4020 SERIES

8, 10 & 12-BIT ECONOMY D/A CONVERTERS

Teledyne Philbrick Models 4020 through 4027 are economy general purpose 8, 10 and 12-bit D/A Converters with either voltage or current output. Utilizing micro-circuit construction, these units offer high reliability combined with good flexibility. For many applications, such as providing analog monitoring of digital data, they provide the answer to the combined requirements of high performance at economical prices.

Unipolar or bipolar operation is available through pin programming on all models except 4026 and 4027. No additional external resistors or references are required. In addition, utilization of the same reference for both scale factor and bipolar offset results in an improved bipolar zero stability. Provisions are made for maintaining the same current through the reference in either unipolar or bipolar operation, maintaining its high degree of temperature stability regardless of the unit's mode of operation.

While internal references are included in all these models, provisions are made for the use of an external reference.

Model	Resolution	Output	Output Range
4020	8-bits	Current	0 to +2 mA, or −1 mA to +1 mA
4021	8-bits	Voltage	0 to −10V, or +5V to −5V
4022	10-bits	Current	0 to +2 mA, or −1 mA to +1 mA
4023	10-bits	Voltage	0 to −10V, or +5V to −5V
4024	12-bits	Current	0 to +2 mA, or −1 mA to +1 mA
4025	12-bits	Voltage	0 to −10V or +5V to −5V
4026	3-digit	Current	0 to +1.25 mA
4027	3-digit	Voltage	0 to −10V

FEATURES

- 8, 10 and 12-bit Linearity
- Voltage or Current Output
- Internal or External Reference
- Unipolar or Bipolar Operation
- 200 nanosec Settling Time

APPLICATIONS

- Display Systems
- Test Equipment
- Instrumentation

OPERATION

Accuracy Consideration

Models 4020 through 4027 are all guaranteed to have a maximum non-linearity of ±1/2 LSB. Output scale factor accuracy is guaranteed to be within 1% of the ideal through the use of a factory adjusted internal feedback resistor between the input and output of the output op amp. For Models 4021, 4023, 4025 and 4027, this resistor is permanently connected across the internal output op amp as shown in Figure 1. On Models 4020, 4022, 4024, and 4026 the use of an external op amp and this resistor will result in an output scale factor accurate to within 1%. The output current of Models 4020 and 4022 is accurate to within 5%, but use of this internal compensated feedback resistor, or selection of a proper external feedback or load resistor will compensate for this value. An external resistor will not compensate for scale factor temperature changes as well as the internal resistor.

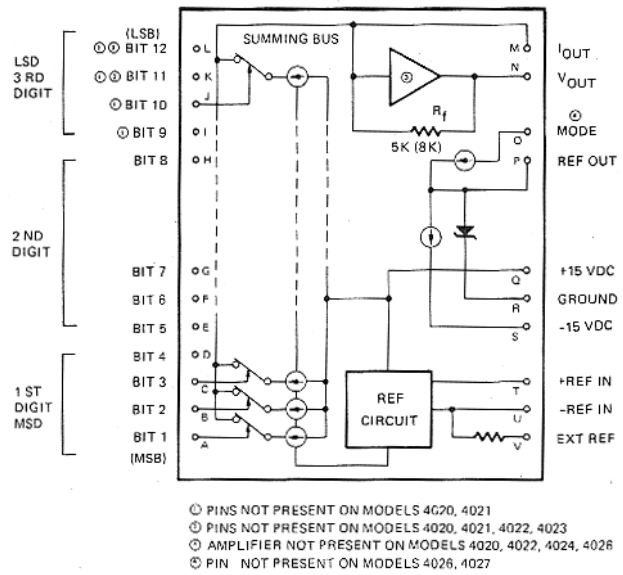


Figure 1. Functional Block Diagram (View towards pins)

Principles of Operation

As shown in Figure 1 (Functional Block Diagram), the output amplifier shown connected between the I_{out} and V_{out} terminals is only included in the voltage output Models 4021, 4023, 4025, and 4027. The 5 kΩ (8 kΩ in 4026 and 4027) resistor Rf is present in all models and is intended for use as the feedback resistor with an external op amp on Models 4020, 4022, 4024, and 4026. The reference circuit provides a high-stability reference for the binary (BCD) weighted current sources. When each current source has its binary (BCD) control input connected to a logic "1" input level, that current source's contribution will appear on the current summing bus which feeds to the I_{out} terminal, and the internal op amp in Models 4021, 4023, 4025, and 4027. In models 4020 through 4025 the mode terminal provides the necessary offset current for bipolar operation.

Logic Inputs

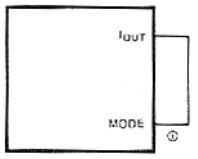
Logic inputs are standard TTL/DTL compatible. If any bits are not to be used, it is necessary to ground the unused LSB's since an "open" bit input line is equivalent to a logic "1". Opening the bit lines should not, however, be used as a means of generating a logic "1" due to the possibilities of noise pick up.

Models 4020 through 4025 use a binary input code. If desired, virtually any other binary code can be used by the addition of the necessary external logic.

Models 4026 and 4027 use a Binary Coded Decimal (BCD) input code.

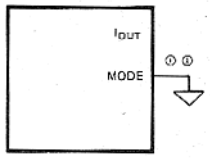
Power Supply Requirements

Models 4020 through 4027 require standard ±15 V dc power. A tolerance of ±3% is allowable on this power. To insure adequate stability, the DAC power terminals should be bypassed to ground with 0.01 microfarad capacitors.



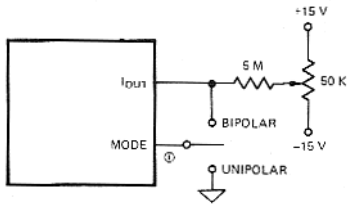
① MODE PIN NOT PRESENT ON MODELS 4026, 4027.

Figure 2A. Bipolar Operation



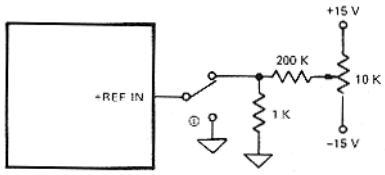
① MODE PIN NOT PRESENT ON MODELS 4026, 4027.
② NO EXTERNAL CONNECTION REQUIRED FOR UNIPOLAR OPERATION ON MODELS 4026, 4027.

Figure 2B. Unipolar Operation



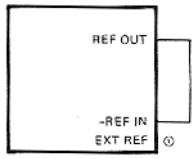
① MODE PIN NOT PRESENT ON MODELS 4026, 4027.
NOTE: USE METAL FILM RESISTOR AND CERMET POT.

Figure 2C. Optional Zero Offset Trim



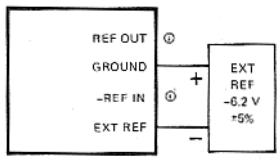
① IF TRIM CIRCUIT NOT USED + REF IN MUST BE GROUNDED
NOTE: USE METAL FILM RESISTORS AND CERMET POT.

Figure 2D. Optional Gain Trim



① NOT CONNECTED

Figure 2E. Internal Reference



① NOT CONNECTED

Figure 2F. External Reference

Trim Procedures

For increased accuracy, all models can be trimmed to tighter tolerances for both Zero Offset and Gain Errors. Figures 2C and 2D show the correct connections for Zero Offset and Gain trimming respectively.

Unipolar Trim Procedure

1. Zero Offset Trim Procedure – Set digital inputs to 000...000. Adjust the 50 kΩ potentiometer shown in Figure 2C for Zero Output.
2. Gain Trim Procedure – Set digital inputs to 111...111 Binary or 1001 1001 1001 BCD. Adjust the 10 kΩ potentiometer shown in Figure 2D for minus Full Scale +1 LSB output for voltage models or plus Full Scale −1 LSB output for current models.

Bipolar Trim Procedure

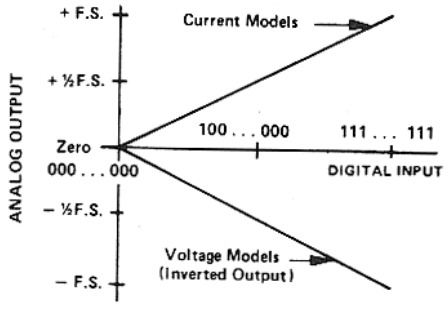
1. Zero Offset Trim Procedure – Set digital inputs to 000...000. Adjust the 50 kΩ potentiometer shown in Figure 2C for plus Full Scale output for voltage models or minus Full Scale output for current models.
2. Gain Trim Procedure – Set digital inputs to 111...111. Adjust the 10 kΩ potentiometer shown in Figure 2D for minus Full Scale +1 LSB output for voltage models or plus Full Scale −1 LSB output for current models.

Unipolar or Bipolar Mode

Models 4020 through 4025 can be operated unipolar or bipolar by proper pin connections. Figures 2A and 2B show the correct connections for bipolar and unipolar operation respectively. Models 4026 and 4027 can only be operated in the unipolar mode, therefore, no external mode connections are required. A graphic display of output vs binary input for unipolar operation is given in Figure 3. Figure 4 is a graphic representation of bipolar output vs. binary input.

Output Considerations

Models 4021, 4023, 4025, and 4027 are supplied with internal output amplifiers. The output of these units in the unipolar mode is 0 to −10 V at ±5 mA max. The negative-going output results from the positive current output of the DAC feeding into the summing point of the output amplifier which acts as an inverting current-to-voltage converter. If desired, the user can reduce the output range of these modules by connecting a resistor across the feedback resistor (I_{out} to V_{out}). Desired output voltage is proportional to the parallel combination of the internal feedback resistor and the external applied resistor, times the Full Scale span. For Models 4021, 4023, and 4025 the internal feedback resistor, R_f, is 5 kΩ, and 8 kΩ for Model 4027.



ANALOG OUTPUT	DIGITAL INPUT
BIT NUMBER (MSB)	1 2 3 . . . n^{-2} n^{-1} n (LSB)
(+)Max Output = (F.S. −1LSB)	1 1 1 . . . 1 1 1
(+)Half Scale	1 0 0 . . . 0 0 0
(+)1 LSB	0 0 0 . . . 0 0 1
Zero	0 0 0 . . . 0 0 0

(+) = (−) for Voltage Models

Each LSB = $\frac{+\text{Full Scale}}{2^n}$

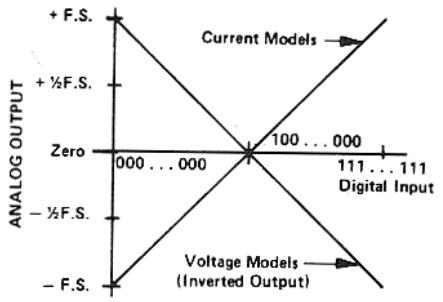
Natural Binary Coding is used with unipolar current models.
Inverted Output Binary coding is used with unipolar voltage models.

Figure 3. Unipolar Output

Models 4020, 4022, and 4024 provide a 0 to +2 mA output in the unipolar mode. Model 4026 provides 0 to +1.25 mA output. They are normally intended to be used with an external output amplifier in applications where other output scale factors are required. For normalized −10 volt output, the internal 5 kΩ resistor (8 kΩ for 4026) should be used as the amplifier's feedback resistor. This will maintain maximum accuracy and minimum scale factor T.C.

Internal and External Reference

Models 4020 through 4027 have both internal and external reference capability. Figures 2E and 2F show the correct connections for internal and external reference respectively.

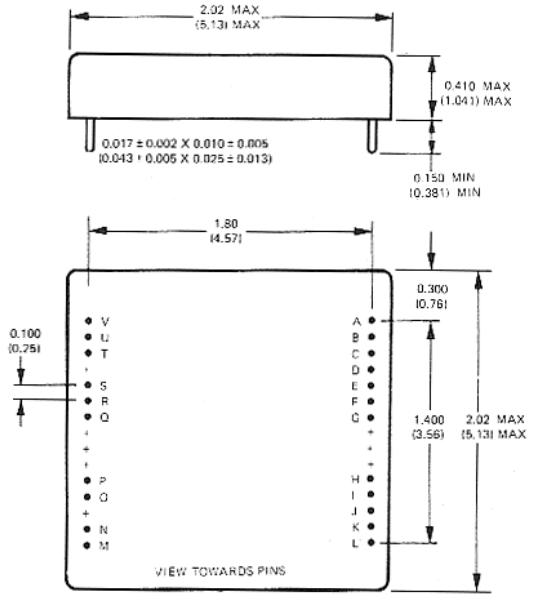


ANALOG OUTPUT	DIGITAL INPUT
BIT NUMBER (MSB)	1 2 3 . . . n^{-2} n^{-1} n (LSB)
(+) Max Output = (F.S. −1LSB)	1 1 1 . . . 1 1 1
(+)Half Scale	1 1 0 . . . 0 0 0
Zero	1 0 0 . . . 0 0 0
(−)Half Scale	0 1 0 . . . 0 0 0
(−)Max Output = (−F.S.)	0 0 0 . . . 0 0 0

(+) = (−) and (−) = (+) for Voltage Models

Offset Binary coding is used for bipolar current models.
Inverted Output Offset Binary coding is used for bipolar voltage models.

Figure 4. Bipolar Output



±0.01 Non-cumulative tolerance between pins
±0.02 Tolerance from case edge to center of pins

DIMENSIONS IN PARENTHESES ARE EXPRESSED IN CENTIMETERS

Optional Socket: Model 6069

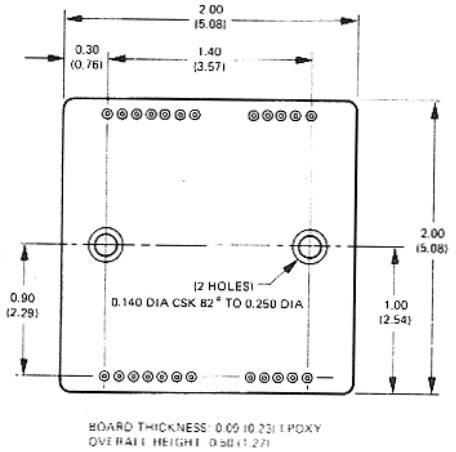


Figure 5. Mechanical Specifications

SPECIFICATIONS (At +25°C, ±15 V, unless otherwise indicated)

	CURRENT OUTPUT MODELS				VOLTAGE OUTPUT MODELS			
MODEL NUMBER	**4020**	**4022**	**4024**	**4026**	**4021**	**4023**	**4025**	**4027**
RESOLUTION	8 Bits	10 Bits	12 Bits	3-Digit	8 Bits	10 Bits	12 Bits	3-Digit
INPUT								
Reference Voltage	−6.2 Vdc ± 5%				−6.2 Vdc ± 5%			
Resistance	6.3 KΩ	6.3 KΩ	4 KΩ	6.3 KΩ	6.3 KΩ	6.3 KΩ	4 KΩ	6.3 KΩ
Power Requirements	±15 Vdc ± 3% @ ±15 mA				±15 Vdc +3% @ ±20 mA		±15 Vdc ±3% @ ±25 mA	
Recommended Philbrick Supply	2210, 2211, 2212				2210, 2211, 2212			
Logic								
Logic Code	Binary or Offset Binary			BCD	Binary or Offset Binary			BCD
Logic Input Current, max.	1.2 mA	1.2 mA	1.6 mA	1.6 mA	1.2 mA	1.2 mA	1.6 mA	1.6 mA
TTL Loads ①	< 1 unit load	< 1 unit load	1 unit load	1 unit load	< 1 unit load	< 1 unit load	1 unit load	1 unit load
Switching Levels, All Digital Inputs ①								
"0" State	⩽ +0.8 V				⩽ +0.8 V			
"1" State	⩾ +2.0 V				⩾ +2.0 V			
TRANSFER CHARACTERISTICS								
Accuracy								
Nonlinearity, max.	± ½ LSB	± ½ LSB	± ½ LSB	± ½ LSB	± ½ LSB	± ½ LSB	± ½ LSB	± ½ LSB
Differential Nonlinearity, max.	±1 LSB	±1 LSB	±1 LSB	±1 LSB	+1 LSB	±1 LSB	±1 LSB	+1 LSB
Zero Offset Error								
Unipolar, max. ①	±3.9 μA	±0.95 μA	±0.2 μA	±0.63 μA	±20 mV	±10 mV	±13 mV	+15 mV
Bipolar, max. ②	±3.9 μA	±0.95 μA	±0.4 μA	---	±20 mV	±5 mV	±2.5 mV	---
Full Scale Error, max. ③	± 5% ②	± 5% ②	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%
Stability								
Differential Nonlinearity vs. Temp.	±10 ppm/°C	±10 ppm/°C	±6 ppm/°C	±10 ppm/°C	±10 ppm/°C	±10 ppm/°C	±6 ppm/°C	±10 ppm/°C
Zero Offset Error vs. Temp.								
Unipolar, max.	±4 ppm/°C	±4 ppm/°C	±4 ppm/°C	±4 ppm/°C	±20 ppm/°C	±20 ppm/°C	±9 ppm/°C	±9 ppm/°C
Bipolar, max.	±40 ppm/°C	±40 ppm/°C	±18 ppm/°C	---	±40 ppm/°C	±40 ppm/°C	±24 ppm/°C	---
Full Scale Error vs. Temp.,max.	±40 ppm/°C	±40 ppm/°C	+30 ppm/°C	±30 ppm/°C	±40 ppm/°C	±40 ppm/°C	±30 ppm/°C	±30 ppm/°C
PSRR, max.	±0.05%/% △ V_S				±0.05%/% △ V_S			
Dynamic Characteristics								
Settling Time to within ½ LSB of Final Value, max.,for a Full Scale Step	300 nsec	300 nsec	300 nsec	300 nsec	25 μsec ④	25 μsec ④	5 μsec	5 μsec
OUTPUT								
Analog								
Full Scale, Unipolar	0 to +2 mA	0 to +2 mA	0 to +2 mA	0 to +1.25 mA	0 to −10 V	0 to −10 V	0 to −10 V	0 to −10 V
Full Scale, Bipolar	−1 to +1 mA	−1 to +1 mA	−1 to +1 mA	---	+5 to −5 V	+5 to −5 V	+5 to −5 V	---
Impedance, Unipolar	8 KΩ ‖ 40 pF	8 KΩ ‖ 40 pF	8 KΩ ‖ 40 pF	8 KΩ ‖ 40 pF	⩽ 0.3 Ω	⩽ 0.3 Ω	⩽ 0.3 Ω	⩽ 0.3 Ω
Impedance, Bipolar	3.5 KΩ ‖ 40 pF	3.5 KΩ ‖ 40 pF	3.5 KΩ ‖ 40 pF	---	⩽ 0.3 Ω	⩽ 0.3 Ω	⩽ 0.3 Ω	---
Compliance, max.	±1 V	±1 V	±0.1 V	±0.1 V	±5 mA	±5 mA	±5 mA	±5 mA
ENVIRONMENTAL REQUIREMENTS								
Operating Temperature	0°C to +70°C				0°C to +70°C			
Storage Temperature	−55°C to +100°C				−55°C to +100°C			
Relative Humidity	95% non-condensing				95% non-condensing			
ABSOLUTE MAXIMUM RATINGS								
Digital Input Voltage	5.5 Vdc	5.5 Vdc	5.5 Vdc	5.5 Vdc	5.5 Vdc	5.5 Vdc	5.5 Vdc	5.5 Vdc
Supply Voltages to Ground	±18 Vdc	±18 Vdc	±18 Vdc	±18 Vdc	±18 Vdc	±18 Vdc	±18 Vdc	±18 Vdc
Short Circuit Protection								
Output to Ground	Indefinitely				Indefinitely			
Output to Supplies	No				No			
Ref. Out to Ground	2 sec				2 sec			

① Standard TTL Load unit is −1.6 mA maximum at +0.4 V (LO) and +40 μA maximum at +2.4 V (HI).

② Adjustable to Zero.

③ When using internal feedback resistor and external op amp, accuracy will be ±1%.

④ Faster units available. Consult factory or your nearest Teledyne Philbrick representative.

TELEDYNE PHILBRICK