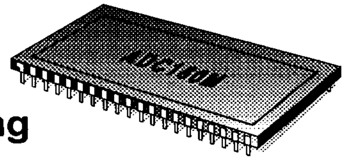
ADC160
Precision 24-Bit Continuously Integrating A/D Converter



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FEATURES

- 22- 24 BIT RESOLUTION
- ±10.48 INPUT RANGE
- 1ppm/°C MAX. SCALE FACTOR ERROR (-55°C to +125°C)
- 2 ppm MAX. LINEARITY ERROR
- AUTO CALIBRATION
- BUS COMPATIBLE
- INTERNAL CLOCK and REFERENCE
- LOW POWER CONSUMPTION (0.4 WATTS)

APPLICATIONS

- INERTIAL GUIDANCE
- TEST EQUIPMENT
- DATA ACQUISITION
- SCIENTIFIC INSTRUMENTS
- MEDICAL INSTRUMENTS
- SEISMOLOGICAL EQUIPMENT
- ROBOTIC SYSTEMS
- WEIGHING SYSTEMS

DESCRIPTION

ADC160 is a high performance 22-bit Integrating Dual slope A/D Converter which provides outstanding performance (accuracy) comparable to the best digital meters. The ADC 160 is available in two operating temperature ranges, -25°C to +85°C and -55°C to +125°C. "M" versions are screened for high reliability and quality.

Type	Temperature Operating Range	Max. Scale Factor Deviation
ADC160C	-25°C to +85°C	60ppm
ADC160CA	-25°C to +85°C	30ppm
ADC160M	-55°C to +125°C	100ppm

ADC160 offers 3 ppm max. linearity error and 1 ppm/°C max. scale factor error over the military temperature range. It also has excellent offset stability at 2 ppm max. which the user can auto zero if desired.

ADC160's compatibility with popular microcomputer buses increases its ease of application in smart systems.

An on-board microprocessor controls all internal functions of the ADC160. Thaler designers have minimized external connections to greatly reduce the problem often encountered when applying ADC's.

Operating from ±15VDC and a +5VDC power supply, ADC160 is packaged in a hermetically sealed 40-pin ceramic DIP package.

Precision test equipment, scientific and medical instruments, and data acquisition systems are primary application areas for the unusually high resolution and accuracy of this ADC.

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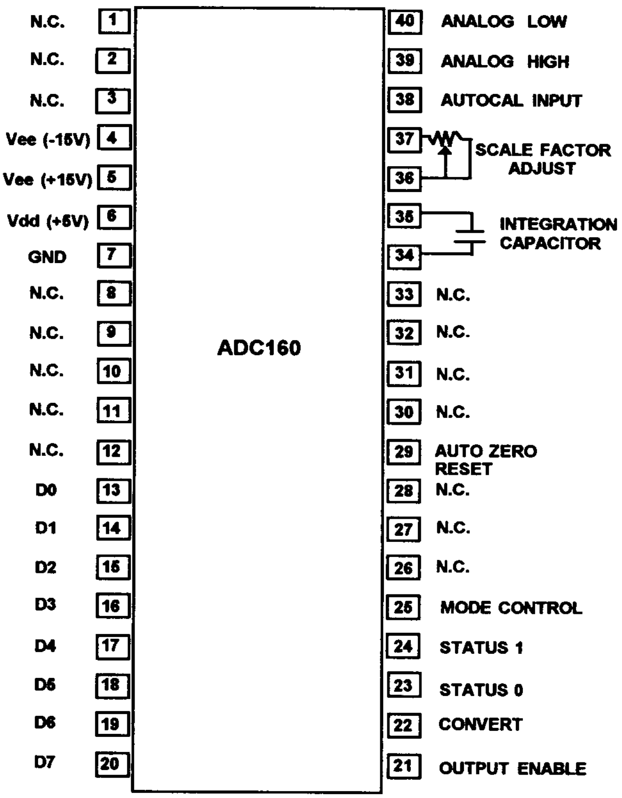
SPECIFICATIONS
MAXIMUM RATING

ADC160

MODEL	ADC160		
PARAMETER	**MIN**	**MAX**	**UNITS**
TEMPERATURE			
Operating Storage		125 160	°C °C
POWER SUPPLY			
V_{CC} V_{EE} V_{DD}		+18 -18 +6	VDC VDC VDC
INPUTS			
Analog Inputs Digital Inputs	V_{EE} 0	V_{CC} V_{DD}	

EXTERNAL CONNECTIONS

(TOP VIEW)



NOTES:

1. **Power Supply Decoupling**
   The ADC160 has internal .1µF decoupling capacitors for all power supply inputs. The internal decoupling capacitors are adequate for applications with relatively short power supply leads (approx. 5") or if additional capacitors are located on a circuit board. For applications with long power supply leads an external capacitor of 10 µF on the +/- 15V inputs and 33 µF on the +5V input is recommended.

2. **Ground**
   The ground connection (pin 7) should be made as solid as possible since ground noise can result in a loss of accuracy. Use of a ground plane is a good approach to maintain the full accuracy of the ADC160.

3. **External Components**
   A .68 µF polystyrene integration capacitor must be connected to pins 34 and 35 with a lead length not exceeding 2". A 20 KΩ potentiometer or 10 KΩ film resistor must be connected to pins 36, 37 for scale factor adjustment.

4. **Analog Inputs**
   In order to avoid differential noise pickup it is recommended to use parallel adjacent lines for the analog inputs (pins 39, 40) on PC boards and shielded lines outside of the PC connections.

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SPECIFICATIONS

ELECTRICAL

ADC160

(Vps = +/- 15V, + 5V, T = 25 Deg. C.)

MODEL	ADC160C			ADC160CA			ADC160M			
PARAMETER	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	
ACCURACY										
Resolution	20		24			*			*	Bits
Input Equivalent Noise		1			*			*		µV
Offset without Auto Zero			4			2			*	ppm
Offset with Auto Zero			1			0.5			*	ppm
Full Scale (note 1)			100			50			*	ppm
Noise (.1-10Hz) @ 10V		6			*			*		µVpp
Nonlinearity		1	3		*	*		*	*	ppm
Normal Mode Rejection [2]	60			*			*			db
TEMPERATURE STABILITY										
Offset			0.2			0.1			*	ppm/° C
Full Scale			1.0			0.5			*	ppm/° C
TIME STABILITY										
Offset		.1			*			*		ppm/month
Full Scale [3]		2			*			*		ppm/24 hrs.
ERROR ALL SOURCES										
24 hrs, +/- 1 Deg. C Amb.			.0005, 2			.0003, 2			*	%, +/- Counts
90 days, +/- 5 Deg. C Amb.			.0010, 2			.0008, 2			*	%, +/- Counts
1 year, +/- 5 Deg. C Amb.			.0015, 2			.0013, 2			*	%, +/- Counts
CONVERSION TIME			1067			*			*	msec
WARM-UP TIME			5			*			*	minutes
POWER SUPPLY REJECTION										
+/- 15 VDC	80			*			*			db
5 VDC	80			*			*			db
ANALOG INPUT CHARACTERISTICS										
Input Range	-10.485760		10.485755	*		*	*		*	V
Bias Current		1.2	3		*			*		nA
Input Impedance		200			*			*		G Ω
POWER SUPPLY VOLTAGES										
+15 V	14.5	15	15.5	*	*	*	*	*	*	V
-15 V	14.5	15	15.5	*	*	*	*	*	*	V
5 v	4.5	5	5.5	*	*	*	*	*	*	V
POWER SUPPLY CURRENTS										
+15 V		13			*			*		mA
-15 V		13			*			*		mA
5 v		12			*			*		mA
DIGITAL INPUTS										
Low			0.8			*			*	V
High	4.0			*			*			V
DIGITAL OUTPUTS										
Low			0.8			*			*	V
High	4.0			*			*			V
AUTO ZERO INPUT										
Low			0.8			*			*	V
High	4.0			*			*			V
CONVERT INPUT										
Low			0.8			*			*	V
High	4.0			*			*			V
TEMPERATURE RANGE	-25		85	*		*	-55		125	° C

* Same as ADC160C

Note: 1) Trimmable to zero 2) 60 Cycle

3) (Max-Min Value) - Noise(.1-10Hz)

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THEORY OF OPERATION

In the ADC160 block diagram (see Figure 1), V_{hi} and V_{low} are the inputs. Both are buffered and fed into a differential, voltage controlled, single output current source. This current is added to the reference current at the input of the op amp integrator. The output of the integrator is fed into a Schmitt trigger, which in turn, is fed into the ADC's timing control circuitry. When the integrator output actuates the Schmitt trigger, the timing circuit changes the direction of the reference current source and the integrator begins integrating in the opposite direction. This continues until the Schmitt trigger is actuated again by the integrator and reverses the direction of the reference current.

The equation for integration times are:

$$Tp = \frac{V X C}{I_{ref} + I_{inp}} \qquad Tm = \frac{V X C}{-I_{ref} + I_{inp}}$$

V = Voltage
C= Integration Capacitor Value
I_{ref} = Reference Current
I_{inp} = Input Current

Resolving these equations produces:

$$I_{inp} = I_{ref} \frac{Tp - Tm}{Tp + Tm}$$

Tp = Time Positive
Tm = Time Negative

The timing control circuitry governs the counters that measure the integration time in both directions.

The ADC160's on-board microprocessor is used to calculate the results of the integration equation above. It is also used to perform error corrections and to control the built-in-auto-cal. function. Note that the µP automatically performs an auto-calibration function at start-up, but it is recommended, to achieve maximum accuracy, that an auto-cal. be performed again after the ADC160 is fully warmed up.

The ADC160 operates in a continuous mode. It processes the result of the previous sample while it collects counts for the present sample. The status lines indicate the byte available at the output bus. The data transfer must be completed in 100 µsec. (see the timing diagram).

When the calculations are complete, the µP places the most significant byte in the output buffer and raises the S_0 flag. When another pulse is placed on the convert line, the middle byte is placed on the output, the S_0 flag is lowered and the S_1 flag raised. When the last pulse is placed in the convert line, the least significant byte is placed in the output buffer and both status flags are high indicating that the ADC160 is ready for another conversion.

Status line summary:

S_1	S_0	
0	0	Conversion in process.
0	1	Conversion complete. MSB in output.
1	0	Middle byte in output register.
1	1	LSB in output. Ready for next conversion.

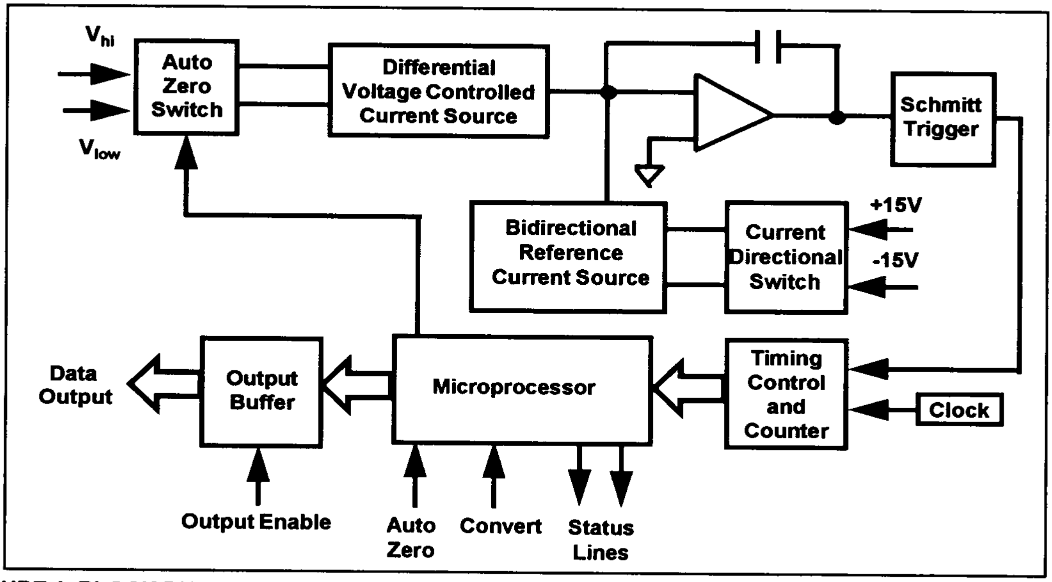

FIGURE 1. BLOCK DIAGRAM

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CONNECTING THE ADC160

POWER SUPPLIES

The power supply lines are connected to pins 4-7. Pin 4 is -15V, pin 5 is +15V, pin 6 is +5V and pin 7 is GND.

OUTPUT DATA LINES

The output data is available in byte form on pins 13-20. Pin 20 is the Most Significant Bit and pin 13 the Least Significant Bit. The data lines go to a high impedance state when the Output Enable line is at a logic one level.

OUTPUT ENABLE (PIN 21)

Data is placed on the Output Data Lines by a logic zero on this line.

DATA TRANSFER (Pin22)

After a conversion cycle is complete, the MSB of the result is available at the data bus. Two subsequent pulses are used to place the lower two bytes on the Output Data Lines.

STATUS LINES (Pins 23, 24)

These lines indicate the present state of the ADC. When the conversion is complete the microprocessor places the MSB of the output data in the output buffer and then raises S_0 to a logic one, indicating that the MSB at the output data is available in the output buffer. When the Convert Line is pulsed the middle byte of the output data is placed in that output buffer and S_1 changes to logic one and S_0 to logic zero. The second pulse places the LSB of the output data in the buffer and both status lines go to the logic one.

The table below shows a summary of the status code.

S_1	S_0	
0	0	Conversion in progress, no data available.
0	1	Conversion complete. MSB in output.
1	0	Middle byte in output register.
1	1	LSB in output. Ready for next conversion.

MODE CONTROL (Pin 25)

This line is used to program the ADC160. The mode control byte is placed on the data bus. Pin 25 is then set to logic high, pin 21 to logic low to accept the control byte. Pin 25 is returned to logic low. The ADC160 has now been reset to the new parameters.

AUTO-ZERO / RESET (Pin 29)

A logic zero on this input will autozero the ADC160 by internally connecting the analog high to analog low. Since the μP is reset, the ADC160 reverts to the factory default settings in the EPROM (ie. 22bits, 60Hz, pin 39 analog high). To select a mode different than the default settings, the mode control must be set after auto zero.

INTEGRATION CAPACITOR (Pin 34, 35)

A .68 μF polystyrene or mylar capacitor must be connected to these pins. Lead length should be as short as possible and not exceed 2".

SCALE FACTOR ADJUST (Pin 36, 37)

The scale factor can be manually adjusted for a range of +/-.02% if a 20k Ohm potentiometer is connected to these pins. If software adjustment is desired, a fixed resistor of 10k Ohms +/- 1% should be connected to these pins.

ANALOG INPUTS (Pin 39, 40)

Both analog inputs are buffered by op-amps and have a common mode rejection of approximately 80dB minimum. To maintain the full accuracy at the ADC it is recommended to keep the input to analog low to less than 0.1VDC.

TIMING DIAGRAMS

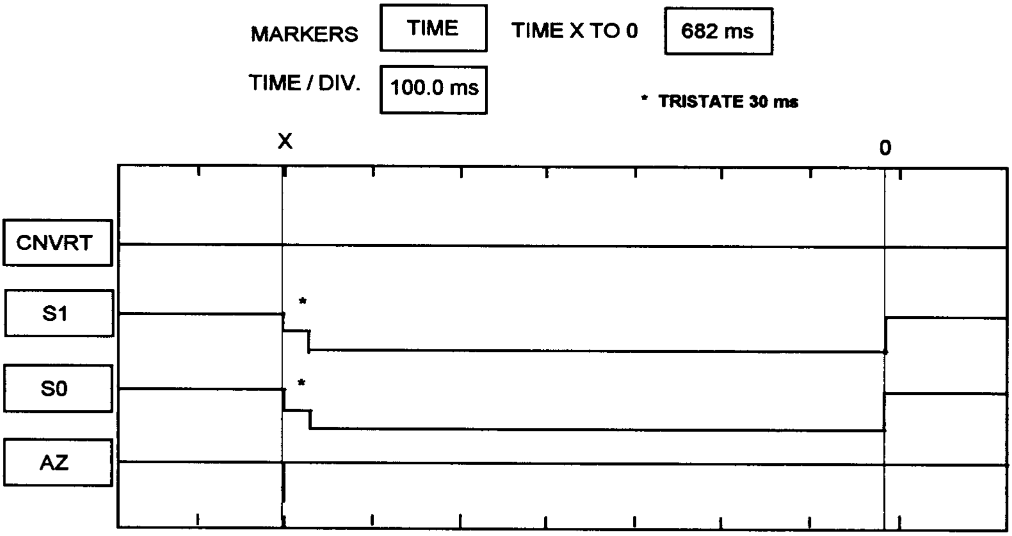

FIGURE 2. AUTO ZERO

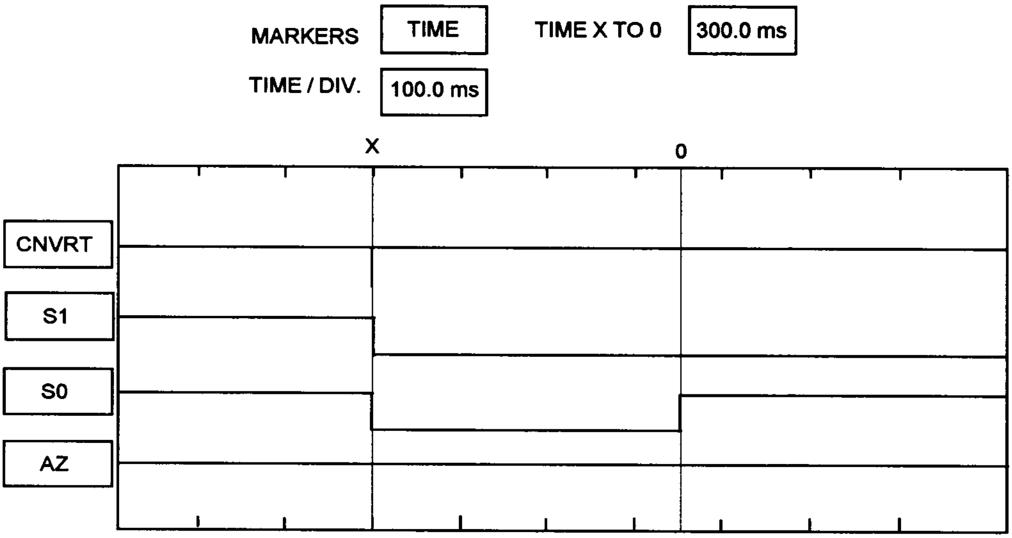

FIGURE 3. CONVERSION (22 BIT)

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TIMING DIAGRAMS

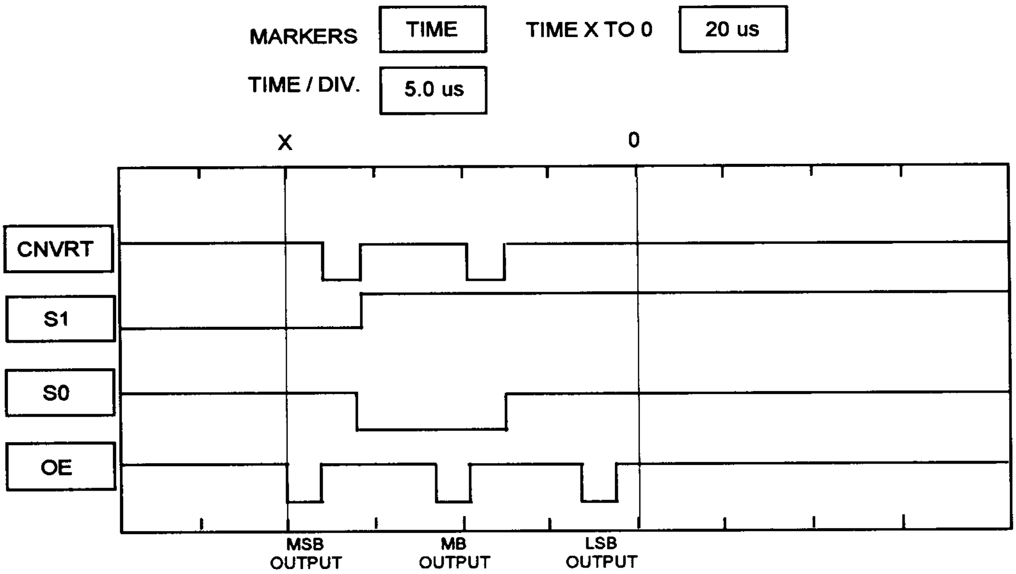
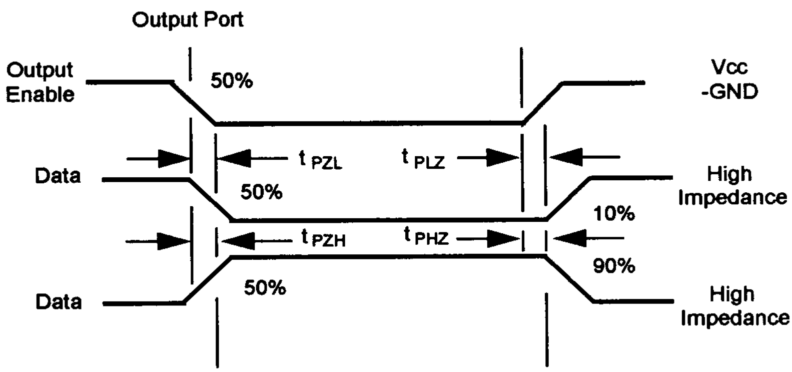


FIGURE 4. DATA OUTPUT



Parameter	Max Value	Units
t_{PZL}	45	ns
t_{PZH}	45	ns
t_{PLZ}	60	ns
t_{PHZ}	60	ns

FIGURE 5. OUTPUT DATA

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TIMING DIAGRAMS

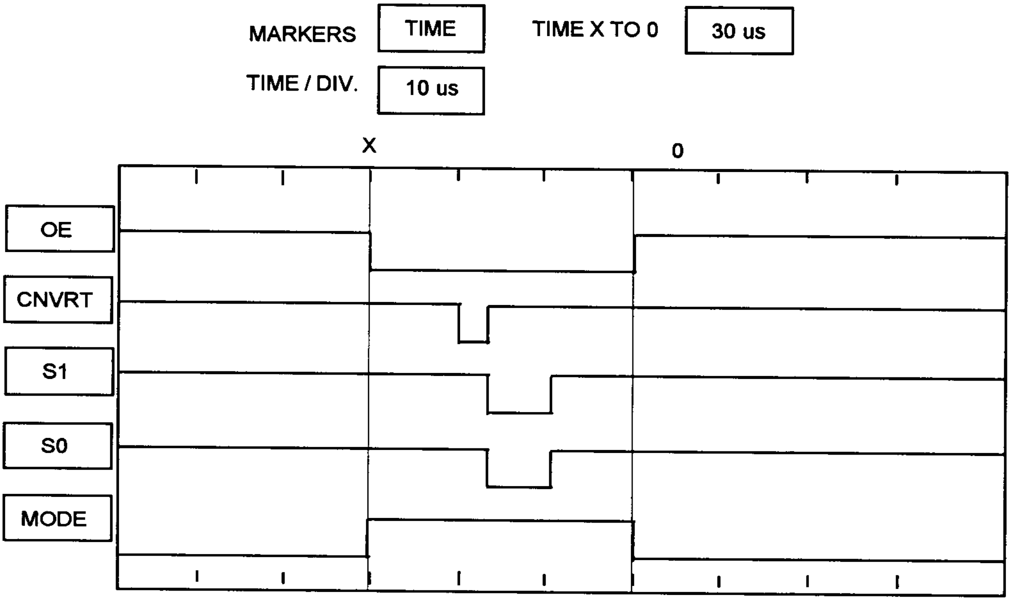

FIGURE 6. MODE CHANGE

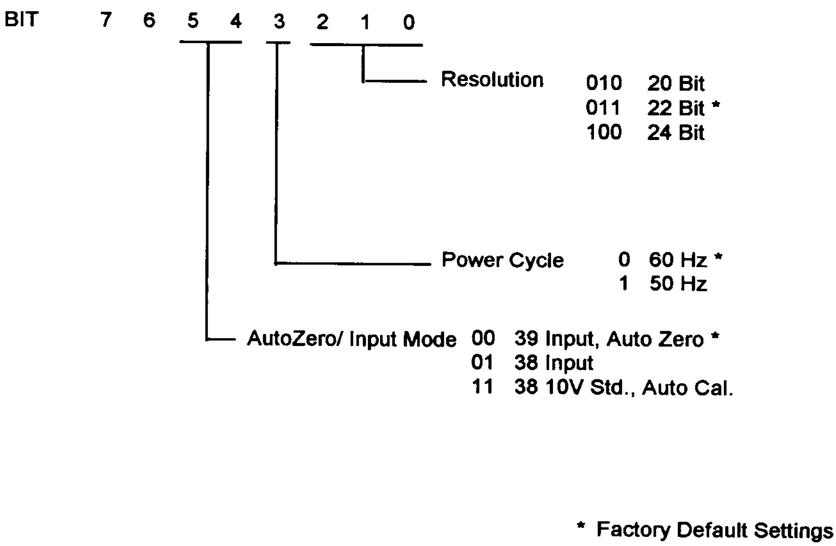

FIGURE 7. MODE CONTROL BYTE

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OUTPUT DATA REPRESENTATION

The output data is represented in BOB (Bipolar Offset Binary) format. The table below shows the output data codes for zero and plus-minus full scale input voltage for the programmable resolution of the converter.

24 Bits
1 LSB = 1.24 μV

Input Voltage	Output Data		
	High Byte	Middle Byte	Low Byte
-10.485760 V	00	00	00
0.0 V	80	00	00
+10.485755 V	FF	FF	FF

22 Bits
1 LSB = 5 μV

Input Voltage	Output Data		
	High Byte	Middle Byte	Low Byte
-10.485760 V	00	00	00
0.0 V	20	00	00
+10.485755 V	3F	FF	FF

20 Bits
1 LSB = 20 μV

Input Voltage	Output Data		
	High Byte	Middle Byte	Low Byte
-10.485760 V	00	00	00
0.0 V	08	00	00
+10.485755 V	10	FF	FF

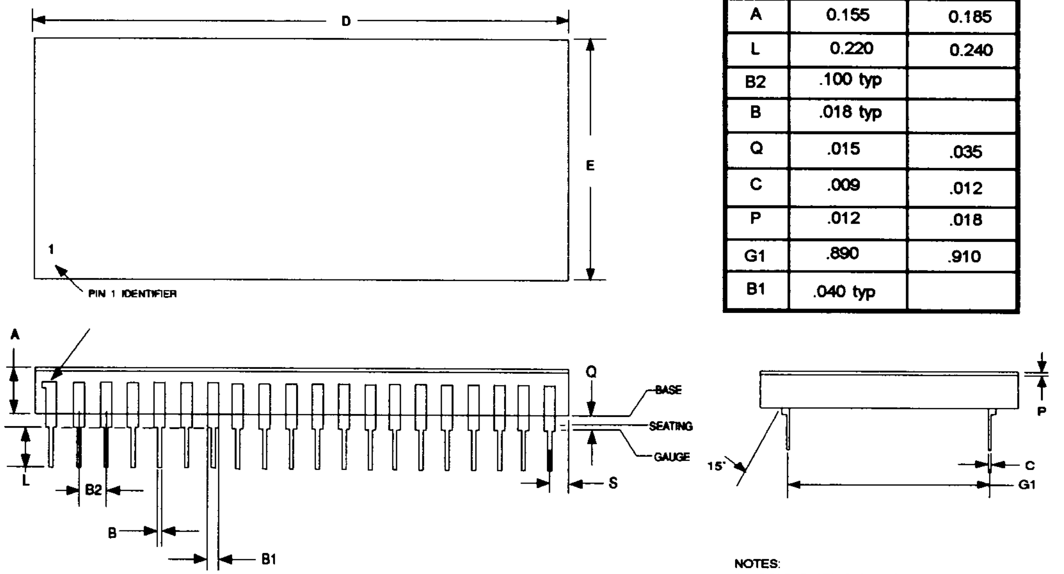
RESOLUTION	LINE CYCLES	CONV. / SEC (60/50 Hz)
20 BITS	4	15 / 12
22 BITS	16	3.7 / 3.1
24 BITS	64	1.2 / .93

Line Cycle at 60 Hz. = 16.667 mS; 50 Hz = 20 mS

FIGURE 8. INTEGRATION TIMES

40-PIN HYBRID PACKAGE

DIM	INCHES MIN	INCHES MAX
E	1.080	1.100
D	2.075	2.115
A	0.155	0.185
L	0.220	0.240
B2	.100 typ	
B	.018 typ	
Q	.015	.035
C	.009	.012
P	.012	.018
G1	.890	.910
B1	.040 typ	



NOTES:
1. GOLD PLATING 60 MICRO INCHES MINIMUM THICKNESS OVER 100 MICRO INCHES NOMINAL THICKNESS OF NICKEL

FIGURE 9. MECHANICAL SPECIFICATIONS

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