

# HD44231P, HD44232P, HD44233P, HD44234P

## Single Chip CODEC with Filters (COMBO)

### Features

- Single Chip CMOS CODEC with Filter In 16-pins DIL Package
- Power Supply Voltage  $\pm 5\text{ V} \pm 5\%$ , Low Power Dissipation (50 mW Typ)
- Follows A-Law (HD44231P, HD44233P)
- Follows  $\mu$ -Law (HD44232P, HD44234P)
- Exceeds CCITT Specifications & D4
- Synchronous (All Devices)/Asynchronous (HD44233P, HD44234P Only) Operation for 2048/1544/1536 kHz PCM Rate
- Internal Clock Generator
- Anti-Aliasing Filter (2nd order CR Active Filter)
- Voltage Reference (Internal-Trimmed)
- Input Amplifier
- Auto-Zero Cancel Circuit Without External Component

### Pin Configuration

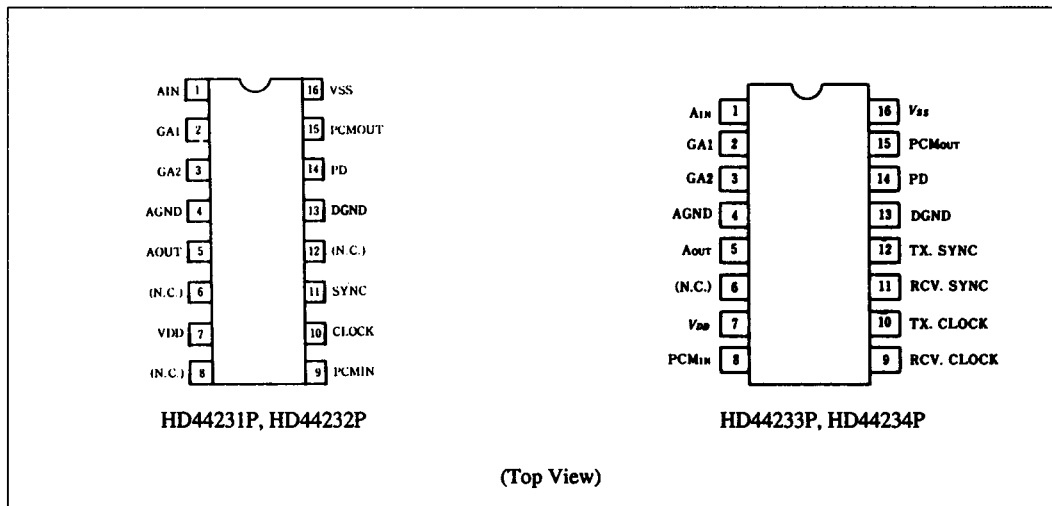


Figure 1 Pin Assignment

### Packaging Information

Part No.	Package
HD44231P	DP-16A
HD44232P	DP-16A
HD44233P	DP-16A
HD44234P	DP-16A

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### References

## **General Description**

The HD44231P, HD44232P, HD44233P, HD44234P are monolithic silicon gate CMOS Companding Encoder/Decoder chips designed to implement the per channel voice frequency Codecs used in PCM systems. The chips contain the band limiting filters and the analog/digital conversion circuits that conform to the A-law or  $\mu$ -Law companding characteristic.

HD44231P and HD44233P are A-Law. HD44232P and HD44234P are  $\mu$ -Law.

These circuits provide the interface between the analog signals of the subscriber loop and digital signals of the PCM highway in a digital telephone switching system. The devices operate from dual power supplies of  $\pm 5$  V.

For a sampling rate of 8 kHz, PCM input/output data rate can be selected from 1536/1544/2048 kHz in synchronous or asynchronous (HD44233, HD44234 only) operation.

## **Functional Description**

Figure 2 shows the simplified block diagram of the HD44231P, HD44232P, HD44233P and HD44234P. The dotted lines are connected internally to get the synchronous devices (HD44231P, HD44232P). The devices contain independent circuitry for processing transmit and receive signals. Switched capacitor filters provide the necessary bandwidth limiting of voice signals in both directions. Circuitry for coding and decoding operates on the principle of successive approximation, using charge redistribution in a binary weighted capacitor array to define segments and a resistor chain to define steps. The relationship between the PCM data word and the audio signal is defined just same as CCITT G711 Table 1 for HD44231P and HD44233P, Table 2 for HD44232P and HD44234P respectively.

A band-gap voltage generator supplies the reference level for the conversion process. 2nd Order CR Active Filter is implemented on chip to avoid the aliasing noise which is caused by the clock of transmit filter.

## **Transmit Section**

Input analog signals first enter the chip at the uncommitted amplifier terminals. This op amp allows gain trim to be used if desired to set the 0 dB or 0 level in the system. This amplifier also operates as the 2nd order analog anti-aliasing filter. This filter eliminates the need for any off-chip filtering as it provides attenuation of 32 dB (typ) at 256 kHz and 40 dB (typ) at 512 kHz, the "effective" clock frequency of the following switched-capacitor Cosine Filter. From the Cosine Filter the signal enters a 5th Order Low-Pass Filter clocked at 128 kHz, followed by a 3rd Order High-Pass Filter clocked at 8 kHz. The resulting band-pass characteristics meet the CCITT, G.712 specifications. The output of the high pass filter is sampled by a capacitor array at the sampling rate of 8 kHz. The 8-bit PCM data is clocked out by the shift clock at one of 1536/1544/2048 kHz. A auto-zero loop (without any external capacitor) provides DC offset cancellation by integrating the sign bit of the PCM data and feeding it back to the non-inverting input of the comparator.

An additional feature of the HD44231P and HD44233P is a signbit fixation circuit to reduce the idle channel noise during quiet periods. It is of particular importance because the A-Law transfer characteristic has "mid-riser" bias which enhances low level signals from crosstalk.

## **Receive Section**

A shift clock, at one of 1536/1544/2048 kHz, clock the PCM data into the input buffer register once every sampling period. A charge proportional to the received PCM data word appears on the decoder capacitor array. A sample and hold initialized to zero by a narrow pulse at the beginning of each sampling period integrates the charge and holds for the rest of the sampling period. A switched-capacitor 5th Order Low-Pass Filter clocked at 128 kHz smooths the sampled and held signal. It also performs the loss equalization to compensate for the  $\sin x/x$  distortion due to the sample and hold operation. The filter output is available for driving electronic hybrids directly as long as the impedance is greater than 600  $\Omega$ .

## **Companding Law**

The encoding and decoding characteristics of the Codecs comply with the requirements of CCITT G711 table

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1 or Table 2, corresponding to their comparing law. The even bits of PCM words are inverted for A-Law devices. Positive logic is used (the High level corresponds to '1').

#### **Power Down Logic**

Powering down the CODEC can be done in several ways. The most direct method is to drive the PD pin to a low level. Stopping SYNC input will also put the chip into the stand-by mode. The input can be held high, low or disconnected. After the chip being activated by these functions, the PCMOUT is in high impedance state and the AOUT is connected to AGND for about 1 ms to avoid the power-on noise.

#### **Voltage Reference Circuit**

A temperature compensated band-gap voltage generator provides a stable reference for the coder and decoder. Two amplifiers buffer the reference and supply it to the coder and decoder independently to minimize crosstalk. This reference voltage is trimmed to ensure a minimum gain error of  $\pm 0.1$  dB at the nominal power supply voltage and the room temperature.

#### **Timing Requirements**

The CODECs do not require that the 8 kHz transmit and receive sampling strobes should be exactly 8 bit periods wide. The device has an internal bit counter that counts the number of data bits shifted. It is reset on the leading (+) edges of the strobe, forcing the PCM output in a high impedance state after the 8th bit is shifted out. This allows the strobe signal to have any duty cycle as long as its repetition rate is 8 kHz and shift clock is synchronized to it. The clock rate can be selected from 1536/1544/2048 kHz.

#### **System Clock**

The basic timing of the Codecs is provided by the shift clock.

This 1.536/1.544/2.048 MHz clock is divided down internally to provide the various filter clocks and the timing for the conversions. No external control signal for the selection is required.

**Pin/Function Descriptions**

Pin	No	Descriptions
* CLOCK	10	One of 1.536, 1.544, 2.048 MHz clock can be accepted with the pins. And they are automatically divided down to provide the internal clocks.
**TX.CLOCK	9	These TTL compatible inputs shift PCM data out of the coder on the positive going edges and PCM data into the decoder on the negative going edges after receiving a positive edge on the SYNC, TX.SYNC/RCV.SYNC respectively.
RCV.CLOCK	10	
* SYNC	11	These TTL compatible pulse inputs (Typ 8 kHz) are used for analog sampling and for initiating the PCM output from the coder and initiate clocking of PCM input data into the decoder. They must be synchronized with the CLOCK, TX.CLOCK/RCV.CLOCK with these positive going edges occurring after the falling edge of the CLOCK, TX.CLOCK/RCV.CLOCK respectively. The width of these signals are not critical. An internal bit counter generates the necessary timing for PCM output and input.
**TX.SYNC	11	
RCV.SYNC	12	
PCMOUT	15	This is a LS-TTL compatible open-drain output. It is active only during transmission of PCM output for 8 bit periods of CLOCK, TX.CLOCK/RCV.CLOCK signal following a positive edge on the SYNC, TX.SYNC/RCV.SYNC input. Data is clocked out by the positive edge of the CLOCK. One 500 $\Omega$ pull-up per 8 Codecs is required.
* PCMIN	9	This is a TTL compatible input for supplying PCM input data to the decoder. Data is clocked in by the negative edge of CLOCK, RCV.CLOCK.
**PCMIN	8	
AIN	1	These three pins are provided for connecting analog signals in the range of $-V_{REF}$ to $+V_{REF}$ to the device. The input stage can be connected as a unity gain amplifier, amplifier with gain or amplifier with adjustable gain. The adjustable gain configuration will facilitate calibration of the transmit channel. AIN is the input of analog signal of the amplifier. GA2 is the output of the amplifier. GA2 shall be loaded by the resistor above 10 k $\Omega$ or directly connected to GA1. GA1 is the negative feed back input of the amplifier. $C_L$ should be less than 100 pF.
GA1	2	
GA2	3	
AOUT	5	This is the buffered output of the recreated analog signal from the received PCM data words. It can drive the impedance of 600 ohms. $C_L$ should be less than 100 pF.
VDD	7	These are power supply pins. VDD and VSS are positive and negative supply pins respectively (Typ +5 V, -5 V). Analog and digital ground pins are separate for minimizing crosstalk.
VSS	16	
AGND	4	
DGND	13	
PD	14	When this TTL compatible input is held low, the chip is put into the powered down mode regardless of strobes. The chip will also power down if the strobes stop. The strobes can be high, low or floating, but as long as they are static, the powered down mode is in effect.  This pin should be pulled-up to VDD to keep the device active or to control On/Off with strobes.

\* : for HD44231P, HD44232P

\*\* : for HD44233P, HD44234P

# HD44231P/HD44232P/HD44233P/HD44234P

## Absolute Maximum Ratings

Item	Rating
V <sub>DD</sub>	-0.3 to +7 V
V <sub>SS</sub>	+0.3 to -7 V
Storage Temperature	-55°C to +125°C
Power Dissipation	0.5 W
Digital Input/Output Voltage	-0.3 V < V <sub>IN</sub> < V <sub>DD</sub> + 0.3
Analog Input/Output Voltage	V <sub>SS</sub> - 0.3 V < V <sub>IN</sub> < V <sub>DD</sub> + 0.3

## Electrical Characteristics

Static Characteristics (V<sub>DD</sub> = 5 ± 0.25 V, V<sub>SS</sub> = -5 ± 0.25 V, V<sub>CC</sub> = 5 ± 0.25 V, T<sub>a</sub> = 0-70°C)

Symbol	Pin	Pin	Descriptions	Min	Typ	Max	Unit	Note/Conditions
	HD44231P	HD44233P						
	HD44232P	HD44234P						
I <sub>DD</sub>	7	7	V <sub>DD</sub> Current (OPE.)		5.5	10	mA	Note 1)
I <sub>SS</sub>	16	16	V <sub>SS</sub> Current (OPE.)	-10	-4.5			A <sub>IN</sub> = 0 V
I <sub>DDST</sub>	7	7	V <sub>DD</sub> Current (St.By.)		0.3	1		PCMIN = +0 CODE
I <sub>SSST</sub>	16	16	V <sub>SS</sub> Current (St.By.)	-0.2				R <sub>L</sub> (GA2) = 10 kΩ R <sub>L</sub> (AOUT) = 600 kΩ
I <sub>L</sub>	1, 2, 9, 10, 14	1, 2, 8, 9, 10, 14	LEAK Current	-10.0		10.0	μA	V <sub>M</sub> = 0.8 V
				-10.0		10.0	μA	V <sub>M</sub> = 2.0 V
						10.0	μA	V <sub>DD</sub> = V <sub>M</sub> = 5.25 V
I <sub>PL</sub>	11	11, 12	Pull Up Current	-100		0	μA	
I <sub>DL</sub>	15	15	Leak Current			10.0	μA	V <sub>DD</sub> = V <sub>M</sub> = 5.25 V
C <sub>AIN2</sub>	1, 2	1, 2	Analog Input Cap.			10	pF	at 1 MHz V <sub>bias</sub> = 0 V
C <sub>DIN</sub>	9, 10, 11, 14	8, 9, 10, 11, 12, 14	Input Capacitance			10	pF	at 1 MHz V <sub>bias</sub> = 0 V
R <sub>OUTA</sub>	5	5	AOUT Resistance		1	10	Ω	
R <sub>OUTG</sub>	3	3	GA2 Resistance			30	Ω	Note 1
V <sub>GSW</sub>	3	3	GA2 Output Swing	-3.0		3.0	V	R <sub>L</sub> = 10 kΩ
V <sub>OFFIN</sub>	1	1	Analog Offset Input	-500		500	mV	Note 1
V <sub>OFFG</sub>	3	3	GA2 Offset Output	-50		50	mV	Note 1
V <sub>OFFA</sub>	5	5	AOUT Offset Output	-50		50	mV	PCMIN = +0 - Code
C <sub>DOUT</sub>	15	15	PCMOUT Capacitance			15.0	pF	at 1 MHz V <sub>bias</sub> = 0 V
V <sub>OL</sub>	15	15	PCMOUT Low Voltage			0.4	V	R <sub>L</sub> = 500 Ω +I <sub>OL</sub> = 0.8 mA
V <sub>OH</sub>	15	15	PCMOUT High Voltage	V <sub>CC</sub> -0.3			V	I <sub>OH</sub> = -150 mA
V <sub>IH</sub>	10, 11, 9, 14	8, 10, 11, 9, 12, 14	Digital Input High Voltage	2.0			V	
V <sub>IL</sub>	10,11 9,14	8, 10, 11, 9, 12, 14	Digital Input Low Voltage			0.8	V	

Note 1) Analog Input Amplifier Gain = 0 dB (Ga1 is connected to GA2)

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**Dynamic Characteristics** ( $V_{DD} = 5 \pm 0.25$  V,  $V_{SS} = -5 \pm 0.25$  V,  $V_{CC} = 5 \pm 0.25$  V,  $T_a = 0$  to  $+70^\circ\text{C}$ )

Sym.	Descriptions	Min	Typ	Max	Unit	Note
FS	Synchronization Rate		8		kHz	
FC	PCM Bit Clock Rate		1536/ 1544/ 2048		kHz	
twc	Clock Pulse Width	200			ns	
twsH	SYNC Pulse High Width	200			ns	
twsL	SYNC Pulse Low Width	8			$\mu\text{s}$	
tr	Logic Input Rise Time	5		50	ns	
tf	Logic Input Fall Time	5		50	ns	
tacs	Previous Clock To SYNC Delay	40			ns	Note 1
tcs	Clock To SYNC Delay			100	ns	Note 1, 3
tcd1	Clock To PCM MSB Delay			170	ns	Note 1, 2, 4
tsd	SYNC To PCM MSB Delay			170	ns	Note 1, 2, 4
tcd	Clock To PCMOUT Delay			180	ns	Note 1, 2, 5
tsu	PCMIN Setup Time	65			ns	Note 1
thd	PCMIN Hold Time	120			ns	Note 1

- Notes
- 1) tr, tf of digital input or clock is assumed 5ns for timing measurement.
  - 2) PCMOUT Load Condition:  $500\ \Omega + 165\ \text{pF} +$  two LS-TTL Equivalent ( $I_{IL} = 0.8\ \text{mA}$ ,  $I_{IH} = -150\ \mu\text{A}$ ) Threshold Level ( $V_{OH} = 2.4\ \text{V}$ ,  $V_{OL} = 0.4\ \text{V}$ )
  - 3) Positive value shows SYNC delay from CLOCK.
  - 4) tcd1, tsd are specified by CLOCK or SYNC which has slower rise time.
  - 5) tcd specification is valid for the data except MSB.

**System Related Characteristics** ( $V_{DD} = 5 \pm 0.25$  V,  $V_{SS} = -5 \pm 0.25$  V,  $V_{CC} = 5 \pm 0.25$  V,  $T_a = 0$  to  $+70^\circ\text{C}$ , Input Amplifier Gain = 0 dB, GA2 Load = 10 k $\Omega$ , Aout Load = 600  $\Omega$ , Synchronous operation. FC (PCM Bit Clock) = 2048 kHz)

**For HD44231P, HD44233P**

Sym	Descriptions	Test Conditions	Min	Typ	Max	Unit	Note
SDA	Signal to Dist (A to A)	820 Hz tone	-45 dBm0	25		dB	p-wgt
			-40	30		dB	
			-30 to +3	35		dB	
SNA	Signal to Dist (A to A)	Noise	-55 dBm0	14		dB	
			-40	29		dB	
			-34	34		dB	
			-27 to -6	36		dB	
			-3	28		dB	
SDX	Signal to Dist (A to D)	820 Hz tone	-45 dBm0	26		dB	p-wgt
			-40	31		dB	
			-30 to +3	36		dB	
SNX	Signal to Dist (A to D)	Noise	-55 dBm0	15		dB	
			-40	30		dB	
			-34	35		dB	
			-27 to -6	37		dB	
SDR	Signal to Dist (D to A)	820 Hz tone	-45 dBm0	26		dB	p-wgt
			-40	31		dB	
			-30 to +3	36		dB	

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Sym.	Descriptions	Test Conditions	Min	Typ	Max	Unit	Note
SNR	Signal to Dist (D to A)	Noise	-55 dBm0	15		dB	
			-40	30		dB	
			-34	35		dB	
			-27 to -6	37		dB	
GTA	Gain Track (A to A)	820 Hz tone Relative to -10 dBm0	-55 to -50	-1.0	1.0	dB	
			-50 to -40	-0.5	0.5	dB	
			-40 to +3	-0.3	0.3		
GNA	Gain Track (A to A)	Noise Relative to -10 dBm0	-60 to	-0.8	0.8	dB	
			-55 dBm0				
			-55 to -10	-0.4	0.4	dB	
GTX	Gain Track (A to D)	820 Hz tone Relative to -10 dBm0	-55 to -50	-0.8	0.8	dB	
			-50 to -40	-0.4	0.4	dB	
			-40 to	-0.2	0.2	dB	
			+3 dBm0				
GNX	Gain Track (A to D)	Noise Relative to -10 dBm0	-60 to	-0.6	0.6	dB	
			-55 dBm0				
			-55 to -40	-0.4	0.4	dB	
			-40 to -10	-0.2	0.2	dB	
GTR	Gain Track (D to A)	820 Hz tone Relative to -10 dBm0	-55 to -50	-0.8	0.8	dB	
			-50 to -40	-0.4	0.4	dB	
			-40 to	-0.2	0.2	dB	
			+3 dBm0				
GNR	Gain Track (D to A)	Noise Relative to -10 dBm0	-60 to	-0.4	0.4	dB	
			-55 dBm0				
			-55 to -10	-0.2	0.2	dB	
FRX	Freq. Response (A to D) (Loss)	Relative to 820 Hz 0dBm0	0.06 kHz	24		dB	
			0.2	0	2.0		
			0.3 to 3	-0.15	0.15		
			3.18	-0.15	0.65		
			3.4	0	0.8		
			3.78	6.5			
FRR	Freq. Response (D to A) (Loss)	Relative to 820 Hz 0 dBm0	0 to 3 kHz	-0.15	0.15	dB	
			3.18	-0.15	0.65		
			3.4	0	0.8		
			3.78	6.5			
AIL	Analog Input Level	820 Hz 0 dBm0	25°C nom.P.S.	1.217	1.231	1.246	Vrms
AOL	Analog Output Level	820 Hz 0 dBm0	25°C nom. P.S.	1.217	1.231	1.246	Vrms
ICNA	Idle Ch. Noise	A to A	AIN = AGND			-78	dBmOP
ICNX	Idle Ch. Noise	A to D	AIN = AGND			-80	dBmOP
ICNR	Idle Ch. Noise	D to A	PCMIN = +0-CODE			-81	dBmOP
XTKA	AIN to AOUT Crosstalk	820 Hz	0 dBm0			-65	dB
XTKD	PCMIN to PCMOUT	820 Hz	0 dBm0			-65	dB

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For HD44232P, HD44234P

Sym.	Descriptions	Test Conditions		Min	Typ	Max	Unit	Note
SDA	Signal to Dist (A to A)	1020 Hz tone	-45 dBm0	25			dB	c-wgt
			-40	30			dB	
			-30 to +3	35			dB	
SDX	Signal to Dist (A to D)	1020Hz tone	-45 dBm0	26			dB	c-wgt
			-40	31			dB	
			-30 to +3	36			dB	
SDR	Signal to Dist (D to A)	1020 Hz tone	-45 dBm0	26			dB	c-wgt
			-40	31			dB	
			-30 to +3	36			dB	
GTA	Gain Tracking (A to A)	1020 Hz tone	-55 to -50 dBm0	-1.0		1.0	dB	
		Relative to	-50 to -40	-0.5		0.5	dB	
		-10 dBm0	-40 to +3	-0.3		0.3	dB	
GTX	Gain Tracking (A to D)	1020 Hz tone	-55 to -50	-0.8		0.8	dB	
		Relative to	-50 to -40	-0.4		0.4	dB	
		-10 dBm0	-40 to +3 dBm0	-0.2		0.2	dB	
GTR	Gain Tracking (D to A)	1020 Hz tone	-55 to -50	-0.8		0.8	dB	
		Relative to	-50 to -40	-0.4		0.4	dB	
		-10 dBm0	-40 to +3 dBm0	-0.2		0.2	dB	
FRX	Freq.Response (A to D)(Loss)	Relative to 1020 Hz 0 dBm0	0.06 kHz	24				dB
			0.2	0		2.0		
			0.3 to 3	-0.15		0.15		
			3.18	-0.15		0.65		
			3.4	0		0.8		
FRR	Freq.Response (D to A) (Loss)	Relative to 1020 Hz 0 dBm0	3.78	6.5				dB
			0 to 3 kHz	-0.15		0.15		
			3.18	-0.15		0.65		
			3.4	0		0.8		
AIL	Analog Input Level	1020 Hz 0 dBm0	25°C nom. P.S.	1.213	1.227	1.241	Vrms	
AOL	Analog Output Level	1020 Hz 0 dBm0	25°C nom. P.S.	1.213	1.227	1.241	Vrms	
ICNA	Idle Ch. Noise	A to A	AIN = AGND			15	dBmCO	
ICNX	Idle Ch. Noise	A to D	AIN = AGND			15	dBmCO	
ICNR	Idle Ch. Noise	D to A	PCMIN = +0-Code			9	dBmCO	
XTKA	AIN to AOUT Crosstalk	1020Hz 0 dBm0				-65	dB	
XTKD	PCMIN to PCMOUT	1020 Hz 0 dBm0				-65	dB	

# HD44231P/HD44232P/HD44233P/HD44234P

## For HD44231P, HD44232P, HD44233P, HD44234P

Sym.	Descriptions	Test Conditions		Min	Typ	Max	Unit	Note
AT	AIL, AOL Variation with temp.	Relative to 25°C nominal P.S.		±20		ppm/°C		
AP	AIL,AOL Variation with P.S.	25°C, Supplies ± 5%			± 0.01		dB	
ALS	Gain Variation over Temp. P.S.	A to D D to A	Initial	-0.2		0.2	dB	Note 1)
AIP	Peak Analog Input			3.0			V	
AOP	Peak Analog Output			2.5			V	
PDL	Propagation Delay	A to A	0 dBmO		450	480	μs	
DD	Delay Distortion	A to A 0 dBmO	0.5 to			1.4		
			0.6 kHz					
			0.6 to 1.0			0.7	ms	rel. to min. delay
			1.0 to 2.6			0.2		
PSRR	PSRR	A to A AIN = AGND 0.3 – 50 kHz	2.6 to 2.8			1.4		
			V <sub>DD</sub> Mod. =	30			dB	
			+5 V + 100 mVop					
			V <sub>SS</sub> Mod. =					
IM1	Intermodulation	A to A(2a-b) a; 0.47 kHz, -4 dBmO b; 0.32, -4	-5 V + 100 mVop	30				
IM2	Intermodulation	A to A(a-b) a; 1.02 kHz, -4 dBmO b; 0.05, -23						
ICS	Single Freq.Noise	A to A AIN = AGND	8,16,24, 32,40 kHz			-50	dBmO	
DIS	Discrimination	A to A 0 dBmO	4.6 to 200 kHz	30			dB	

Note 1) Total variation of GAIN including the initial fluctuation temperature variation and power supply dependence (0 to 70°C, V<sub>DD</sub>/V<sub>SS</sub> = ± 5 V ± 5%)

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