

DAC7800 DAC7801 DAC7802

SBAS005A – DECEMBER 2001

Dual Monolithic CMOS 12-Bit Multiplying DIGITAL-TO-ANALOG CONVERTERS

FEATURES

- TWO DACs IN A 0.3" WIDE PACKAGE
- SINGLE +5V SUPPLY
- HIGH SPEED DIGITAL INTERFACE:
 Serial—DAC7800
 8 + 4-Bit Parallel—DAC7801
 12-Bit Parallel—DAC7802
- MONOTONIC OVER TEMPERATURE
- LOW CROSSTALK: -94dB min
- FULLY SPECIFIED OVER -40°C TO $+85^{\circ}\text{C}$

DESCRIPTION

The DAC7800, DAC7801 and DAC7802 are members of a new family of monolithic dual 12-bit CMOS multiplying Digital-to-Analog Converters (DACs). The digital interface speed and the AC multiplying performance are achieved by using an advanced CMOS process optimized for data conversion circuits. High stability on-chip resistors provide true 12-bit integral and differential linearity over the wide industrial temperature range of -40°C to $+85^{\circ}\text{C}$.

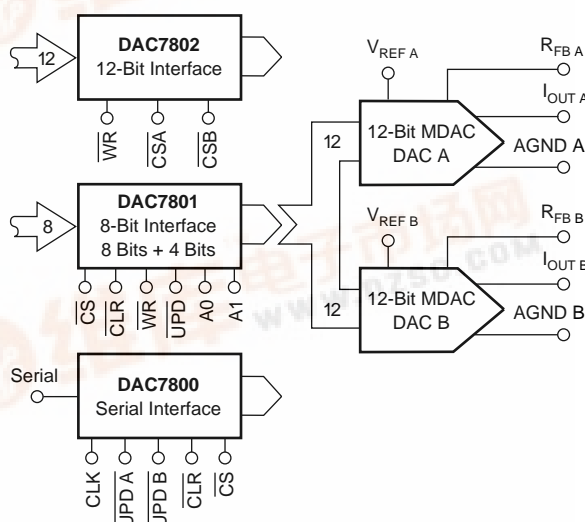
DAC7800 features a serial interface capable of clocking-in data at a rate of at least 10MHz. Serial data is clocked (edge triggered) MSB first into a 24-bit shift register and then latched into each DAC separately or simultaneously as required by the application. An asynchronous CLEAR control is provided for power-on reset or system calibration functions. It is packaged in a 16-pin 0.3" wide plastic DIP.

DAC7801 has a 2-byte (8 + 4) double-buffered interface. Data is first loaded (level transferred) into the input registers in two steps for each DAC. Then both DACs are updated simultaneously. DAC7801 features an asynchronous CLEAR control. DAC7801 is packaged in a 24-pin 0.3" wide plastic DIP.

APPLICATIONS

- PROCESS CONTROL OUTPUTS
- ATE PIN ELECTRONICS LEVEL SETTING
- PROGRAMMABLE FILTERS
- PROGRAMMABLE GAIN CIRCUITS
- AUTO-CALIBRATION CIRCUITS

DAC7802 has a single-buffered 12-bit data word interface. Parallel data is loaded (edge triggered) into the single DAC register for each DAC. DAC7802 is packaged in a 24-pin 0.3" wide plastic DIP.



ABSOLUTE MAXIMUM RATINGS

At $T_A = +25^\circ\text{C}$, unless otherwise noted.

V_{DD} to AGND	0V, +7V
V_{DD} to DGND	0V, +7V
AGND to DGND	-0.3, V_{DD}
Digital Input to DGND	-0.3, $V_{DD} + 0.3$
$V_{REF A}$, $V_{REF B}$ to AGND	$\pm 16\text{V}$
$V_{REF A}$, $V_{REF B}$ to DGND	$\pm 16\text{V}$
$I_{OUT A}$, $I_{OUT B}$ to AGND	-0.3, V_{DD}
Storage Temperature Range	-55°C to $+125^\circ\text{C}$
Operating Temperature Range	-40°C to $+85^\circ\text{C}$
Lead Temperature (soldering, 10s)	$+300^\circ\text{C}$
Junction Temperature	$+175^\circ\text{C}$



ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments 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	RELATIVE ACCURACY	GAIN ERROR	PACKAGE-LEAD	PACKAGE DESIGNATOR ⁽¹⁾	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
DAC7800KP	$\pm 1\text{LSB}$	$\pm 3\text{LSB}$	DIP-16	N	-40°C to $+85^\circ\text{C}$	DAC7800KP	DAC7800KP	Rails, 25
DAC7800LP	$\pm 1/2 \text{ LSB}$	$\pm 1\text{LSB}$	DIP-16	N		DAC7800LP	DAC7800LP	Rails, 25
DAC7800KU	—	—	SO-16	DW	-40°C to $+85^\circ\text{C}$	DAC7800KU	DAC7800KU/1K	Tape and Reel, 1000
DAC7800LU	—	—	SO-16	DW		DAC7800LU	DAC7800LU/1K	Tape and Reel, 1000
DAC7801KP	$\pm 1\text{LSB}$	$\pm 3\text{LSB}$	DIP-24	NT	-40°C to $+85^\circ\text{C}$	DAC7801KP	DAC7801KP	Rails, 15
DAC7801LP	$\pm 1/2 \text{ LSB}$	$\pm 1\text{LSB}$	DIP-24	NT		DAC7801LP	DAC7801LP	Rails, 15
DAC7801KU	—	—	SO-24	DW	-40°C to $+85^\circ\text{C}$	DAC7801KU	DAC7801KU/1K	Tape and Reel, 1000
DAC7801LU	—	—	SO-24	DW		DAC7801LU	DAC7801LU/1K	Tape and Reel, 1000
DAC7802KP	$\pm 1\text{LSB}$	$\pm 3\text{LSB}$	DIP-24	NTG	-40°C to $+85^\circ\text{C}$	DAC7802KP	DAC7802KP	Rails, 15
DAC7802LP	$\pm 1/2 \text{ LSB}$	$\pm 1\text{LSB}$	DIP-24	NTG		DAC7802LP	DAC7802LP	Rails, 15
DAC7802KU	—	—	SO-24	DW	-40°C to $+85^\circ\text{C}$	DAC7802KU	DAC7802KU/1K	Tape and Reel, 1000
DAC7802LU	—	—	SO-24	DW		DAC7802LU	DAC7802LU/1K	Tape and Reel, 1000

NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

ELECTRICAL CHARACTERISTICS

At $V_{DD} = +5\text{VDC}$, $V_{REF A} = V_{REF B} = +10\text{V}$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, unless otherwise noted.

PARAMETER	CONDITIONS	DAC7800, 7801, 7802K			DAC7800, 7801, 7802L			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
ACCURACY								
Resolution		12			*			Bits
Relative Accuracy				± 1			$\pm 1/2$	LSB
Differential Nonlinearity				± 1			*	LSB
Gain Error				± 3			± 1	LSB
Gain Temperature Coefficient ⁽¹⁾	Measured Using $R_{FB A}$ and $R_{FB B}$. All Registers Loaded with All 1s.		2	5		*	*	ppm/ $^\circ\text{C}$
Output Leakage Current	$T_A = +25^\circ\text{C}$ $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		0.005	10		*	*	nA
			3	150		*	*	nA
REFERENCE INPUT								
Input Resistance		6	10	14	*	*	*	k Ω
Input Resistance Match			0.5	3		*	2	%
DIGITAL INPUTS								
V_{IH} (Input HIGH Voltage)		2			*			V
V_{IL} (Input LOW Voltage)				0.8			*	V
I_{IN} (Input Current)	$T_A = +25^\circ\text{C}$ $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			± 1			*	μA
				± 10			*	μA
C_{IN} (Input Capacitance)			0.8	10		*	*	pF
POWER SUPPLY								
V_{DD}		4.5		5.5	*		*	V
I_{DD}			0.2	2		*	*	mA
Power-Supply Rejection	V_{DD} from 4.5V to 5.5V			0.002			*	%/%

* Same specification as for DAC7800, 7801, 7802K.

AC PERFORMANCE

OUTPUT OP AMP IS OPA602.

At $V_{DD} = +5VDC$, $V_{REF A} = V_{REF B} = +10V$, $T_A = +25^\circ C$, unless otherwise noted. These specifications are fully characterized but not subject to test.

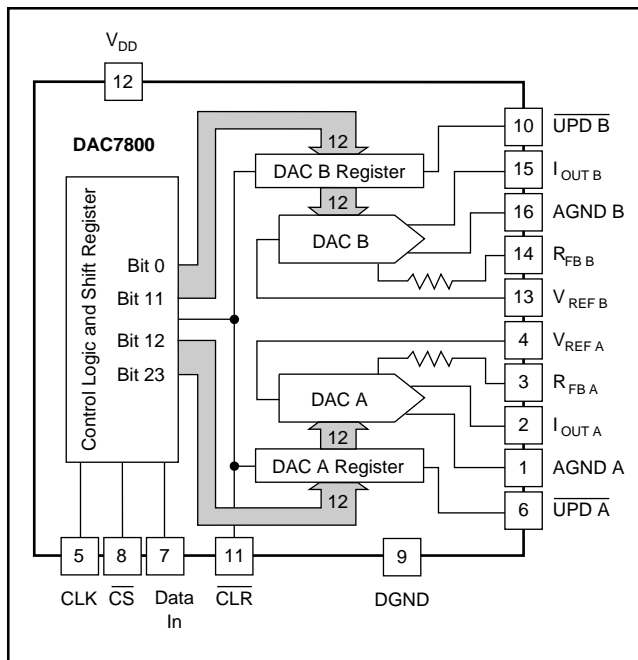
PARAMETER	CONDITIONS	DAC7800, 7801, 7802K			DAC7800, 7801, 7802L			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
OUTPUT CURRENT SETTLING TIME	To 0.01% of Full-Scale $R_L = 100\Omega$, $C_L = 13pF$		0.4	0.8		*	*	μs
DIGITAL-TO-ANALOG GLITCH IMPULSE	$V_{REF A} = V_{REF B} = 0V$ $R_L = 100\Omega$, $C_L = 13pF$		0.9			*		nV-s
AC FEEDTHROUGH	$f_{VREF} = 10kHz$		-75	-72		*	*	dB
OUTPUT CAPACITANCE	DAC Loaded with All 0s DAC Loaded with All 1s		30 70	50 100		*	*	pF pF
CHANNEL-TO-CHANNEL ISOLATION $V_{REF A}$ to $I_{OUT B}$	$f_{VREF A} = 10kHz$ $V_{REF B} = 0V$, Both DACs Loaded with 1s	-90	-94		*	*		dB
$V_{REF B}$ to $I_{OUT A}$	$f_{VREF B} = 10kHz$ $V_{REF A} = 0V$, Both DACs Loaded with 1s	-90	-101		*	*		dB
DIGITAL CROSSTALK	Full-Scale Transition $R_L = 100\Omega$, $C_L = 13pF$		0.9			*		nV-s

* Same specification as for DAC7800, 7801, and 7802K.

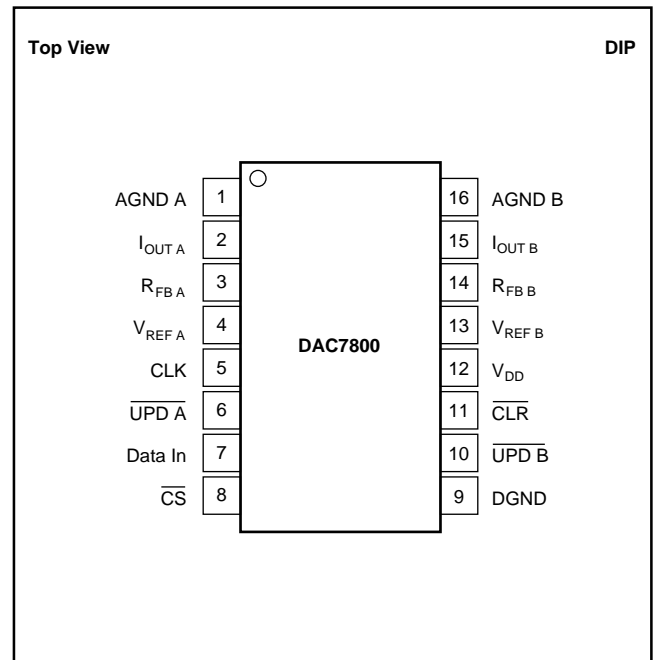
NOTE: (1) Ensured but not tested.

DAC7800

BLOCK DIAGRAM



PIN CONFIGURATION



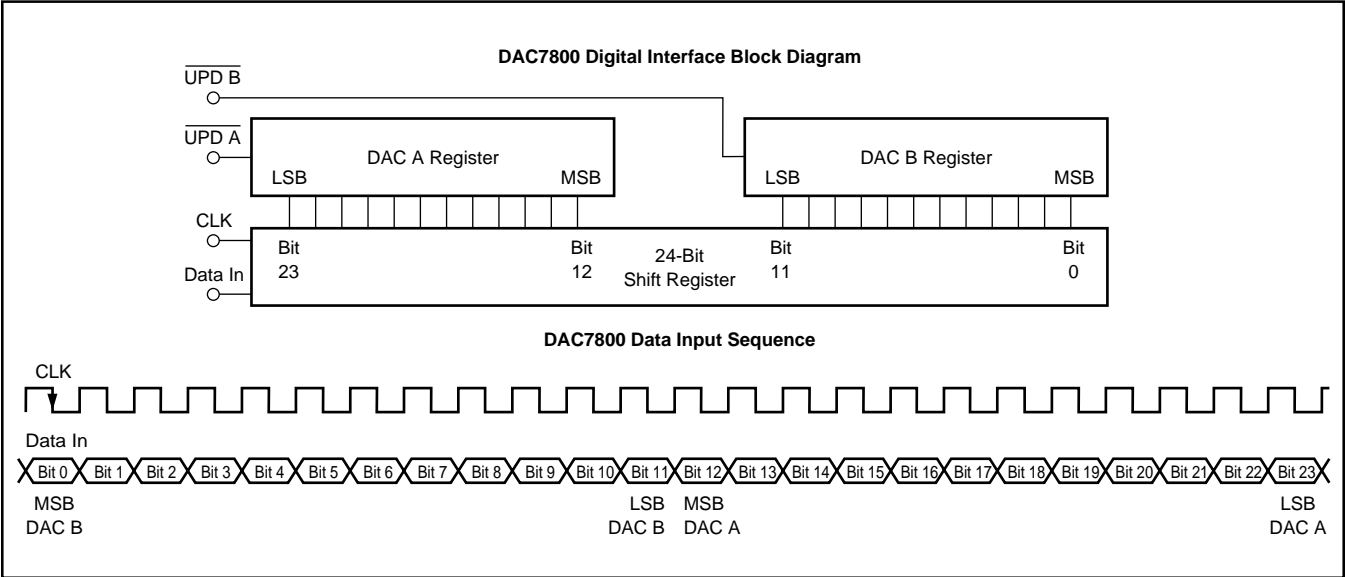
LOGIC TRUTH TABLE

CLK	UPD A	UPD B	CS	CLR	FUNCTION
X	X	X	X	0	All register contents set to 0's (asynchronous).
X	X	X	1	X	No data transfer.
1	X	X	0	1	Input data is clocked into input register (location Bit 23) and previous data shifts.
X	0	1	0	1	Input register bits 23 (LSB) - 12 (MSB) are loaded into DAC A.
X	1	0	0	1	Input register bits 11 (LSB) - 0 (MSB) are loaded into DAC B.
X	0	0	0	1	Input register bits 23 (LSB) - 12 (MSB) are loaded into DAC A, and input register bits 11 (LSB) - 0 (MSB) are loaded into DAC B.

X = Don't care. 1 means falling edge triggered.

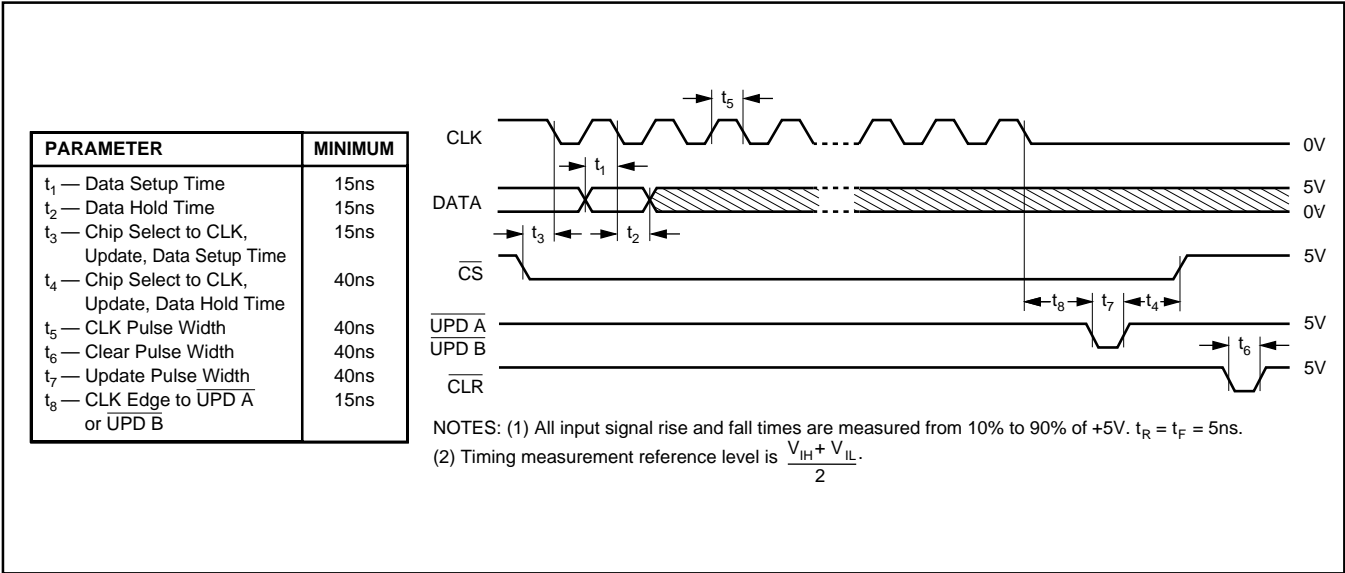
DAC7800 (Cont.)

DATA INPUT FORMAT



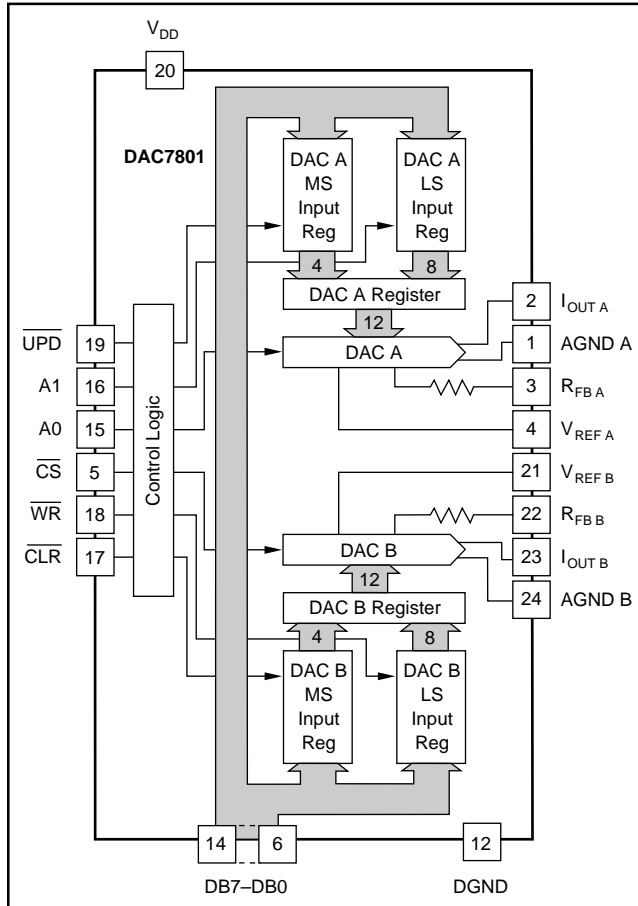
TIMING CHARACTERISTICS

$V_{DD} = +5V$, $V_{REF A} = V_{REF B} = +10V$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$.

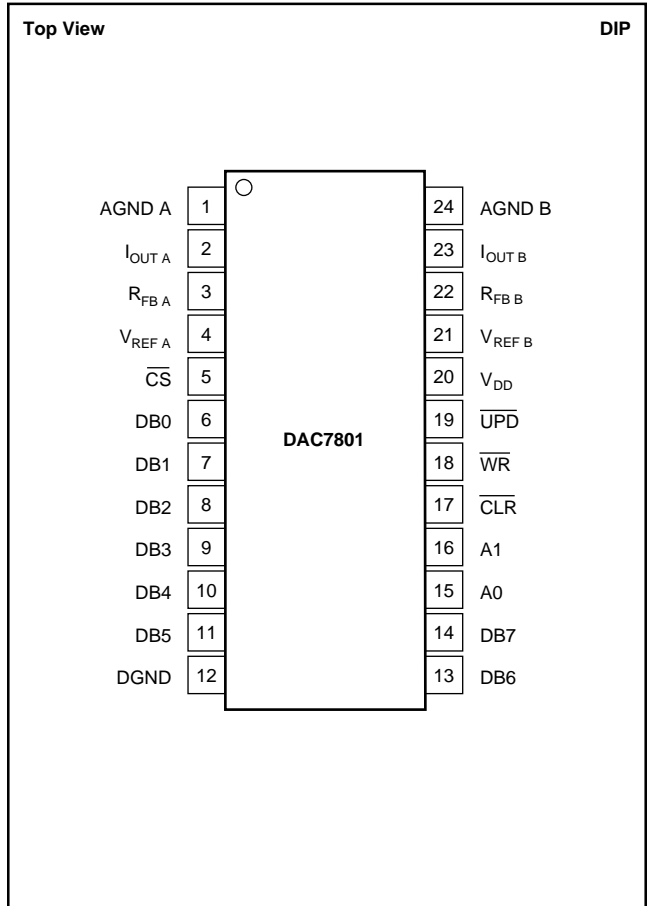


DAC7801

BLOCK DIAGRAM



PIN CONFIGURATION



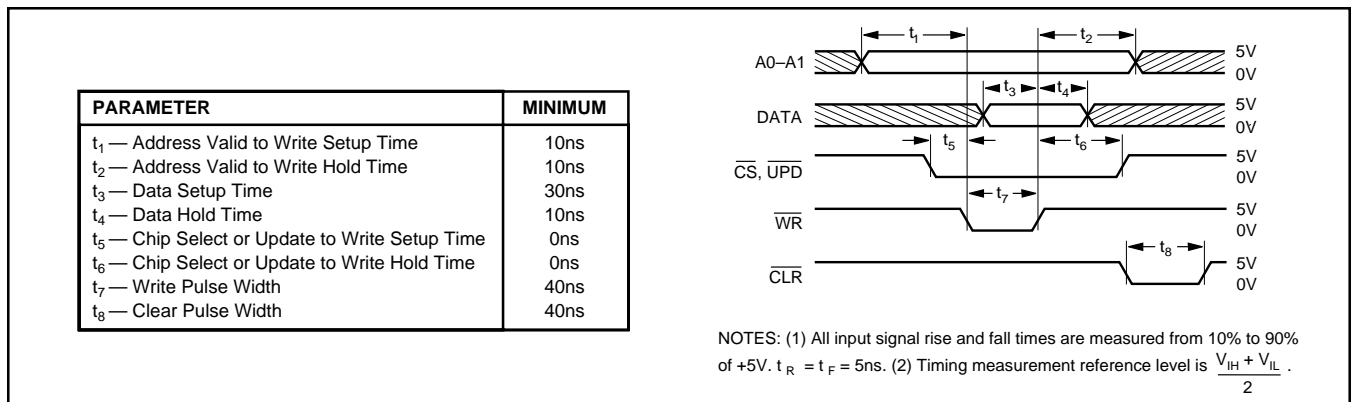
LOGIC TRUTH TABLE

CLR	UPD	CS	WR	A1	A0	FUNCTION
1	1	1	X	X	X	No Data Transfer
1	1	X	1	X	X	No Data Transfer
0	X	X	X	X	X	All Registers Cleared
1	1	0	0	0	0	DAC A LS Input Register Loaded with DB7 - DB0 (LSB)
1	1	0	0	0	1	DAC A MS Input Register Loaded with DB3 (MSB) - DB0
1	1	0	0	1	0	DAC B LS Input Register Loaded with DB7 - DB0 (LSB)
1	1	0	0	1	1	DAC B MS Input Register Loaded with DB3 (MSB) - DB0
1	0	1	0	X	X	DAC A, DAC B Registers Updated Simultaneously from Input Registers
1	0	0	0	X	X	DAC A, DAC B Registers are Transparent

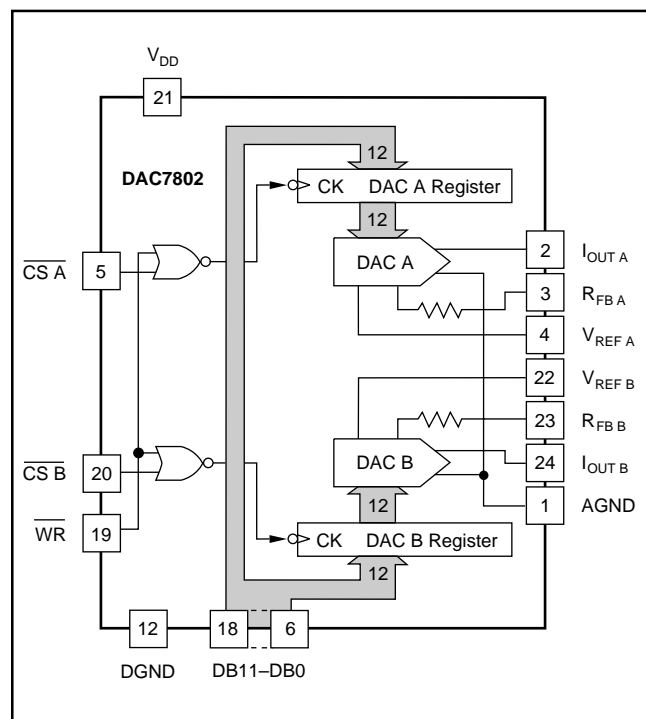
X = Don't care.

TIMING CHARACTERISTICS

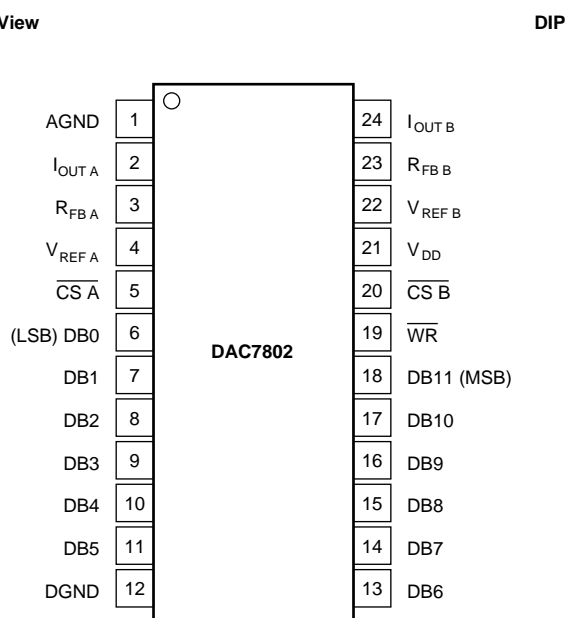
$V_{DD} = +5V$, $V_{REF A} = V_{REF B} = +10V$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$.



BLOCK DIAGRAM

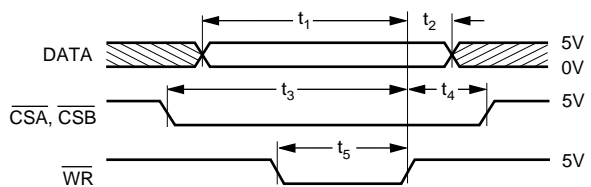


Top View



At $V_{DD} = +5V$, and $T_A = -40^{\circ}C$ to $+85^{\circ}C$.

PARAMETER	MINIMUM
t ₁ - Data Setup Time	20ns
t ₂ - Data Hold Time	15ns
t ₃ - Chip Select to Write Setup Time	30ns
t ₄ - Chip Select to Write Hold Time	0ns
t ₅ - Write Pulse Width	30ns



NOTES: (1) All input signal rise and fall times are measured from 10% to 90% of +5V. $t_R = t_F = 5\text{ns}$. (2) Timing measurement reference level is $\frac{V_{IH} + V_{IL}}{2}$.

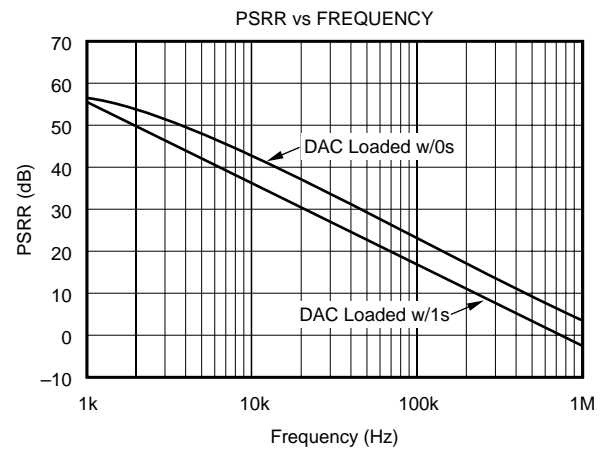
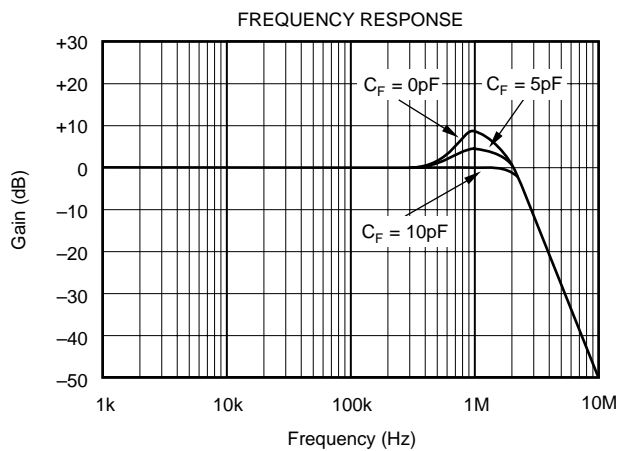
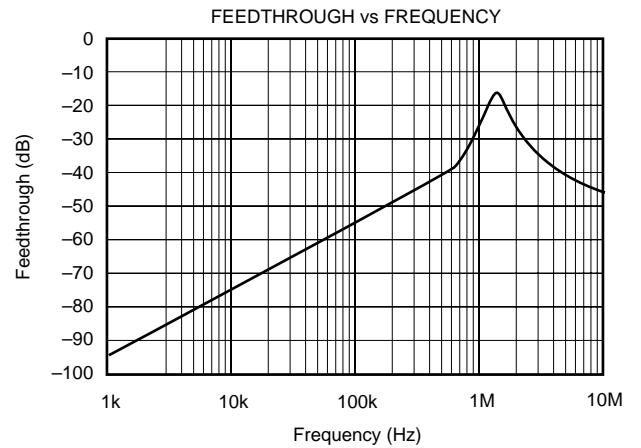
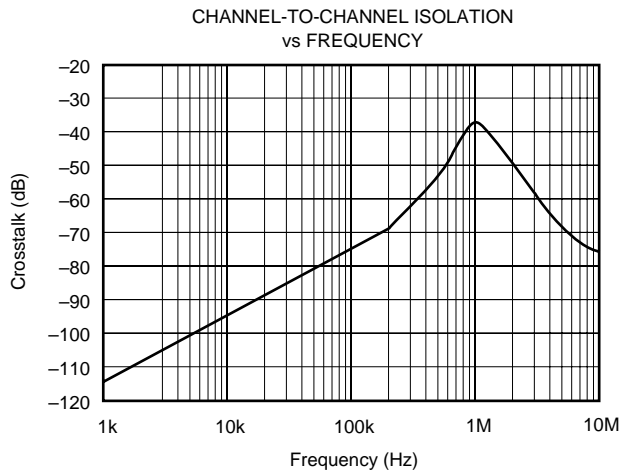
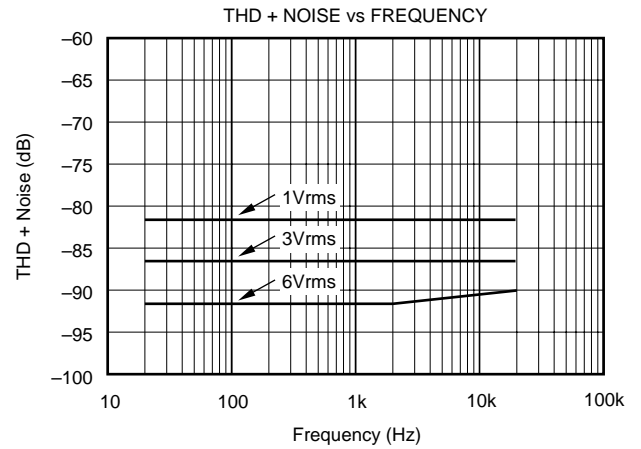
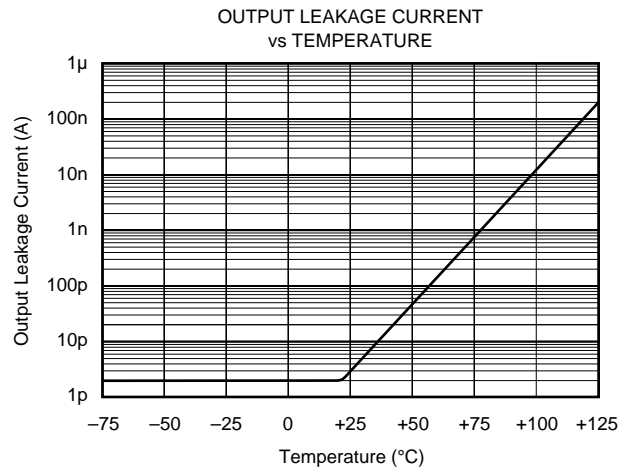
CSA	CSB	WR	FUNCTION
X	X	1	No Data Transfer
1	1	X	No Data Transfer
\uparrow	\uparrow	0	A Rising Edge on $\overline{\text{CSA}}$ or $\overline{\text{CSB}}$ Loads Data to the Respective DAC
0	1	\uparrow	DAC A Register Loaded from Data Bus
1	0	\uparrow	DAC B Register Loaded from Data Bus
0	0	\uparrow	DAC A and DAC B Registers Loaded from Data Bus

X = Don't care. \uparrow means rising edge triggered.

TYPICAL CHARACTERISTICS

OUTPUT OP AMP IS OPA602.

$T_A = +25^\circ\text{C}$, $V_{DD} = +5\text{V}$.



DISCUSSION OF SPECIFICATIONS

RELATIVE ACCURACY

This term, also known as end point linearity or integral linearity, describes the transfer function of analog output to digital input code. Relative accuracy describes the deviation from a straight line, after zero and full-scale errors have been adjusted to zero.

DIFFERENTIAL NONLINEARITY

Differential nonlinearity is the deviation from an ideal 1LSB change in the output when the input code changes by 1LSB. A differential nonlinearity specification of 1LSB maximum ensures monotonicity.

GAIN ERROR

Gain error is the difference between the full-scale DAC output and the ideal value. The ideal full scale output value for the DAC780x is $-(4095/4096)V_{REF}$. Gain error may be adjusted to zero using external trims, see Figures 5 and 7.

OUTPUT LEAKAGE CURRENT

The current which appears at $I_{OUT A}$ and $I_{OUT B}$ with the DAC loaded with all zeros.

OUTPUT CAPACITANCE

The parasitic capacitance measured from $I_{OUT A}$ or $I_{OUT B}$ to AGND.

CHANNEL-TO-CHANNEL ISOLATION

The AC output error due to capacitive coupling from DAC A to DAC B or DAC B to DAC A.

MULTIPLYING FEEDTHROUGH ERROR

The AC output error due to capacitive coupling from V_{REF} to I_{OUT} with the DAC loaded with all zeros.

OUTPUT CURRENT SETTLING TIME

The time required for the output current to settle to within $\pm 0.01\%$ of final value for a full-scale step.

DIGITAL-TO-ANALOG GLITCH ENERGY

The integrated area of the glitch pulse measured in nanovolt-seconds. The key contributor to DAC glitch is charge injected by digital logic switching transients.

DIGITAL CROSSTALK

Glitch impulse measured at the output of one DAC but caused by a full-scale transition on the other DAC. The integrated area of the glitch pulse is measured in nanovolt-seconds.

CIRCUIT DESCRIPTION

Figure 1 shows a simplified schematic of one half of a DAC780x. The current from the $V_{REF A}$ pin is switched between $I_{OUT A}$ and AGND by 12 single-pole double-throw CMOS switches. This maintains a constant current in each leg of the ladder regardless of the input code. The input resistance at V_{REF} is therefore

constant and can be driven by either a voltage or current, AC or DC, positive or negative polarity, and have a voltage range up to $\pm 20V$.

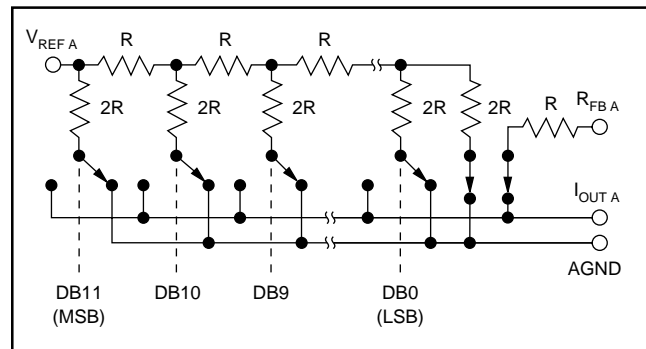


FIGURE 1. Simplified Circuit Diagram for DAC A.

A CMOS switch transistor, included in series with the ladder terminating resistor and in series with the feedback resistor, $R_{FB A}$, compensates for the temperature drift of the ON resistance of the ladder switches.

Figure 2 shows an equivalent circuit for DAC A. C_{OUT} is the output capacitance due to the N-channel switches and varies from about 30pF to 70pF with digital input code. The current source I_{LKG} is the combination of surface and junction leakages to the substrate. I_{LKG} approximately doubles every $10^{\circ}C$. R_O is the equivalent output resistance of the DAC and it varies with input code.

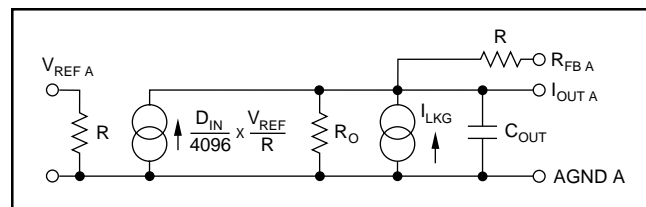


FIGURE 2. Equivalent Circuit for DAC A.

INSTALLATION

ESD PROTECTION

All digital inputs of the DAC780x incorporate on-chip ESD protection circuitry. This protection is designed to withstand 2.5kV (using the Human Body Model, 100pF and 1500 Ω). However, industry standard ESD protection methods should be used when handling or storing these components. When not in use, devices should be stored in conductive foam or rails. The foam or rails should be discharged to the destination socket potential before devices are removed.

POWER-SUPPLY CONNECTIONS

The DAC780x are designed to operate on $V_{DD} = +5V \pm 10\%$. For optimum performance and noise rejection, power-supply decoupling capacitors C_D should be added as shown in the application circuits. These capacitors (1 μF tantalum recommended) should be located close to the DAC. AGND and

DGND should be connected together at one point only, preferably at the power-supply ground point. Separate returns minimize current flow in low-level signal paths if properly connected. Output op amp analog common (+ input) should be connected as near to the AGND pins of the DAC780x as possible.

WIRING PRECAUTIONS

To minimize AC feedthrough when designing a PC board, care should be taken to minimize capacitive coupling between the V_{REF} lines and the I_{OUT} lines. Similarly, capacitive coupling between DACs may compromise the channel-to-channel isolation. Coupling from any of the digital control or data lines might degrade the glitch and digital crosstalk performance. Solder the DAC780x directly into the PC board without a socket. Sockets add parasitic capacitance (which can degrade AC performance).

AMPLIFIER OFFSET VOLTAGE

The output amplifier used with the DAC780x should have low input offset voltage to preserve the transfer function linearity. The voltage output of the amplifier has an error component which is the offset voltage of the op amp multiplied by the “noise gain” of the circuit. This “noise gain” is equal to $(R_F/R_O + 1)$ where R_O is the output impedance of the DAC I_{OUT} terminal and R_F is the feedback network impedance. The nonlinearity occurs due to the output impedance varying with code. If the 0 code case is excluded (where $R_O = \text{infinity}$), the R_O will vary from $R/3R$ providing a “noise gain” variation between $4/3$ and 2 . In addition, the variation of R_O is nonlinear with code, and the largest steps in R_O occur at major code transitions where the worst differential nonlinearity is also likely to be experienced. The nonlinearity seen at the amplifier output is $2V_{OS} - 4V_{OS}/3 = 2V_{OS}/3$. Thus, to maintain good nonlinearity the op amp offset should be much less than $1/2$ LSB.

UNIPOLAR CONFIGURATION

Figure 3 shows DAC780x in a typical unipolar (two-quadrant) multiplying configuration. The analog output values versus digital input code are listed in Table II. The operational amplifiers used in this circuit can be single amplifiers such as the OPA602, or a dual amplifier such as the OPA2107. C1 and C2 provide phase compensation to minimize settling time and overshoot when using a high speed operational amplifier. If an application requires the DAC to have zero gain error, the circuit shown in Figure 4 may be used. Resistors R_2 and R_4 induce a positive gain error greater than worst-case initial negative gain error. Trim resistors R_1 and R_3 provide a variable negative gain error and have sufficient trim range to correct for the worst-case initial positive gain error plus the error produced by R_2 and R_4 .

BIPOLAR CONFIGURATION

See Figure 5 for the DAC780x in a typical bipolar (four-quadrant) multiplying configuration. See Table III for the listing of the analog output values versus digital input code.

DATA INPUT	ANALOG OUTPUT
MSB ↓ ↓ LSB	
1111 1111 1111	$-V_{REF}$ (4095/4096)
1000 0000 0000	$-V_{REF}$ (2048/4096) = $-1/2V_{REF}$
0000 0000 0001	$-V_{REF}$ (1/4096)
0000 0000 0000	0 Volts

TABLE II. Unipolar Output Code.

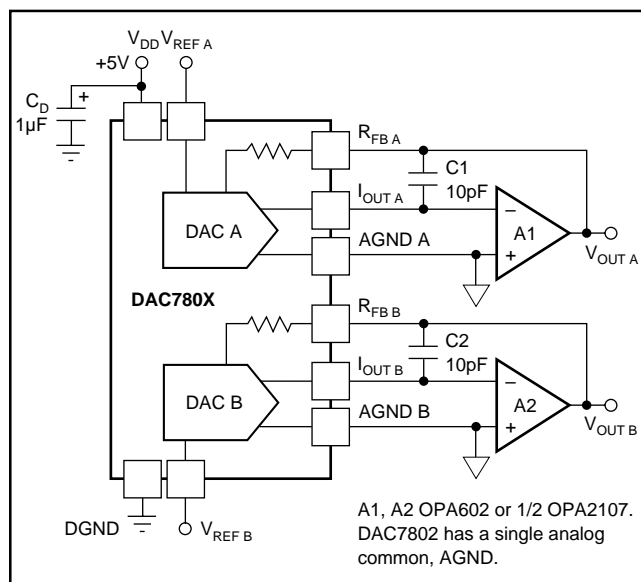


FIGURE 3. Unipolar Configuration.

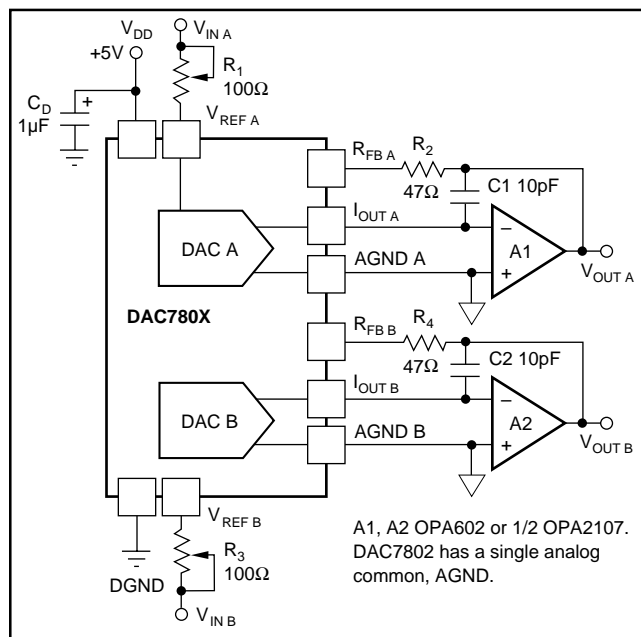


FIGURE 4. Unipolar Configuration with Gain Trim.

The operational amplifiers used in this circuit can be single amplifiers such as the OPA602, a dual amplifier such as the OPA2107, or a quad amplifier like the OPA404. C1 and C2 provide phase compensation to minimize settling time and overshoot when using a high speed operational amplifier. The bipolar offset resistors R_5 – R_7 and R_8 – R_{10} should be ratio-matched to 0.01% to ensure the specified gain error performance.

TABLE III. Bipolar Output Code.

10-BIT PLUS SIGN BAO

For a bipolar DAC with 13 bits

Another option, see Figure 8, also produces a 12-bit plus sign output without the additional switch and digital control line.

DIGITALLY PROGRAMMABLE ACTIVE FILTER

See Figure 9 for the DAC780x in a digitally programmed mode.

The center frequency is determined by $f_c = 1/2\pi RC$ where R is the ladder resistance of the DAC (typical value, 10k Ω) and C

Note that the ladder resistance of the DAC may vary from device to device. Thus, for best tracking, DAC2 and DAC3

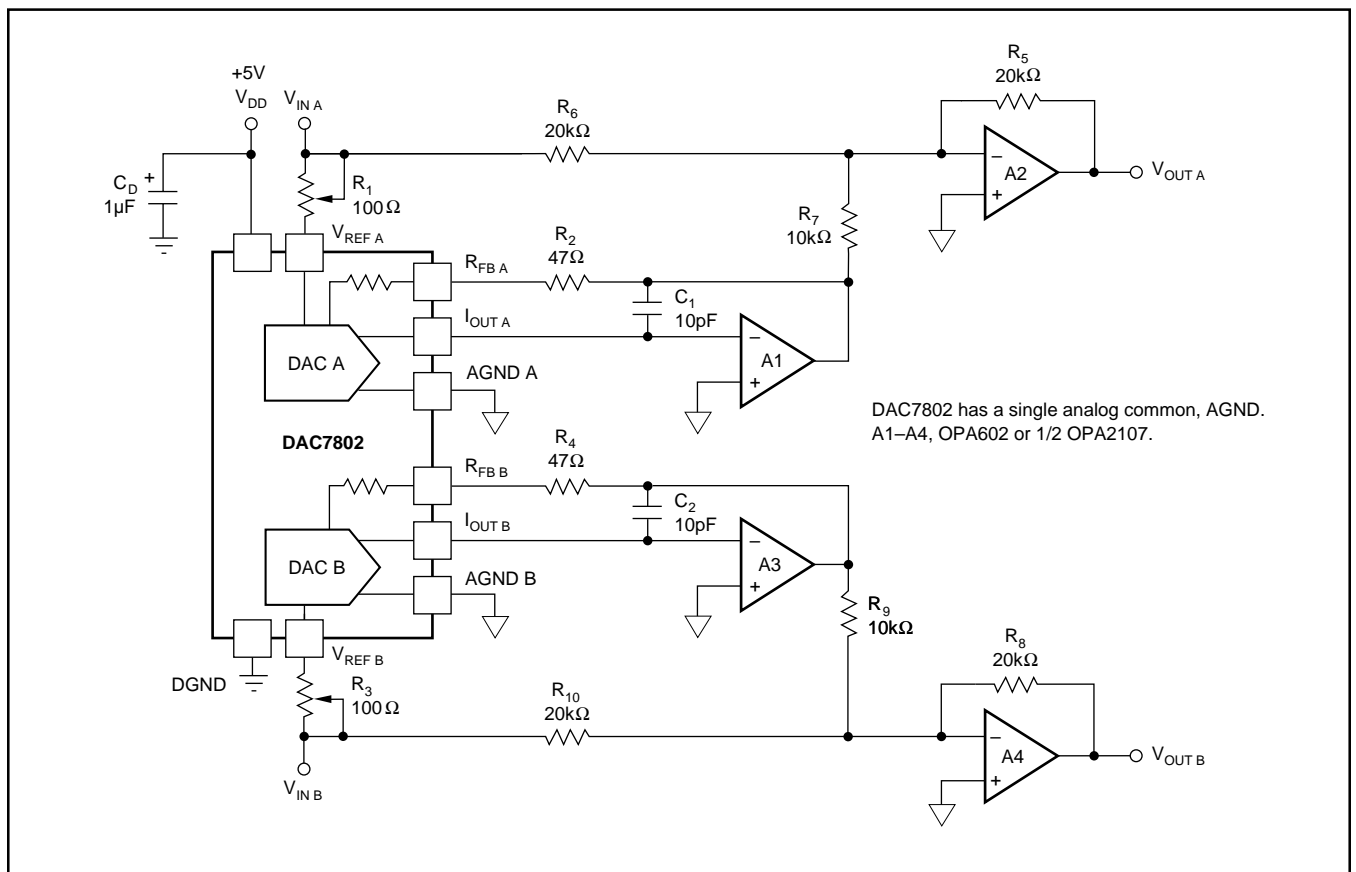


FIGURE 6. Bipolar Configuration with Gain Trim.

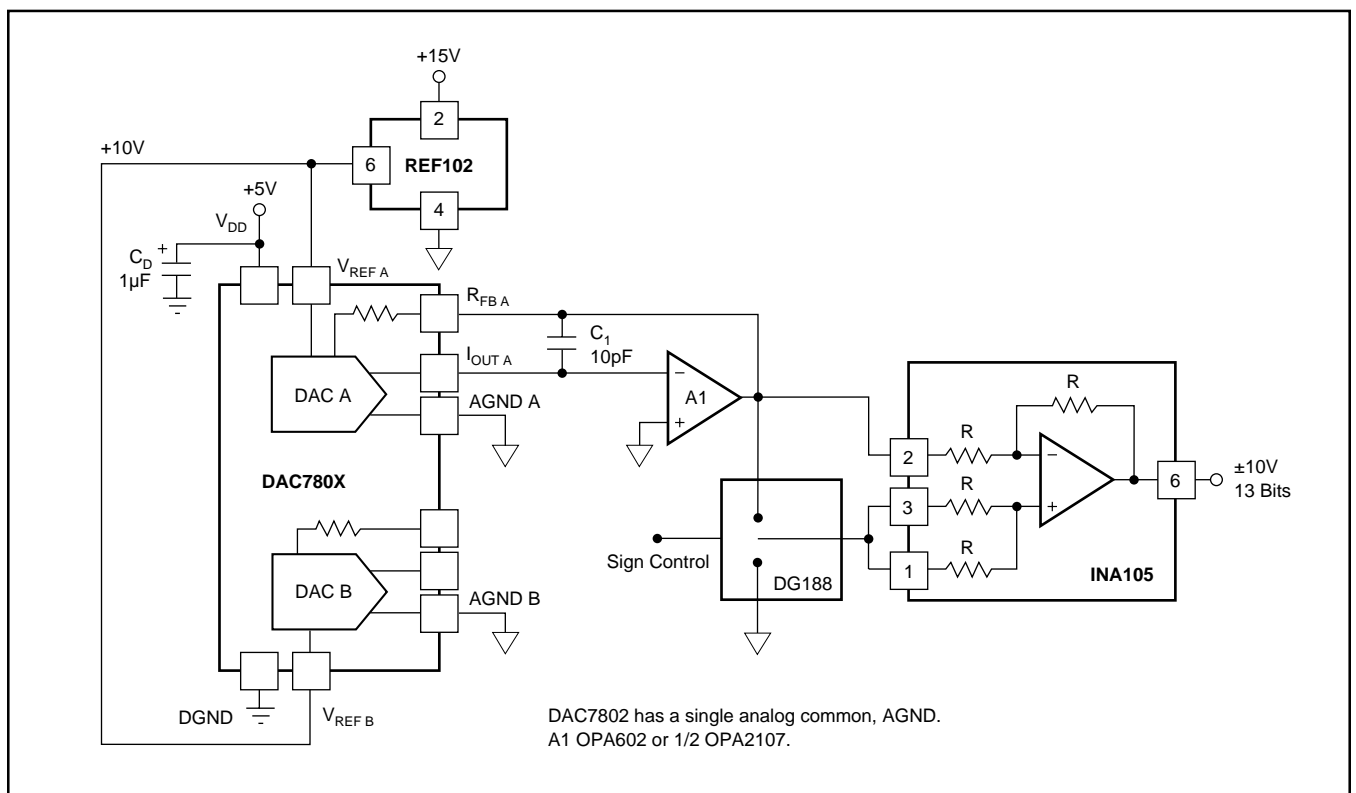


FIGURE 7. 12-Bit Plus Sign DAC.

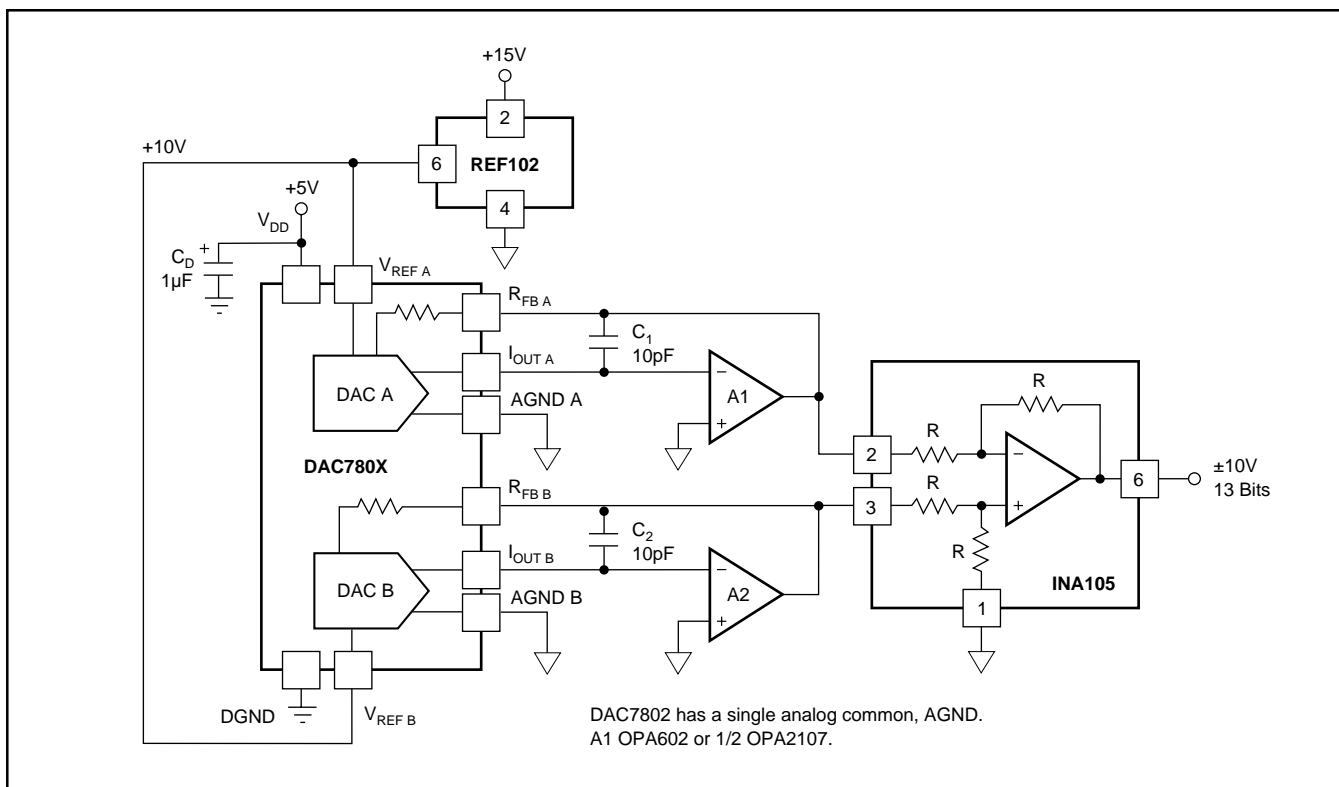


FIGURE 8. 13-Bit Bipolar DAC.

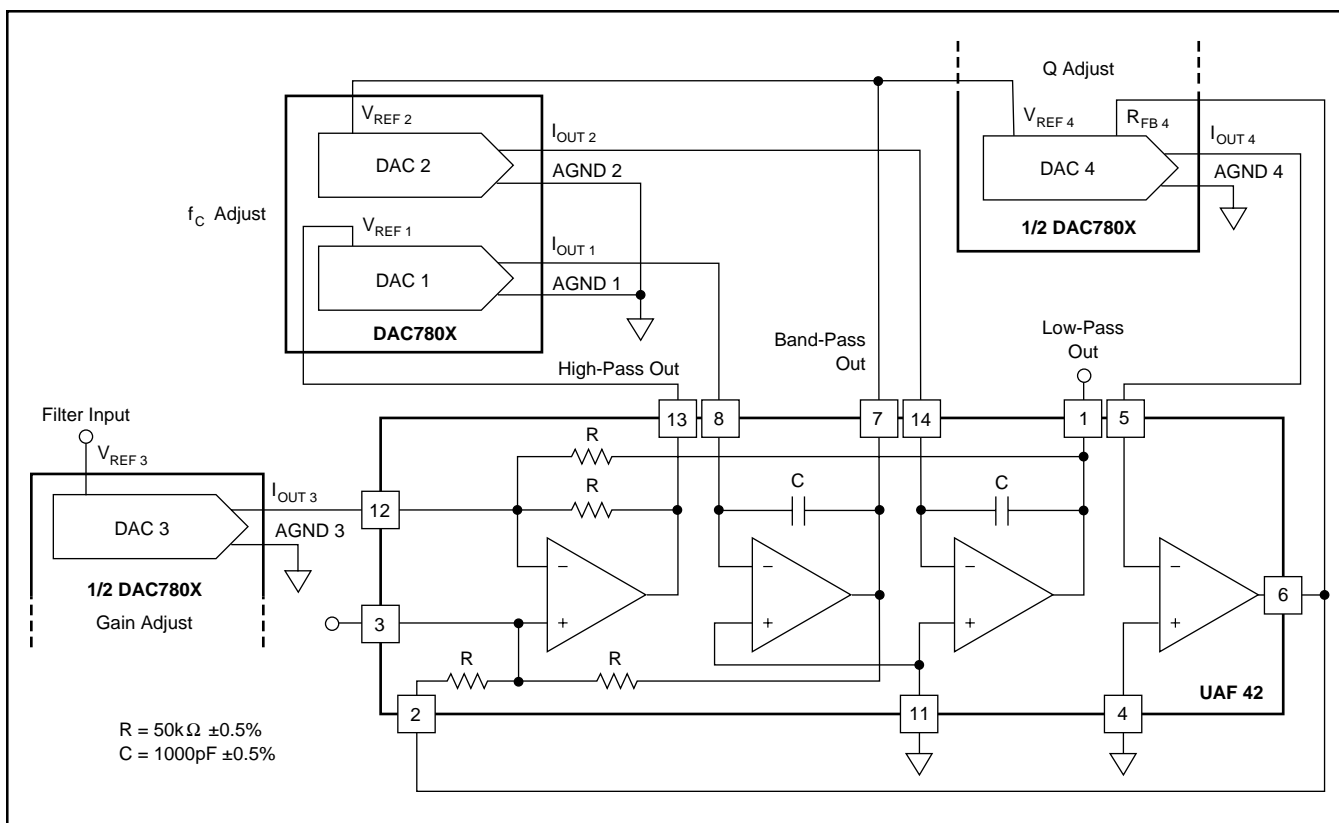


FIGURE 9. Digitally Programmable Universal Active Filter.

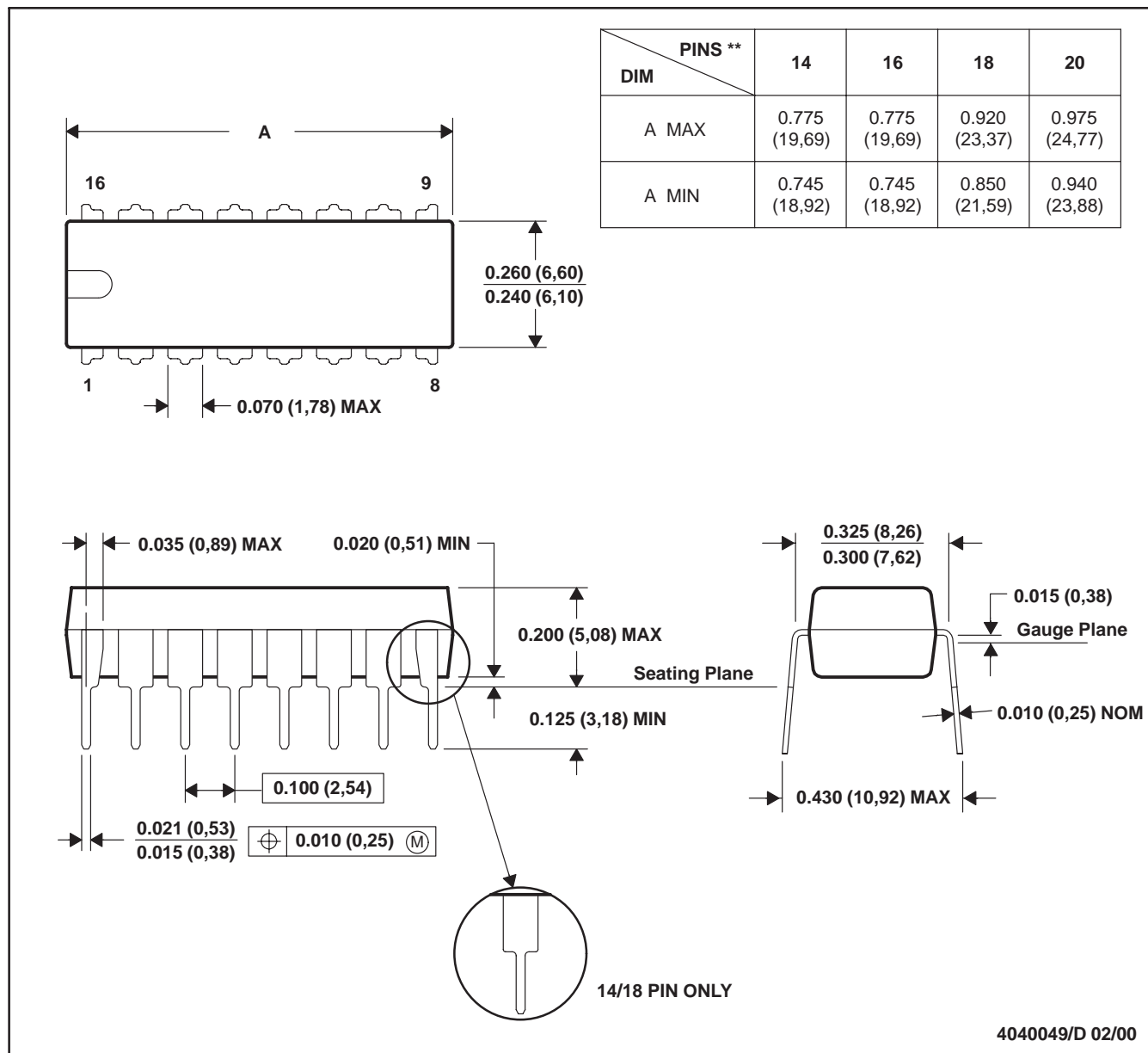
PACKAGE DRAWINGS

MPDI002B – JANUARY 1995 – REVISED FEBRUARY 2000

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN

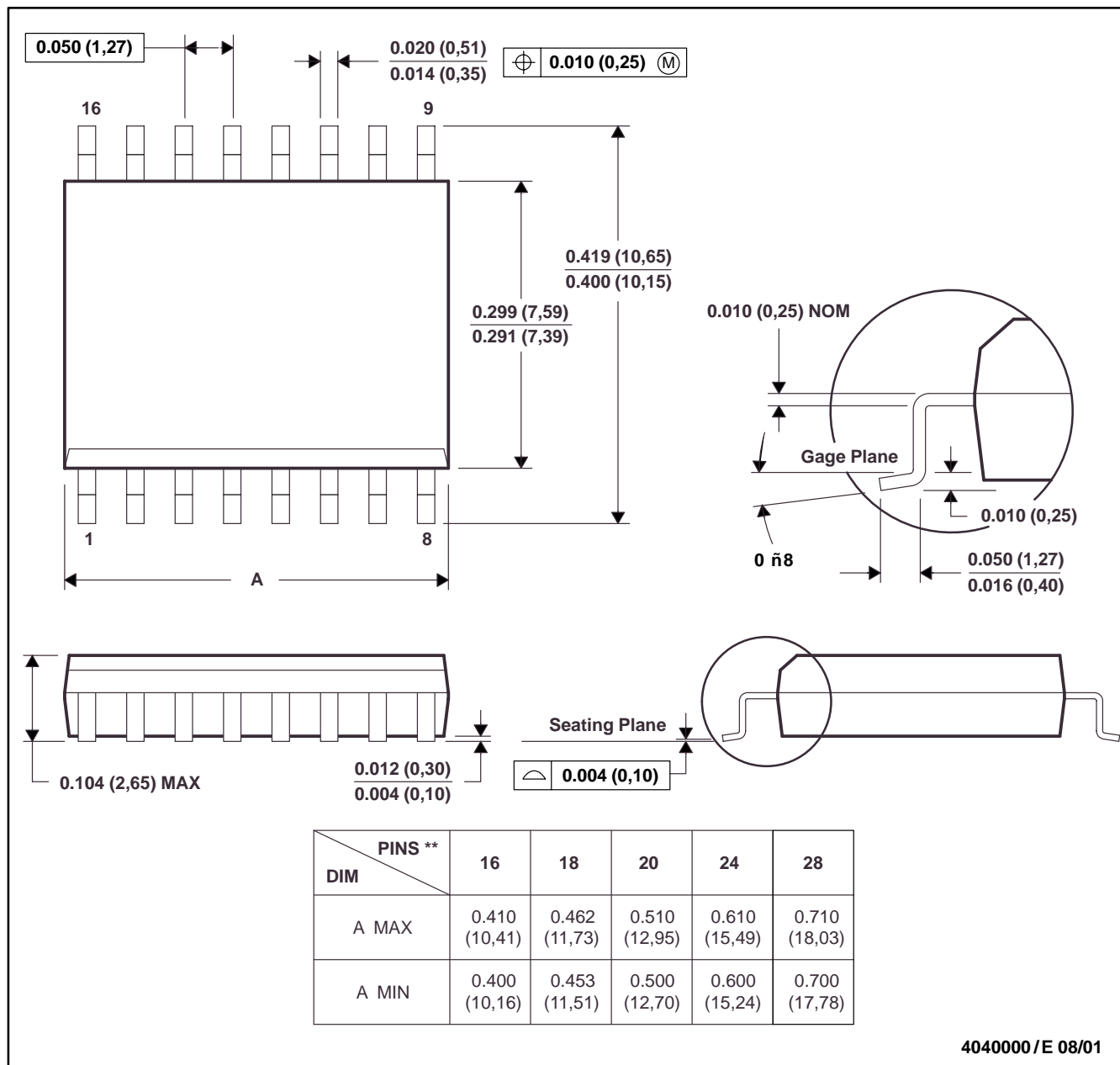


- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-001 (20-pin package is shorter than MS-001).

DW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

16 PINS SHOWN

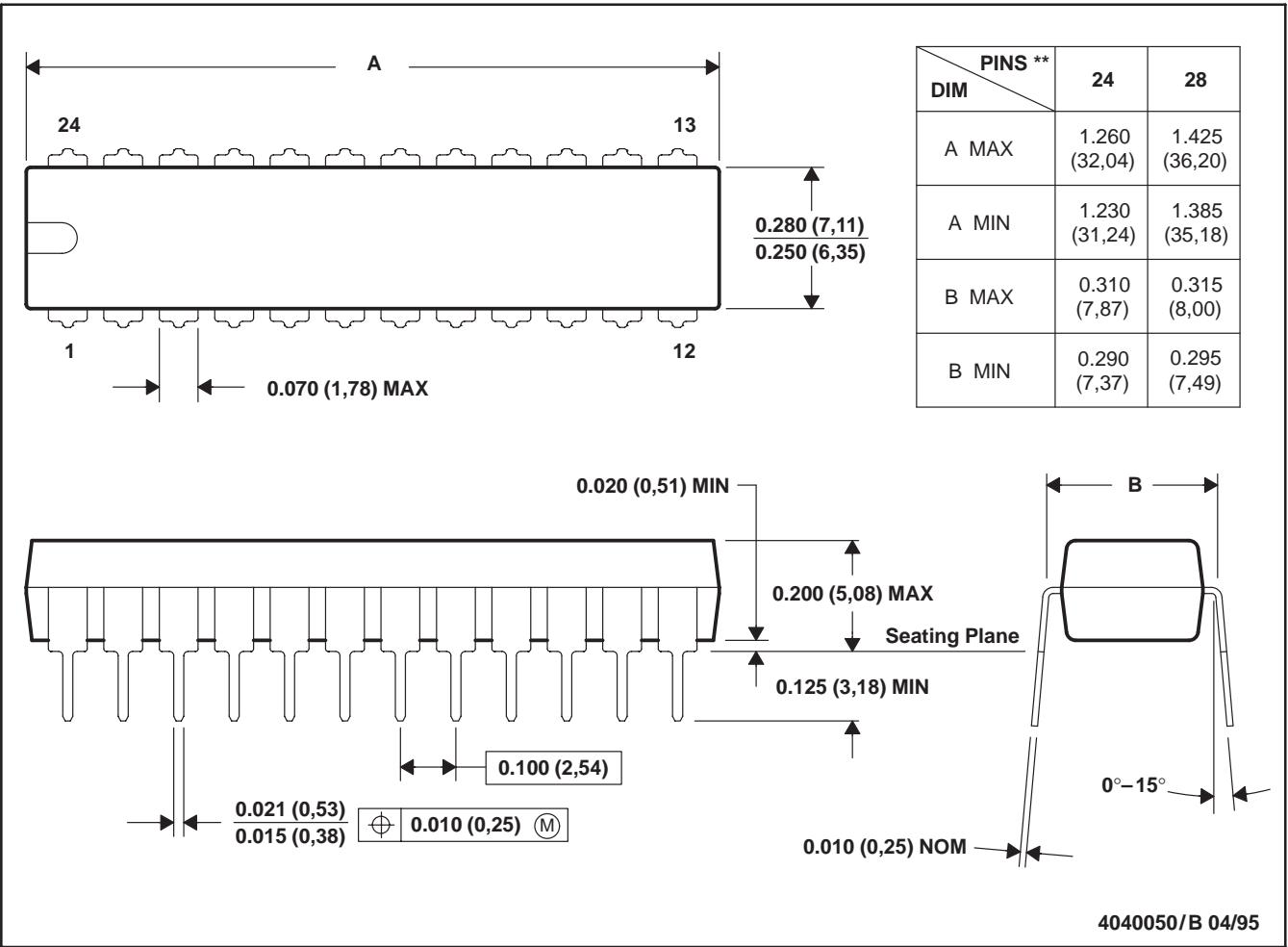


- NOTES:
- All linear dimensions are in inches (millimeters).
 - This drawing is subject to change without notice.
 - Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
 - Falls within JEDEC MS-013

NT (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

24 PINS SHOWN



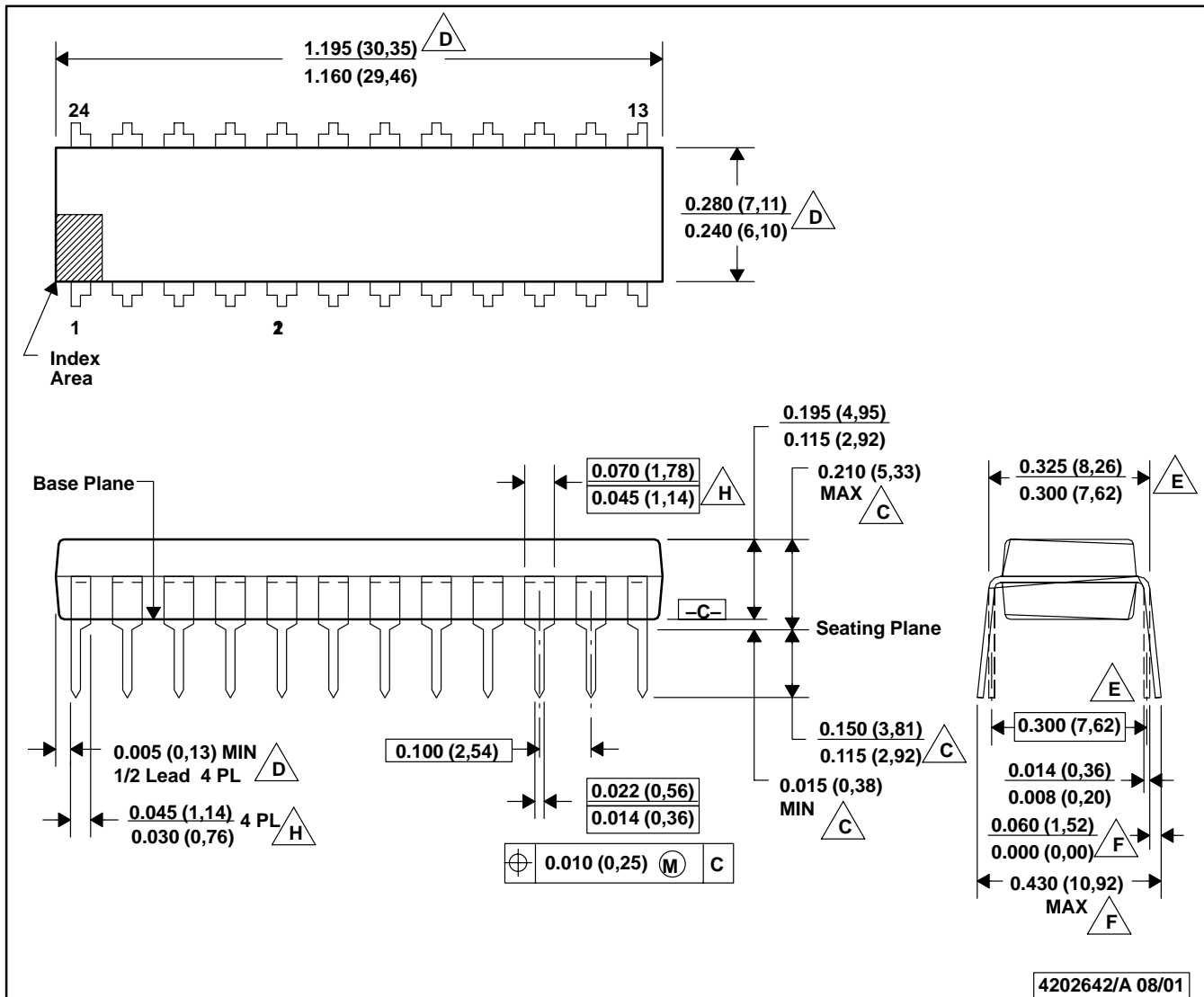
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.

PACKAGE DRAWINGS (Cont)

MPDI066 – AUGUST 2001

NTG (R-PDIP-T24)

PLASTIC DUAL-IN-LINE



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Dimensions are measured with the package seated in JEDEC seating plane gauge GS-3.
- D. Dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010 (0,25).
- E. Dimensions measured with the leads constrained to be perpendicular to Datum C.
- F. Dimensions are measured at the lead tips with the leads unconstrained.
- G. Pointed or rounded lead tips are preferred to ease insertion.
- H. Maximum dimensions do not include dambar protrusions. Dambars protrusions shall not exceed 0.010 (0,25).

- I. Distance between leads including dambar protrusions to be 0.005 (0,13) minimum.
- J. A visual index feature must be located within the cross-hatched area.
- K. For automatic insertion, any raised irregularity on the top surface (step, mesa, etc.) shall be symmetrical about the lateral and longitudinal package centerlines.
- L. Controlling dimension in inches.
- M. Falls within JEDEC MS-011-AB.

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