	1702	177	27	15	8.5	7	6
640	1.875	1067	219	32	18	11.5	8.5	7.5
480	2.5	800	234	36	21	13	10	8.5
96	12.5	160	637	89	55	32	24	20
80	15	133	686	99	63	37	26	22
32	37.5	53	1033	152	89	53	39	34
16	75	26.7	1343	202	120	71	53	48
5	240	8.33	2121	340	198	124	99	86
2	600	3.33	3536	552	311	198	156	140
1	1200	1.67	10,200	1360	707	389	26	209

Table 11. Effective Resolution (Peak-to-Peak Resolution) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1[1]	Gain of 8[1]	Gain of 16[1]	Gain of 32[1]	Gain of 64[1]	Gain of 128[1]
1023	1.175	1702	24 (23)	24 (22.5)	24 (22.5)	24 (22.5)	24 (21.5)	23.5 (21)
640	1.875	1067	24 (22.5)	24 (22.5)	24 (22.5)	24 (22)	24 (21.5)	23.5 (20.5)
480	2.5	800	24 (22.5)	24 (22.5)	24 (22)	24 (22)	24 (21)	23 (20.5)
96	12.5	160	24 (21)	24 (21)	23.5 (20.5)	23 (20.5)	22.5 (20)	22 (19)
80	15	133	24 (21)	23.5 (21)	23.5 (20.5)	23 (20.5)	22.5 (20)	22 (19)
32	37.5	53	23 (20.5)	23 (20)	23 (20)	22.5 (20)	22 (19)	21 (18.5)
16	75	26.7	23 (20)	22.5 (20)	22.5 (19.5)	22 (19.5)	21.5 (19)	20.5 (18)
5	240	8.33	22 (19.5)	22 (19)	21.5 (19)	21.5 (18.5)	20.5 (18)	20 (17)
2	600	3.33	21.5 (18.5)	21 (18.5)	21 (18)	20.5 (18)	20 (17)	19 (16.5)
1	1200	1.67	20 (17)	20 (17)	20 (17)	19.5 (17)	19 (16.5)	18.5 (16)

[1] The output peak-to-peak (p-p) resolution is listed in parentheses.

SINC³ CHOP ENABLED

Table 12. RMS Noise (nV) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1	Gain of 8	Gain of 16	Gain of 32	Gain of 64	Gain of 128
1023	1.56	1282	191	30	16.5	10	8	6.5
640	2.5	800	226	36	19	12	9	8.5
480	3.33	600	248	43	25	14	11	9
96	16.6	120	708	95	61	36	25	21
80	20	100	743	103	68	39	29	23
32	50	40	1061	159	92	57	41	36
16	100	20	1380	218	124	78	59	52
5	320	6.25	2829	418	234	142	106	94
2	800	2.5	40,100	4950	2475	1273	637	347
1	1600	1.25	312,550	38,540	19,800	9900	4950	2440

Table 13. Effective Resolution (Peak-to-Peak Resolution) vs. Gain and Output Data Rate

Filter Word (Decimal)	Output Data Rate (Hz)	Settling Time (ms)	Gain of 1[1]	Gain of 8[1]	Gain of 16[1]	Gain of 32[1]	Gain of 64[1]	Gain of 128[1]
1023	1.56	1282	24 (23)	24 (22.5)	24 (22.5)	24 (22)	24 (21.5)	23.5 (21)
640	2.5	800	24 (22.5)	24 (22.5)	24 (22)	24 (22)	24 (21.5)	23 (20.5)
480	3.33	600	24 (22.5)	24 (22)	24 (22)	24 (21.5)	24 (21)	23 (20.5)
96	16.6	120	24 (21)	23.5 (21)	23.5 (20.5)	23 (20.5)	22.5 (20)	22 (19)
80	20	100	23.5 (21)	23.5 (21)	23 (20.5)	23 (20)	22.5 (19.5)	21.5 (19)
32	50	40	23 (20.5)	23 (20)	22.5 (20)	22.5 (19.5)	22 (19)	21 (18.5)
16	100	20	23 (20)	22.5 (19.5)	22.5 (19.5)	22 (19)	21.5 (18.5)	20.5 (18)
5	320	6.25	22 (19)	21.5 (19)	21.5 (18.5)	21 (18.5)	20.5 (18)	19.5 (17)
2	800	2.5	18 (15)	18 (15)	18 (15)	18 (15)	18 (15)	18 (15)
1	1600	1.25	15 (12)	15 (12.5)	15 (12)	15 (12)	15 (12)	15 (12)

[1] The output peak-to-peak (p-p) resolution is listed in parentheses.

ON-CHIP REGISTERS

The ADC is controlled and configured via a number of on-chip registers, which are described in the following sections. In the descriptions, set implies a Logic 1 state and cleared implies a Logic 0 state, unless otherwise noted.

COMMUNICATIONS REGISTER

(RS2, RS1, RS0 = 0, 0, 0)

The communications register is an 8-bit write-only register. All communications to the part must start with a write operation to the communications register. The data written to the communications register determines whether the next operation is a read or write operation and in which register this operation takes place. For read or write operations, when the subsequent read or write operation to the selected register is complete, the interface returns to where it expects a write operation to the communications register. This is the default state of the interface and, on power-up or after a reset, the ADC is in this default state waiting for a write operation to the communications register. In situations where the interface sequence is lost, a write operation of at least 40 serial clock cycles with DIN high returns the ADC to this default state by resetting the entire part. Table 14 outlines the bit designations for the communications register. CR0 through CR7 indicate the bit locations, CR denoting that the bits are in the communications register. CR7 denotes the first bit of the data stream. The number in parentheses indicates the power-on/reset default status of that bit.

CR7	CR6	CR5	CR4	CR3	CR2	CR1	CR0
$\overline{\text{WEN}}$(0)	R/$\overline{\text{W}}$(0)	RS2(0)	RS1(0)	RS0(0)	CREAD(0)	0(0)	0(0)

Table 14. Communications Register Bit Designations

Bit Location	Bit Name	Description
CR7	$\overline{\text{WEN}}$	Write enable bit. A 0 must be written to this bit for a write to the communications register to occur. If a 1 is the first bit written, the part does not clock on to subsequent bits in the register. It stays at this bit location until a 0 is written to this bit. After a 0 is written to the $\overline{\text{WEN}}$ bit, the next seven bits are loaded to the communications register.
CR6	R/$\overline{\text{W}}$	A 0 in this bit location indicates that the next operation is a write to a specified register. A 1 in this position indicates that the next operation is a read from the designated register.
CR5 to CR3	RS2 to RS0	Register address bits. These address bits are used to select which registers of the ADC are selected during the serial interface communication. See Table 15.
CR2	CREAD	Continuous read of the data register. When this bit is set to 1 (and the data register is selected), the serial interface is configured so that the data register can be continuously read; that is, the contents of the data register are automatically placed on the DOUT pin when the SCLK pulses are applied after the $\overline{\text{RDY}}$ pin goes low to indicate that a conversion is complete. The communications register does not have to be written to for subsequent data reads. To enable continuous read, the instruction 01011100 must be written to the communications register. To disable continuous read, the instruction 01011000 must be written to the communications register while the $\overline{\text{RDY}}$ pin is low. While continuous read is enabled, the ADC monitors activity on the DIN line so that it can receive the instruction to disable continuous read. Additionally, a reset occurs if 40 consecutive 1s are seen on DIN. Therefore, DIN should be held low until an instruction is to be written to the device.
CR1 to CR0		These bits must be programmed to Logic 0 for correct operation.

Table 15. Register Selection

RS2	RS1	RS0	Register	Register Size
0	0	0	Communications register during a write operation	8 bits
0	0	0	Status register during a read operation	8 bits
0	0	1	Mode register	24 bits
0	1	0	Configuration register	24 bits
0	1	1	Data register/data register plus status information	24 bits/32 bits
1	0	0	ID register	8 bits
1	0	1	GPOCON register	8 bits
1	1	0	Offset register	24 bits
1	1	1	Full-scale register	24 bits

STATUS REGISTER

(RS2, RS1, RS0 = 0, 0, 0; Power-On/Reset = 0x80)

The status register is an 8-bit, read-only register. To access the ADC status register, the user must write to the communications register, select the next operation to be a read, and load Bit RS2, Bit RS1, and Bit RS0 with 0. Table 16 outlines the bit designations for the status register. SR0 through SR7 indicate the bit locations, SR denoting that the bits are in the status register. SR7 denotes the first bit of the data stream. The number in parentheses indicates the power-on/reset default status of that bit.

SR7	**SR6**	**SR5**	**SR4**	**SR3**	**SR2**	**SR1**	**SR0**
$\overline{\text{RDY}}$(1)	ERR(0)	NOREF(0)	Parity(0)	0(0)	CHD2(0)	CHD1(0)	CHD0(0)

Table 16. Status Register Bit Designations

Bit Location	Bit Name	Description
SR7	$\overline{\text{RDY}}$	Ready bit for the ADC. Cleared when data is written to the ADC data register. The $\overline{\text{RDY}}$ bit is set automatically after the ADC data register is read, or a period of time before the data register is updated with a new conversion result, to indicate to the user that the conversion data should not be read. It is also set when the part is placed in power-down mode or idle mode or when $\overline{\text{SYNC}}$ is taken low. The end of a conversion is also indicated by the DOUT/$\overline{\text{RDY}}$ pin. This pin can be used as an alternative to the status register for monitoring the ADC for conversion data.
SR6	ERR	ADC error bit. This bit is written to at the same time as the $\overline{\text{RDY}}$ bit. The ERR bit is set to indicate that the result written to the ADC data register is clamped to all 0s or all 1s. Error sources include overrange or underrange or the absence of a reference voltage. The bit is cleared by a write operation to start a conversion.
SR5	NOREF	No external reference bit. This bit is set to indicate that the selected reference (REFIN1 or REFIN2) is at a voltage that is below a specified threshold. When set, conversion results are clamped to all 1s. This bit is cleared to indicate that a valid reference is applied to the selected reference pins. The NOREF bit is enabled by setting the REFDET bit in the configuration register to 1.
SR4	Parity	Parity check of the data register. If the ENPAR bit in the mode register is set, the parity bit is set if there is an odd number of 1s in the data register. It is cleared if there is an even number of 1s in the data register. The DAT_STA bit in the mode register should be set when the parity check is used. When the DAT_STA bit is set, the contents of the status register are transmitted along with the data for each data register read.
SR3	0	This bit will be set to 0.
SR2 to SR0	CHD2 to CHD0	These bits indicate which channel corresponds to the data register contents. They do not indicate which channel is presently being converted but indicate which channel was selected when the conversion contained in the data register was generated.

MODE REGISTER

(RS2, RS1, RS0 = 0, 0, 1; Power-On/Reset = 0x080060)

The mode register is a 24-bit register from which data can be read or to which data can be written. This register is used to select the operating mode, the output data rate, and the clock source. Table 17 outlines the bit designations for the mode register. MR0 through MR23 indicate the bit locations, MR denoting that the bits are in the mode register. MR23 denotes the first bit of the data stream. The number in parentheses indicates the power-on/reset default status of that bit. Any write to the mode register resets the modulator and filter and sets the $\overline{\text{RDY}}$ bit.

MR23	**MR22**	**MR21**	**MR20**	**MR19**	**MR18**	**MR17**	**MR16**
MD2(0)	MD1(0)	MD0(0)	DAT_STA(0)	CLK1(1)	CLK0(0)	0	0
MR15	**MR14**	**MR13**	**MR12**	**MR11**	**MR10**	**MR9**	**MR8**
Sinc3(0)	0	ENPAR(0)	0	Single(0)	REJ60(0)	FS9(0)	FS8(0)
MR7	**MR6**	**MR5**	**MR4**	**MR3**	**MR2**	**MR1**	**MR0**
FS7(0)	FS6(1)	FS5(1)	FS4(0)	FS3(0)	FS2(0)	FS1(0)	FS0(0)

Table 17. Mode Register Bit Designations

Bit Location	Bit Name	Description
MR23 to MR21	MD2 to MD0	Mode select bits. These bits select the operating mode of the AD7190 (see Table 18).
MR20	DAT_STA	This bit enables the transmission of status register contents after each data register read. When DAT_STA is set, the contents of the status register are transmitted along with each data register read. This function is useful when several channels are selected because the status register identifies the channel to which the data register value corresponds.
MR19 to MR18	CLK1 to CLK0	These bits are used to select the clock source for the AD7190. Either the on-chip 4.92 MHz clock or an external clock can be used. The ability to use an external clock allows several AD7190 devices to be synchronized. Also, 50 Hz/60 Hz rejection is improved when an accurate external clock drives the AD7190.
		CLK1 / **CLK0** / **ADC Clock Source**
		0 / 0 / External crystal. The external crystal is connected from MCLK1 to MCLK2.
		0 / 1 / External clock. The external clock is applied to the MCLK2 pin.
		1 / 0 / Internal 4.92 MHz clock. Pin MCLK2 is tristated.
		1 / 1 / Internal 4.92 MHz clock. The internal clock is available on MCLK2.
MR17 to MR16		These bits must be programmed with a Logic 0 for correct operation.
MR15	SINC3	$Sinc^3$ filter select bit. When this bit is cleared, the $sinc^4$ filter is used (default value). When this bit is set, the $sinc^3$ filter is used. The benefit of the $sinc^3$ filter compared to the $sinc^4$ filter is its lower settling time when chop is disabled. For a given output data rate, f_{ADC}, the $sinc^3$ filter has a settling time of $3/f_{ADC}$ while the $sinc^4$ filter has a settling time of $4/f_{ADC}$. The $sinc^4$ filter, due to its deeper notches, gives better 50 Hz/60 Hz rejection. At low output data rates, both filters give similar rms noise and similar no missing codes for a given output data rate. At higher output data rates (FS values less than 5), the $sinc^4$ filter gives better performance than the $sinc^3$ filter for rms noise and no missing codes.
MR14		This bit must be programmed with a Logic 0 for correct operation.
MR13	ENPAR	Enable parity bit. When ENPAR is set, parity checking on the data register is enabled. The DAT_STA bit in the mode register should be set when the parity check is used. When the DAT_STA bit is set, the contents of the status register are transmitted along with the data for each data register read.
MR12		This bit must be programmed with a Logic 0 for correct operation.
MR11	Single	Single cycle conversion enable bit. When this bit is set, the AD7190 settles in one conversion cycle so that it functions as a zero latency ADC. This bit has no affect when multiple analog input channels are enabled or when the single conversion mode is selected.
MR10	REJ60	This bit enables a notch at 60 Hz when the first notch of the sinc filter is at 50 Hz. When REJ60 is set, a filter notch is placed at 60 Hz when the sinc filter first notch is at 50 Hz. This allows simultaneous 50 Hz/60 Hz rejection.
MR9 to MR0	FS9 to FS0	Filter output data rate select bits. The 10 bits of data programmed into these bits determine the filter cutoff frequency, the position of the first notch of the filter, and the output data rate for the part. In association with the gain selection, it also determines the output noise (and, therefore, the effective resolution) of the device. (see Table 6 through Table 13) When chop is disabled and continuous conversion mode is selected, the output data rate equals $Output\ Data\ Rate = (fmod/64)/FS$ where *FS* is the decimal equivalent of the code in bits FS0 to FS9 and is in the range 1 to 1023, and *fmod* is the modulator frequency, which is equal to MCLK/16. With a nominal MCLK of 4.92 MHz, this results in a output data rate from 4.69 Hz to 4.8 kHz. With chop disabled, the filter first notch frequency is equal to the output data rate when converting on a single channel. When chop is enabled, the output data rate equals $Output\ Data\ Rate = (fmod/64)/(N \times FS)$ where: *FS* is the decimal equivalent of the code in Bit FS0 to Bit FS9 and is in the range 1 to 1023. *fmod* is the modulator frequency, which is equal to MCLK/16. With a nominal MCLK of 4.92 MHz, this results in a conversion rate from 4.69/N Hz to 4.8/N kHz, where N is the order of the sinc filter. The sinc filter's first notch frequency is equal to N × Output Data Rate. The chopping introduces notches at odd integer multiples of (Output Data Rate/2).

Table 18. Operating Modes

MD2	MD1	MD0	Mode
0	0	0	Continuous conversion mode (default). In continuous conversion mode, the ADC continuously performs conversions and places the result in the data register. The DOUT/ $\overline{RDY}$ pin and the $\overline{RDY}$ bit in the status register go low when a conversion is complete. The user can read these conversions by setting the CREAD bit in the communications register to 1, which enables continuous read. When continuous read is enabled, the conversions are automatically placed on the DOUT line when SCLK pulses are applied. Alternatively, the user can instruct the ADC to output each conversion by writing to the communications register. After power-on, a reset, or a reconfiguration of the ADC, the complete settling time of the filter is required to generate the first valid conversion. Subsequent conversions are available at the selected output data rate, which is dependent on filter choice.
0	0	1	Single conversion mode. When single conversion mode is selected, the ADC powers up and performs a single conversion on the selected channel. The internal clock requires up to 1 ms to power up and settle. The ADC then performs the conversion, which requires the complete settling time of the filter. The conversion result is placed in the data register, $\overline{RDY}$ goes low, and the ADC returns to power-down mode. The conversion remains in the data register and $\overline{RDY}$ remains active (low) until the data is read or another conversion is performed.
0	1	0	Idle mode. In idle mode, the ADC filter and modulator are held in a reset state even though the modulator clocks are still provided.
0	1	1	Power-down mode. In power-down mode, all AD7190 circuitry, except the bridge power-down switch, is powered down. The bridge power-down switch remains active because the user may need to power up the sensor prior to powering up the AD7190 for settling reasons. The external crystal, if selected, remains active.
1	0	0	Internal zero-scale calibration. An internal short is automatically connected to the input. $\overline{RDY}$ goes high when the calibration is initiated and returns low when the calibration is complete. The ADC is placed in idle mode following a calibration. The measured offset coefficient is placed in the offset register of the selected channel.
1	0	1	Internal full-scale calibration. A full-scale input voltage is automatically connected to the input for this calibration. $\overline{RDY}$ goes high when the calibration is initiated and returns low when the calibration is complete. The ADC is placed in idle mode following a calibration. The measured full-scale coefficient is placed in the full-scale register of the selected channel. A full-scale calibration is required each time the gain of a channel is changed to minimize the full-scale error.
1	1	0	System zero-scale calibration. The user should connect the system zero-scale input to the channel input pins as selected by the CH7 to CH0 bits in the configuration register. $\overline{RDY}$ goes high when the calibration is initiated and returns low when the calibration is complete. The ADC is placed in idle mode following a calibration. The measured offset coefficient is placed in the offset register of the selected channel. A system zero-scale calibration is required each time the gain of a channel is changed.
1	1	1	System full-scale calibration. The user should connect the system full-scale input to the channel input pins as selected by the CH7 to CH0 bits in the configuration register. $\overline{RDY}$ goes high when the calibration is initiated and returns low when the calibration is complete. The ADC is placed in idle mode following a calibration. The measured full-scale coefficient is placed in the full-scale register of the selected channel. A full-scale calibration is required each time the gain of a channel is changed.

CONFIGURATION REGISTER

(RS2, RS1, RS0 = 0, 1, 0; Power-On/Reset = 0x000117)

The configuration register is a 24-bit register from which data can be read or to which data can be written. This register is used to configure the ADC for unipolar or bipolar mode, to enable or disable the buffer, to enable or disable the burnout currents, to select the gain, and to select the analog input channel.

Table 19 outlines the bit designations for the configuration register. CON0 through CON23 indicate the bit locations. CON denotes that the bits are in the configuration register. CON23 denotes the first bit of the data stream. The number in parentheses indicates the power-on/reset default status of that bit.

CON23	CON22	CON21	CON20	CON19	CON18	CON17	CON16
Chop(0)	0(0)	0(0)	REFSEL(0)	0(0)	0(0)	0(0)	(0)
CON15	**CON14**	**CON13**	**CON12**	**CON11**	**CON10**	**CON9**	**CON8**
CH7(0)	CH6(0)	CH5(0)	CH4(0)	CH3(0)	CH2(0)	CH1(0)	CH0(1)
CON7	**CON6**	**CON5**	**CON4**	**CON3**	**CON2**	**CON1**	**CON0**
Burn(0)	REFDET(0)	0(0)	BUF(1)	U/$\overline{B}$ (0)	G2(1)	G1(1)	G0(1)

Table 19. Configuration Register Bit Designations

Bit Location	Bit Name	Description				
CON23	Chop	Chop enable bit. When the chop bit is cleared, chop is disabled. When the chop bit is set, chop is enabled. When chop is enabled, the offset and offset drift of the ADC are continuously minimized. However, this increases the conversion time and settling time of the ADC. For example, when FS = 96 decimal and the sinc^4 filter is selected, the conversion time with chop enabled equals 80 ms and the settling time equals 160 ms. With chop disabled, higher conversion rates are allowed. For an FS word of 96 decimal and the sinc^4 filter selected, the conversion time is 20 ms and the settling time is 80 ms. However, at low gains, periodic calibrations may be required to remove the offset and offset drift.				
CON22, CON21		These bits must be programmed with a Logic 0 for correct operation.				
CON20	REFSEL	Reference select bits. The reference source for the ADC is selected using these bits.				
		REFSEL	**Reference Voltage**			
		0	External reference applied between REFIN1(+) and REFIN1(−).			
		1	External reference applied between the P1/REFIN2(+) and P0/REFIN2(-) pins.			
CON19 to CON16		These bits must be programmed with a Logic 0 for correct operation.				
CON15 to CON8	CH7 to CH0	Channel select bits. These bits are used to select which channels are enabled on the AD7190. See Table 20. Several channels can be selected, and the AD7190 automatically sequences them. The conversion on each channel requires the complete settling time.				
CON7	Burn	When this bit is set to 1, the 500 nA current sources in the signal path are enabled. When burn = 0, the burnout currents are disabled. The burnout currents can be enabled only when the buffer is active and when chop is disabled.				
CON6	REFDET	Enables the reference detect function. When set, the NOREF bit in the status register indicates when the external reference being used by the ADC is open circuit or less than 0.6 V maximum. The reference detect circuitry only operates when the ADC is active.				
CON5		This bit must be programmed with a Logic 0 for correct operation.				
CON4	BUF	Enables the buffer on the analog inputs. If cleared, the analog inputs are unbuffered, lowering the power consumption of the device. If set, the analog inputs are buffered, allowing the user to place source impedances on the front end without contributing gain errors to the system. With the buffer disabled, the voltage on the analog input pins can be from 50 mV below AGND to 50 mV above AV_{DD}. When the buffer is enabled, it requires some headroom; therefore, the voltage on any input pin must be limited to 250 mV within the power supply rails.				
CON3	U/$\overline{B}$	Polarity select bit. When this bit is set, unipolar operation is selected. When this bit is cleared, bipolar operation is selected.				
CON2 to CON0	G2 to G0	Gain select bits. Written by the user to select the ADC input range as follows:				
		G2	**G1**	**G0**	**Gain**	**ADC Input Range (5 V Reference, Bipolar Mode)**
		0	0	0	1	±5 V
		0	0	1	Reserved	
		0	1	0	Reserved	
		0	1	1	8	±625 mV
		1	0	0	16	±312.5 mV
		1	0	1	32	±156.2 mV
		1	1	0	64	±78.125 mV
		1	1	1	128	±39.06 mV

Table 20. Channel Selection

Channel Enable Bits in the Configuration Register								Channel Enabled			
CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0	Positive Input AIN(+)	Negative Input AIN(−)	Status Register Bits CHD[2:0]	Calibration Register Pair
							1	AIN1	AIN2	000	0
						1		AIN3	AIN4	001	1
					1			Temperature sensor		010	None
				1				AIN2	AIN2	011	0
			1					AIN1	AINCOM	100	0
		1						AIN2	AINCOM	101	1
	1							AIN3	AINCOM	110	2
1								AIN4	AINCOM	111	3

DATA REGISTER

(RS2, RS1, RS0 = 0, 1, 1; Power-On/Reset = 0x000000)

The conversion result from the ADC is stored in this data register. This is a read-only, 24-bit register. On completion of a read operation from this register, the RDY pin/bit is set. When the DAT_STA bit in the mode register is set to 1, the contents of the status register are appended to each 24-bit conversion. This is advisable when several analog input channels are enabled because the three LSBs of the status register (CHD2 to CHD0) identify the channel from which the conversion originated.

ID REGISTER

RS2, RS1, RS0 = 1, 0, 0; Power-On/Reset = 0xX4

The identification number for the AD7190 is stored in the ID register. This is a read-only register.

GPOCON REGISTER

(RS2, RS1, RS0 = 1, 0, 1; Power-On/Reset = 0x00)

The GPOCON register is an 8-bit register from which data can be read or to which data can be written. This register is used to enable the general-purpose digital outputs.

Table 21 outlines the bit designations for the GPOCON register. GP0 through GP7 indicate the bit locations. GP denotes that the bits are in the GPOCON register. GP7 denotes the first bit of the data stream. The number in parentheses indicates the power-on/reset default status of that bit.