



# ADC-908

CMOS MICROPROCESSOR-COMPATIBLE  
FAST 8-BIT A/D CONVERTER

Precision Monolithics Inc.

## FEATURES

- 8-Bit Resolution and Accuracy
- No Missing Codes over Full Temperature Range
- 6 $\mu$ s Conversion Time
- Flexible  $\mu$ P Interface
- 2.5mA Maximum Standby Current
- Replaces AD7574 with Improved Speed
- Available in Die Form

## ORDERING INFORMATION †

PACKAGE: 18-PIN DIP AND SO				
INL (LSB)	DNL (LSB)	MILITARY* TEMPERATURE -55°C TO +125°C	EXTENDED INDUSTRIAL TEMPERATURE -40°C TO +85°C	COMMERCIAL TEMPERATURE 0°C TO +70°C
$\pm 1/2$	$\pm 3/4$	ADC908AX	ADC908EX	ADC908GP
$\pm 3/4$	$\pm 7/8$	ADC908BX	ADC908FX	—
$\pm 3/4$	$\pm 7/8$	—	ADC908FP	—
$\pm 3/4$	$\pm 7/8$	—	ADC908FS	—

\* For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.

† Burn-in is available on commercial and industrial temperature range parts in CerDIP, plastic DIP, and TO-can packages. For ordering information, see PMI's Data Book, Section 2.

## GENERAL DESCRIPTION

The ADC-908 is a monolithic CMOS successive-approximation analog-to-digital converter. When used with a 1.35MHz clock, a conversion time of 6 $\mu$ s is achieved, with full accuracy over the operating temperature range.

The ADC-908 outputs use 3-state logic, allowing direct connection to the data bus or system input port. Active-LOW chip select ( $\overline{CS}$ ) and read/write ( $\overline{RD}$ ) inputs are used to control all

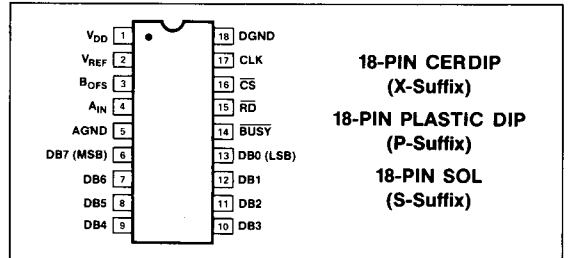
operations. This input structure permits the ADC-908 to be used as a memory-mapped input device. Depending on the control timing waveforms, the ADC-908 is interfaced like static RAM, ROM, or slow memory.

The low power consumption of the ADC-908 is derived from a single +5V supply. A negative reference voltage must also be supplied. Optimum accuracy is achieved when the reference is at -10.00V with a low output resistance. For a low-cost precision -10V/-10.24V reference, ask your PMI sales representative about the REF-08.

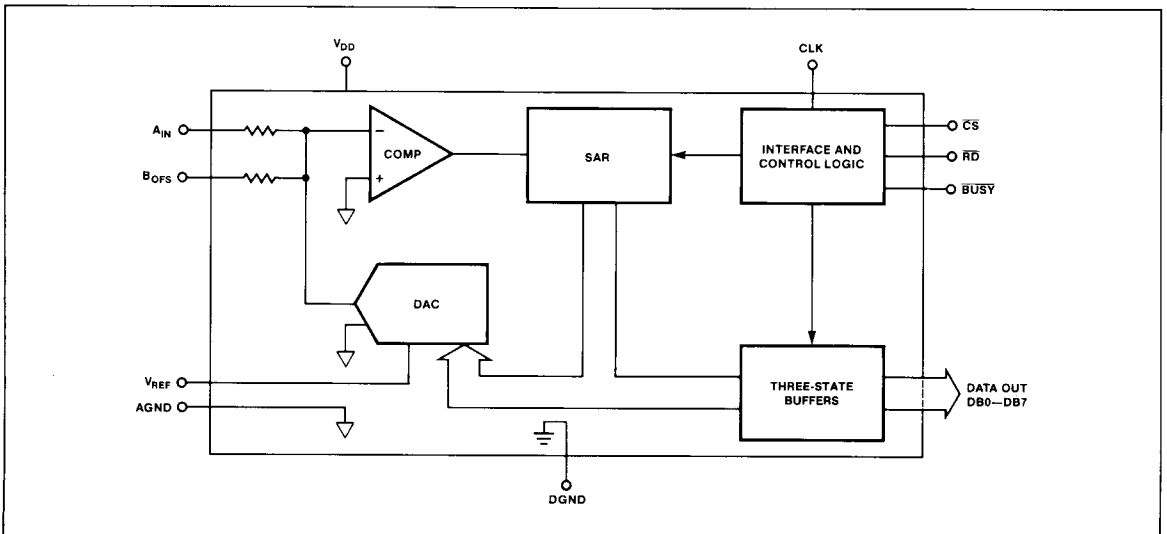
With its on-board comparator, interface logic, optional internal clock, and +5V operation, the ADC-908 is the ideal low-cost solution for microprocessor-based 8-bit A/D systems.

PMI's ADC-908 is pin-and-function compatible with the PM-7574, but offers faster conversion time and faster microprocessor bus interface timing. Conversion time has been reduced by 60% and most key timing specifications, including data access time, START command propagation delay ( $t_{WBPD}$ ), and reset time, have been improved.

## PIN CONNECTIONS



## FUNCTIONAL DIAGRAM



**ABSOLUTE MAXIMUM RATINGS** ( $T_A = +25^\circ\text{C}$ , unless otherwise noted)

$V_{DD}$ to AGND	0V, +7.0V
$V_{DD}$ to DGND	0V, +7.0V
AGND to DGND	-0.3V, $V_{DD}$
CS, RD to DGND	-0.3V, $V_{DD} + -0.3V$
DB <sub>0</sub> -DB <sub>7</sub> to DGND	-0.3V, $V_{DD}$
CLK, BUSY to DGND	-0.3, $V_{DD}$
$B_{OFS}$ , $A_{IN}$	$\pm 20V$
$V_{REF}$	0V, -20V
<b>Operating Temperature Range</b>	
ADC-908AX, BX	-55°C to +125°C
ADC-908EX, FX, FP, FS	-40°C to +85°C
ADC-908GP	0°C to +70°C

Storage Temperature	-65°C to +150°C
Lead Temperature (Soldering, 10 sec)	+300°C

PACKAGE TYPE	$\theta_{JA}$ (Note 2)	$\theta_{JC}$	UNITS
18-Pin Hermetic DIP (X)	79	11	°C/W
18-Pin Plastic DIP (P)	70	30	°C/W
18-Pin SOL (S)	88	25	°C/W

**NOTES:**

- Digital pins are zener protected. However, proper ESD handling precautions are recommended.
- $\theta_{JA}$  is specified for worst case mounting conditions, i.e.,  $\theta_{JA}$  is specified for device in socket for TO, CerDIP, P-DIP, and LCC packages;  $\theta_{JA}$  is specified for device soldered to printed circuit board for SO and PLCC packages.

**ELECTRICAL CHARACTERISTICS** at  $V_{DD} = +5V$ ,  $V_{REF} = -10V$ , Unipolar Configuration,  $R_{CLK} = 43k\Omega$ ,  $C_{CLK} = 100pF$ ;  $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$  for ADC-908E/F,  $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$  for ADC-908G,  $-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$  for ADC-908A/B, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	ADC-908			UNITS
			MIN	TYP	MAX	
<b>ACCURACY</b>						
Resolution	N		8	-	-	Bits
Integral Nonlinearity	INL	A/E/G Grades	-1/2	-	+1/2	LSB
		B/F Grades	-3/4	-	+3/4	
Differential Nonlinearity	DNL	A/E/G Grades	-3/4	-	+3/4	LSB
		B/F Grades	-7/8	-	+7/8	
Gain Error	$G_{FSE}$	A/E/G Grades	-3	-	+3	LSB
		$T_A = +25^\circ\text{C}$	-4.5	-	+4.5	
		$T_A = \text{Full Temp Range}$	-5	-	+5	
		$T_A = \text{Full Temp Range}$	-6.5	-	+6.5	
Offset Error	$V_{ZSE}$	A/E/G Grades	-30	-	+30	mV
		$T_A = +25^\circ\text{C}$	-50	-	+50	
		$T_A = \text{Full Temp Range}$	-60	-	+60	
		$T_A = \text{Full Temp Range}$	-80	-	+80	
<b>ANALOG INPUTS</b>						
Resistance Mismatch $B_{OFS}$ to $A_{IN}$	$\Delta R_{AB}$		-1	-	+1	%
Input Resistance at $V_{REF}$ (Note 1)	$R_{REF}$		5	-	15	k $\Omega$
Input Resistance at $B_{OFS}$ , $A_{IN}$	$R_{BOFS}$ $R_{AIN}$		10	-	30	k $\Omega$
Reference Voltage Range	$V_{REF}$	Specified Conversion Accuracy	-	-10	-	V
Reference Voltage Range	$V_{REF}$	Degraded Conversion Accuracy	-5	-	-15	V
Reference Current (Note 6)	$I_{REF}$	Conversion Complete Prior to Reset	-	-	2.4	mA
<b>Nominal Analog Input Range</b>						
Unipolar Mode	$V_{INU}$		-	0 to $ V_{REF} $	-	V
Bipolar Mode	$V_{INB}$		-	$- V_{REF} $ to $+ V_{REF} $	-	V



**ELECTRICAL CHARACTERISTICS** at  $V_{DD} = +5V$ ,  $V_{REF} = -10V$ , Unipolar Configuration,  $R_{CLK} = 43k\Omega$ ,  $C_{CLK} = 100pF$ ;  $-40^{\circ}C \leq T_A \leq +85^{\circ}C$  for ADC-908E/F,  $0^{\circ}C \leq T_A \leq +70^{\circ}C$  for ADC-908G,  $-55^{\circ}C \leq T_A \leq +125^{\circ}C$  for ADC-908A/B, unless otherwise noted.  
Continued

PARAMETER	SYMBOL	CONDITIONS	ADC-908			UNITS
			MIN	TYP	MAX	
<b>LOGIC INPUTS</b>						
Input HIGH Voltage RD, CS Inputs	$V_{IH}$		2.4	—	—	V
Input LOW Voltage RD, CS Inputs	$V_{IL}$		—	—	0.8	V
Input Current RD, CS Inputs	$I_{IN}$	$T_A = +25^{\circ}C$ $T_A = \text{Full Temp Range}$	—	—	1 10	$\mu A$
Input Capacitance RD, CS Inputs (Note 6)	$C_{IN}$		—	—	5	pF
Input HIGH Voltage, Clock Input	$V_{IH}$		2.4	—	—	V
Input LOW Voltage, Clock Input	$V_{IL}$		—	—	0.8	V
Input HIGH Current, Clock Input	$I_{IH}$		—	—	2	mA
Input LOW Current, Clock Input	$I_{IL}$	$T_A = +25^{\circ}C$ $T_A = \text{Full Temp Range}$	—	—	1 10	$\mu A$
<b>LOGIC OUTPUTS</b>						
Output HIGH Voltage BUSY, DB0-7	$V_{OH}$	$I_{SOURCE} = 40\mu A$	4.0	—	—	V
Output LOW Voltage BUSY, DB0-7	$V_{OL}$	$I_{SINK} = 1.6mA$	—	—	0.4	V
Floating Leakage Current, DB0-7	$I_{LKG}$	$T_A = +25^{\circ}C$ $T_A = \text{Full Temp Range}$	—	—	1 10	$\mu A$
Floating State Output Capacitance	$C_{OZ}$	(Note 6)	—	—	7	pF
<b>POWER REQUIREMENTS</b>						
Standby Current	$I_{DD}$	$V_{DD} = +4.75V \text{ to } +5.25V$	—	—	2.5	mA
<b>DIGITAL INTERFACE TIMING</b>						
CS Minimum Pulse Width (Note 6)	$t_{CS}$	$T_A = +25^{\circ}C$	60	—	—	ns
		$T_A = T_{MIN}$	50	—	—	
		$T_A = T_{MAX}$	90	—	—	
RD to CS Setup Time (Note 6)	$t_{wscs}$		0	—	—	ns
CS to BUSY Propagation Delay (Note 6)	$t_{CBPD}$	BUSY Load = 20pF				ns
		$T_A = +25^{\circ}C$	—	—	120	
		$T_A = T_{MIN}$	—	—	100	
		$T_A = T_{MAX}$	—	—	150	
		BUSY Load = 100pF				
$T_A = +25^{\circ}C$	—	—	150			
$T_A = T_{MIN}$	—	—	120			
$T_A = T_{MAX}$	—	—	200			
BUSY to RD Setup Time (Notes 2, 6)	$t_{BSR}$		0	—	—	ns
BUSY to CS Setup Time (Note 6)	$t_{Bscs}$		0	—	—	ns

**ELECTRICAL CHARACTERISTICS** at  $V_{DD} = +5V$ ,  $V_{REF} = -10V$ , Unipolar Configuration,  $R_{CLK} = 43k\Omega$ ,  $C_{CLK} = 100pF$ ;  $-40^\circ C \leq T_A \leq +85^\circ C$  for ADC-908E/F,  $0^\circ C \leq T_A \leq +70^\circ C$  for ADC-908G,  $-55^\circ C \leq T_A \leq +125^\circ C$  for ADC-908A/B, unless otherwise noted.

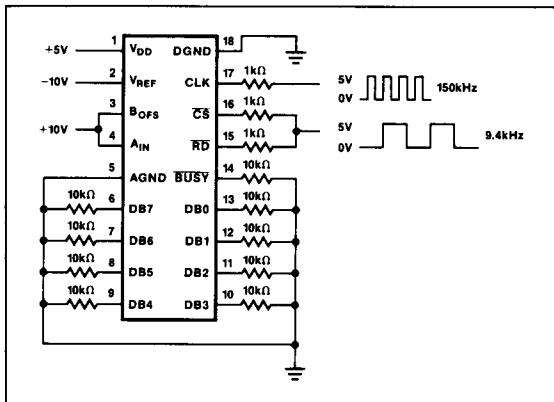
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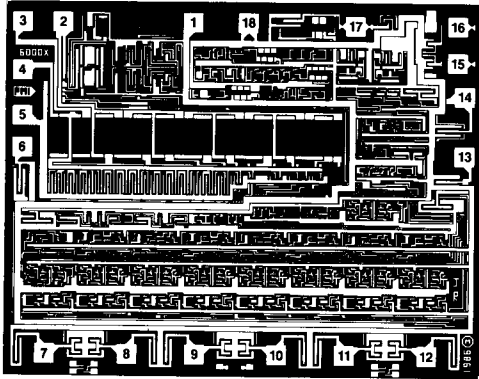
PARAMETER	SYMBOL	CONDITIONS	ADC-908			UNITS
			MIN	TYP	MAX	
Data Access Time (Note 6)	$t_{RAD}$	$C_L = 20pF$				
		$T_A = +25^\circ C$	—	—	140	
		$T_A = T_{MIN}$	—	—	100	
		$T_A = T_{MAX}$	—	—	200	
		$C_L = 100pF$	—	—	—	ns
		$T_A = +25^\circ C$	—	—	170	
		$T_A = T_{MIN}$	—	—	150	
		$T_A = T_{MAX}$	—	—	230	
Data Hold Time (Notes 3, 6)	$t_{RHD}$	$T_A = +25^\circ C$ (Note 3)	30	—	100	
		$T_A = T_{MIN}$	20	—	70	ns
		$T_A = T_{MAX}$	40	—	140	
$\overline{CS}$ to $\overline{RD}$ Hold Time (Note 6)	$t_{RHCS}$	$T_A = +25^\circ C$	—	—	200	
		$T_A = T_{MIN}$	—	—	120	ns
		$T_A = T_{MAX}$	—	—	250	
Reset Time Requirement (Note 6)	$t_{RESET}$	$T_A = +25^\circ C$	450	—	—	
		$T_A = \text{Full Temp. Range}$	500	—	—	ns
Conversion Time (Note 4)	$t_{CONVERT}$	Static RAM Mode				
		External Clock				
		$f = 1.35MHz$	—	—	6	$\mu s$
(Notes 4, 5, 6)		ROM Mode				
		Internal Clock	—	—	7	
$\overline{RD}$ HIGH to $\overline{BUSY}$ Propagation Delay, ROM Mode (Notes 4, 5, 6)	$t_{WBPD}$	$C_L = 20pF$				
		$T_A = +25^\circ C$	—	—	600	
		$T_A = T_{MIN}$	—	—	400	ns
		$T_A = T_{MAX}$	—	—	800	

**NOTES:**

- For optimum gain accuracy over the full temperature range, the source resistance at pin 2 should be kept low.
- In ROM mode,  $\overline{RD}$  can go LOW prior to  $\overline{BUSY} = \text{HIGH}$ , but must not return HIGH until  $\overline{BUSY} = \text{HIGH}$ .
- Output loading 10pF. A 3k $\Omega$  pullup resistor to +5V is used for  $V_{OL}$  to High-Z, for  $V_{OH}$  to High-Z, a 3k $\Omega$  pulldown to GND is used. Measured to 0.5V output change.
- When using the ADC-908 internal oscillator, actual conversion time depends on clock resistor and capacitor as well as temperature.
- ROM interface mode conversion times are typically 1 $\mu s$  longer than conversion times for other modes, but the ROM interface mode includes an automatic reset in the conversion time.
- Guaranteed but not tested.

**BURN-IN CIRCUIT**



**DICE CHARACTERISTICS**


**DIE SIZE 0.129 × 0.103 inch, 13,287 sq. mils**  
 (3.28 × 2.62 mm, 8.58 sq. mm)

- |              |              |
|--------------|--------------|
| 1. $V_{DD}$  | 10. DB3      |
| 2. $V_{REF}$ | 11. DB2      |
| 3. $B_{OFS}$ | 12. DB1      |
| 4. $A_{IN}$  | 13. DB0(LSB) |
| 5. AGND      | 14. BUSY     |
| 6. DB7(MSB)  | 15. RD       |
| 7. DB6       | 16. CS       |
| 8. DB5       | 17. CLK      |
| 9. DB4       | 18. DGND     |

For additional DICE ordering information, refer to PMI's Data Book, Section 2.

**WAFER TEST LIMITS** at  $V_{DD} = +5V$ ,  $V_{REF} = -10.000V$ ,  $AGND = DGND = 0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	ADC-908	
			LIMIT	UNITS
<b>STATIC ACCURACY</b>				
Resolution	N		8	Bits MIN
Integral Nonlinearity	INL		$\pm 3/4$	LSB MAX
Differential Nonlinearity	DNL		$\pm 7/8$	LSB MAX
Gain Error	$G_{FSE}$		$\pm 5$	LSB MAX
Offset Error	$V_{ZSE}$		$\pm 60$	mV MAX
<b>ANALOG INPUTS</b>				
Resistance Mismatch $B_{OFS}$ to $A_{IN}$	$\Delta R_{AB}$		$\pm 1$	% MAX
Input Resistance at $V_{REF}$	$R_{REF}$		5/15	$k\Omega$ MIN/MAX
Input Resistance at $B_{OFS}$ , $A_{IN}$	$R_{B_{OFS}}, R_{IN}$		10/30	$k\Omega$ MIN/MAX
<b>DIGITAL INPUTS</b>				
Input HIGH Voltage at RD, CS Inputs	$V_{IH}$		2.4	V MIN
Input LOW Voltage at RD, CS Inputs	$V_{IL}$		0.8	V MAX
Input Current RD, CS Inputs	$I_{IN}$		$\pm 1$	$\mu A$ MAX
Input HIGH Voltage Clock Input	$V_{IH}$		2.4	V MIN
Input LOW Voltage Clock Input	$V_{IL}$		0.8	V MAX
Input HIGH Current Clock Input	$I_{IH}$		2	mA MAX
Input LOW Current Clock Input	$I_{IL}$		1	$\mu A$ MAX

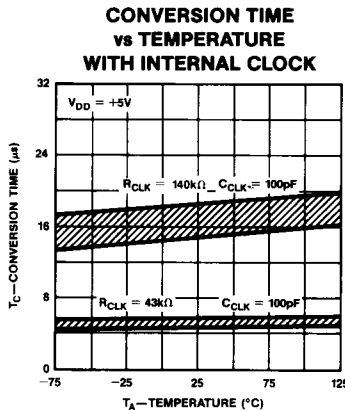
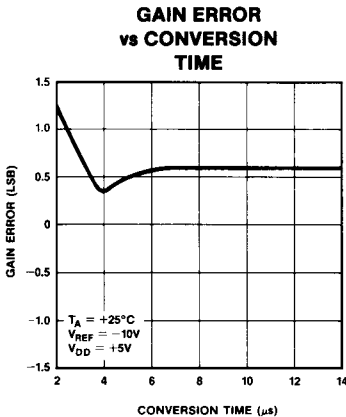
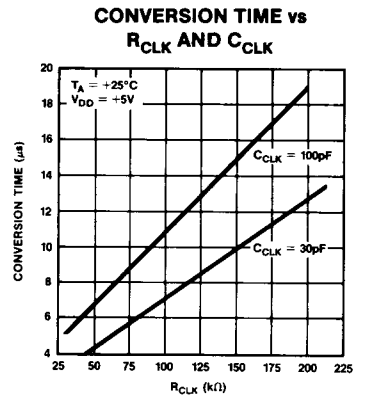
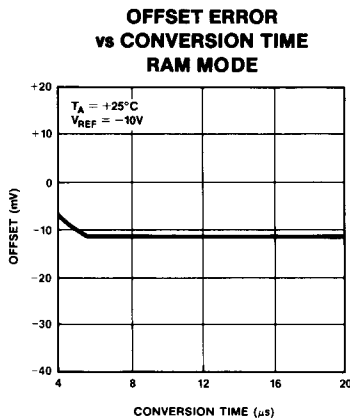
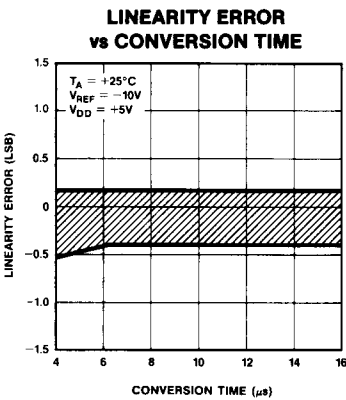


WAFER TEST LIMITS at  $V_{DD} = +5V$ ,  $V_{REF} = -10.000V$ ,  $AGND = DGND = 0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted. (Continued)

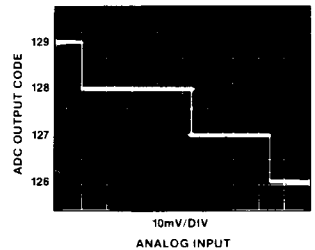
PARAMETER	SYMBOL	CONDITIONS	ADC-908 LIMIT	UNITS
<b>DIGITAL OUTPUTS</b>				
Output HIGH Voltage BUSY, DB0-7	$V_{OH}$	$I_{SOURCE} = 40\mu A$	4	V MIN
Output LOW Voltage BUSY, DB0-7	$V_{OL}$	$I_{SINK} = 1.6mA$	0.4	V MAX
Floating Leakage Current	$I_{LKG}$		1	$\mu A$
<b>POWER REQUIREMENTS</b>				
Standby Current	$I_{DD}$	$V_{DD} = +4.75V$ to $5.25V$	2.5	mA MAX
<b>TIMING</b>				
Conversion Time	$t_{CONVERT}$	Static RAM Mode, External Clock, $f = 1.35MHz$	6	$\mu s$ MAX

**NOTE:** Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

**TYPICAL PERFORMANCE CHARACTERISTICS**



**CONVERSION UNCERTAINTY AROUND MAJOR CARRY**



12

ANALOG-TO-DIGITAL CONVERTERS

## GENERAL CIRCUIT INFORMATION

The ADC-908 is an 8-bit analog-to-digital converter which uses a successive approximation technique to convert an unknown analog input into a digital code output. The control logic inputs allow easy interface to most microprocessors while three-state outputs allow direct connection to the data bus. Most applications require only passive RC clock components, a  $-10V$  reference, and a  $+5V$  power supply. The RC-timed internal clock may be used, or an external clock may be applied to the ADC to maximize performance.

When a Start Conversion command is applied to the  $\overline{CS}$  or  $\overline{RD}$  inputs (see Operating Descriptions for details),  $\overline{BUSY}$  goes LOW indicating a conversion in progress.  $\overline{BUSY}$  may be used as an interrupt to halt the controlling microprocessor during conversion or may be polled to prevent premature data reads.

Starting with the most significant bit (MSB), each successive bit in the DAC is turned on (see Figure 1). The comparator then decides if the DAC output is less than or greater than the signal being converted, and that bit is latched on or off, respectively, before proceeding to the next lower bit and repeating the cycle. When all eight bits have been tested,  $\overline{BUSY}$  goes HIGH, signaling a completed conversion.

Under control of the  $\overline{RD}$  input, the three-state data outputs (D0-D7) change from high-impedance to presenting the new conversion results to the data bus. Following the data read,  $\overline{RD}$  returns HIGH resetting the SAR to 1000 0000 and preparing the ADC for its next conversion.

## PIN FUNCTIONS

**NOTE:** For greater detail on digital input functions, consult Truth Tables and Timing Diagrams.

- Pin 1.  $V_{DD}$  Power Supply input,  $+5V$ .
- Pin 2.  $V_{REF}$  Voltage Reference input, nominal  $-10V$ .
- Pin 3.  $B_{OFS}$  Bipolar Offset input.  $+10V$  input for bipolar mode operation, tie to  $V_{IN}$  for unipolar mode operation.
- Pin 4.  $A_{IN}$  Analog Input.  $0V$  to  $+10V$  in unipolar mode,  $-10V$  to  $+10V$  in bipolar mode.

- Pin 14.  $\overline{BUSY}$  Conversion status output.  $\overline{BUSY}$  indicates conversion in progress by going LOW at start of conversion and returning HIGH at end of conversion. May be used to interrupt controlling microprocessor or to gate control inputs.
- Pin 15.  $\overline{RD}$  READ input. Used to read data (on falling edge) and to reset converter (on rising edge).
- Pin 16.  $\overline{CS}$  Chip Select input. Asserted to allow ADC operation. Starts conversion when converter is in reset condition. Note: Holding  $\overline{CS}$  HIGH will not prevent a rising edge on  $\overline{RD}$  from resetting the converter.
- Pin 17. CLK External clock input/internal clock RC timing input.

## APPLICATIONS INFORMATION

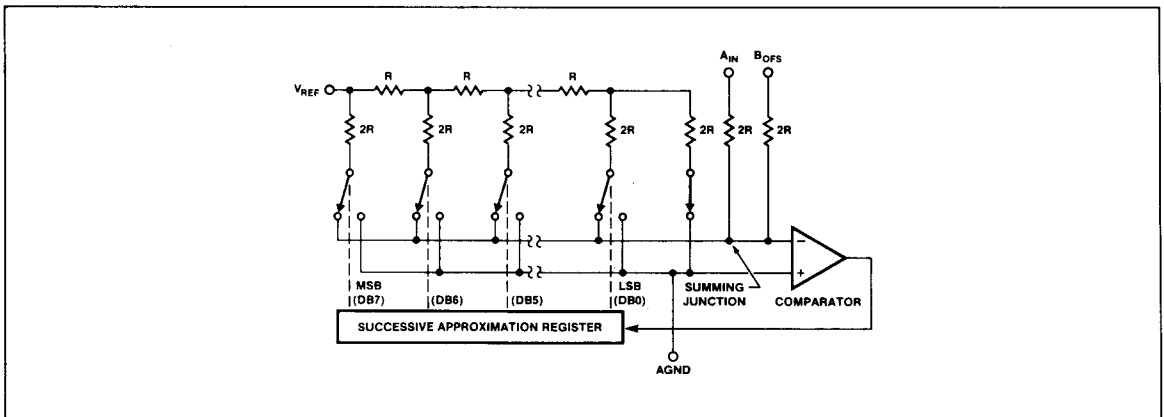
The ADC-908 may be interfaced as if it were a static RAM, a ROM, or a slow-memory device. Each of these interface modes has its own timing and software requirements as described below. These requirements must be rigidly met, as improper timing may cause the ADC-908 to change modes.

### HOW TO CHOOSE AN OPERATING MODE

The static-RAM interface mode offers advantages in a tightly controlled hardware and software environment, where the relationship between WRITE and READ instruction pairs is certain. As long as minimum timing is satisfied, converted data may be read at any convenient time after conversion. The use of separate commands to start a conversion, and then read the results, is conceptually easy. However, if the software is subject to uncontrolled modifications, then the paired relationship between WRITE and READ instructions may be lost. Resulting software bugs may result in converted data of unknown age, or altogether invalid data being read.

By contrast, the ROM mode may be more resistant to software bugs. As long as minimum timing is satisfied, each READ instruction obtains new, valid data. However, since the data

FIGURE 1: D/A Converter Used in ADC-908



output at any previous READ instruction is obtained from a conversion performed just after the previous READ instruction, data may be out-of-date. To be sure of obtaining up-to-date data, READ instructions may be coded in pairs (with some NOPs between them); use only the data from the second READ in each pair. The first READ starts the conversion, acting as a substitute for the static-RAM mode WRITE command; the second READ gets the results. The advantage of the ROM mode is the use of a single command, rather than the alternating READ-WRITE required by static-RAM mode.

The slow-memory mode is the simplest mode of all. It is the method of choice where compact coding is essential, or where software bugs are a hazard. In this mode, a single READ instruction will initiate a data conversion, interrupt the microprocessor until completion (WAIT states are introduced), then read the results. If the system throughput tolerates WAIT states, and the hardware is correct, then the slow-memory mode is virtually immune to subsequent software modifications.

#### OPERATING DESCRIPTION: STATIC-RAM MODE

In this mode, input  $\overline{CS}$  is derived from the ADC-908 address decoder, and input  $\overline{RD}$  is derived from an active-LOW memory READ signal. (See Figure 2.)

To start a conversion, execute a memory WRITE to the ADC-908. The completed conversion data is obtained by executing a memory READ to the ADC-908. During conversion, output  $\overline{BUSY}$  will be LOW. Do not attempt to read data until  $\overline{BUSY}$  returns HIGH. The required minimum time between WRITE and READ is usually obtained by including one or more NOP or other program instructions. The use of branch or conditional commands between the WRITE and READ instructions is not recommended due to the possibility of software bugs.

It is important that the WRITE and READ commands be alternately executed. A WRITE instruction has no effect unless the results of the previous WRITE have already been read. Once data has been read, the ADC-908 is internally reset. In other words, two or more READ operations cannot be used in

succession, since only the first READ will produce valid data. A new conversion must be started using WRITE, and the conversion must be completed, before a new READ will produce valid data.

TABLE 1: Truth Table, Static RAM Mode

INPUTS		OUTPUTS		ADC-908 OPERATION
CS	RD	BUSY	DB7-DB0	
L	H	H	HIGH-Z	Start Convert (Write Cycle)
L	$\downarrow$	H	HIGH-Z to DATA	Read Data (Read Cycle)
L	$\uparrow$	H	DATA to HIGH-Z	Reset Converter
H	X (Note 1)	X	HIGH-Z	No Effect (Not Selected)
L	H	L	HIGH-Z	No Effect (Converter Busy)
L	$\downarrow$	L	HIGH-Z	No Effect (Converter Busy)
L	$\uparrow$ (Note 1)	L	HIGH-Z	Conversion Error Not Allowed

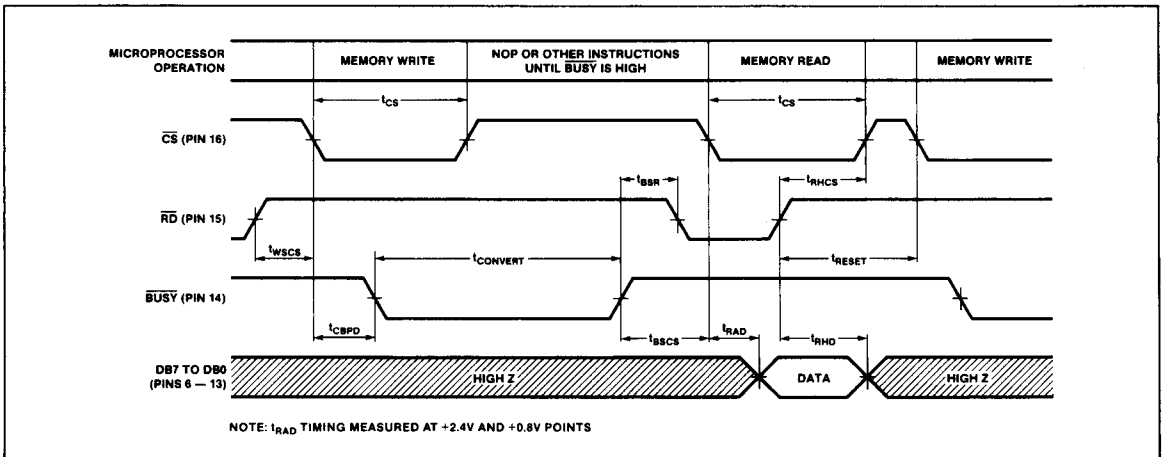
NOTE 1: If  $\overline{RD}$  goes LOW to HIGH, the ADC is internally reset, regardless of the states of  $\overline{CS}$  or  $\overline{BUSY}$ .

#### OPERATING DESCRIPTION: ROM MODE

In ROM mode, input  $\overline{CS}$  is tied LOW, and input  $\overline{RD}$  is derived from the ADC-908 address decoder. To satisfy timing, it is recommended that the decoder be enabled by a system MEMRD (8080), VMA (6800), or similar strobe. (See Figure 3.)

In ROM mode, data is read by executing a READ instruction to the ADC-908 address. At the conclusion of the READ instruction, the ADC-908 automatically resets itself and then proceeds to perform a new data conversion. Output  $\overline{BUSY}$  is LOW during conversion. A new READ instruction to the ADC-908 must not be executed until  $\overline{BUSY}$  returns HIGH.

FIGURE 2: Static RAM Mode Timing Diagram





This requirement may be met by inserting NOP or other program instructions between consecutive READ operations. Conditional or branch instructions may be used, but keep in mind that data may become out-of-date if excessive time elapses between consecutive READ instructions.

**TABLE 2: Truth Table, ROM Mode**

INPUTS		OUTPUTS		ADC-908 OPERATION
CS	RD	BUSY	DB7-DB0	
L		H	HIGH-Z to DATA	Read Data
L			DATA to HIGH-Z	Reset and Start New Conversion
L		L	HIGH-Z	No Effect (Converter Busy)
L		L	HIGH-Z	Conversion Error Not Allowed

**NOTE 1:** If RD goes LOW to HIGH, the ADC is internally reset, regardless of the states of CS or BUSY.

**OPERATING DESCRIPTION: SLOW-MEMORY MODE**

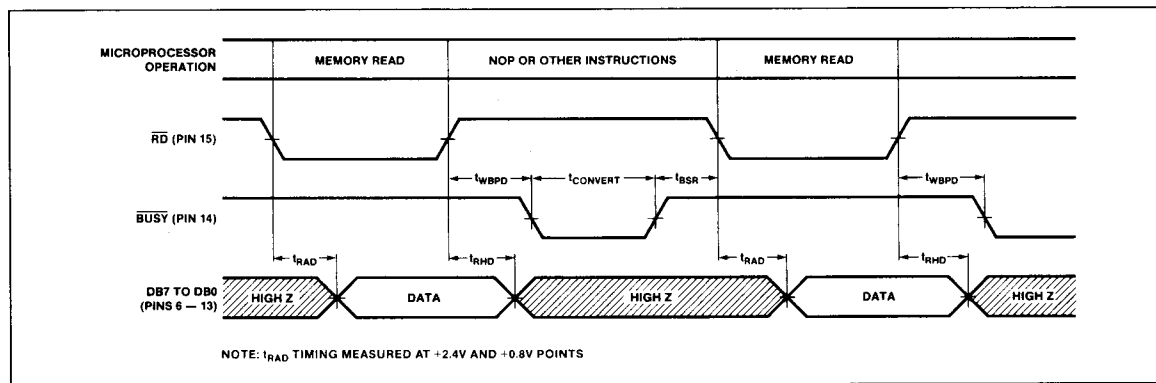
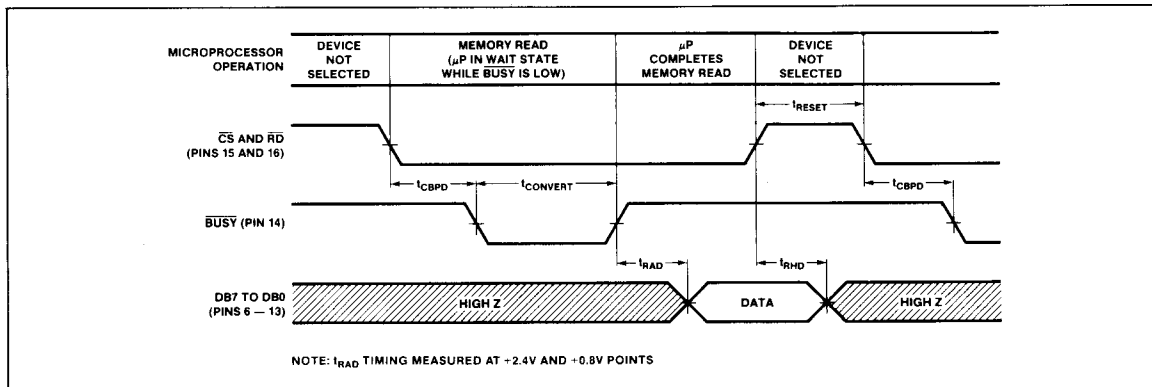
The slow-memory mode is intended for systems in which the ADC-908 BUSY output is used as an interrupt to force the

microprocessor into WAIT states during data conversion.

In slow-memory mode, inputs  $\overline{CS}$  and  $\overline{RD}$  are tied together. The common RD and CS signal is derived from the ADC-908 address decoder. To satisfy the timing requirements, it is advisable to latch the address using ALE (8085) or SYNC (8080). For 8080 or 8085-based systems, connect the microprocessor READY input to the ADC-908 BUSY output. (See Figure 4.)

**TABLE 3: Truth Table, Slow-Memory Mode**

INPUTS		OUTPUTS		ADC-908 OPERATION
CS & RD	BUSY	DB7-DB0		
H	H	HIGH-Z		No Effect (Not Selected)
		HIGH-Z		Start Conversion
L	L	HIGH-Z		Conversion in Progress. $\mu$ P in WAIT State
L		HIGH-Z to DATA		Conversion Complete. Read Data
	H	DATA to HIGH-Z		Reset and Deselect Converter

**FIGURE 3: ROM Mode Timing Diagram ( $\overline{CS}$  Held LOW)**

**FIGURE 4: Slow-Memory Mode Timing Diagram ( $\overline{CS}$  and  $\overline{RD}$  Tied Together)**


Do not execute a WRITE instruction at the ADC-908 address when in slow-memory mode, since bus conflicts will arise. In some architectures, an accidental WRITE instruction may be locked out in hardware, by proper strobing of the ADC-908 address decoder.

**INITIALIZATION**

In all operating modes, the ADC-908 is initialized by executing a READ instruction to the ADC-908 address. The data obtained should be ignored.

**CLOCK OSCILLATOR**

The ADC-908 may be used with its internal asynchronous clock oscillator. An external resistor and capacitor are required. Typical values are  $R = 43k\Omega$  and  $C = 100pF$ , for conversion times in the  $6\mu s$  range. For applications in which the fastest conversion times are required, an external clock is recommended. The external clock must be gated by the use of a 74125-type three-state buffer, with an output pullup resistor. Optimum conversion accuracy is obtained when  $\overline{CS}$  goes LOW on a positive clock edge. The maximum external clock frequency is 1.35MHz (See Figure 5 and 6.)

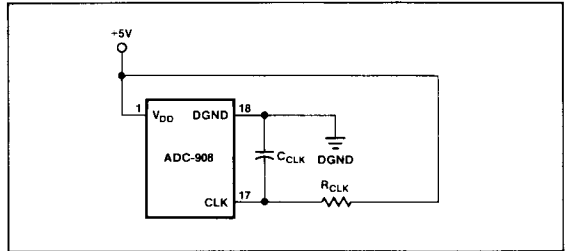
**REFERENCE VOLTAGE**

A negative reference voltage must be applied to the ADC-908  $V_{REF}$  input. Optimum full-scale accuracy is obtained using  $-10.00V$ , although  $V_{REF}$  may be  $-5.00V$ ,  $-10.24V$ , or other voltages within its specified range.

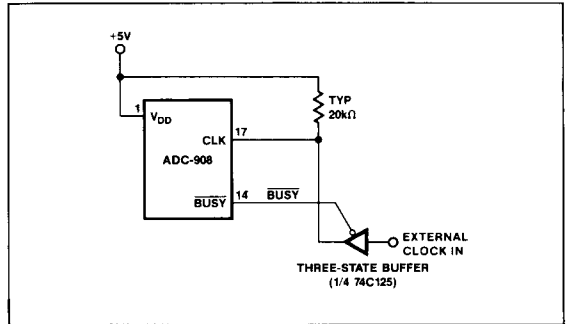
Over the full temperature range, optimum gain accuracy is obtained when the input to the  $V_{REF}$  pin is from a low-impedance source. A resistor or trimmer may be used in series with the  $V_{REF}$  pin, but this trim technique is not as accurate as a low-impedance source. (See Figure 7.)

For a cost-effective  $-10.00V$  or  $-10.24V$  reference with excellent accuracy and low temperature coefficient, ask for PMI's REF-08. Consult your sales representative for availability.

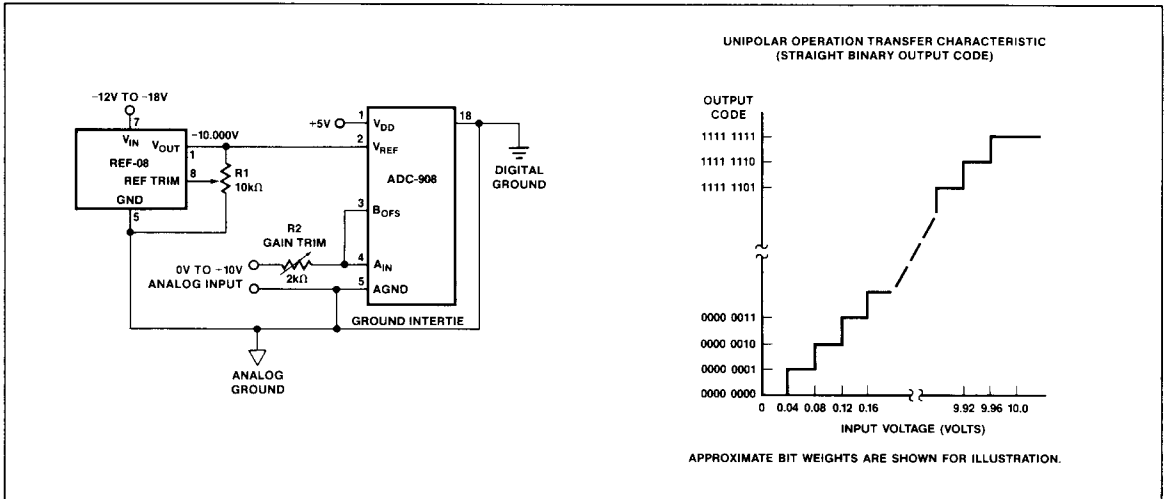
**FIGURE 5: Using the Internal Clock Oscillator**



**FIGURE 6: Using an External Clock**



**FIGURE 7: Unipolar Operation**



**ANALOG INPUT VOLTAGE**

The ADC-908 unipolar operation is obtained when the analog input voltage is between 0V and  $|V_{REF}|$ . With the  $A_{IN}$  and  $B_{OFS}$  pins tied together, input 0V will correspond to code 0000 0000, and input full-scale will correspond to code 1111 1111.

Bipolar operation is obtained by using the  $B_{OFS}$  input to offset the  $A_{IN}$  input voltage. For example, with  $V_{REF} = -10V$ , an offset voltage of +10V may be applied to  $B_{OFS}$ . The analog signal range will then be  $-10V$  to  $+10V$  at  $A_{IN}$ . Code 0000 0000 will correspond to  $-10V$ , and positive full scale will be code 1111 1111. Calibration may be performed using trimmers in series with  $A_{IN}$  and  $B_{OFS}$ . (See Figure 8).

Another method of obtaining bipolar operation is to use an op-amp with gain =  $-1/2$ , to sum the analog signal with the reference voltage. With a  $-10V$  reference and  $-10V$  to  $+10V$  analog signal, the op amp output will then be 0V to  $+10V$ . This signal is then treated as an ordinary unipolar input to the ADC-908. With this arrangement, input  $+10V$  corresponds to code 0000 0000, and negative full-scale corresponds to code 1111 1111.

**UNIPOLAR BINARY OPERATION**

Figure 7 shows the analog circuit connections for unipolar operation. The REF-08 supplies the necessary  $-10V$  reference input.

Calibration for offset should be made before gain calibration is attempted.

Offset calibration must be performed in the signal conditioning circuitry which drives the  $A_{IN}$  input.

To adjust offset:

- 1) Apply  $-39.1mV$  (1 LSB) to the input of the buffer amplifier driving  $A_{IN}$ .
- 2) While performing continuous conversions, adjust the buffer amplifier's offset adjustment potentiometer until DB7 to DB1 are LOW and DB0 (LSB) flickers.

Following offset calibration, full scale gain can be calibrated:

- 1) Apply  $-9.961V$  to the input of the buffer amplifier.

- 2) While performing continuous conversions, adjust the reference trim pot until DB7 to DB1 are HIGH, and DB0 (LSB) flickers.

**BIPOLAR OPERATION**

**Offset Binary**—Figure 8 shows a circuit for offset binary bipolar operation. Offset correction should be made at the buffer amplifier driving  $A_{IN}$ . Gain error correction should be accomplished by adjusting  $V_{REF}$ .

To calibrate this circuit:

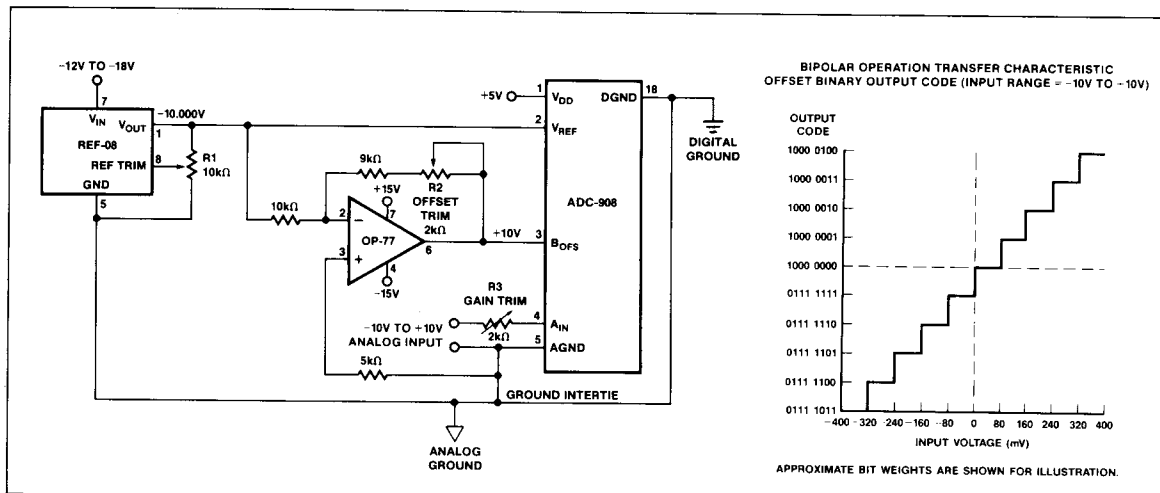
- 1) Adjust R1 until  $V_{REF} = -10.00V$ .
- 2) Adjust R2 and R3 to their mid-points.
- 3) Apply  $+10.000V$  to the input buffer amplifier.
- 4) While performing continuous conversions, adjust R2 until DB7 to DB1 are LOW and DB0 (LSB) flickers.
- 5) Ground the input of the input buffer circuit.
- 6) While performing continuous conversions, adjust R3 until the ADC's output code flickers between 0111 1111 and 1000 0000.
- 7) Apply  $-10.000V$  to the signal input.
- 8) While performing continuous conversions, adjust R1 until DB7 to DB1 are LOW and the DB0 (LSB) flickers.
- 9) Apply  $+9.922V$  to the signal input.
- 10) If the ADC output code is not 1111 1110  $\pm 1$  bit, repeat the calibration procedure, omitting step 1.

**Complementary Offset Binary**—Figure 9 shows a complementary offset binary circuit. In this bipolar mode, the  $+10V$  to  $-10V$  analog input is conditioned to a 0 to  $+10V$  signal range for normal unipolar conversion.

In calibrating this circuit, adjust offset before gain.

Offset Adjustment:

- 1) Adjust R1 until  $V_{REF} = -10.000V$ .
- 2) Adjust R3 to its mid-point.
- 3) Adjust R2 until its tap is at 0V.
- 4) Ground the analog input.
- 5) While performing continuous conversions, adjust R2 until the ADC output flickers between 0111 1111 and 1000 0000.

**FIGURE 8:** Offset Binary Operation

**Gain Adjustment:**

- 1) Apply +9.922V across the analog input.
- 2) While performing continuous conversions, adjust R3 until DB7 to DB1 are HIGH and DB0 (LSB) flickers.

**DIGITAL CONSIDERATIONS**

**Control Timing**—Fresh data from a recent conversion must be read before beginning a new conversion. Following the data READ, as  $\overline{RD}$  goes HIGH, it resets the SAR and clears the data from the previous conversion.

The timing restrictions detailed in the interface timing diagrams must be observed to prevent the ADC-908 from changing interface modes. For example, if  $\overline{CS}$  is held LOW too long while in RAM mode, the converter will change to ROM mode and initiate a new conversion.

**Logic Deglitching**—Unrelated activity on the address bus may cause unexpected glitch inputs to the ADC. The glitches may cause unwanted READs, resets, or conversions. In ROM or RAM modes, these may be avoided by gating the address decode logic with RD or WR (8080) or VMA (6800). In slow-memory mode, ALE (8085) or SYNC (8080) may be used to latch the address.

**Initialization**—Following power-up, the SAR is in an unknown state. Executing a memory READ (disregard the data) will reset the ADC.

**ANALOG CONSIDERATIONS**

**Analog Input Impedances**—Low impedance sources must be used to drive the  $V_{REF}$ ,  $A_{IN}$ , and  $B_{OFS}$  inputs. Excessive source

impedances may cause errors due to the loading effects of the inputs' finite impedances.

**Ground Management**—AGND and DGND pins should be connected at or near the ADC to minimize noise effects. If the two grounds cannot be connected near the ADC, the grounds should be clamped with back-to-back Schottky diodes between the AGND and DGND pins.

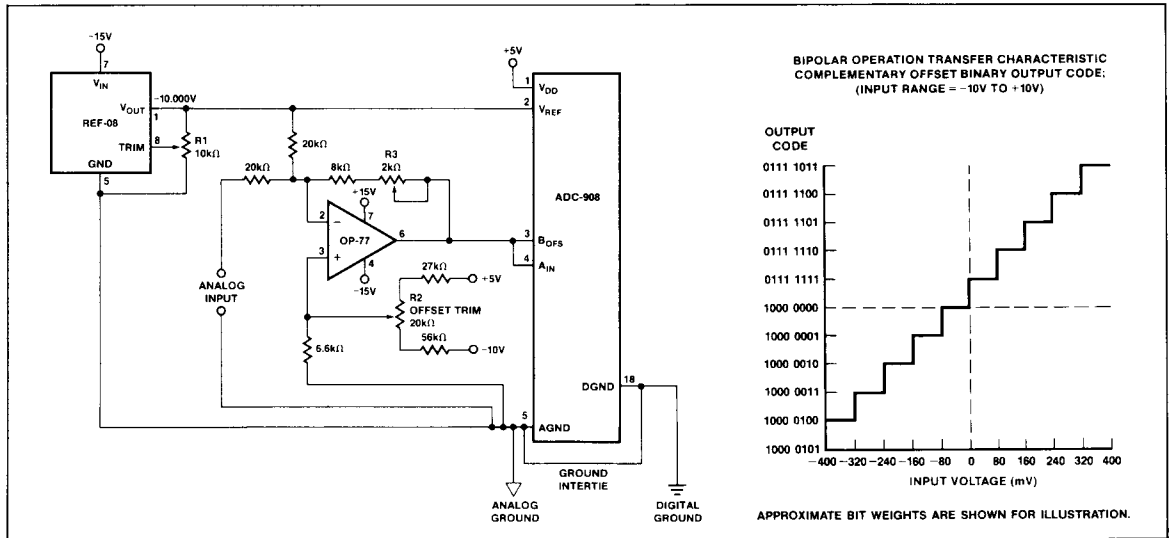
**Offset Correction**—Conversion offset errors may be corrected by counter-offsetting the buffer amplifier driving  $A_{IN}$ . This offset correction may be accomplished by applying a correction current to the buffer's summing junction or by tapping a voltage divider sitting between  $V_{DD}$  and  $V_{REF}$ , and applying this tap voltage to the noninverting input of the buffer.

**Ratiometric Operation**—The R-2R type DAC in the ADC-908 permits ratiometric operation of the ADC. Performance degradation may, however, occur as  $V_{REF}$  varies from  $-10.000V$ . This decrease in performance is due to comparator limitations including offset-voltage, gain, and input noise.

The ADC-908 uses the reference as a power supply for the comparator to increase speed and accuracy. Reference voltages of a magnitude less than  $-9V$  must be avoided for accurate comparator operation. For best accuracy, the use of a  $0.1\mu F$  bypass capacitor from  $V_{REF}$  (Pin 2 to AGND) is recommended.

**Power Supply Bypassing**—For best accuracy,  $V_{DD}$  (Pin 1) should be bypassed to AGND with a  $0.1\mu F$  capacitor.

**FIGURE 9: Complementary Offset Bipolar Operation**



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