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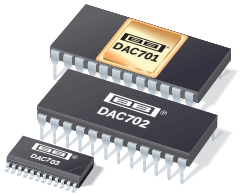



# DAC701
# DAC702
# DAC703

# Monolithic 16-Bit DIGITAL-TO-ANALOG CONVERTERS

## FEATURES

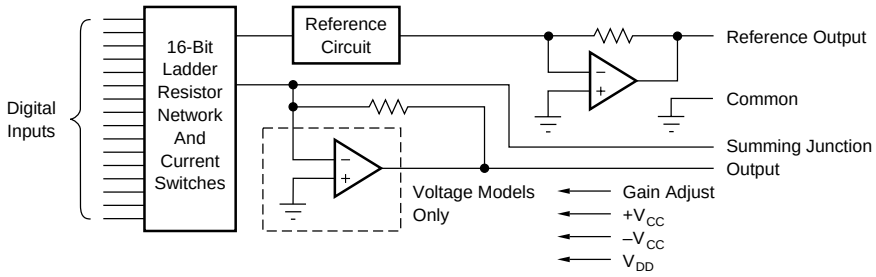
- $V_{OUT}$ AND $I_{OUT}$ MODELS
- HIGH ACCURACY:
  Linearity Error ±0.0015% of FSR max
  Differential Linearity Error ±0.003% of FSR max
- MONOTONIC (at 15 bits) OVER FULL SPECIFICATION TEMPERATURE RANGE
- PIN-COMPATIBLE WITH DAC70, DAC71, DAC72
- DUAL-IN-LINE PLASTIC AND HERMETIC CERAMIC AND SOIC

## DESCRIPTION

The DAC70X family comprise of complete 16-bit digital-to-analog converters that includes a precision buried-zener voltage reference and a low-noise, fast-settling output operational amplifier (voltage output models), all on one small monolithic chip. A combination of current-switch design techniques accomplishes not only 15-bit monotonicity over the entire specified temperature range, but also a maximum end-point linearity error of ±0.0015% of full-scale range. Total full-scale gain drift is limited to ±10ppm/°C maximum (LH and CH grades).

Digital inputs are complementary binary coded and are TTL-, LSTTL-, 54/74C- and 54/74HC-compatible over the entire temperature range. Outputs of 0 to +10V, ±10V, 0 to –2mA, and ±1mA are available.

These D/A converters are packaged in hermetic 24-pin ceramic side-brazed or molded plastic. The DIP-packaged parts are pin-compatible with the voltage and current output DAC71 and DAC72 model families. The DAC702 is also pin-compatible with the DAC70 model family. In addition, the DAC703 is offered in a 24-pin SOIC package for surface mount applications.

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# SPECIFICATIONS

At +25°C and rated power supplies, unless otherwise noted.

| PARAMETER | DAC702/703J | | | DAC701/702/703K | | | DAC701/702/703B, S | | | DAC701/702/703L, C | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| **INPUT** | | | | | | | | | | | | | |
| **DIGITAL INPUT** | | | | | | | | | | | | | |
| Resolution | | | 16 | | | * | | | * | | | * | Bits |
| Digital Inputs [1] | | | | | | | | | | | | | |
| $V_{IH}$ | +2.4 | | $+V_{CC}$ | * | | * | * | | * | * | | * | V |
| $V_{IL}$ | –1.0 | | +0.8 | * | | * | * | | * | * | | * | V |
| $I_{IH}$, $V_I$ = +2.7V | | | +40 | | | * | | | * | | | * | µA |
| $I_{IL}$, $V_I$ = +0.4V | | –0.35 | –0.5 | | * | * | | * | * | | * | * | mA |
| **TRANSFER CHARACTERISTICS** | | | | | | | | | | | | | |
| **ACCURACY** [2] | | | | | | | | | | | | | |
| Linearity Error [4] | | ±0.0015 | ±0.006 | | * | ±0.003 | | * | * | | ±0.00075 | ±0.0015 | % of FSR [3] |
| Differential Linearity Error [4] | | ±0.003 | ±0.012 | | * | ±0.006 | | * | * | | ±0.0015 | ±0.003 | % of FSR |
| Differential Linearity Error at Bipolar Zero (DAC702/703) [4] | | | | | ±0.003 | ±0.006 | | ±0.0015 | ±0.003 | | * | * | % of FSR |
| Gain Error [5] | | ±0.07 | ±0.30 | | * | ±0.15 | | ±0.05 | ±0.10 | | * | * | % |
| Zero Error [5, 6] | | ±0.05 | ±0.10 | | * | * | | * | * | | * | * | % of FSR |
| Monotonicity Over Spec. Temp Range | 13 | | | 14 | | | * | | | 15 | | | Bits |
| **DRIFT** (over specification temperature range) Total Error Over Temperature Range (all models) [7] | | ±0.08 | | | * | ±0.15 | | ±0.05 | ±0.10 | | * | * | % of FSR |
| Total Full Scale Drift: | | | | | | | | | | | | | |
| DAC701 | | ±10 | | | * | ±30 | | ±8.5 | ±18 | | ±6 | ±13 | ppm of FSR/°C |
| DAC702/703 | | ±10 | | | * | ±25 | | ±7 | ±15 | | * | * | ppm of FSR/°C |
| Gain Drift (all models) | | ±10 | ±30 | | * | ±25 | | ±7 | ±15 | | ±5 | ±10 | ppm/°C |
| Zero Drift: | | | | | | | | | | | | | |
| DAC701 | | | | | ±2.5 | ±5 | | ±1.5 | ±3 | | * | * | ppm of FSR/°C |
| DAC702/703 | | ±5 | ±15 | | * | ±12 | | ±4 | ±10 | | ±2.5 | ±5 | ppm of FSR/°C |
| Differential Linearity Over Temp. [4] | | | ±0.012 | | | +0.009, –0.006 | | | * | | | +0.006, –0.003 | % of FSR |
| Linearity Error Over Temp. [4] | | | ±0.012 | | | ±0.006 | | | * | | | ±0.003 | % of FSR |
| **SETTLING TIME** (to ±0.003% of FSR) [8] | | | | | | | | | | | | | |
| DAC701/703 ($V_{OUT}$ Models) | | | | | | | | | | | | | |
| Full Scale Step, 2kΩ Load | | 4 | | | * | 8 | | * | * | | * | * | µs |
| 1LSB Step at Worst-Case Code [9] | | 2.5 | | | * | | | * | | | * | | µs |
| Slew Rate | | 10 | | | * | | | * | | | * | | V/µs |
| DAC702 ($I_{OUT}$ Models) | | | | | | | | | | | | | |
| Full Scale Step (2mA), | | | | | | | | | | | | | |
| 10 to 100Ω Load | | 350 | | | * | 1000 | | * | * | | * | * | ns |
| 1kΩ Load | | 1 | | | * | 3 | | * | * | | * | * | µs |
| **OUTPUT** | | | | | | | | | | | | | |
| **VOLTAGE OUTPUT MODELS** | | | | | | | | | | | | | |
| DAC701 (CSB Code) | | | | | 0 to +10 | | | * | | | | | V |
| DAC703 (COB Code) | | ±10 | | | * | | | * | | | * | | V |
| Output Current | ±5 | | | * | | | * | | | * | | | mA |
| Output Impedance | | 0.15 | | | * | | | * | | | * | | Ω |
| Short Circuit to Common Duration | | Indefinite | | | * | | | * | | | * | | |
| **CURRENT OUTPUT MODELS** | | | | | | | | | | | | | |
| DAC702 (COB Code) [10] | | ±1 | | | * | | | * | | | * | | mA |
| Output Impedance [10] | | 2.45 | | | * | | | * | | | * | | kΩ |
| Compliance Voltage | | ±2.5 | | | * | | | * | | | * | | V |

# SPECIFICATIONS (CONT)

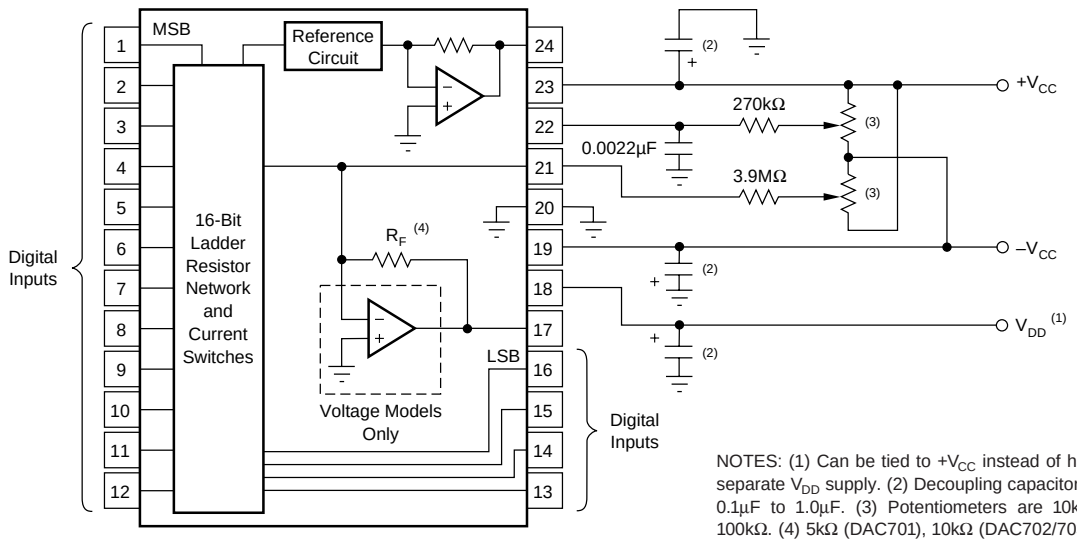
At +25°C and rated power supplies, unless otherwise noted.

| PARAMETER | DAC702/703J | | | DAC701/702/703K | | | DAC701/702/703B, S | | | DAC701/702/703L, C | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| **REFERENCE VOLTAGE** | | | | | | | | | | | | | |
| Voltage | | +6.3 | | +6.0 | +6.3 | +6.6 | +6.24 | +6.3 | +6.36 | * | * | * | V |
| Source Current Available for External Loads | | +2.5 | | +1.5 | * | | * | * | | * | * | | mA |
| Temperature Coefficient | | ±10 | | | * | ±25 | | * | ±15 | | * | * | ppm/°C |
| Short Circuit to Common Duration | | Indefinite | | | * | | | * | | | * | | |
| **POWER SUPPLY REQUIREMENTS** | | | | | | | | | | | | | |
| Voltage: $+V_{CC}$ | 13.5 | 15 | 16.5 | * | * | * | * | * | * | * | * | * | V |
| $-V_{CC}$ | 13.5 | 15 | 16.5 | * | * | * | * | * | * | * | * | * | V |
| $V_{DD}$ | +4.5 | +5 | +16.5 | * | * | * | * | * | * | * | * | * | V |
| Current (No Load): | | | | | | | | | | | | | |
| DAC702 | | | | | | | | | | | | | |
| ($I_{OUT}$ Models) | | | | | | | | | | | | | |
| $+V_{CC}$ | | +10 | +25 | | * | * | | * | * | | * | * | mA |
| $-V_{CC}$ | | –13 | –25 | | * | * | | * | * | | * | * | mA |
| $V_{DD}$ | | +4 | +8 | | * | * | | * | * | | * | * | mA |
| DAC701/703 | | | | | | | | | | | | | |
| ($V_{OUT}$ Models) | | | | | | | | | | | | | |
| $+V_{CC}$ | | +16 | +30 | | * | * | | * | * | | * | * | mA |
| $-V_{CC}$ | | –18 | –30 | | * | * | | * | * | | * | * | mA |
| $V_{DD}$ | | +4 | +8 | | * | * | | * | * | | * | * | mA |
| Power Dissipation: | | | | | | | | | | | | | |
| ($V_{DD}$ = +5.0V)(11) | | | | | | | | | | | | | |
| DAC702 | | 365 | | | * | 790 | | * | 630 | | * | * | mW |
| DAC701/703 | | 530 | | | * | 940 | | * | 780 | | * | * | mW |
| Power Supply Rejection: | | | | | | | | | | | | | |
| $+V_{CC}$ | | ±0.0015 | ±0.006 | | * | * | | * | ±0.003 | | * | * | % of FSR/%$V_{CC}$ |
| $-V_{CC}$ | | ±0.0015 | ±0.006 | | * | * | | * | ±0.003 | | * | * | % of FSR/%$V_{CC}$ |
| $V_{DD}$ | | ±0.0001 | ±0.001 | | * | * | | * | * | | * | * | % of FSR/%$V_{DD}$ |
| **TEMPERATURE RANGE** | | | | | | | | | | | | | |
| Specification: | | | | | | | | | | | | | |
| B, C Grades | | | | | | | –25 | | +85 | * | | * | °C |
| S Grades | | | | | | | –55 | | +125 | | | | °C |
| J, K, L Grades | 0 | | +70 | * | | * | | | | 0 | | +70 | °C |
| Storage: Ceramic | | | | –60 | | +150 | * | | * | * | | * | °C |
| Plastic, SOIC | –60 | | +100 | * | | * | | | | | | | °C |

* Specification same as model to the left.

NOTES: (1) Digital inputs are TTL, LSTTL, 54/74C, 54/74HC, and 54/74HTC compatible over the operating voltage range of $V_{DD}$ = +5V to +15V and over the specified temperature range. The input switching threshold remains at the TTL threshold of 1.4V over the supply range of $V_{DD}$ = +5V to +15V. As logic "0" and logic "1" inputs vary over 0V to +0.8V and +2.4V to +10V respectively, the change in the D/A converter output voltage will not exceed ±0.0015% of FSR for the LH and CH grades, ±0.003% of FSR for the BH grade and ±0.006% of FSR for the KG grade. (2) DAC702 (current-output models) is specified and tested with an external output operational amplifier connected using the internal feedback resistor in all parameters except settling time. (3) FSR means full-scale range and is 20V for the ±10V range (DAC703), 10V for the 0 to +10V range (DAC701). FSR is 2mA for the ±1mA range (DAC702). (4) ±0.0015% of full-scale range is equivalent to 1LSB in 15-bit resolution. ±0.003% of full-scale range is equivalent to 1LSB in 14-bit resolution. ±0.006% of full-scale range is equivalent to 1LSB in 13-bit resolution. (5) Adjustable to zero with external trim potentiometer. Adjusting the gain potentiometer rotates the transfer function around the zero point. (6) Error at input code $FFFF_H$ for DAC701, $7FFF_H$ for DAC702 and DAC703. (7) With gain and zero errors adjusted to zero at +25°C. (8) Maximum represents the 3σ limit. Not 100% tested for this parameter. (9) At the major carry, $7FFF_H$ to $8000_H$ and $8000_H$ to $7FFF_H$. (10) Tolerance on output impedance and output current is ±30%. (11) Power dissipation is an additional 40mW when $V_{DD}$ is operated at +15V.

## CONNECTION DIAGRAMS




NOTES: (1) Can be tied to $+V_{CC}$ instead of having separate $V_{DD}$ supply. (2) Decoupling capacitors are 0.1µF to 1.0µF. (3) Potentiometers are 10kΩ to 100kΩ. (4) 5kΩ (DAC701), 10kΩ (DAC702/703).

## PIN ASSIGNMENTS

| PIN # | ALL PACKAGES | |
|---|---|---|
| | DAC702 | DAC701/703 |
| 1 | Bit 1 (MSB) | Bit 1 (MSB) |
| 2 | Bit 2 | Bit 2 |
| 3 | Bit 3 | Bit 3 |
| 4 | Bit 4 | Bit 4 |
| 5 | Bit 5 | Bit 5 |
| 6 | Bit 6 | Bit 6 |
| 7 | Bit 7 | Bit 7 |
| 8 | Bit 8 | Bit 8 |
| 9 | Bit 9 | Bit 9 |
| 10 | Bit 10 | Bit 10 |
| 11 | Bit 11 | Bit 11 |
| 12 | Bit 12 | Bit 12 |
| 13 | Bit 13 | Bit 13 |
| 14 | Bit 14 | Bit 14 |
| 15 | Bit 15 | Bit 15 |
| 16 | Bit 16 (LSB) | Bit 16 (LSB) |
| 17 | $R_{FEEDBACK}$ | $V_{OUT}$ |
| 18 | $V_{DD}$ | $V_{DD}$ |
| 19 | $-V_{CC}$ | $-V_{CC}$ |
| 20 | Common | Common |
| 21 | $I_{OUT}$ | Summing Junction (Zero Adjust) |
| 22 | Gain Adjust | Gain Adjust |
| 23 | $+V_{CC}$ | $+V_{CC}$ |
| 24 | +6.3V Reference Output | +6.3V Reference Output |

## ABSOLUTE MAXIMUM RATINGS(1)

| | |
|---|---|
| $+V_{CC}$ to Common | 0V, +18V |
| $-V_{CC}$ to Common | 0V, –18V |
| $V_{DD}$ to Common | 0V, +18V |
| Digital Data Inputs to Common | –1V, +18V |
| Reference Out to Common | Indefinite Short to Common |
| External Voltage Applied to $R_F$ (DAC702) | ±18V |
| External Voltage Applied to D/A Output (DAC701/703) | –5V to +5V |
| $V_{OUT}$ (DAC701/703) | Indefinite Short to Common |
| Power Dissipation | 1W |
| Storage Temperature | –60°C to +150°C |
| Lead Temperature (soldering, 10s) | 300°C |

NOTE: (1) Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## PACKAGE/ORDERING INFORMATION

| PRODUCT | PACKAGE | PACKAGE DRAWING NUMBER[1] | OUTPUT CONFIGURATION | TEMPERATURE RANGE | LINEARITY ERROR, MAX AT+25°C (% of FSR) | GAIN DRIFT, MAX (ppm/°C) |
|---|---|---|---|---|---|---|
| DAC703JP | 24-Pin Plastic DIP | 167 | ±1mA, ±10V | 0°C to +70°C | ±0.006 | ±30 |
| DAC703KP | 24-Pin Plastic DIP | 167 | ±1mA, ±10V | 0°C to +70°C | ±0.003 | ±25 |
| DAC701KH | 24-Pin Ceramic DIP | 165 | 0 to –2mA, 0 to +10V | 0°C to +70°C | ±0.003 | ±25 |
| DAC702KH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | 0°C to +70°C | ±0.003 | ±25 |
| DAC703KH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | 0°C to +70°C | ±0.003 | ±25 |
| DAC701BH | 24-Pin Ceramic DIP | 165 | 0 to –2mA, 0 to +10V | –25°C to +85°C | ±0.003 | ±15 |
| DAC702BH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | –25°C to +85°C | ±0.003 | ±15 |
| DAC703BH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | –25°C to +85°C | ±0.003 | ±15 |
| DAC701LH | 24-Pin Ceramic DIP | 165 | 0 to –2mA, 0 to +10V | 0°C to +70°C | ±0.0015 | ±10 |
| DAC702LH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | 0°C to +70°C | ±0.0015 | ±10 |
| DAC703LH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | 0°C to +70°C | ±0.0015 | ±10 |
| DAC701CH | 24-Pin Ceramic DIP | 165 | 0 to –2mA, 0 to +10V | –25°C to +85°C | ±0.0015 | ±10 |
| DAC702CH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | –25°C to +85°C | ±0.0015 | ±10 |
| DAC703CH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | –25°C to +85°C | ±0.0015 | ±10 |
| DAC701SH | 24-Pin Ceramic DIP | 165 | 0 to –2mA, 0 to +10V | –55°C to +125°C | ±0.003 | ±15 |
| DAC702SH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | –55°C to +125°C | ±0.003 | ±15 |
| DAC703SH | 24-Pin Ceramic DIP | 165 | ±1mA, ±10V | –55°C to +125°C | ±0.003 | ±15 |
| DAC703JU | 24-Pin SOIC | 239 | ±10V | 0°C to +70°C | ±0.006 | ±30 |
| DAC703KU | 24-Pin SOIC | 239 | ±10V | 0°C to +70°C | ±0.003 | ±25 |

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

# DISCUSSION OF SPECIFICATIONS

## DIGITAL INPUT CODES

The DAC701/702/703 accept complementary digital input codes in either binary format (CSB, unipolar or COB, bipolar). The COB models DAC702/703 may be connected by the user for either complementary offset binary (COB) or complementary two's complement (CTC) codes (see Table I).

| DIGITAL INPUT CODES | ANALOG OUTPUT | | |
|---|---|---|---|
| | DAC701 Complementary Straight Binary (CSB) | DAC702/703 Complementary Offset Binary (COB) | DAC702/703 Complementary Two's Complement (CTC)* |
| $0000_H$ | + Full Scale | + Full Scale | –1LSB |
| $7FFF_H$ | +1/2 Full Scale | Bipolar Zero | – Full Scale |
| $8000_H$ | +1/2 Full Scale –1LSB | –1LSB | + Full Scale |
| $FFFF_H$ | Zero | – Full Scale | Bipolar Zero |

* Invert the MSB of the COB code with an external inverter to obtain CTC code.

TABLE I. Digital Input Codes.

## ACCURACY

### Linearity

This specification describes one of the most important measures of performance of a D/A converter. Linearity error is the deviation of the analog output from a straight line drawn through the end points (all bits ON point and all bits OFF point).

### Differential Linearity Error

Differential linearity error (DLE) of a D/A converter is the deviation from an ideal 1LSB change in the output from one adjacent output state to the next. A differential linearity error specification of ±1/2LSB means that the output step sizes can be between 1/2LSB and 3/2LSB when the input changes from one adjacent input state to the next. A negative DLE specification of no more than –1LSB (–0.006% for 14-bit resolution) insures monotonicity.

### Monotonicity

Monotonicity assures that the analog output will increase or remain the same for increasing input digital codes. The DAC701/702/703 are specified to be monotonic to 14 bits over the entire specification temperature range.

## DRIFT

### Gain Drift

Gain drift is a measure of the change in the full-scale range output over temperature expressed in parts per million per degree centigrade (ppm/°C). Gain drift is established by: (1) testing the end point differences for each D/A at $t_{MIN}$, +25°C and $t_{MAX}$; (2) calculating the gain error with respect to the +25°C value; and (3) dividing by the temperature change.

### Zero Drift

Zero drift is a measure of the change in the output with $FFFF_H$ (DAC701) applied to the digital inputs over the specified temperature range. For the bipolar models, zero is measured at $7FFF_H$ (bipolar zero) applied to the digital inputs. This code corresponds to zero volts (DAC703) or zero milliamps (DAC702) at the analog output. The maximum change in offset at $t_{MIN}$ or $t_{MAX}$ is referenced to the zero error at +25°C and is divided by the temperature change. This drift is expressed in parts per million of full scale range per degree centigrade (ppm of FSR/°C).

## SETTLING TIME

Settling time of the D/A is the total time required for the analog output to settle within an error band around its final value after a change in digital input. Refer to Figure 1 for typical values for this family of products.

### Voltage Output

Settling times are specified to ±0.003% of FSR (±1/2LSB for 14 bits) for two input conditions: a full-scale range change of 20V (DAC703) or 10V (DAC701) and a 1LSB change at the "major carry," the point at which the worst-case settling time occurs. (This is the worst-case point since all of the input bits change when going from one code to the next).

### Current Output

Settling times are specified to ±0.003% of FSR for a full-scale range change for two output load conditions: one for 10Ω to 100Ω and one for 1000Ω. It is specified this way because the output RC time constant becomes the dominant factor in determining settling time for large resistive loads.

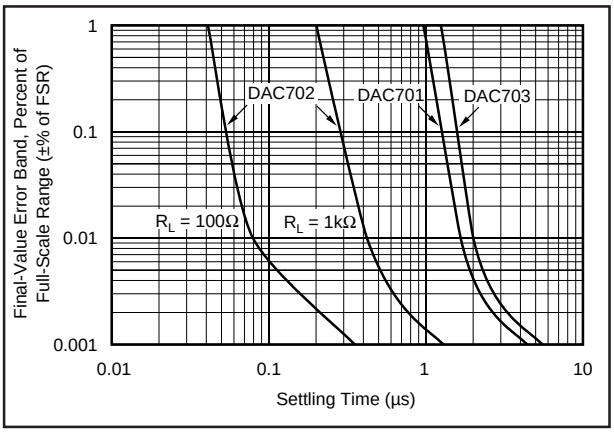



FIGURE 1. Final-Value Error Band vs Full-Scale Range Settling Time.

## COMPLIANCE VOLTAGE

Compliance voltage applies only to current output models. It is the maximum voltage swing allowed on the output current pin while still being able to maintain specified accuracy.

### POWER SUPPLY SENSITIVITY

Power supply sensitivity is a measure of the effect of a change in a power supply voltage on the D/A converter output. It is defined as a percent of FSR change in the output per percent of change in either the positive supply ($+V_{CC}$), negative supply ($-V_{CC}$) or logic supply ($V_{DD}$) about the nominal power supply voltages (see Figure 2).

It is specified for DC or low frequency changes. The typical performance curve in Figure 2 shows the effect of high frequency changes in power supply voltages.

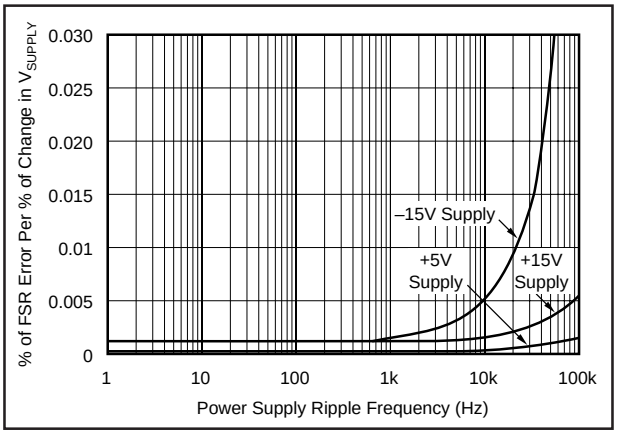



FIGURE 2. Power Supply Rejection vs Power Supply Ripple Frequency.

### REFERENCE SUPPLY

All models have an internal low-noise +6.3V reference voltage derived from an on-chip buried zener diode. This reference voltage, available to the user, has a tolerance of ±5% (KH models) and ±1% (BH models). A minimum of 1.5mA is available for external loads. Since the output impedance of the reference output is typically 1W, the external load should remain constant.

If a varying load is to be driven by the reference supply, an external buffer amplifier is recommended to drive the load in order to isolate the bipolar offset (connected internally to the reference) from load variations.

## OPERATING INSTRUCTIONS

### POWER SUPPLY CONNECTIONS

For optimum performance and noise rejection, power supply decoupling capacitors should be added as shown in the Connection Diagram. 1µF tantalum capacitors should be located close to the D/A converter.

### EXTERNAL ZERO AND GAIN ADJUSTMENT

Zero and gain may be trimmed by installing external zero and gain potentiometers. Connect these potentiometers as shown in the Connection Diagram and adjust as described below. TCR of the potentiometers should be 100ppm/°C or less. The 3.9MΩ and 270kΩ resistors (±20% carbon or better) should be located close to the D/A converter to prevent noise pickup. If it is not convenient to use these high-value resistors, an equivalent "T" network, as shown in Figure 3, may be substituted in place of the 3.9MΩ part. A 0.001µF to 0.01µF ceramic capacitor should be connected from Gain Adjust to Common to prevent noise pickup. Refer to Figures 4 and 5 for the relationship of zero and gain adjustments to unipolar and bipolar D/A converters.

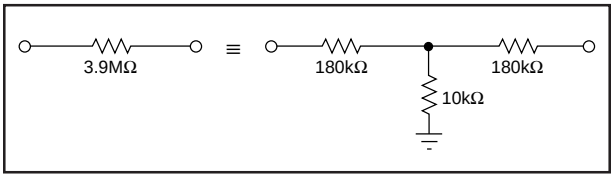



FIGURE 3. Equivalent Resistances.

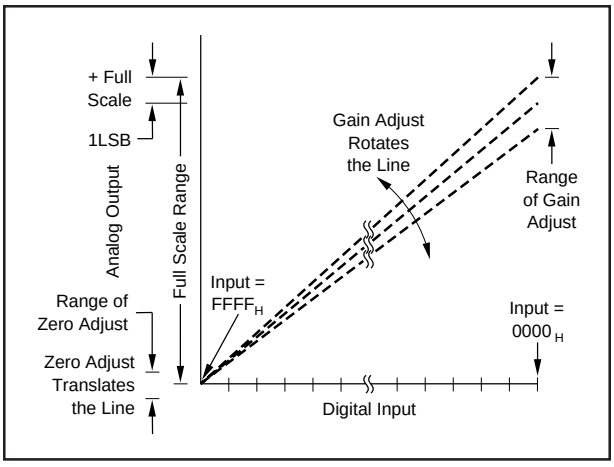



FIGURE 4. Relationship of Zero and Gain Adjustments for Unipolar D/A Converters, DAC701.

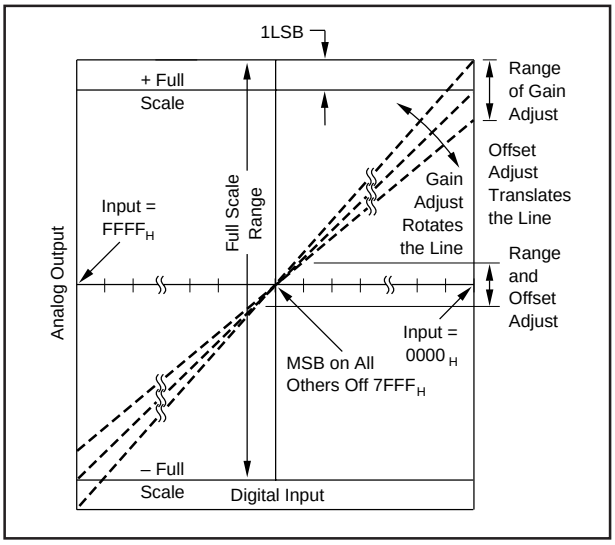



FIGURE 5. Relationship of Zero and Gain Adjustments for Bipolar D/A Converters, DAC702 and DAC703.

### Zero Adjustment

For unipolar (CSB) configurations, apply the digital input code that produces zero voltage or zero current output and adjust the zero potentiometer for zero output.

For bipolar (COB, CTC) configurations, apply the digital input code that produces zero output voltage or current. See Table II for corresponding codes and the Connection Diagram for zero adjustment circuit connections. Zero calibration should be made before gain calibration.

### Gain Adjustment

Apply the digital input that gives the maximum positive output voltage. Adjust the gain potentiometer for this positive full scale voltage. See Table II for positive full scale voltages and the Connection Diagram for gain adjustment circuit connections.

## INSTALLATION CONSIDERATIONS

This D/A converter family is laser-trimmed to 14-bit linearity. The design of the device makes the 16-bit resolution available. If 16-bit resolution is not required, bit 15 and bit 16 should be connected to $V_{DD}$ through a single 1kΩ resistor.

Due to the extremely high resolution and linearity of the D/A converter, system design problems such as grounding and contact resistance become very important. For a 16-bit converter with a 10V full-scale range, 1LSB is 153µV. With a load current of 5mA, series wiring and connector resistance of only 30mΩ will cause the output to be in error by 1LSB. To understand what this means in terms of a system layout, the resistance of #23 wire is about 0.021Ω/ft. Neglecting contact resistance, less than 18 inches of wire will produce a 1LSB error in the analog output voltage!

In Figures 6, 7, and 8, lead and contact resistances are represented by $R_1$ through $R_5$. As long as the load resistance $R_L$ is constant, $R_2$ simply introduces a gain error and can be removed during initial calibration. $R_3$ is part of $R_L$, if the output voltage is sensed at Common, and therefore introduces no error. If $R_L$ is variable, then $R_2$ should be less than $R_{L\,MIN}/2^{16}$ to reduce voltage drops due to wiring to less than 1LSB. For example, if $R_{L\,MIN}$ is 5kΩ, then $R_2$ should be less than 0.08Ω. $R_L$ should be located as close as possible to the D/A converter for optimum performance. The effect of $R_4$ is negligible.

In many applications it is impractical to sense the output voltage at the output pin. Sensing the output voltage at the system ground point is permissible with the DAC700 family because the D/A converter is designed to have a constant return current of approximately 2mA flowing from Common. The variation in this current is under 20µA (with changing input codes), therefore $R_4$ can be as large as 3Ω without adversely affecting the linearity of the D/A converter. The voltage drop across $R_4$ ($R_4$ x 2mA) appears as a zero error and can be removed with the zero calibration adjustment. This alternate sensing point (the system ground point) is shown in Figures 6, 7, and 8.

Figures 7 and 8 show two methods of connecting the current output models (DAC702) with external precision output op amps. By sensing the output voltage at the load resistor (ie, by connecting $R_F$ to the output of $A_1$ at $R_L$), the effect of $R_1$ and $R_2$ is greatly reduced. $R_1$ will cause a gain error but is independent of the value of $R_L$ and can be eliminated by initial calibration adjustments. The effect of $R_2$ is negligible because it is inside the feedback loop of the output op amp and is therefore greatly reduced by the loop gain.

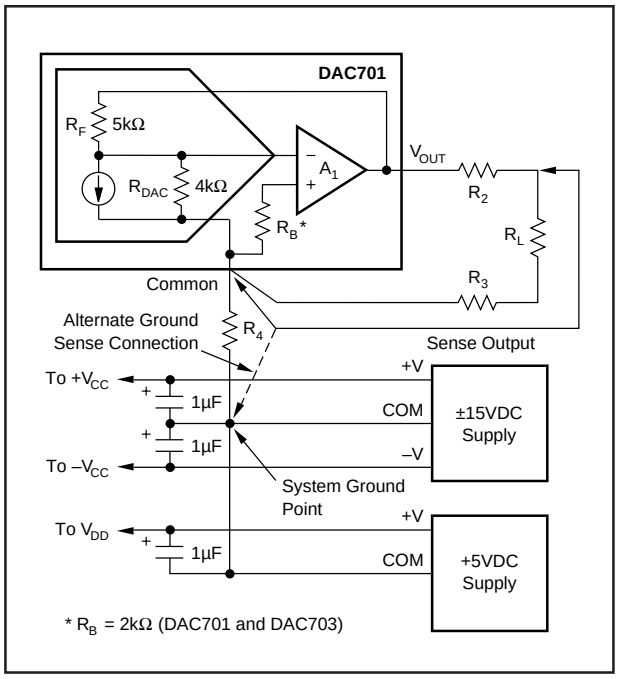



FIGURE 6. Output Circuit for Voltage Models.

| VOLTAGE OUTPUT MODELS | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | ANALOG OUTPUT | | | | | |
| | | DAC701 UNIPOLAR | | | DAC703 BIPOLAR | | |
| DIGITAL INPUT CODE | | 16-BIT | 15-BIT | 14-BIT | 16-BIT | 15-BIT | 14-BIT |
| 1LSB | (μV) | 153 | 305 | 610 | 305 | 610 | 1224 |
| $0000_H$ | (V) | +9.99985 | +9.99969 | +9.99939 | +9.99960 | +9.99939 | +9.99878 |
| $FFFF_H$ | (V) | 0 | 0 | 0 | –10.0000 | –10.0000 | –10.0000 |

| ANALOG OUTPUT MODEL | | | | |
|---|---|---|---|---|
| | | ANALOG OUTPUT | | |
| | | | DAC702 BIPOLAR | |
| DIGITAL INPUT CODE | | 16-BIT | 15-BIT | 14-BIT |
| 1LSB | (μA) | 0.031 | 0.061 | 0.122 |
| $0000_H$ | (mA) | –0.99997 | –0.99994 | –0.99988 |
| $FFFF_H$ | (mA) | +1.00000 | +1.00000 | +1.00000 |

TABLE II. Digital Input and Analog Output Relationships.

If the output cannot be sensed at Common or the system ground point as mentioned above, the differential output circuit shown in Figure 8 is recommended. In this circuit the output voltage is sensed at the load common and not at the D/A converter common as in the previous circuits. The value of $R_6$ and $R_7$ must be adjusted for maximum common-mode rejection at $R_L$. Note that if $R_3$ is negligible, the circuit of Figure 8 can be reduced to the one shown in Figure 7. Again the effect of $R_4$ is negligible.

The D/A converter and the wiring to its connectors should be located to provide optimum isolation from sources of RFI and EMI. The key concept in elimination of RF radiation or pickup is loop area; therefore, signal leads and their return conductors should be kept close together. This reduces the external magnetic field along with any radiation. Also, if a single lead and its return conductor are wired close together, they present a small flux-capture cross section for any external field. This reduces radiation pickup in the circuit.

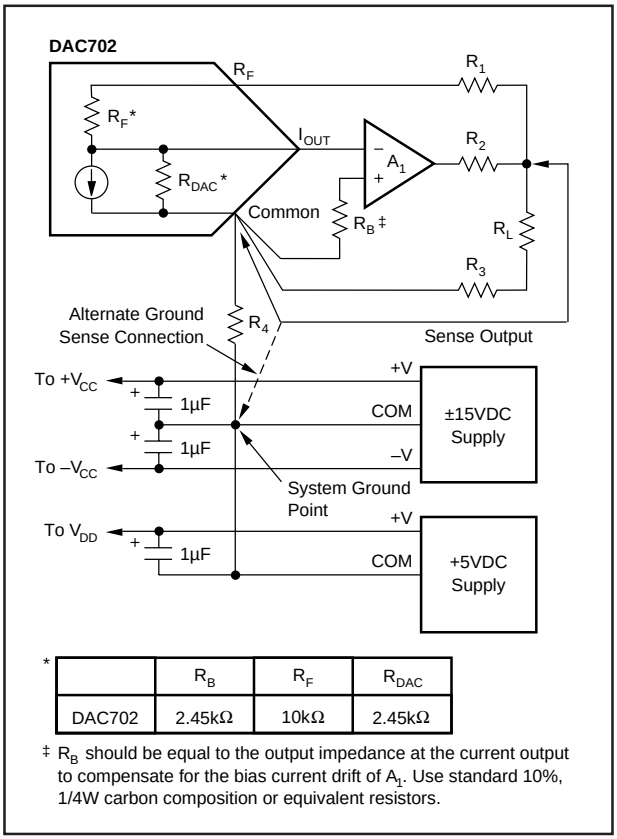



FIGURE 7. Preferred External Op Amp Configuration.

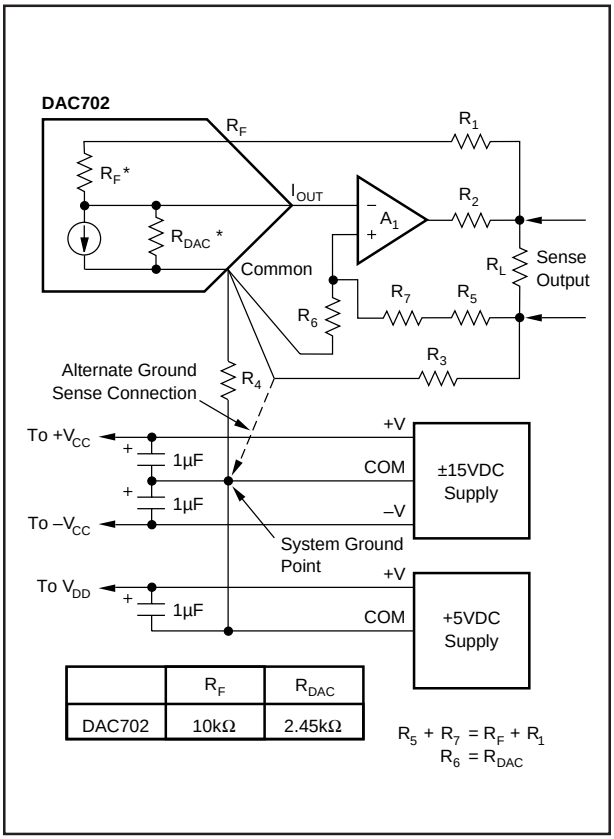



FIGURE 8. Differential Sensing Output Op Amp Configuration.

# APPLICATIONS

## DRIVING AN EXTERNAL OP AMP WITH CURRENT OUTPUT D/AS

DAC702 is current output devices and will drive the summing junction of an op amp to produce an output voltage as shown in Figure 9. Use of the internal feedback resistor is required to obtain specified gain accuracy and low gain drift.

DAC702 can be scaled for any desired voltage range with an external feedback resistor, but at the expense of increased drifts of up to ±50ppm/°C. The resistors in the DAC702 ratio track to ±1ppm/°C but their absolute TCR may be as high as ±50ppm/°C.

An alternative method of scaling the output voltage of the D/A converter and preserving the low gain drift is shown in Figure 10.

## OUTPUTS LARGER THAN 20V RANGE

For output voltage ranges larger than ±10V, a high voltage op amp may be employed with an external feedback resistor. Use $I_{OUT}$ values of ±1mA for bipolar voltage ranges and –2mA for unipolar voltage ranges (see Figure 11). Use protection diodes as shown when a high voltage op amp is used.

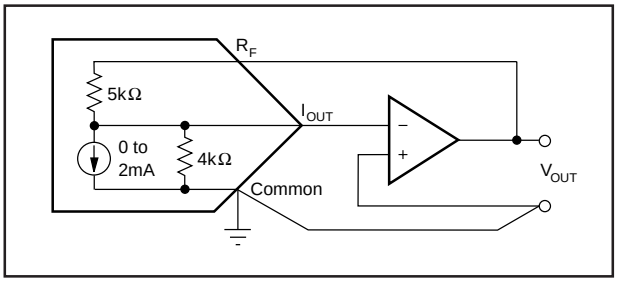



FIGURE 9. External Op Amp Using Internal Feedback Resistors.

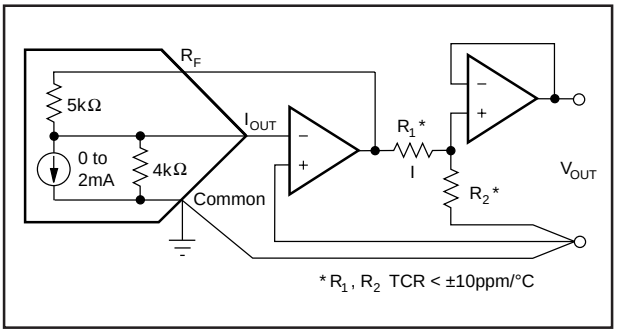



FIGURE 10. External Op Amp Using Internal and External Feedback Resistors to Maintain Low Gain Drift.

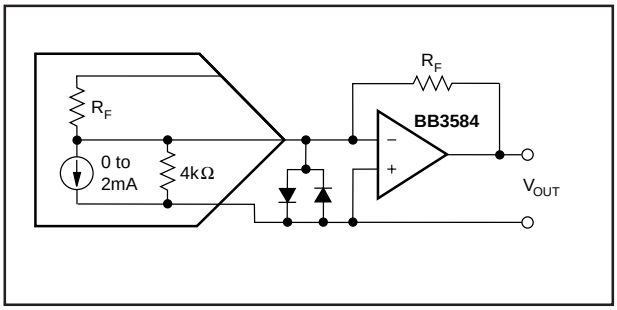



FIGURE 11. External Op Amp Using External Feedback Resistors.

## PACKAGING INFORMATION

| ORDERABLE DEVICE | STATUS(1) | PACKAGE TYPE | PACKAGE DRAWING | PINS | PACKAGE QTY |
|---|---|---|---|---|---|
| DAC701KH | OBSOLETE | CDIP SB | JDM | 24 | |
| DAC703BH | OBSOLETE | CDIP SB | JDM | 24 | |
| DAC703BH-BI | OBSOLETE | CDIP SB | JD | 24 | |
| DAC703CH | OBSOLETE | CDIP SB | JDM | 24 | |
| DAC703CH-BI | OBSOLETE | CDIP SB | JD | 24 | |
| DAC703JP | OBSOLETE | PDIP | NTA | 24 | |
| DAC703KH | OBSOLETE | CDIP SB | JDM | 24 | |
| DAC703KH-4 | OBSOLETE | CDIP SB | JDM | 24 | |
| DAC703KH-BI | OBSOLETE | CDIP SB | JDM | 24 | |
| DAC703KP | OBSOLETE | PDIP | NTA | 24 | |
| DAC703LH | OBSOLETE | CDIP SB | JDM | 24 | |
| DAC703SH | OBSOLETE | CDIP SB | JDM | 24 | |

(1) The marketing status values are defined as follows:
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**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

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