

# TDA9901

Wideband differential digital controlled variable gain amplifier

Rev. 04 — 14 August 2008

Product data sheet

## 1. General description

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The TDA9901 is a wideband, low-noise amplifier with differential inputs and outputs. The TDA9901 incorporates an Automatic Gain Control (AGC) function with digital control. The TDA9901 is optimized for fast switching between different gain settings, preserving small phase and amplitude error.

The TDA9901 presents an excellent combination of low noise and good linearity for a wide input frequency range. The TDA9901 is optimized for processing Input Frequency (IF) signals. It is also suited for many other applications as a general purpose digitally controlled variable gain amplifier.

The TDA9901 is able to operate from 4.75 V to 5.25 V supply for the analog part and from 3.0 V to 5.25 V for the digital part.

## 2. Features

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- 130 MHz, -3 dB small signal bandwidth
- Digitally controlled gain
- Transistor-Transistor Logic (TTL) and CMOS compatible digital inputs (3.3 V or 5 V)
- TTL single-ended or differential clock input with Positive Emitter-Coupled Logic (PECL) compatibility
- 24 dB gain control range
- Four steps of 6 dB plus 6 dB fixed gain
- 30 dB gain maximum
- High impedance differential inputs
- Low impedance differential inputs
- High power supply rejection
- 125 nV/ $\sqrt{\text{Hz}}$  output voltage noise density at 30 dB gain
- Fast gain settling
- Dual control modes: transparent or latched

## 3. Applications

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- Linear AGC systems
- Wireless infrastructure
- Fixed network
- Instrumentation
- Multipurpose amplifier
- Driver for differential ADCs (e.g. ADC1206S040/055/070 and ADC1006055/070)

## 4. Quick reference data

**Table 1. Quick reference data**

$V_{DDA} = V11$  to  $V12 = 4.75$  V to 5.25 V;  $V_{DDD} = V18$  to  $V17 = 3.0$  V to 5.25 V;  $V_{SSA}$  and  $V_{SSD}$  shorted together;  $T_{amb} = -40$  °C to +85 °C; typical values measured at  $V_{CCA} = 5.0$  V;  $V_{CCD} = 3.3$  V and  $T_{amb} = 25$  °C unless otherwise specified [1].

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{DDA}$	analog supply voltage		4.75	5.0	5.25	V
$V_{DDD}$	digital supply voltage		3.0	3.3	5.25	V
$I_{DDA}$	analog supply current		-	30	36	mA
$I_{DDD}$	digital supply current		-	3.0	5.0	mA
$G_{min}$	minimum gain	DC input:				
		$T_{amb} = 25$ °C	5.78	6.11	6.40	dB
		all temperatures	5.7	6.11	6.46	dB
$G_{max}$	maximum gain	DC input:				
		$T_{amb} = 25$ °C	29.9	30.5	30.9	dB
		all temperatures	29.3	30.5	31.5	dB
$B_{-3dB}$	-3 dB bandwidth	$V_{o(dif)(p-p)} = 0.125$ V; $T_{amb} = 25$ °C	110	130	-	MHz
$P_{tot}$	total power dissipation		-	160	216	mW

[1] Due to on-chip regulator behavior a warm-up time of 1 minute (typical) is recommended for optimal performance.

## 5. Ordering information

**Table 2. Ordering information**

Type number	Package		
	Name	Description	Version
TDA9901TS	SSOP20	plastic shrink small outline package; 20 leads; body width 4.4 mm	SOT266-1

6. Block diagram

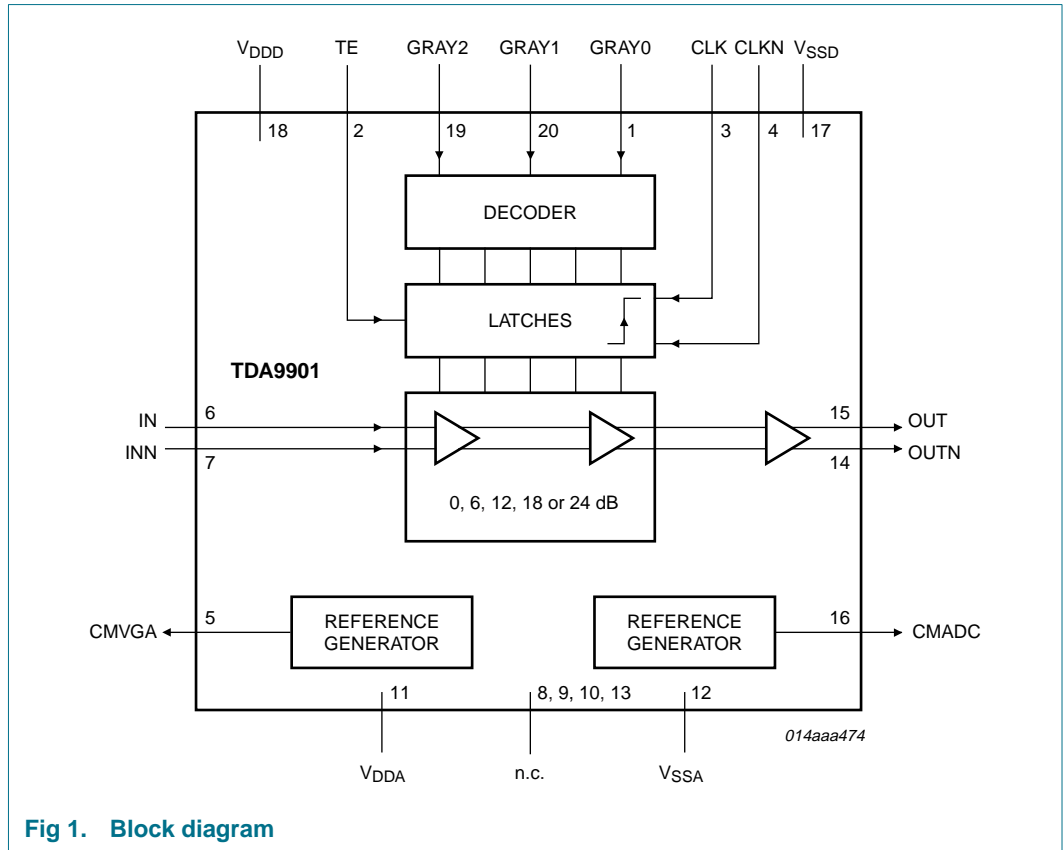


Fig 1. Block diagram

## 7. Pinning information

### 7.1 Pinning

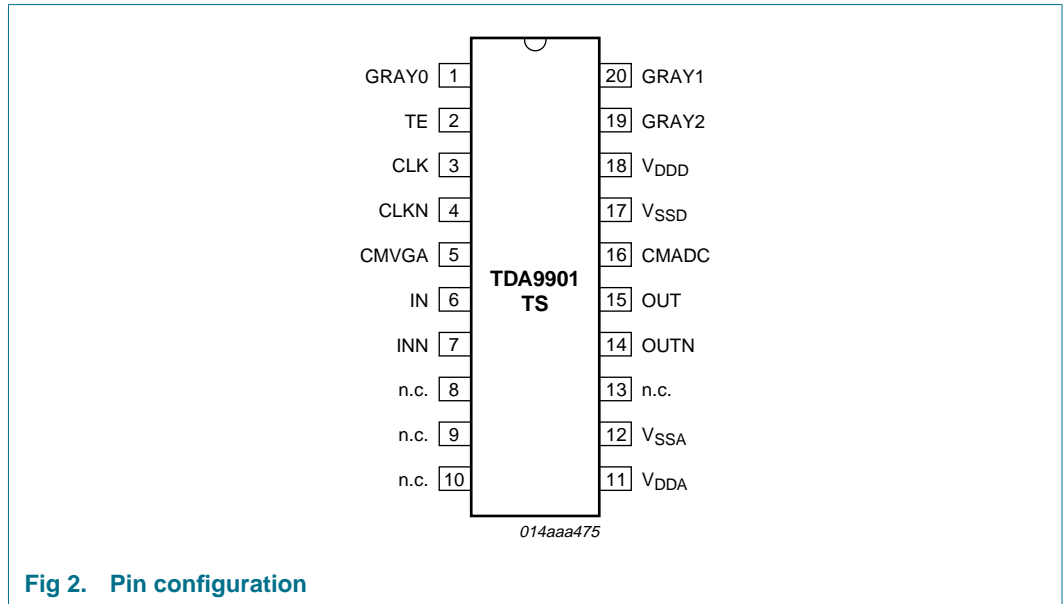


Fig 2. Pin configuration

### 7.2 Pin description

Table 3. Pin description

Symbol	Pin	Description
GRAY0	1	digital control signal bit 0 input (Least Significant Bit (LSB))
TE	2	transparent enable input
CLK	3	clock input for gain control setting
CLKN	4	inverting clock input for gain control setting (active LOW)
CMVGA	5	regulator output common mode VGA input
IN	6	non-inverting analog input
INN	7	inverting analog input (active LOW)
n.c.	8	not connected
n.c.	9	not connected
n.c.	10	not connected
V <sub>DDA</sub>	11	analog supply voltage
V <sub>SSA</sub>	12	analog ground
n.c.	13	not connected
OUTN	14	inverting analog output (active LOW)
OUT	15	non-inverting analog output
CMADC	16	regulator output common mode ADC input
V <sub>SSD</sub>	17	digital ground

**Table 3.** Pin description ...continued

Symbol	Pin	Description
V <sub>DDD</sub>	18	digital supply voltage
GRAY2	19	digital control signal bit 2 input (Most Significant Bit (MSB))
GRAY1	20	digital control signal bit 1 input

## 8. Functional description

The TDA9901 provides a digitally controlled variable gain function for high-frequency applications.

The TDA9901 can be operated in two different modes, depending on the value at pin TE. When TE is at logic 1, the gain can be instantly controlled when the clock signal is HIGH (transparent mode). The gain is fixed during the LOW period of the clock. When TE is at logic 0 the gain of the TDA9901 is changed at the rising edge of the clock signal.

## 9. Limiting values

**Table 4.** Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
V <sub>DDA</sub>	analog supply voltage		-0.3	+7.0	V
V <sub>DDD</sub>	digital supply voltage		-0.3	+7.0	V
$\Delta V_{DD}$	supply voltage difference	V <sub>DDA</sub> - V <sub>DDD</sub>	-0.1	+4.0	V
V <sub>I</sub>	input voltage		-0.3	+7.0	V
I <sub>O</sub>	output current		-	10	mA
T <sub>stg</sub>	storage temperature		-55	+150	°C
T <sub>amb</sub>	ambient temperature		-40	+85	°C
T <sub>j</sub>	junction temperature		-	150	°C

## 10. Thermal characteristics

**Table 5.** Thermal characteristics

Symbol	Parameter	Conditions	Value	Unit
R <sub>th(j-a)</sub>	thermal resistance from junction to ambient	in free air	120	K/W

## 11. Characteristics

**Table 6. Characteristics**

$V_{DDA} = V11$  to  $V12 = 4.75$  V to 5.25 V;  $V_{DDD} = V18$  to  $V17 = 3.0$  V to 5.25 V;  $V_{SSA}$  and  $V_{SSD}$  shorted together;  $T_{amb} = -40$  °C to +85 °C; typical values measured at  $V_{CCA} = 5.0$  V;  $V_{CCD} = 3.3$  V and  $T_{amb} = 25$  °C unless otherwise specified [1].

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Supplies</b>						
$V_{DDA}$	analog supply voltage		4.75	5.0	5.25	V
$V_{DDD}$	digital supply voltage		3.0	3.3	5.25	V
$\Delta V_{DD}$	supply voltage difference	$V_{DDA} - V_{DDD}$	-0.2	-	+2.5	V
$I_{DDA}$	analog supply current		-	30	36	mA
$I_{DDD}$	digital supply current		-	3.0	5.0	mA
$P_{tot}$	total power dissipation		-	160	216	mW
<b>Variable gain amplifier transfer characteristics</b>						
$B_{-3dB}$	-3 dB bandwidth	$V_{o(dif)(p-p)} = 0.125$ V; $T_{amb} = 25$ °C	110	130	-	MHz
$t_{d(grp)}$	group delay time	up to $f_i = 20$ MHz; minimum gain; $T_{amb} = 25$ °C	-	2.5	-	ns
$\Delta t_{d(grp)}$	group delay time variation	6 dB gain step; $T_{amb} = 25$ °C	-	-	300	ps
$t_s$	settling time	10 % to 90 % maximum output transition; $C_{L(max)} = 5$ pF on each output; $T_{amb} = 25$ °C	-	-	3.6	ns
$G_{step}$	step of gain	DC input: $T_{amb} = 25$ °C	5.88	6.09	6.28	dB
		all temperatures	5.6	6.09	6.56	dB
$G_{min}$	minimum gain	DC input: $T_{amb} = 25$ °C	5.78	6.11	6.40	dB
		all temperatures	5.7	6.11	6.46	dB
$G_{max}$	maximum gain	DC input: $T_{amb} = 25$ °C	29.9	30.5	30.9	dB
		all temperatures	29.3	30.5	31.5	dB
$\Delta G/\Delta T$	gain variation with temperature	minimum gain	-	-1.0	-	mdB/°C
		maximum gain	-	-7.5	-	mdB/°C
$\Delta G/\Delta V_{CC}$	gain variation with supply voltage	minimum gain	-	15	25	mdB/V
$\Delta V_{i(offset)}$	offset input voltage variation	6 dB gain step	-	0.8	-	mV
NF	noise figure	$R_s = 100$ $\Omega$ ; $f_i = 20$ MHz				
		minimum gain	-	29.1	-	dB
		maximum gain	-	9.9	-	dB

**Table 6. Characteristics ...continued**

$V_{DDA} = V11$  to  $V12 = 4.75$  V to 5.25 V;  $V_{DDD} = V18$  to  $V17 = 3.0$  V to 5.25 V;  $V_{SSA}$  and  $V_{SSD}$  shorted together;  $T_{amb} = -40$  °C to +85 °C; typical values measured at  $V_{CCA} = 5.0$  V;  $V_{CCD} = 3.3$  V and  $T_{amb} = 25$  °C unless otherwise specified [1].

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{n(o)(eq)}$	equivalent output noise voltage	$R_s = 100 \Omega$ ; $f_i = 20$ MHz; $T_{amb} = 25$ °C				
		$G = 6$ dB	-	75	-	nV/ $\sqrt{\text{Hz}}$
		$G = 12$ dB	-	82	-	nV/ $\sqrt{\text{Hz}}$
		$G = 18$ dB	-	97	-	nV/ $\sqrt{\text{Hz}}$
		$G = 24$ dB	-	91	-	nV/ $\sqrt{\text{Hz}}$
		$G = 30$ dB	-	124	-	nV/ $\sqrt{\text{Hz}}$
PSRR	power supply rejection ratio	minimum gain; $V_{DDA}$				
		0 MHz to 20 MHz	-	57	-	dB
		20 MHz to 100 MHz	-	39	-	dB
		minimum gain; $V_{DDD}$				
		0 MHz to 20 MHz	-	67	-	dB
		20 MHz to 100 MHz	-	51	-	dB
CMRR	common mode rejection ratio	0 MHz to 20 MHz	-	75	-	dB
		20 MHz to 100 MHz	-	45	-	dB

**Analog inputs**

$V_{i(p-p)(max)}$	maximum peak-to-peak input voltage	minimum gain	-	1.0	-	V
		maximum gain	-	60.4	-	mV
$V_{i(cm)}$	common-mode input voltage		2.0	2.7	$V_{DDA} - 1.9$	V
$I_i$	input current	$V_{i(cm)} = 2.7$ V	-	55	-	$\mu\text{A}$
$R_i$	input resistance		10	-	-	k $\Omega$
$C_i$	input capacitance		-	-	5	pF

**Analog outputs[2]**

$V_{o(dif)(p-p)max}$	maximum peak-to-peak differential output voltage	maximum gain	2.0	-	-	V
		minimum gain	2.0	-	-	V
$V_{O(cm)}$	common-mode output voltage	referenced to $V_{DDA}$ ; $T_{amb} = 25$ °C	$V_{DDA} - 2.56$	$V_{DDA} - 2.42$	$V_{DDA} - 2.29$	V
$\Delta V_{O(cm)}/\Delta T$	common-mode output voltage variation with temperature		-	-1.8	-	mV/°C
$SR_{se}$	single-ended slew rate		-	275	-	V/ $\mu\text{s}$
$R_o$	output resistance		-	15	26	$\Omega$
$C_o$	output capacitance		-	3	-	pF

**Variable gain amplifier dynamic performance;  $C_L = 5$  pF;  $R_L = 680 \Omega$ ; see Figure 6, 7, 8, 9 and 10**

$\alpha_{2H}$	second harmonic level	$V_o = V_{o(max)}$				
		$f_i = 0.5$ MHz	-	-80	-67	dBc
		$f_i = 4.43$ MHz	-	-77	-67	dBc
		$f_i = 12.5$ MHz	-	-76	-65	dBc
		$f_i = 21.4$ MHz	-	-74	-62	dBc

**Table 6. Characteristics ...continued**

$V_{DDA} = V11$  to  $V12 = 4.75$  V to 5.25 V;  $V_{DD} = V18$  to  $V17 = 3.0$  V to 5.25 V;  $V_{SSA}$  and  $V_{SSD}$  shorted together;  $T_{amb} = -40$  °C to +85 °C; typical values measured at  $V_{CCA} = 5.0$  V;  $V_{CCD} = 3.3$  V and  $T_{amb} = 25$  °C unless otherwise specified [1].

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$\alpha_{3H}$	third harmonic level	$V_o = V_{o(max)}$ ; $T_{amb} = 25$ °C				
		$f_i = 0.5$ MHz	-	-64	-60	dBc
		$f_i = 4.43$ MHz	-	-64	-59	dBc
		$f_i = 12.5$ MHz	-	-62	-58	dBc
$\Delta\alpha_{3H}/\Delta T$	third harmonic level variation with temperature	$f_i = 21.4$ MHz	-	80	-	mdB/°C

**Reference voltage output ADC: pin CMADC**

$V_{ref}$	reference voltage	referenced to $V_{DDA}$ ; $T_{amb} = 25$ °C	$V_{DDA} - 1.64$	$V_{DDA} - 1.45$	$V_{DDA} - 1.26$	V
$R_o$	output resistance	$T_{amb} = 25$ °C	-	17	26	$\Omega$
$\Delta V_{o(ref)}/\Delta T$	reference output voltage variation with temperature		-	-0.11	-	mV/°C
$I_{o(max)}$	maximum output current		-	1.0	-	mA
$C_o$	output capacitance		-	3	-	pF

**Reference voltage output VGA: pin CMVGA**

$V_{ref}$	reference voltage	referenced to $V_{DDA}$ ; $T_{amb} = 25$ °C	$V_{DDA} - 2.48$	$V_{DDA} - 2.30$	$V_{DDA} - 2.17$	V
$R_o$	output resistance	$T_{amb} = 25$ °C	-	9	20	$\Omega$
$\Delta V_{o(ref)}/\Delta T$	reference output voltage variation with temperature		-	1.75	-	mV/°C
$I_{o(max)}$	maximum output current		-	1.0	-	mA
$C_o$	output capacitance		-	3	-	pF

**Gain switching characteristics (in latched mode);  $f_{clk} = 52$  MHz;  $T_{amb} = 25$  °C; see Figure 3**

$t_h$	hold time		2.0	-	-	ns
$t_{su}$	set-up time		3.8	-	-	ns
$t_w$	pulse width		5.8	-	-	ns
$t_{PD}$	propagation delay		-	4.2	5.9	ns
$t_s$	settling time	10 % to 90 % full scale if $\pm 6$ dB gain change	[3]	2.6	3.2	ns

**Gain switching characteristics (in transparent mode);  $f_{clk} = 52$  MHz;  $T_{amb} = 25$  °C; see Figure 4**

$t_{PD}$	propagation delay		-	6.7	9.5	ns
$t_s$	settling time	10 % to 90 % full scale if $\pm 6$ dB gain change	[4]	5.4	6.9	ns

**Clock timing input: pins CLK and CLKN (see Figure 3)**

$f_{clk(max)}$	maximum clock frequency		52	-	-	MHz
$t_{w(clk)L}$	LOW clock pulse width		4.0	-	-	ns
$t_{w(clk)H}$	HIGH clock pulse width		4.0	-	-	ns



**Table 6. Characteristics ...continued**

$V_{DDA} = V11$  to  $V12 = 4.75$  V to  $5.25$  V;  $V_{DDD} = V18$  to  $V17 = 3.0$  V to  $5.25$  V;  $V_{SSA}$  and  $V_{SSD}$  shorted together;  $T_{amb} = -40$  °C to  $+85$  °C; typical values measured at  $V_{CCA} = 5.0$  V;  $V_{CCD} = 3.3$  V and  $T_{amb} = 25$  °C unless otherwise specified [1].

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_r$	rise time		-	4.0	-	ns
$t_f$	fall time		-	4.0	-	ns
<b>Digital inputs: pins TE, GRAY0, GRAY1 and GRAY2</b>						
$V_{IL}$	LOW-level input voltage		0	-	0.8	V
$V_{IH}$	HIGH-level input voltage		2.0	-	$V_{DDD}$	V
$I_{IH}$	HIGH-level input current		-10	-	+10	μA
$I_{IL}$	LOW-level input current		-10	-	+10	μA
$C_i$	input capacitance		-	-	3	pF
<b>Clock inputs in TTL mode</b>						
$V_{IL}$	LOW-level input voltage		[5] 0	-	0.8	V
$V_{IH}$	HIGH-level input voltage		[5] 2.0	-	$V_{DDD}$	V
$I_{IH}$	HIGH-level input current		15	-	80	μA
$I_{IL}$	LOW-level input current		-40	-	-10	μA
$C_i$	input capacitance		-	-	2	pF
<b>Clock inputs in differential mode</b>						
$V_{IL}$	LOW-level input voltage	$V_{DDA} = 5.0$ V	[6] 3.19	-	3.52	V
$V_{IH}$	HIGH-level input voltage	$V_{DDA} = 5.0$ V	[6] 3.83	-	4.12	V
$I_{IH}$	HIGH-level input current		15	-	80	μA
$I_{IL}$	LOW-level input current		-40	-	-5	μA
$C_i$	input capacitance		-	-	2	pF
$V_{i(dif)(p-p)}$	peak-to-peak differential input voltage	DC voltage level = 2.5 V	0.1	-	2.0	V

- [1] Due to the behavior of the on-chip regulator a warm-up time of 1 minute (typical) is recommended for optimal performance.
- [2] The analog output voltages are positive with respect to  $V_{SSA}$ .
- [3] In latching mode (pin TE LOW), the gain settling is latched at the rising edge of the clock input.
- [4] In transparent mode, the gain settling is directly controlled by the input data pattern.
- [5] The circuit may be used with a single TTL clock on CLK or CLKN. The unused clock pin has to be decoupled to ground with a 100 nF capacitance.
- [6] There are four modes of operation for the clock inputs in non-TTL mode:
- PECL mode 1: (DC level vary 1 : 1 with  $V_{DDA}$ ) CLK and CLKN inputs are differential PECL levels.
  - PECL mode 2: (DC level vary 1 : 1 with  $V_{DDA}$ ) CLK input is at PECL level and gain change takes place on the rising edge of the clock input signal when in latched mode. A DC level of 3.65 V has to be applied on CLKN decoupled to  $V_{SSD}$  via a 100 nF capacitor.
  - PECL mode 3: (DC level vary 1 : 1 with  $V_{DDA}$ ) CLKN input is at PECL level and gain change takes place on the rising edge of the clock input signal when in latched mode. A DC level of 3.65 V has to be applied on CLK decoupled to  $V_{SSD}$  via a 100 nF capacitor.
  - AC driving mode 4: when driving the CLK input directly and with any AC signal of minimum 0.1 V (p-p) and with a DC level of 2.5 V, the gain change takes place on the rising edge of the clock signal. When driving the CLKN input with the same signal, gain change takes place on the falling edge of the clock signal. NXP Semiconductors recommends decoupling of the CLKN or CLK input to  $V_{SSD}$  via a 100 nF capacitor.

12. Additional information relating to [Table 6](#)

Table 7. Input coding

State	Gray input data code Pins Gray2, Gray1, Gray0			Gain (dB)
	D2	D1	D0	
0	0	0	0	minimum
1	0	0	1	minimum + 6
2	0	1	1	minimum + 12
3	0	1	0	minimum + 18
4	1	1	0	minimum + 24
other	-	-	-	minimum + 24

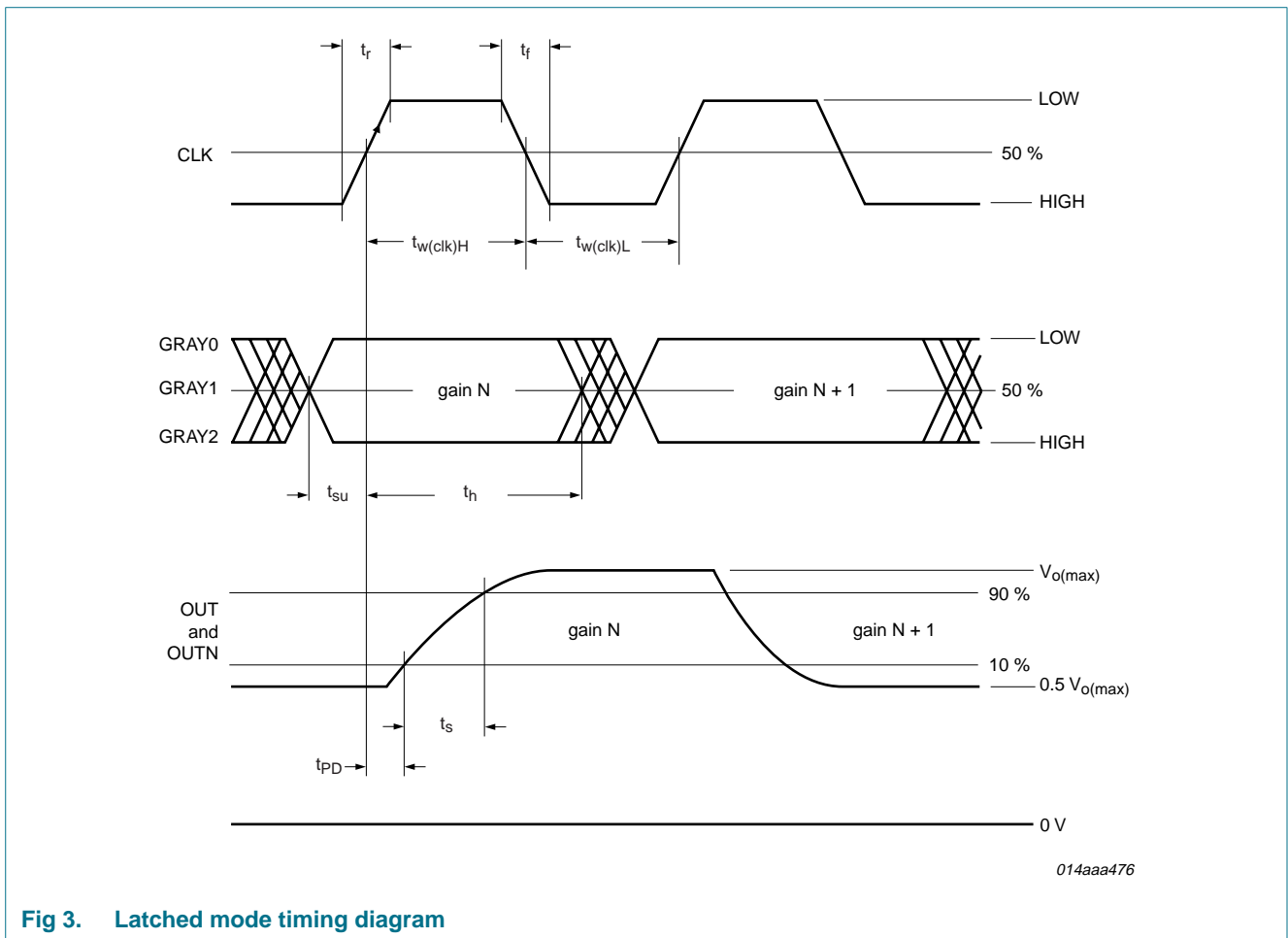


Fig 3. Latched mode timing diagram

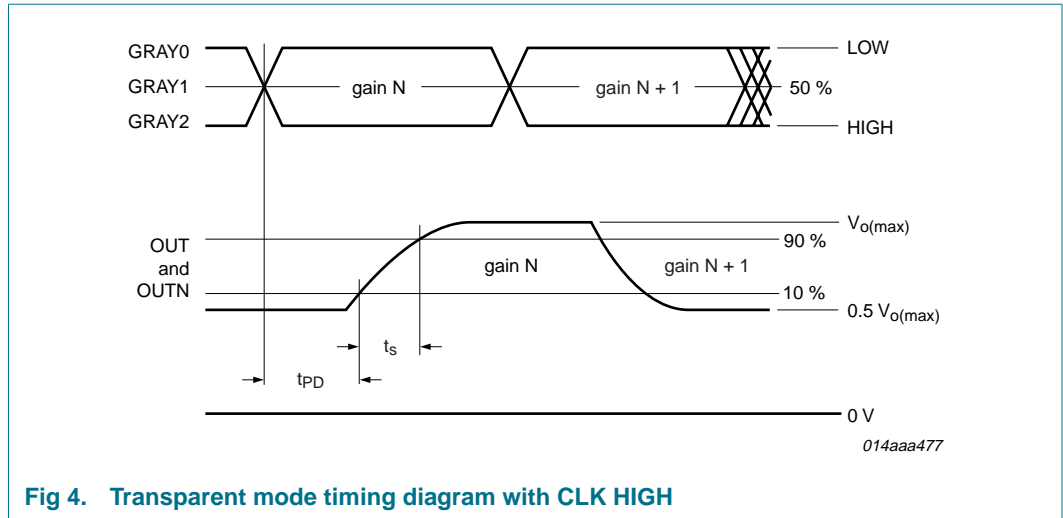
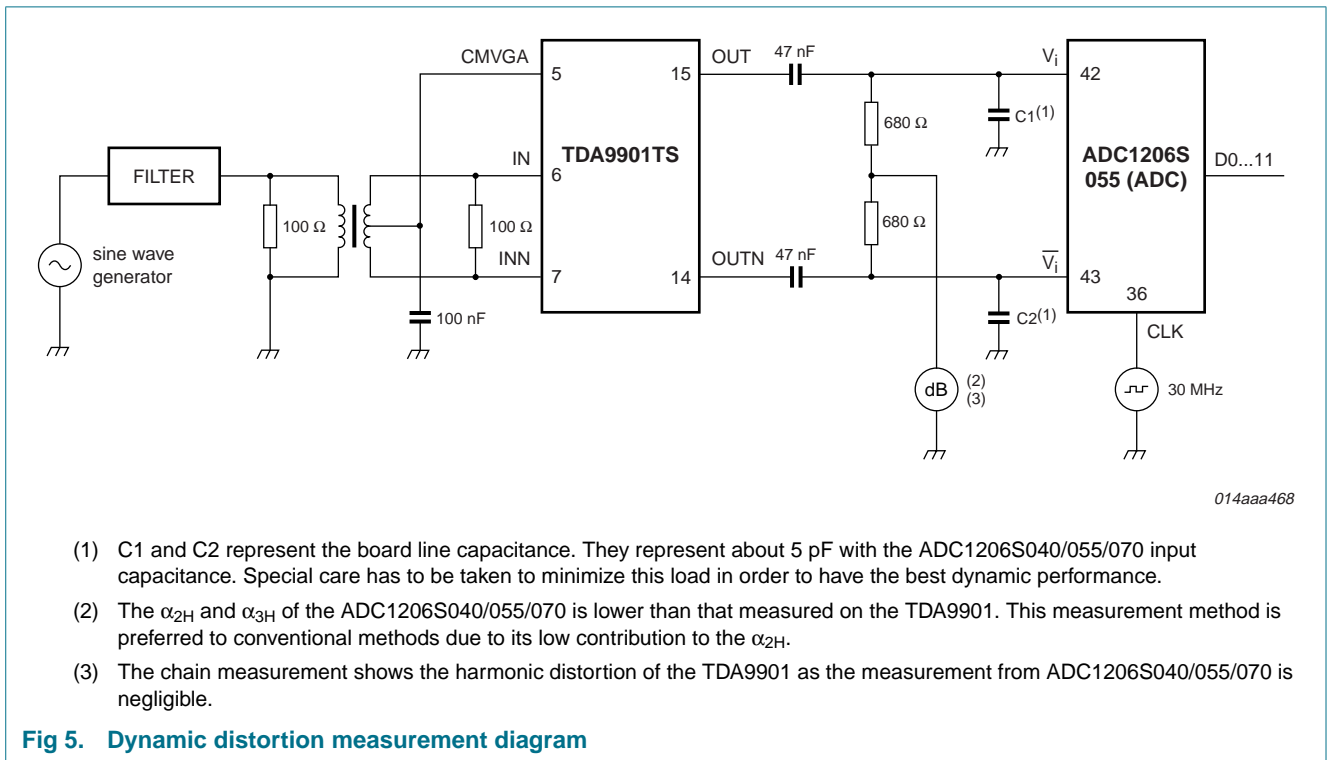
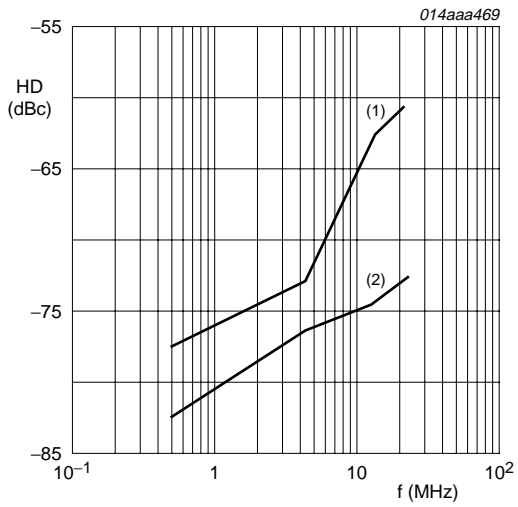


Fig 4. Transparent mode timing diagram with CLK HIGH



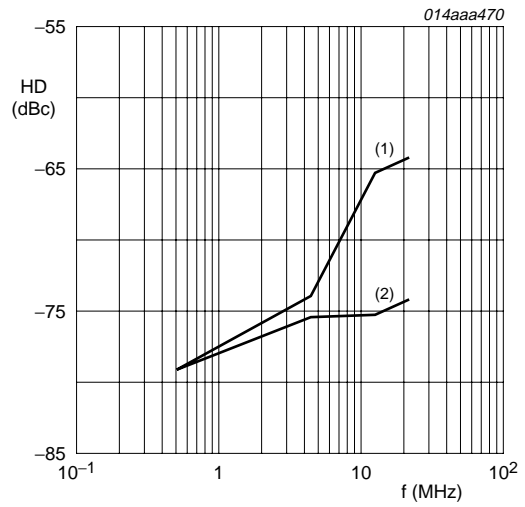
- (1) C1 and C2 represent the board line capacitance. They represent about 5 pF with the ADC1206S040/055/070 input capacitance. Special care has to be taken to minimize this load in order to have the best dynamic performance.
- (2) The  $\alpha_{2H}$  and  $\alpha_{3H}$  of the ADC1206S040/055/070 is lower than that measured on the TDA9901. This measurement method is preferred to conventional methods due to its low contribution to the  $\alpha_{2H}$ .
- (3) The chain measurement shows the harmonic distortion of the TDA9901 as the measurement from ADC1206S040/055/070 is negligible.

Fig 5. Dynamic distortion measurement diagram



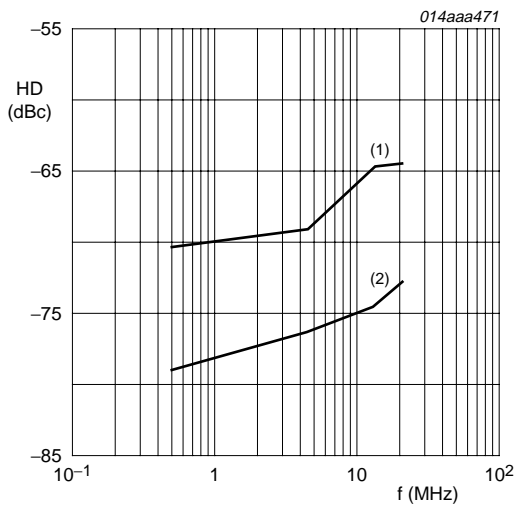
(1)  $\alpha_{3H}$ .  
 (2)  $\alpha_{2H}$ .  
 Typical condition; 2 V (p-p) differential output

**Fig 6. Harmonic Distortion (HD) as a function of frequency for minimum gain**



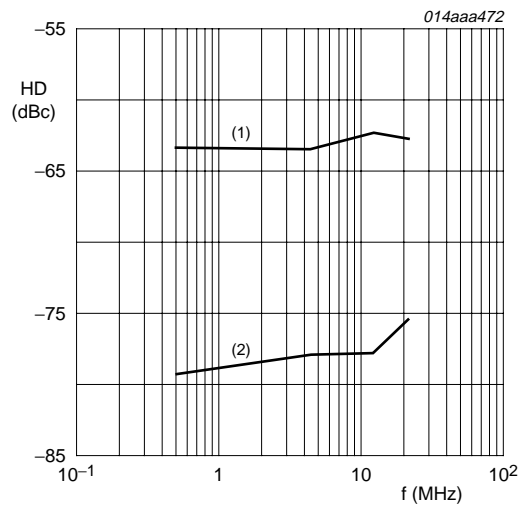
(1)  $\alpha_{3H}$ .  
 (2)  $\alpha_{2H}$ .  
 Typical condition; 2 V (p-p) differential output

**Fig 7. Harmonic Distortion (HD) as a function of frequency for minimum gain plus 6 dB**



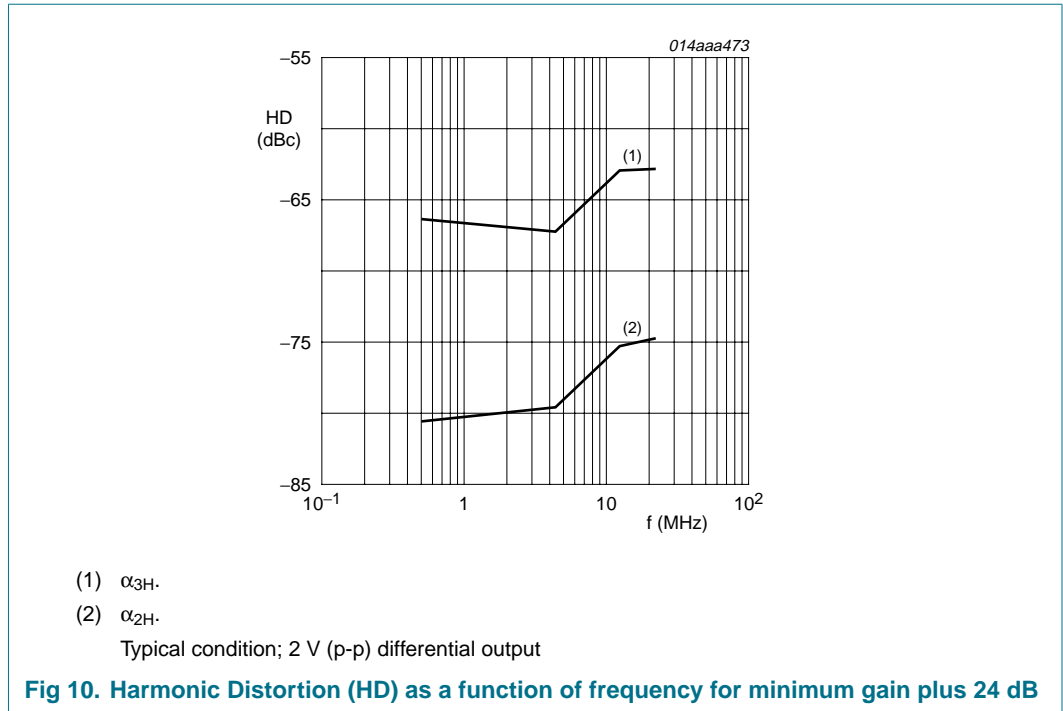
(1)  $\alpha_{3H}$ .  
 (2)  $\alpha_{2H}$ .  
 Typical condition; 2 V (p-p) differential output

**Fig 8. Harmonic Distortion (HD) as a function of frequency for minimum gain plus 12 dB**



(1)  $\alpha_{3H}$ .  
 (2)  $\alpha_{2H}$ .  
 Typical condition; 2 V (p-p) differential output

**Fig 9. Harmonic Distortion (HD) as a function of frequency for minimum gain plus 18 dB**



### 13. Application information

#### 13.1 Application diagrams

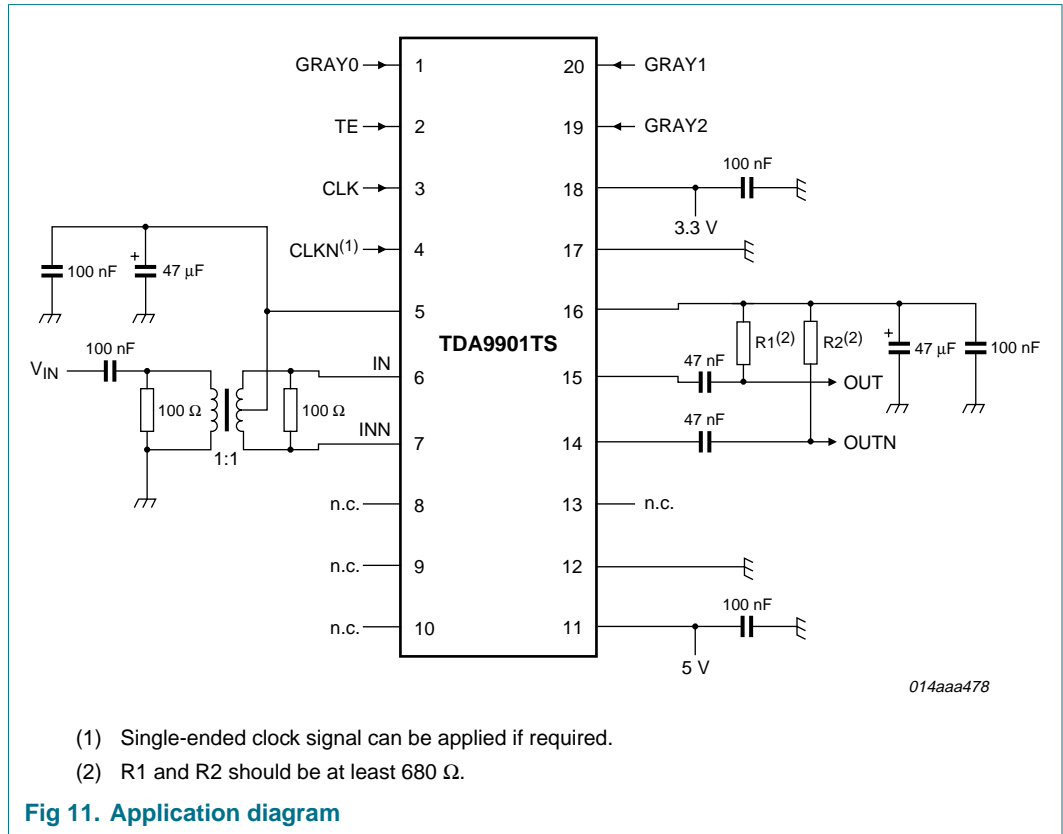


Fig 11. Application diagram

#### 13.2 Recommended companion chip

Table 8. Recommended companion chips

Type number	Description	Sampling frequency
ADC1006S055	Single 10 bits ADC	55 MHz
ADC1006S070	Single 10 bits ADC	70 MHz
ADC1206S040	Single 12 bits ADC	40 MHz
ADC1206S055	Single 12 bits ADC	55 MHz
ADC1206S070	Single 12 bits ADC	70 MHz

14. Package outline

SSOP20: plastic shrink small outline package; 20 leads; body width 4.4 mm

SOT266-1

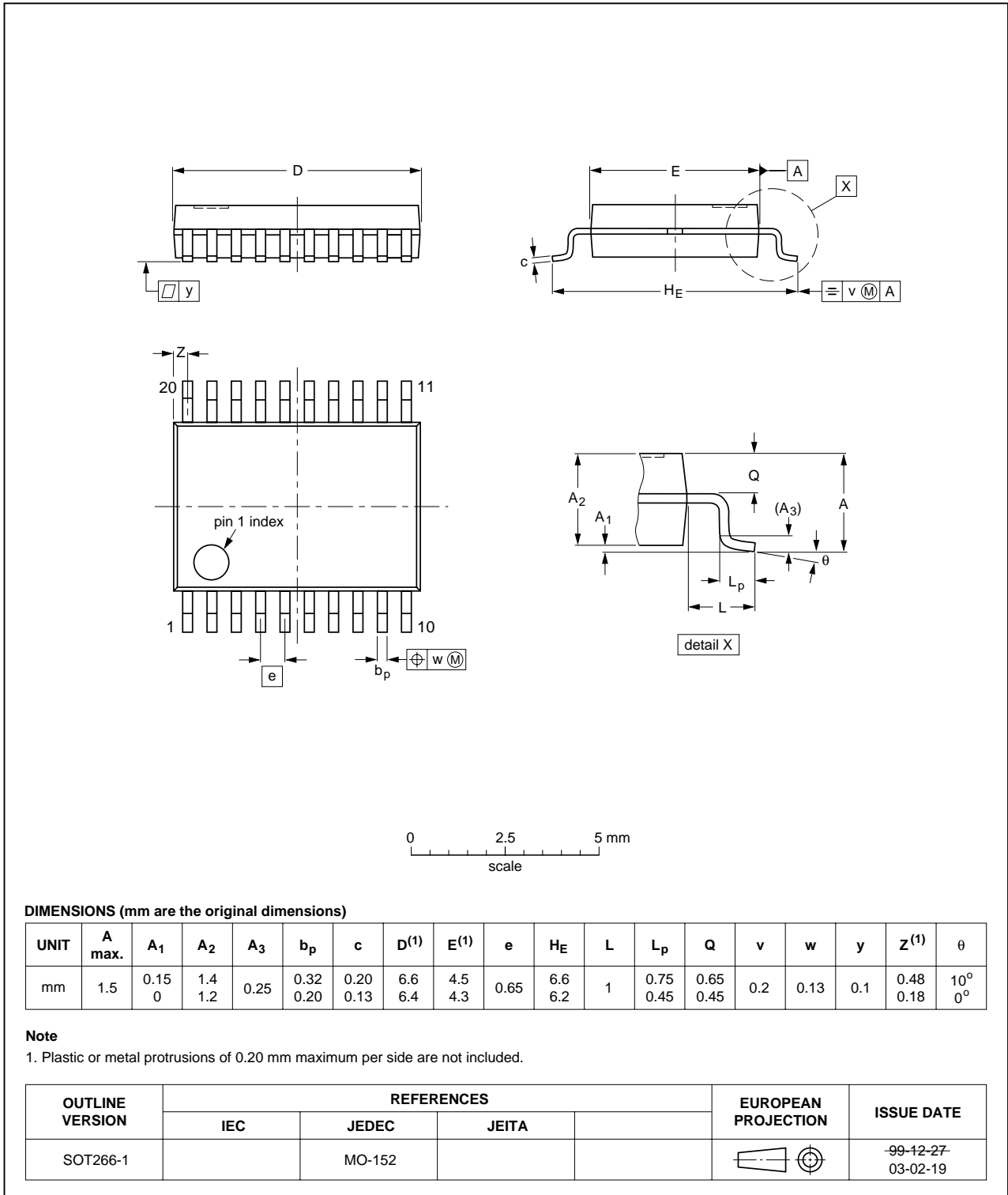


Fig 12. Package outline SOT266-1 (SSOP20)

## 15. Revision history

**Table 9. Revision history**

Document ID	Release date	Data sheet status	Change notice	Supersedes
TDA9901_4	20080814	Product data sheet	-	TDA9901_3
Modifications:		<ul style="list-style-type: none"><li>• Correction made to <math>\Delta V_{DD}</math> conditions in <a href="#">Table 4</a>.</li><li>• Corrections made to values of <math>t_{d(grp)}</math> and <math>G_{step}</math> in <a href="#">Table 6</a>.</li></ul>		
TDA9901_3	20080611	Product specification	-	TDA9901_2
TDA9901_2	19991008	Product specification	-	TDA9901_N_1
TDA9901_N_1	19980415	Product specification	-	-



## 16. Legal information

### 16.1 Data sheet status

Document status <sup>[1][2]</sup>	Product status <sup>[3]</sup>	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

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