

FEATURES

Enhanced Replacement for LF347 and TL084

AC PERFORMANCE

1 ms Settling to 0.01% for 10 V Step

20 V/ms Slew Rate

0.0003% Total Harmonic Distortion (THD)

4 MHz Unity Gain Bandwidth

DC PERFORMANCE

0.5 mV max Offset Voltage (AD713K)

20 mV/°C max Drift (AD713K)

200 V/mV min Open Loop Gain (AD713K)

2 mV p-p typ Noise, 0.1 Hz to 10 Hz

True 14-Bit Accuracy

Single Version: AD711, Dual Version: AD712

Available in 16-Pin SOIC, 14-Pin Plastic DIP and

Hermetic Cerdip Packages

Standard Military Drawing Available

APPLICATIONS

Active Filters

Quad Output Buffers for 12- and 14-Bit DACs

Input Buffers for Precision ADCs

Photo Diode Preamplifier Application

PRODUCT DESCRIPTION

The AD713 is a quad operational amplifier, consisting of four AD711 BiFET op amps. These precision monolithic op amps offer excellent dc characteristics plus rapid settling times, high slew rates, and ample bandwidths. In addition, the AD713 provides the close matching ac and dc characteristics inherent to amplifiers sharing the same monolithic die.

The single-pole response of the AD713 provides fast settling: 1 μ s to 0.01%. This feature, combined with its high dc precision, makes the AD713 suitable for use as a buffer amplifier for 12- or 14-bit DACs and ADCs. It is also an excellent choice for use in active filters in 12-, 14- and 16-bit data acquisition systems. Furthermore, the AD713's low total harmonic distortion (THD) level of 0.0003% and very close matching ac characteristics make it an ideal amplifier for many demanding audio applications.

The AD713 is internally compensated for stable operation at unity gain and is available in seven performance grades. The AD713J and AD713K are rated over the commercial temperature range of 0°C to 70°C. The AD713A and AD713B are rated over the industrial temperature of -40°C to +85°C. The AD713S and AD713T are rated over the military temperature range of -55°C to +125°C and are available processed to standard microcircuit drawings.

REV. C

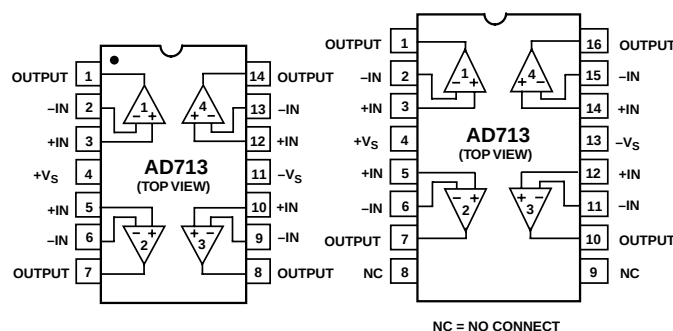
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CONNECTION DIAGRAMS

Plastic (N) and

Cerdip (Q) Packages

SOIC (R) Package



The AD713 is offered in a 16-pin SOIC, 14-pin plastic DIP and hermetic cerdip package.

PRODUCT HIGHLIGHTS

1. The AD713 is a high speed BiFET op amp that offers excellent performance at competitive prices. It upgrades the performance of circuits using op amps such as the TL074, TL084, LT1058, LF347 and OPA404.
2. Slew rate is 100% tested for a guaranteed minimum of 16 V/ μ s (J, A and S Grades).
3. The combination of Analog Devices' advanced processing technology, laser wafer drift trimming and well-matched ion-implanted JFETs provides outstanding dc precision. Input offset voltage, input bias current and input offset current are specified in the warmed-up condition and are 100% tested.
4. Very close matching of ac characteristics between the four amplifiers makes the AD713 ideal for high quality active filter applications.

AD713—SPECIFICATIONS (V_S = ±15 V @ T_A = 25°C unless otherwise noted)

Parameter	Conditions	Min	AD713J/A/S Typ	Max	Min	AD713K/B/T Typ	Max	Unit
INPUT OFFSET VOLTAGE ¹								
Initial Offset	T _{MIN} to T _{MAX}		0.3	1.5		0.2	0.5	mV
Offset			0.5	2/2/2		0.4	0.7/0.7/1.0	mV
vs. Temp			5			5	20/20/15	μV/°C
vs. Supply		78	95		84	100		dB
Long-Term Stability	T _{MIN} to T _{MAX}	76/76/76	95		84	100		dB
			15			15		μV/Month
INPUT BIAS CURRENT ²	V _{CM} = 0 V		40	150		40	75	pA
	V _{CM} = 0 V @ T _{MAX}			3.4/9.6/154			1.7/4.8/77	nA
	V _{CM} = ±10 V		55	200		55	120	pA
INPUT OFFSET CURRENT	V _{CM} = 0 V		10	75		10	35	pA
	V _{CM} = 0 V @ T _{MAX}			1.7/4.8/77			0.8/2.2/36	nA
MATCHING CHARACTERISTICS								
Input Offset Voltage	T _{MIN} to T _{MAX}		0.5	1.8		0.4	0.8	mV
			0.7	2.3/2.3/2.3		0.6	1.0/1.0/1.3	mV
Input Offset Voltage Drift			8			6	25	μV/°C
Input Bias Current	f = 1 kHz		10	100		10	35	pA
Crosstalk	f = 100 kHz			-130			-130	dB
				-95			-95	dB
FREQUENCY RESPONSE								
Small Signal Bandwidth	Unity Gain	3.0	4.0		3.4	4.0		MHz
Full Power Response	V _O = 20 V p-p		200			200		kHz
Slew Rate	Unity Gain	16	20		18	20		V/μs
Settling Time to 0.01%			1.0	1.2		1.0	1.2	μs
Total Harmonic Distortion	f = 1 kHz; R _L ≥ 2 kΩ; V _O = 3 V rms		0.0003			0.0003		%
INPUT IMPEDANCE								
Differential			3×10 ¹² 5.5			3×10 ¹² 5.5		Ω pF
Common Mode			3×10 ¹² 5.5			3×10 ¹² 5.5		Ω pF
INPUT VOLTAGE RANGE								
Differential ³			±20			±20		V
Common-Mode Voltage ⁴			+14.5, -11.5			+14.5, -11.5		V
	T _{MIN} to T _{MAX}	-11		+13	-11		+13	V
Common Mode	V _{CM} = ±10 V	78	88		84	94		dB
Rejection Ratio	T _{MIN} to T _{MAX}	76/76/76	84		82	90		dB
	V _{CM} = ±11 V	72	84		78	90		dB
	T _{MIN} to T _{MAX}	70/70/70	80		74	84		dB
INPUT VOLTAGE NOISE	0.1 Hz to 10 Hz		2			2		μV p-p
	f = 10 Hz		45			45		nV/√Hz
	f = 100 Hz		22			22		nV/√Hz
	f = 1 kHz		18			18		nV/√Hz
	f = 10 kHz		16			16		nV/√Hz
INPUT CURRENT NOISE	f = 1 kHz		0.01			0.01		pA/√Hz
OPEN-LOOP GAIN	V _O = ±10 V; R _L ≥ 2 kΩ	150	400		200	400		V/mV
	T _{MIN} to T _{MAX}	100/100/100			100			V/mV
OUTPUT CHARACTERISTICS								
Voltage	R _L ≥ 2 kΩ	+13, -12.5	+13.9, -13.3		+13, -12.5	+13.9, -13.3		V
	T _{MIN} to T _{MAX}	±12/±12/±12	+13.8, -13.1		±12	+13.8, -13.1		V
Current	Short Circuit		25			25		mA
POWER SUPPLY								
Rated Performance			±15			±15		V
Operating Range		±4.5		±18	±4.5		±18	V
Quiescent Current			10.0	13.5		10.0	12.0	mA
TRANSISTOR COUNT	# of Transistors		120			120		

NOTES

¹Input Offset Voltage specifications are guaranteed after 5 minutes of operation at T_A = 25°C.

²Bias Current specifications are guaranteed maximum at either input after 5 minutes of operation at T_A = 25°C. For higher temperatures, the current doubles every 10°C.

³Defined as voltage between inputs, such that neither exceeds ±10 V from ground.

⁴Typically exceeding -14.1 V negative common-mode voltage on either input results in an output phase reversal.

Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS^{1,2}

Supply Voltage	±18 V
Internal Power Dissipation ²	
Input Voltage ³	±18 V
Output Short-Circuit Duration (For One Amplifier)	Indefinite
Differential Input Voltage	+V _S and -V _S
Storage Temperature Range (Q)	-65°C to +150°C
Storage Temperature Range (N, R)	-65°C to +125°C
Operating Temperature Range	
AD713J/K	0°C to 70°C
AD713A/B	-40°C to +85°C
AD713S/T	-55°C to +125°C
Lead Temperature Range (Soldering 60 sec)	300°C

NOTES

¹Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

²Thermal Characteristics:

14-Pin Plastic Package:	$\theta_{JC} = 30^{\circ}\text{C/Watt}$; $\theta_{JA} = 100^{\circ}\text{C/Watt}$
14-Pin Cerdip Package:	$\theta_{JC} = 30^{\circ}\text{C/Watt}$; $\theta_{JA} = 110^{\circ}\text{C/Watt}$
16-Pin SOIC Package:	$\theta_{JC} = 30^{\circ}\text{C/Watt}$

Watt; $\theta_{JA} = 100^{\circ}\text{C/Watt}$

³For supply voltages less than ±18 V, the absolute maximum input voltage is equal to the supply voltage.

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option ¹
AD713AQ	-40°C to +85°C	14-Pin Ceramic DIP	Q-14
AD713BQ	-40°C to +85°C	14-Pin Ceramic DIP	Q-14
AD713JN	0°C to 70°C	14-Pin Plastic DIP	N-14
AD713JR-16	0°C to 70°C	16-Pin Plastic SOIC	R-16
AD713JR-16-REEL	0°C to 70°C	16-Pin Plastic SOIC	R-16
AD713JR-16-REEL7	0°C to 70°C	16-Pin Plastic SOIC	R-16
AD713KN	0°C to 70°C	14-Pin Plastic DIP	N-14
AD713SQ ²	-55°C to +125°C	14-Pin Ceramic DIP	Q-14
AD713TQ ²	-55°C to +125°C	14-Pin Ceramic DIP	Q-14
5962-9063301MCA	-55°C to +125°C	14-Pin Ceramic DIP	Q-14
5962-9063302MCA ²	-55°C to +125°C	14-Pin Ceramic DIP	Q-14

¹N = Plastic DIP; Q = Cerdip; R = Small Outline IC (SOIC).

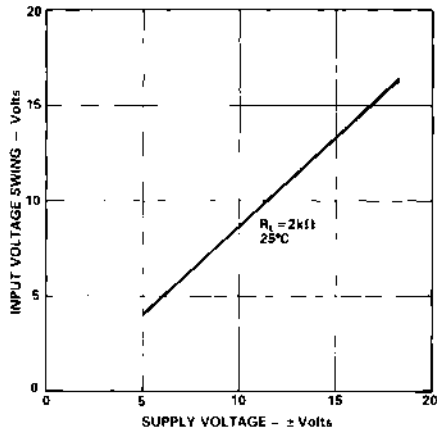
²Not for new designs. Obsolete April 2002.

CAUTION

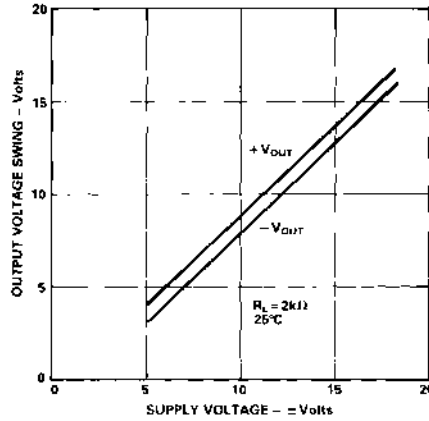
ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD713 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.



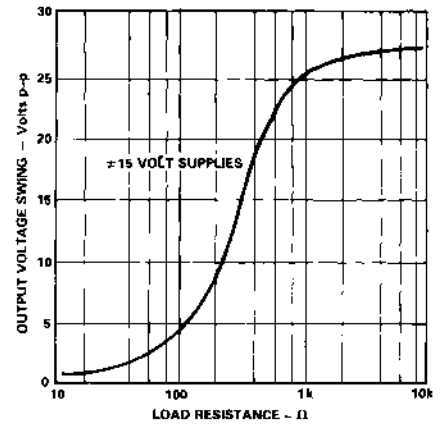
AD713—Typical Performance Characteristics



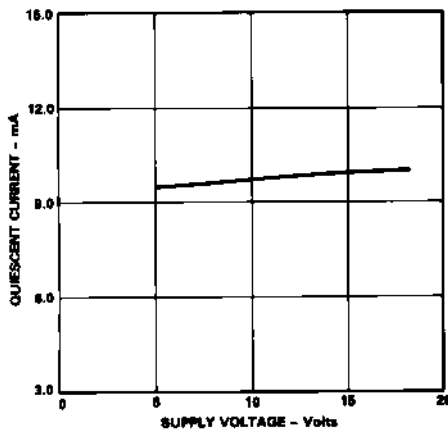
TPC 1. Input Voltage Swing vs. Supply Voltage



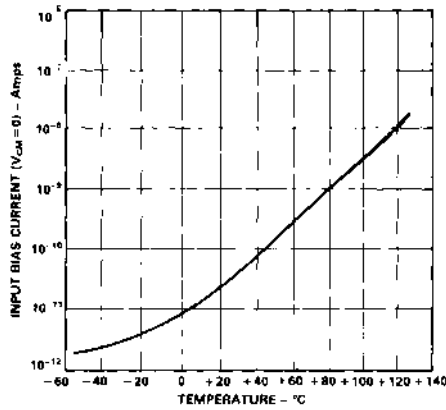
TPC 2. Output Voltage Swing vs. Supply Voltage



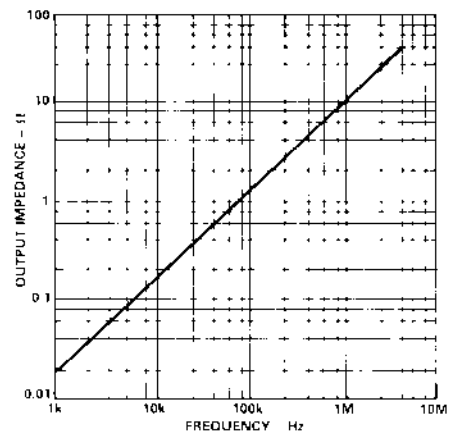
TPC 3. Output Voltage Swing vs. Load Resistance



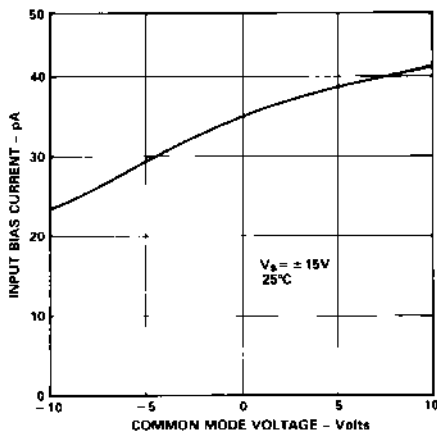
TPC 4. Quiescent Current vs. Supply Voltage



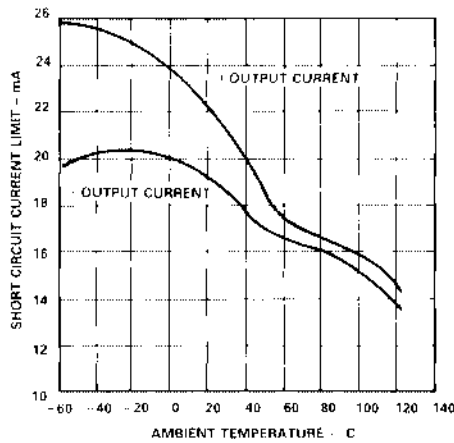
TPC 5. Input Bias Current vs. Temperature



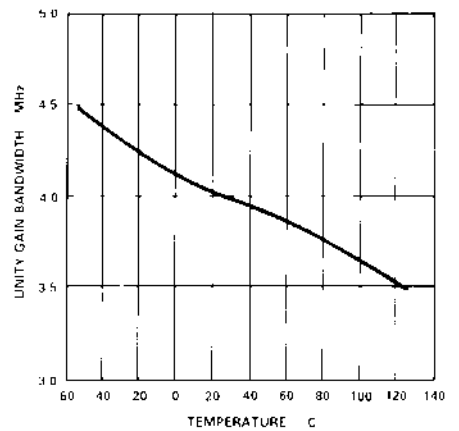
TPC 6. Output Impedance vs. Frequency, $G = 1$



TPC 7. Input Bias Current vs. Common Mode Voltage

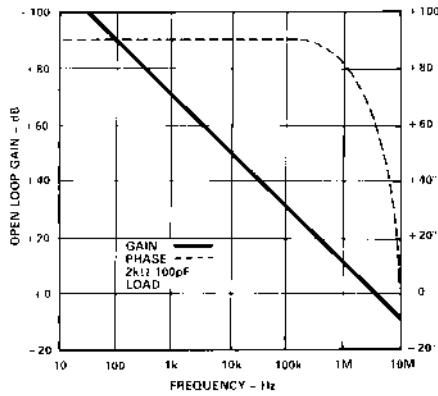


TPC 8. Short-Circuit Current Limit vs. Temperature

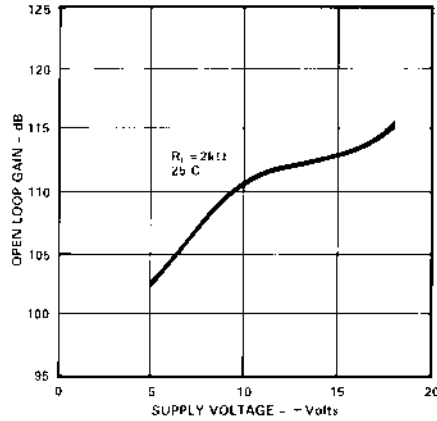


TPC 9. Gain Bandwidth Product vs. Temperature

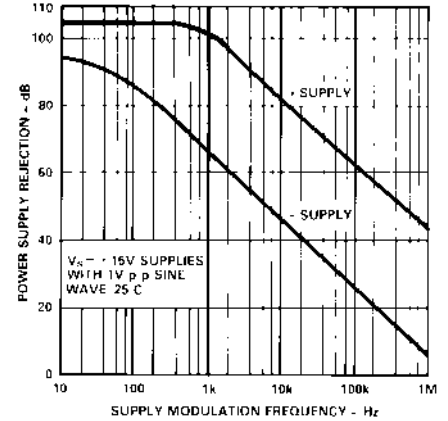
Typical Performance Characteristics—AD713



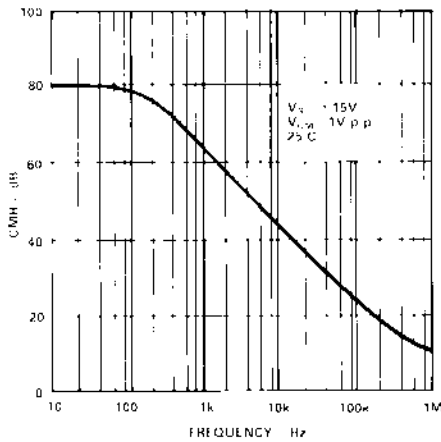
TPC 10. Open-Loop Gain and Phase Margin vs. Frequency



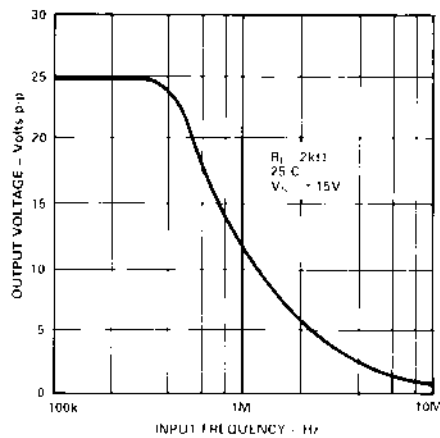
TPC 11. Open-Loop Gain vs. Supply Voltage



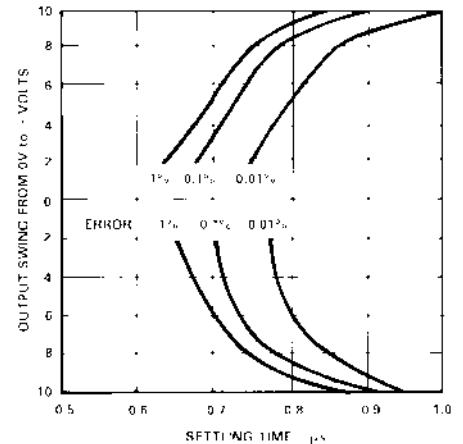
TPC 12. Power Supply Rejection vs. Frequency



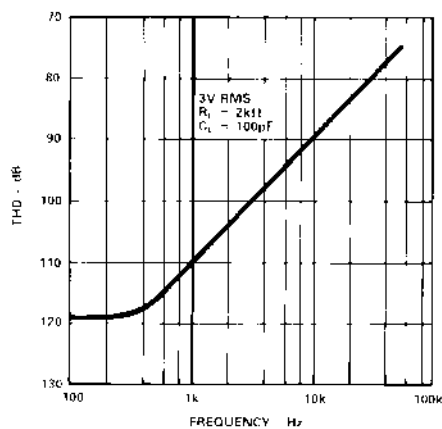
TPC 13. Common Mode Rejection vs. Frequency



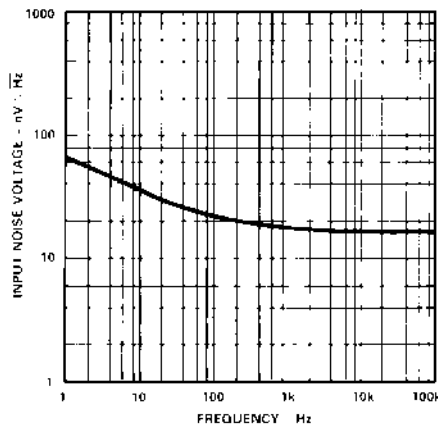
TPC 14. Large Signal Frequency Response



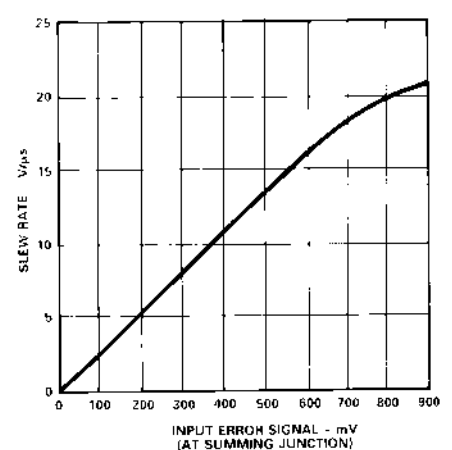
TPC 15. Output Swing and Error vs. Settling Time



TPC 16. Total Harmonic Distortion vs. Frequency

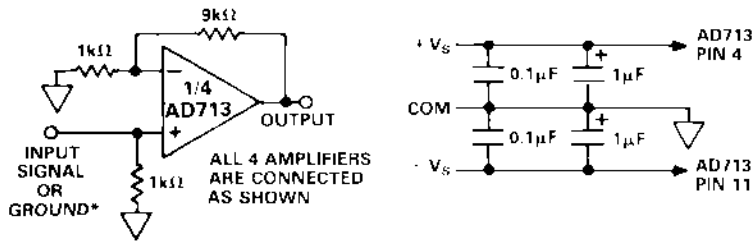


TPC 17. Input Noise Voltage Spectral Density



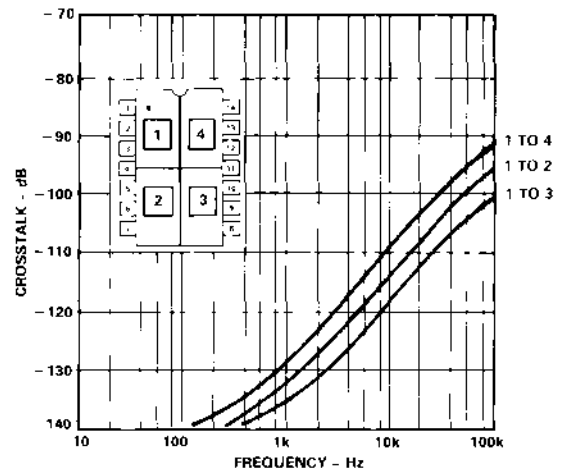
TPC 18. Slew Rate vs. Input Error Signal

AD713

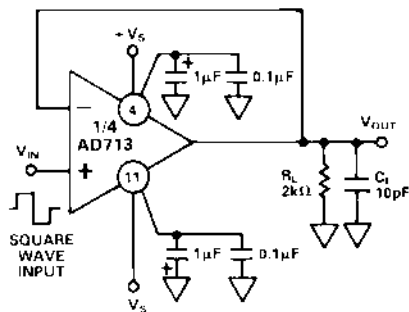


*THE SIGNAL INPUT (1kHz SINEWAVE, 2V p-p) IS APPLIED TO ONE AMPLIFIER AT A TIME. THE OUTPUTS OF THE OTHER THREE AMPLIFIERS ARE THEN MEASURED FOR CROSSTALK.

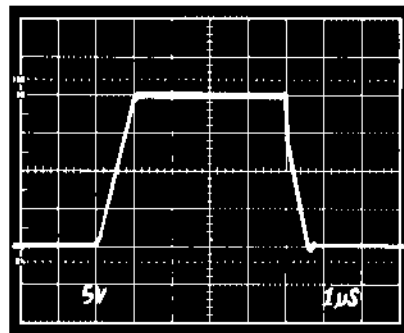
TPC 19. Crosstalk Test Circuit



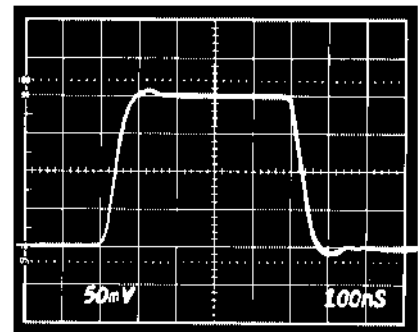
TPC 20. Crosstalk vs. Frequency



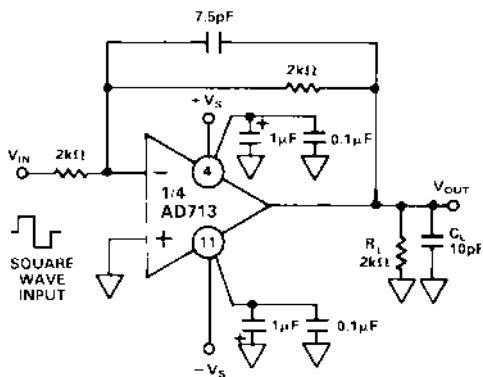
TPC 21a. Unity Gain Follower



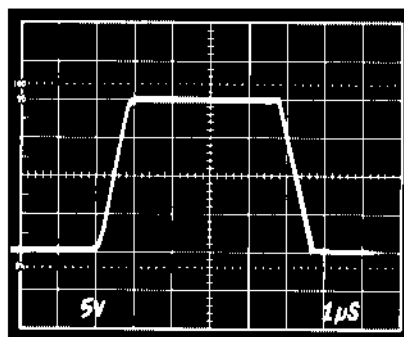
TPC 21b. Unity Gain Follower Pulse Response (Large Signal)



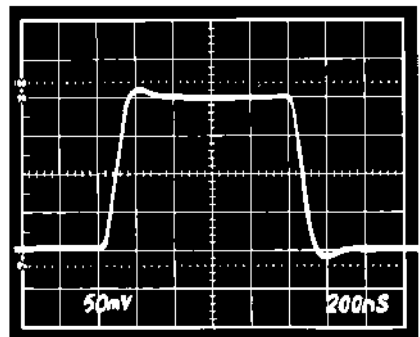
TPC 22b. Unity Gain Inverter Pulse Response (Large Signal)



TPC 22a. Unity Gain Inverter



TPC 21c. Unity Gain Follower Pulse Response (Small Signal)



TPC 22c. Unity Gain Inverter Pulse Response (Small Signal)

The photos of Figures 2 and 3 show the dynamic response of the AD713 while operating in the settling time test circuit of Figure 1. The input of the settling time fixture is driven by a flat-top pulse generator. The error signal output from the false summing node of A1, the AD713 under test, is clamped, amplified by op amp A2 and then clamped again.

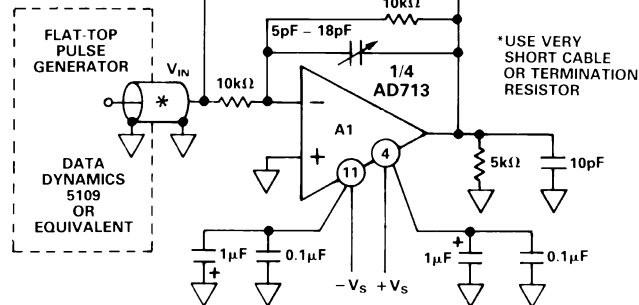


Figure 1. Settling Time Test Circuit

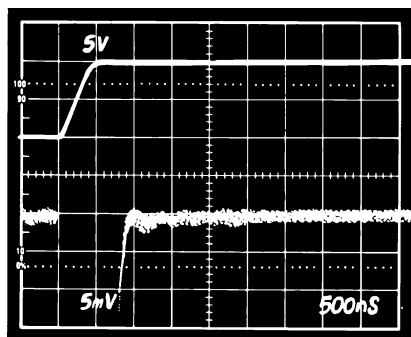
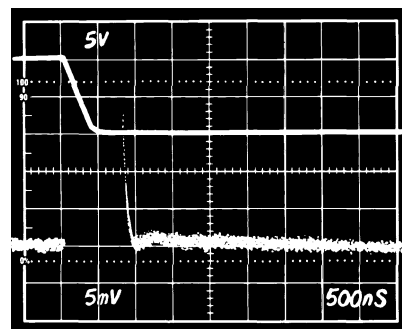


Figure 2. Settling Characteristics 0 V to +10 V Step.
Upper Trace: Output of AD713 Under Test (5 V/div).
Lower Trace: Amplified Error Voltage (0.01%/div)

The error signal is thus clamped twice: once to prevent overloading amplifier A2 and then a second time to avoid overloading the oscilloscope preamp. A Tektronix oscilloscope preamp type 7A26 was carefully chosen because it recovers from the approximately 0.4 V overload quickly enough to allow accurate measurement of the AD713's 1 μ s settling time. Amplifier A2 is a very high speed FET input op amp; it provides a voltage gain of 10, amplifying the error signal output of the AD713 under test (providing an overall gain of 5).



*Figure 3. Settling Characteristics to -10 V Step.
Upper Trace: Output of AD713 Under Test (5 V/div).
Lower Trace: Amplified Error Voltage (0.01%/div)*

POWER SUPPLY BYPASSING

The power supply connections to the AD713 must maintain a low impedance to ground over a bandwidth of 4 MHz or more. This is especially important when driving a significant resistive or capacitive load, since all current delivered to the load comes from the power supplies. Multiple high quality bypass capacitors are recommended for each power supply line in any critical application. A 0.1 μF ceramic and a 1 μF electrolytic capacitor as shown in Figure 4 placed as close as possible to the amplifier (with short lead lengths to power supply common) will assure adequate high frequency bypassing in most applications. A minimum bypass capacitance of 0.1 μF should be used for any application.

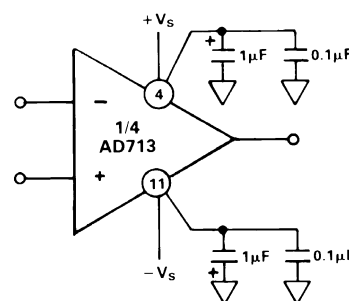


Figure 4. Recommended Power Supply Bypassing

AD713

A HIGH SPEED INSTRUMENTATION AMPLIFIER CIRCUIT

The instrumentation amplifier circuit shown in Figure 5 can provide a range of gains from unity up to 1000 and higher using only a single AD713. The circuit bandwidth is 1.2 MHz at a gain of 1 and 250 kHz at a gain of 10; settling time for the entire circuit is less than 5 μ s to within 0.01% for a 10 V step, ($G = 10$). Other uses for amplifier A4 include an active data guard and an active sense input.

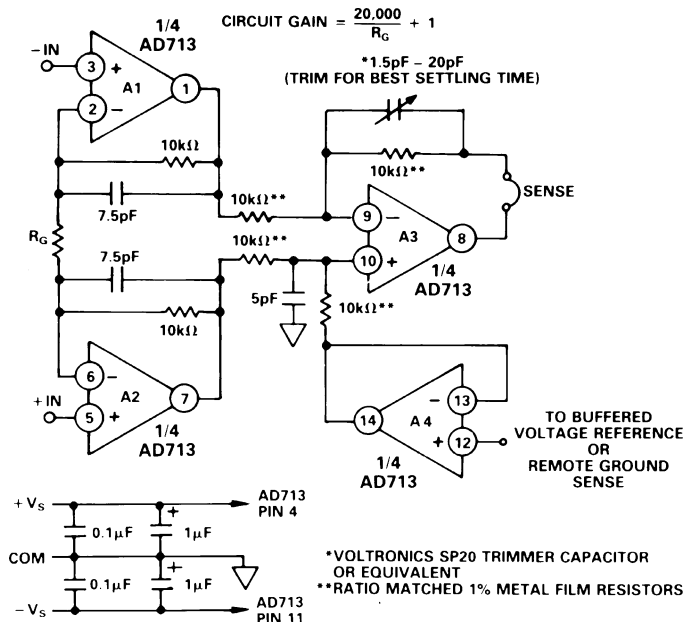


Figure 5. A High Speed Instrumentation Amplifier Circuit

Table I provides a performance summary for this circuit. The photo of Figure 6 shows the pulse response of this circuit for a gain of 10.

Table I. Performance Summary for the High Speed Instrumentation Amplifier Circuit

Gain	R_G	Bandwidth	T Settle (0.01%)
1	NC	1.2 MHz	2 μ s
2	20 k Ω	1.0 MHz	2 μ s
10	4.04 k Ω	0.25 MHz	5 μ s

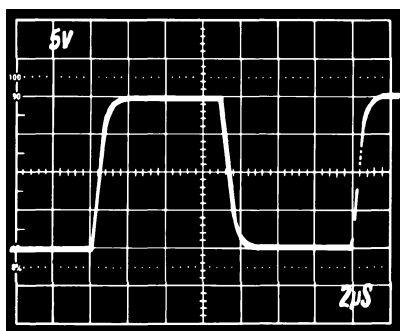


Figure 6. The Pulse Response of the High Speed Instrumentation Amplifier. Gain = 10

A HIGH SPEED FOUR OP AMP CASCADED AMPLIFIER CIRCUIT

Figure 7 shows how the four amplifiers of the AD713 may be connected in cascade to form a high gain, high bandwidth amplifier. This gain of 100 amplifier has a –3 dB bandwidth greater than 600 kHz.

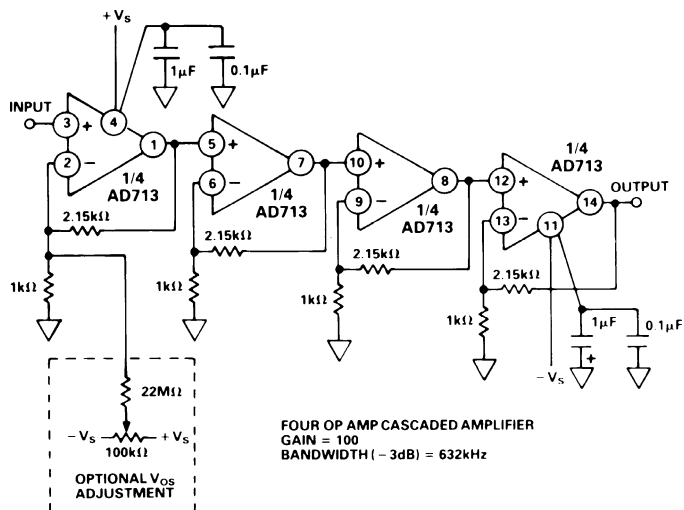


Figure 7. A High Speed Four Op Amp Cascaded Amplifier Circuit

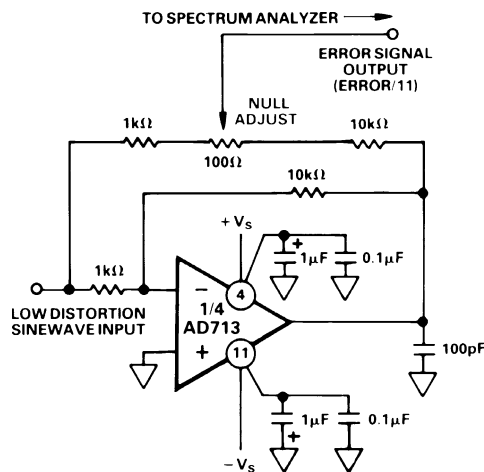


Figure 8. THD Test Circuit

HIGH SPEED OP AMP APPLICATIONS AND TECHNIQUES

DAC Buffers (I-to-V Converters)

The wide input dynamic range of JFET amplifiers makes them ideal for use in both waveform reconstruction and digital-audio DAC applications. The AD713, in conjunction with the AD1860 DAC, can achieve 0.0016% THD (here at a 4fs or a 176.4 kHz update rate) without requiring the use of a deglitcher. Just such a circuit is shown in Figure 9. The 470 pF feedback capacitor used with IC2a, along with op amp IC2b and its associated components, together form a 3-pole low-pass filter. Each or all of these poles can be tailored for the desired attenuation and phase characteristics required for a particular application. In this application, one half of an AD713 serves each channel in a two-channel stereo system.

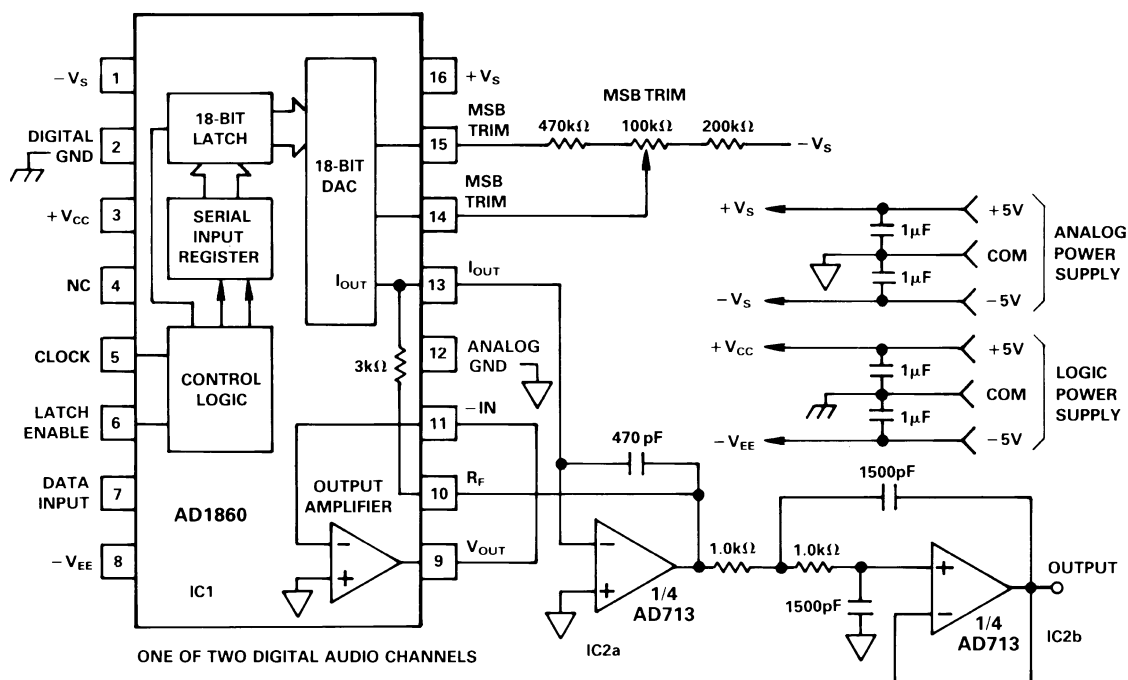


Figure 9. A D/A Converter Circuit for Digital Audio

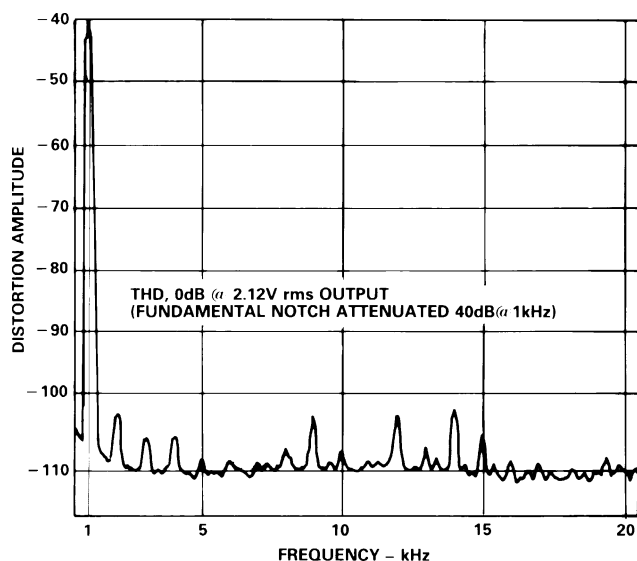


Figure 10. Harmonic Distortion as Frequency for the Digital Audio Circuit of Figure 9

Driving the Analog Input of an A/D Converter

An op amp driving the analog input of an A/D converter, such as that shown in Figure 11, must be capable of maintaining a constant output voltage under dynamically changing load conditions. In successive approximation converters, the input current is compared to a series of switched trial currents. The comparison point is diode clamped but may vary by several hundred millivolts, resulting in high frequency modulation of the A/D input current. The output impedance of a feedback amplifier is made artificially low by its loop gain. At high frequencies, where the loop gain is low, the amplifier output impedance can approach its open loop value.

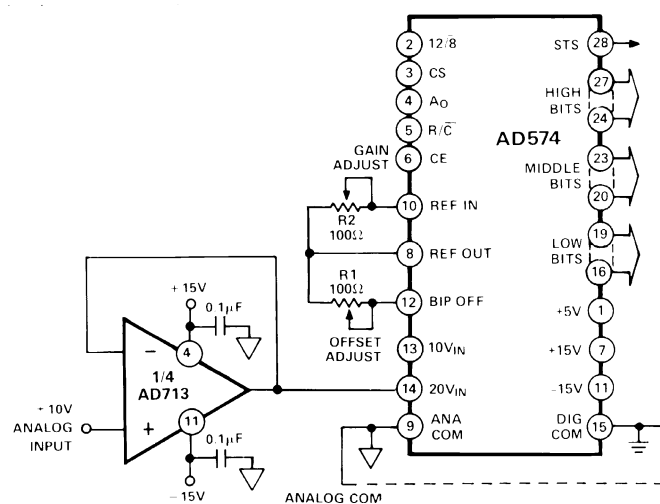


Figure 11. The AD713 as an ADC Buffer

Most IC amplifiers exhibit a minimum open loop output impedance of $25\ \Omega$, due to current limiting resistors. A few hundred microamps reflected from the change in converter loading can introduce errors in instantaneous input voltage. If the A/D conversion speed is not excessive and the bandwidth of the amplifier is sufficient, the amplifier's output will return to the nominal value before the converter makes its comparison. However, many amplifiers have relatively narrow bandwidths, yielding slow recovery from output transients. The AD713 is ideally suited as a driver for A/D converters since it offers both a wide bandwidth and a high open loop gain.

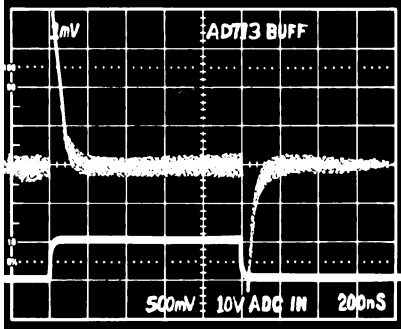


Figure 12. Buffer Recovery Time Source Current = 2 mA

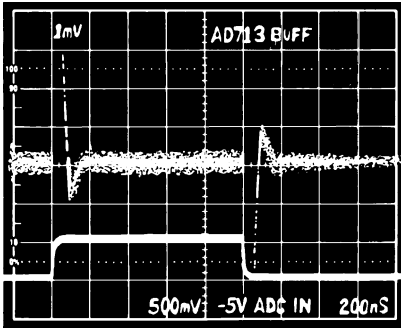


Figure 13. Buffer Recovery Time Sink Current = 1 mA

Driving A Large Capacitive Load

The circuit of Figure 14 employs a 100 Ω isolation resistor which enables the amplifier to drive capacitive loads exceeding 1500 pF; the resistor effectively isolates the high frequency feedback from the load and stabilizes the circuit. Low frequency feedback is returned to the amplifier summing junction via the low pass filter formed by the 100 Ω series resistor and the load capacitance, C1. Figure 15 shows a typical transient response for this connection.

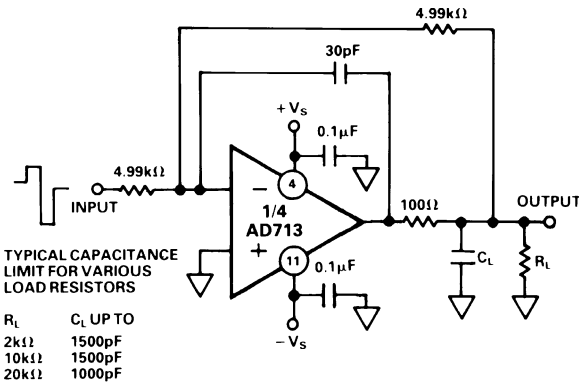


Figure 14. Circuit for Driving a Large Capacitance Load

Table II. Recommended Trim Resistor Values vs. Grades for AD7545 for $V_D = 5$ V

Trim Resistor	JN/AQ/SD	KN/BQ/TD	LN/CQ/UD	GLN/GCQ/GUD
R1	500 Ω	200 Ω	100 Ω	20 Ω
R2	150 Ω	68 Ω	33 Ω	6.8 Ω

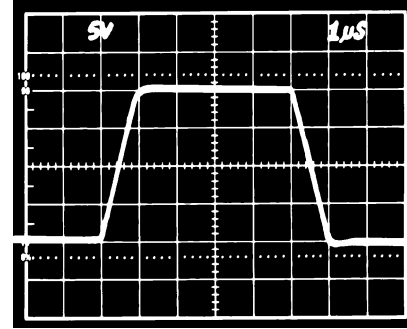


Figure 15. Transient Response, $R_L = 2$ k Ω , $C_L = 500$ pF

CMOS DAC APPLICATIONS

The AD713 is an excellent output amplifier for CMOS DACs. It can be used to perform both 2 and 4 quadrant operation. The output impedance of a DAC using an inverted R-2R ladder approaches R for codes containing many "1"s, 3R for codes containing a single "1" and infinity for codes containing all zeros.

For example, the output resistance of the AD7545 will modulate between 11 k Ω and 33 k Ω . Therefore, with the DAC's internal feedback resistance of 11 k Ω , the noise gain will vary from 2 to 4/3. This changing noise gain modulates the effect of the input offset voltage of the amplifier, resulting in nonlinear DAC amplifier performance. The AD713, with its guaranteed 1.5 mV input offset voltage, minimizes this effect achieving 12-bit performance.

Figures 16 and 17 show the AD713 and a 12-bit CMOS DAC, the AD7545, configured for either a unipolar binary (2-quadrant multiplication) or bipolar (4-quadrant multiplication) operation. Capacitor C1 provides phase compensation which reduces overshoot and ringing.

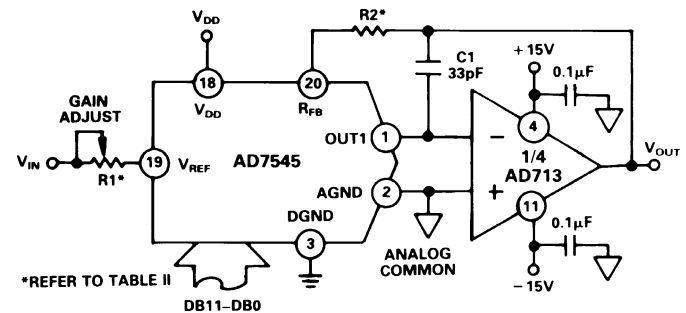


Figure 16. Unipolar Binary Operation

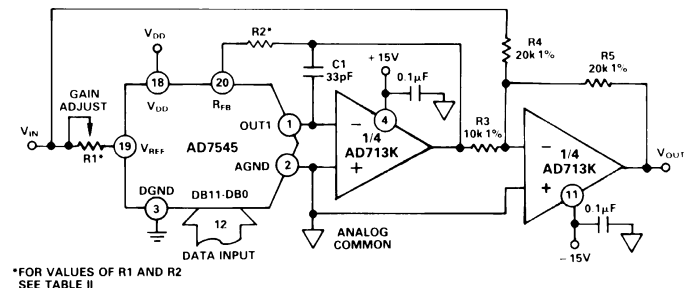


Figure 17. Bipolar Operation



$$C_1 = C_2, R_1 = R_2, R_4 = R_5$$

$$f_c = \frac{1}{2\pi R_1 C_1}$$

$$Q = \frac{R_3}{R_4} \cdot \frac{R_{IF}}{R_{FBB1}}$$

$$A_O = - \frac{R_F}{R_S}$$

DAC equivalent resistance equals
 $256 \times (\text{DAC Ladder resistance})$

DAC Digital Code

Figure 18. A Programmable State Variable Filter Circuit

A Programmable State Variable Filter

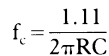
This filter provides low pass, high pass and band pass outputs and is ideally suited for applications where microprocessor control of filter parameters is required. The programmable range for component values shown is $f_c = 0$ to 15 kHz and $Q = 0.3$ to 4.5.

The closely matched and uniform ac characteristics of the AD713 make it ideal for use in GIC (gyrator) and FDNR (frequency dependent negative resistor) filter applications. Figures

Figure 21 shows a 7-pole antialiasing filter for a $2 \times$ oversampling (88.2 kHz) digital audio application. This filter has <0.05 dB pass band ripple and $19.8 \pm 0.3 \mu\text{s}$ delay, dc-20 kHz and will handle a 5 V rms signal ($V_S = \pm 15$ V) with no overload at any internal nodes.

$$f_C = \frac{1.11}{2\pi RC}$$

where all resistors and capacitors scale equally. Resistors R3–R8 should not be greater than 2 k Ω in value, to prevent parasitic oscillations caused by the amplifier's input capacitance.



$$C_1 = C_2 = C_3 = C_4 = C$$

$$R_1 = R_2 = 4.76R$$

$$R_{11} = 4.32R$$

$$R_3 = R_4 = R_5 = R_6 = R_7 = R_8 = R_9 = R_{10} = R$$

Figure 19. A 1/3 Octave Filter Circuit

AD713

If this is not practical, small lead capacitances (10–20 pF) should be added across R5 and R6. Figures 20 and 22 show the output amplitude vs. frequency of these filters.

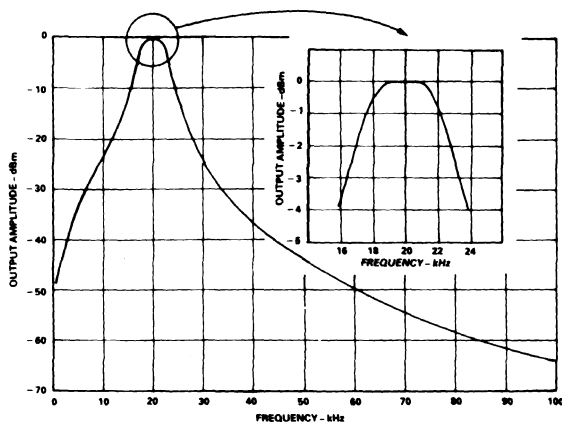


Figure 20. Output Amplitude vs. Frequency of 1/3 Octave Filter

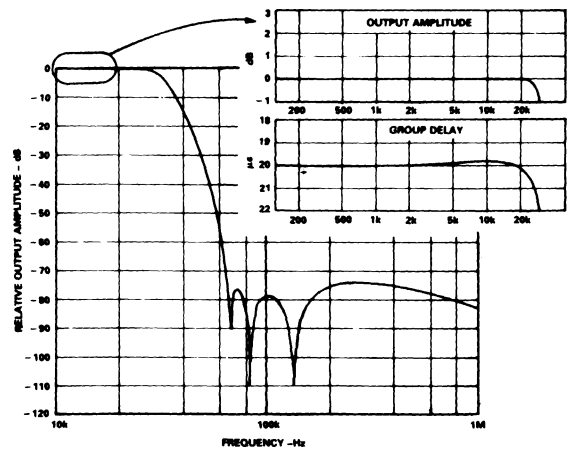


Figure 22. Relative Output Amplitude vs. Frequency of Antialiasing Filter

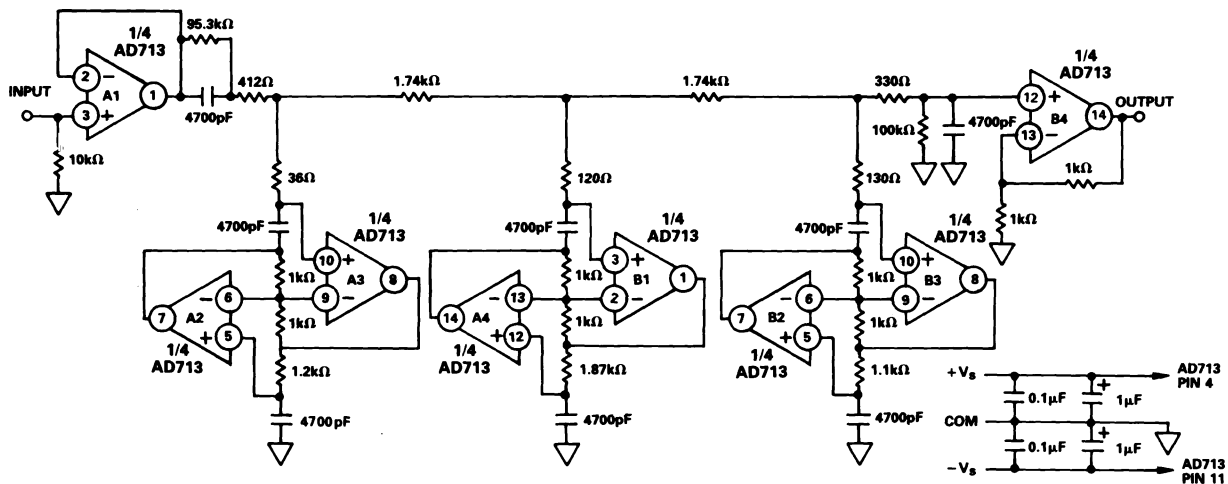
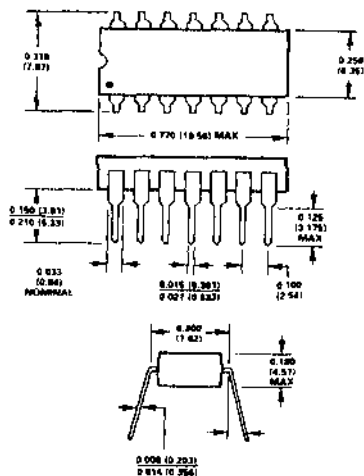


Figure 21. An Antialiasing Filter

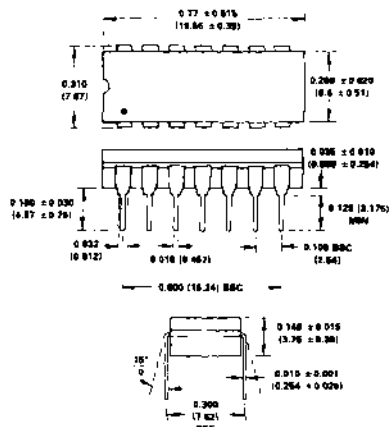
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

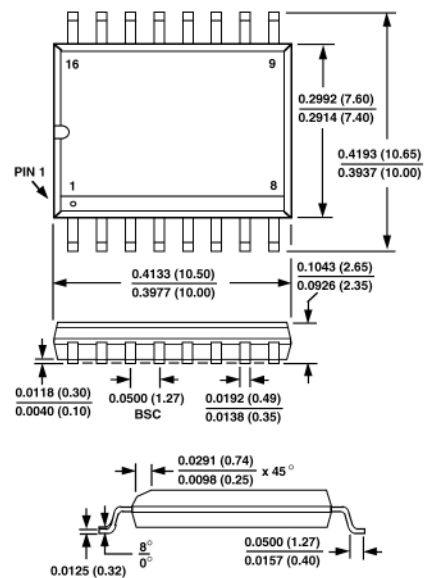
14-Pin Plastic (N-14A) DIP Package



14-Pin Cerdip (Q-14) Package



16-Pin SOIC (R-16) Package



Revision History

Location	Page
10/01—Data Sheet changed from REV. B to REV. C.	
Edits to FEATURES	1
Edits to PRODUCT DESCRIPTION	1
Edits to ORDERING GUIDE	3
Edits to METALLIZATION PHOTOGRAPH	3

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