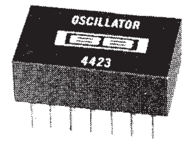


SBFS020A − JANUARY 1978 − REVISED JUNE 2004

Precision Quadrature Oscillator

FEATURES

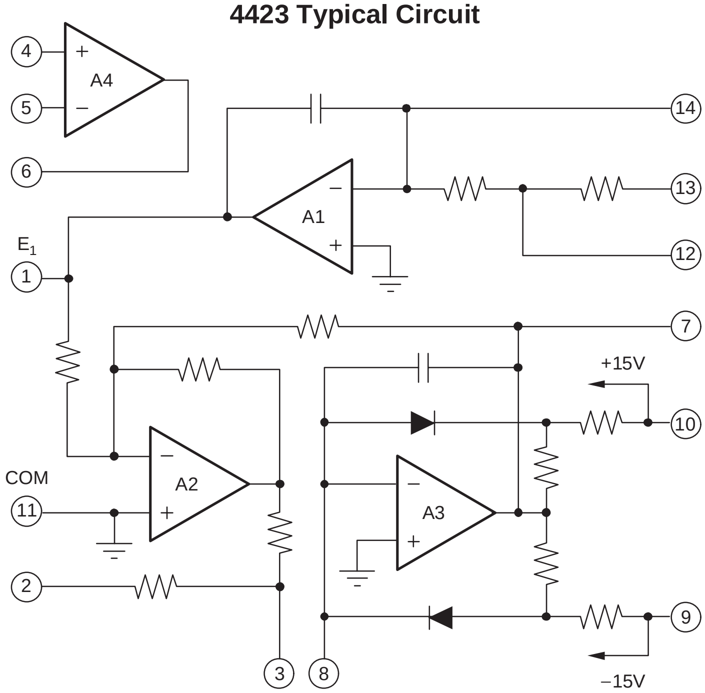
- **Sine and Cosine Outputs**
- **Resistor-Programmable Frequency**
- **Wide Frequency Range: 0.002Hz to 20kHz**
- **Low Distortion: 0.2% max up to 5kHz**
- **Easy Adjustments**
- **Small Size**
- **Low Cost**

DESCRIPTION

The Model 4423 is a precision quadrature oscillator. It has two outputs 90 degrees out of phase with each other, thus making sine and cosine wave outputs available at the same time. The 4423 is resistor-programmable and is easy to use. It has low distortion (0.2% max up to 5kHz) and excellent frequency and amplitude stability.

The Model 4423 also includes an uncommitted operational amplifier that may be used as a buffer, level shifter, or as an independent operational amplifier. The 4423 is packaged in a versatile, small, low-cost DIP package.

4423 Typical Circuit



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.

ORDERING INFORMATION

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR(1)	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
4423	PDIP-14	NSQ	0°C to +70°C	4423P	4423P	Tube, 50

(1) For the most current package and ordering information, see the package option addendum located at the end of this data sheet.

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted(1)

	4423	UNIT
Supply voltage	±18	V
Output short to common	Continuous	
Operating temperature	−25 to +85	°C
Storage temperature	−55 to +125	°C
Lead temperature (soldering, 10s)	300	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

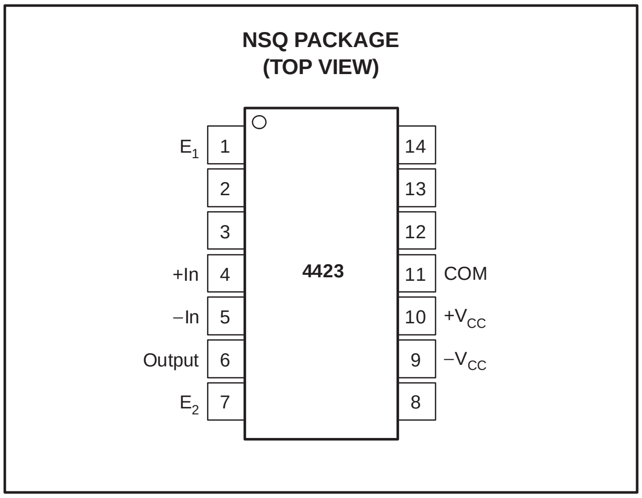
ELECTRICAL CHARACTERISTICS

Specifications typical at +25°C and ±15VDC power supply, unless otherwise noted.

PARAMETER	TEST CONDITIONS	4423P MIN	4423P TYP	4423P MAX	UNITS
Frequency					
Initial frequency	No adjustments	20.0	21.0	22.0	kHz
Frequency range	Using two resistors only	2		20	kHz
	Using two resistors and two capacitors	0.002		20k	Hz
Accuracy of frequency equation(1)			±1	±5	%
Stability vs temperature			±50	±100	ppm/°C
Quadrature phase error			±0.1		degrees
Distortion					
Sine output (pin 1)	0.002Hz to 5kHz			0.2	%
	5kHz to 20kHz			0.5	%
Cosine output (pin 7)	0.002Hz to 5kHz		0.2		%
	5kHz to 20kHz		0.8		%
Distortion vs temperature			0.015		%/°C
Output					
Amplitude (sine)	At 20kHz	6.5	7	7.5	Vrms
	vs temperature		0.05		%/°C
	vs supply		0.4		V/V
Output current		1.5	5		mA
Output impedance				1	Ω
Uncommitted Op Amp					
Input offset voltage			1.5		mV
Input bias current			275		nA
Input impedance			1		MΩ
Open loop gain			90		dB
Output current		5			mA
Power Supply					
Rated supply voltage			±15		V
Supply voltage range		±12		±18	V
Quiescent current			±9	±18	mA
Temperature Range					
Specified		0		+70	°C
Operating		−25		+85	°C
Storage		−55		+125	°C

(1) May be trimmed for better accuracy.

PIN ASSIGNMENTS



Terminal Functions

TERMINAL NAME	NO.	DESCRIPTION
E_1	1	Sine output
	2	Frequency adjustment
	3	Frequency adjustment
+In	4	Uncommitted op amp
−In	5	Uncommitted op amp
Output	6	Uncommitted op amp
E_2	7	Cosine output
	8	Frequency adjustment
$-V_{CC}$	9	−15VDC
$+V_{CC}$	10	+15VDC
COM	11	Ground
	12	Frequency adjustment
	13	Frequency adjustment
	14	Frequency adjustment

TYPICAL CHARACTERISTICS

Specifications typical at +25°C and ±15VDC power supply, unless otherwise noted.

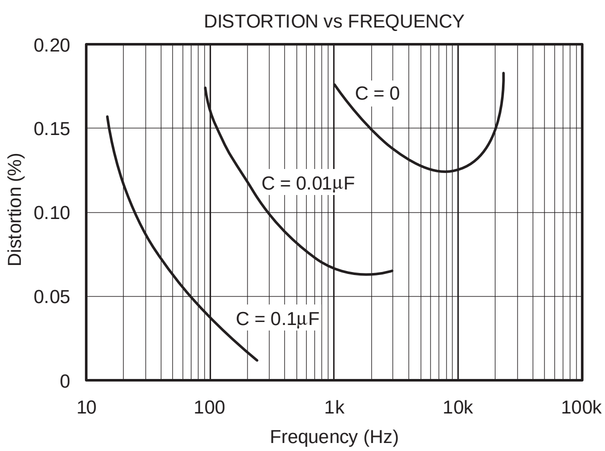


Figure 1

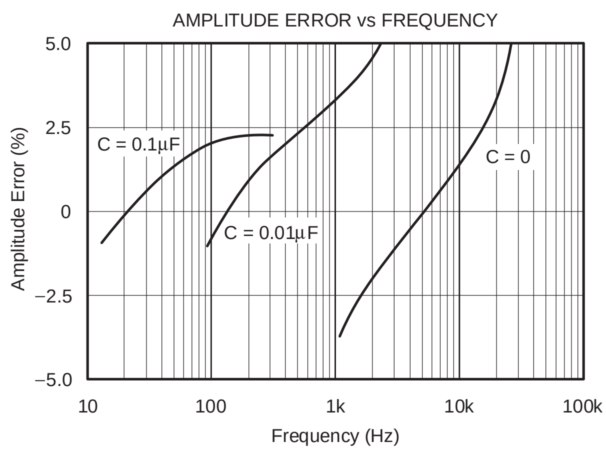


Figure 2

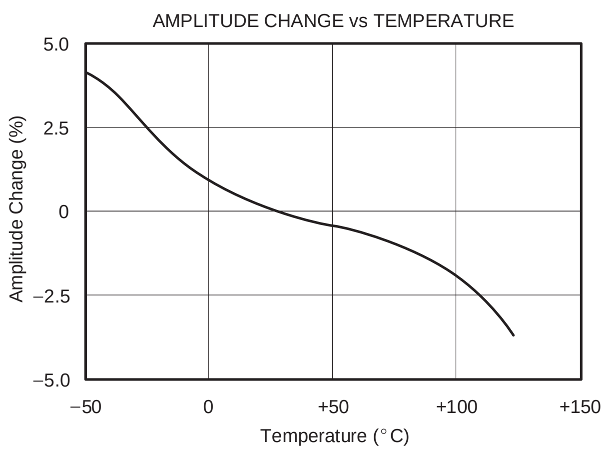


Figure 3

EXTERNAL CONNECTIONS

20kHz Quadrature Oscillator

The 4423 does not require any external component to obtain a 20kHz quadrature oscillator. The connection diagram is shown in Figure 4.

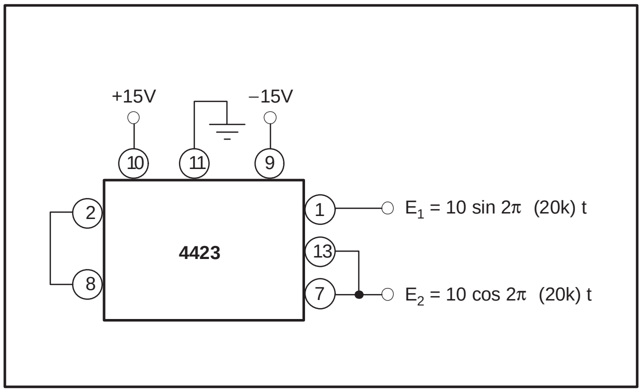


Figure 4.

Resistor-Programmable Quadrature Oscillator

For resistor-programmable frequencies in the 2kHz to 20kHz frequency range, the connection diagram is provided in Figure 5. Note that only two resistors of equal value are required. Resistor R can be expressed by Equation (1).

$$R = \frac{3.785f}{42.05 - 2f} \quad (1)$$

Where:

R is in kΩ,

f is in kHz.

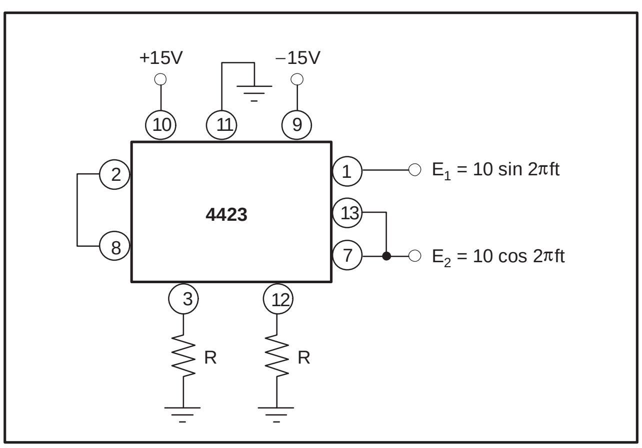


Figure 5.

Quadrature Oscillator Programmable to 0.002Hz

For oscillator frequencies below 2kHz, the use of two capacitors of equal value is recommended, as shown in Figure 6.The connections shown in Figure 6 can be used to obtain oscillator frequency outputs in the 0.002Hz to 20kHz range.

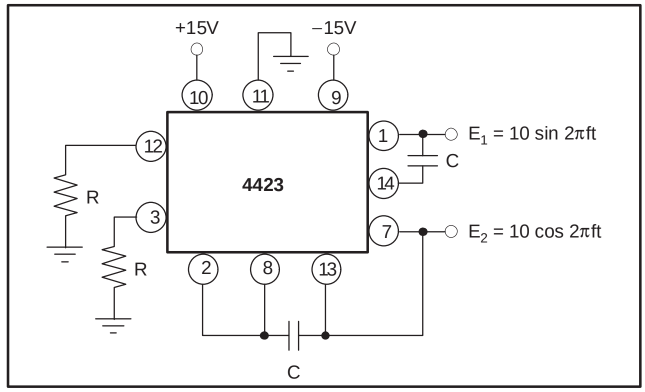


Figure 6.

Frequency f can be expressed by Equation (2).

$$f = \frac{42.05R}{(C + 0.001)(3.785 + 2R)} \quad (2)$$

Where:

f is in Hz.

C is in μF.

R is in kΩ.

For best results, the capacitor values shown in Table 1 should be selected with respect to their frequency ranges.

Table 1. Recommended Capacitor Values

f	20kHz to 2kHz	2kHz to 200Hz	200Hz to 20Hz
C	0	0.01μF	0.1μF
20Hz to 2Hz	2Hz to 0.2Hz	0.2Hz to 0.02Hz	0.02Hz to 0.002Hz
1μF	10μF	100μF	1000μF

After selecting the capacitor for a particular frequency, the value of the required resistor can be obtained by using the resistor selection curve shown in Figure 7 or by Equation (3).

$$R = \frac{3.785f(C + 0.001)}{42.05 - 2f(C + 0.001)} \quad (3)$$

Where:

R is in kΩ.

f is in Hz.

C is in µF.

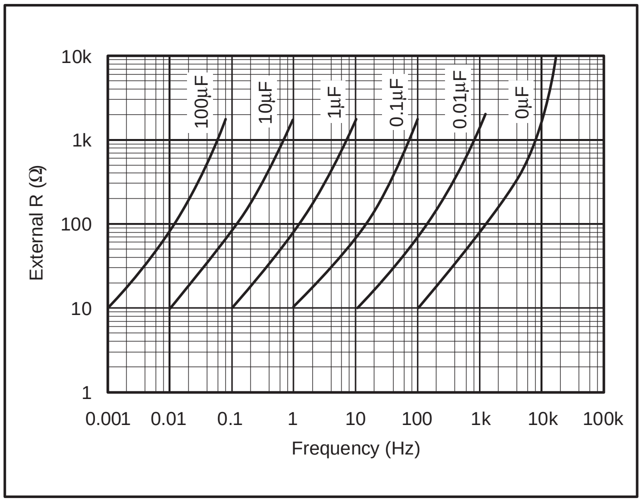


Figure 7.

RECOMMENDED CAPACITOR TYPES

There are various types of capacitors available for use. There are polarized (DC) capacitors and nonpolarized (AC) capacitors available. Of these two types, polarized capacitors cannot be used with the 4423 to set the frequencies.

Commonly-available nonpolarized capacitors include NPO ceramic, silver mica, Teflon, polystyrene, polycarbonate, mylar, and ceramic disc. A comparison of capacitor types is shown in Table 2.

Table 2. Comparison of Nonpolarized Capacitors

CAPACITOR TYPE	CAPACITANCE RANGE (µF)	TEMPERATURE COEFFICIENTS (ppm/°C)	DISSIPATION FACTOR (%)
NPO Ceramic	5pF to 0.1µF	30	0.05
Silver Mica	5pF to 0.047µF	60	0.05
Teflon	0.001 to 100	200	0.01
Polystyrene	0.001 to 500	100	0.03
Polycarbonate	0.001 to 1000	90	0.08
Metallized Teflon	0.001 to 100	60	0.1
Metallized Polycarbonate	0.001 to 1000	10	0.4
Mylar	0.001 to 1000	700	0.7
Metallized Mylar	0.001 to 2000	700	1
Ceramic Disc	5pF to 0.5µF	10,000	3

Choosing a capacitor to use with the 4423 depends mainly on the application, error budget, and cost budget. Note that the specifications of the 4423 do not include the error contribution of the external components. Errors sourced by external components normally have to be added to the 4423 specifications.

As a general selection criteria, TI recommends the use of Table 2. If the capacitor is found unsuitable due to its size, cost, or availability, then move down the list for the next best selection. In any case, do not choose or use any capacitors with dissipation factors greater than 1%. Such capacitors would stop 4423 oscillation.

DISSIPATION FACTOR (DF)

A capacitor can be modeled by an ideal capacitor in parallel with an internal resistor whose value depends on its dissipation factor (DF). Mathematically, internal resistor R is given by Equation (4).

$$R = \frac{1}{2\pi fC(DF)} \quad (4)$$

Where:

R is in Ω.

f is in Hz.

C is in farads.

For example, the DF of ceramic disc capacitors is on the order of 3%, which for a 0.01μF capacitor would be comparable to an internal resistor of 530kΩ at 1kHz. The 530kΩ value resistor is small enough to stop the 4423 oscillator from oscillating.

Some capacitor manufacturers use the terms *Power Factor* (PF) or *Q Factor* (Q) instead of dissipation factor. These terms are similar in meaning and are mathematically related by Equations (5) and (6).

$$(PF) = \frac{(DF)}{\sqrt{1 + (DF)^2}} \tag{5}$$

$$Q = \frac{1}{(DF)} \tag{6}$$

OSCILLATION AMPLITUDE

It takes a finite time to build up the amplitude of the oscillation to its final full-scale value. There is a relationship between the amplitude build-up time and the frequency. The lower the frequency, the longer the amplitude build-up time. For example, it typically takes 250 seconds at 1Hz, 30 seconds at 10Hz, 4 seconds at 100Hz, 400 milliseconds at 1kHz, and 40 milliseconds at 10kHz oscillator frequencies.

There are two methods available to shorten this normal amplitude build-up time. There is also a relationship between the amplitude build-up time and distortion at final amplitude value. When the amplitude build-up time is shortened, the distortion can become worse.

One method to shorten the amplitude build-up time is to connect a resistor between pin 3 and pin 14. The lower the value of this resistor, the shorter the time to build up amplitude of the oscillation. Conversely, the distortion of the output waveform worsens. For example, a 100kΩ resistor would shorten the amplitude build-up time, from 15 seconds to 1 second at 20kHz frequency, but the distortion could be degraded from typically 0.05% to 0.5%.

The other method is to momentarily insert a 1kΩ resistor via a reset switch between pin 3 and pin 14. The amplitude of oscillation is built up instantaneously when the reset switch is pushed. There will be no degradation of distortion with this method since the 1kΩ resistor does not remain in the circuit continuously.

PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
4423P	NRND	PDIP	NSQ	14		TBD	Call TI	N / A for Pkg Type

[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
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.

[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

[3] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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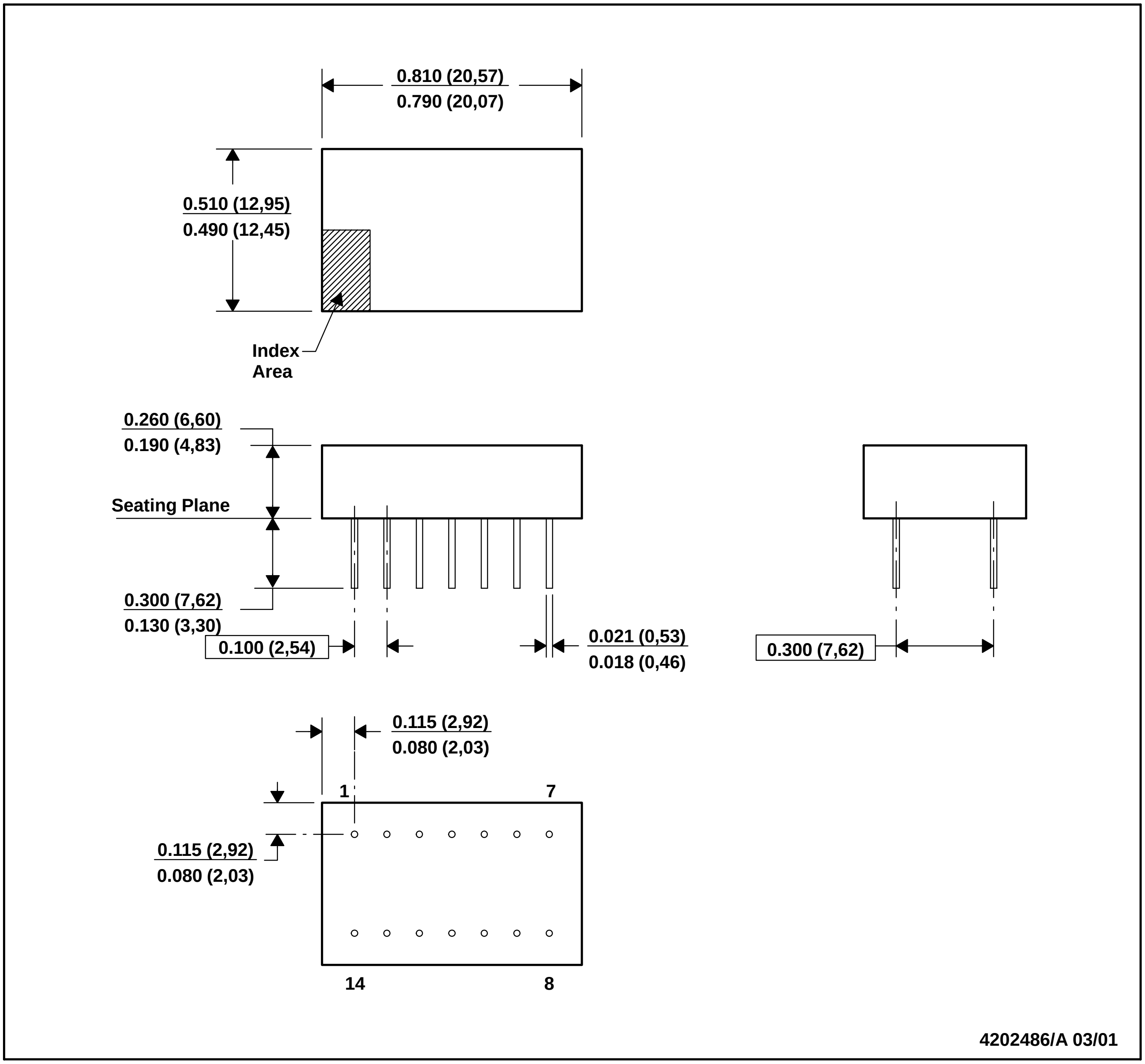
NSQ (R–PDIP–P14) **PLASTIC DUAL-IN-LINE**



NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
D. Pin numbers shown for reference only. Numbers may not be marked on package.
E. A visual index feature must be located within the cross-hatched area.