TCS7191B

2.8W Non-Clip Class-D Audio Power Amplifier

GENERAL DESCRIPTION

The TCS7191B is a 2.8W high efficiency, non-clip, filterless, Class-D audio power amplifier. It operates from 2.7V to 5.5V supply. When powered with 5V supply voltage, the TCS7191B is capable of delivering 2.8W into 4Ω load or 1.65W into 8Ω load, with THD+D less than 10%.

The TCS7191B features a non-clip output control, which detects the output clipping caused by the over-level input signal and automatically adjusts the dynamic range of the output signal to prevent the distortion of the audio signal. The non-clip output control also eliminates the output clipping due to a low battery supply voltage.

As a Class-D power amplifier, the TCS7191B features high efficiency, up to 90%, and high PSRR, 75dB at 217Hz, which make the device ideal for use in battery-powered portable devices. It also features minimized click-and-pop noise during turn-on and turn-off transitions.

APPLICATIONS

- Cellular handsets
- Portable navigation devices
- Multimedia internet devices

FEATURES

- Non-clip control to suppress output clipping
- Filterless Class-D operation
- High efficiency up to 90%
- Output power at 5V supply
  - 1.65W (8Ω load, 10% THD+N)
  - 1.35W (8Ω load, 1% THD+N)
  - 2.8W (4Ω load, 10% THD+N)
  - 2.25W (4Ω load, 1% THD+N)
- Low THD+N: 0.1% (typical) @ 1KHz
  (VDD=3.6V, RL=4Ω, PO=0.65W)
- Low quiescent current: 2.2mA @ VDD=3.6V (8Ω load)
- Low shutdown current: 0.1μA (typical)
- High PSRR: 75dB (typical)
- Two gain settings: 18/24 dB
- One-wire control for the selection of operating mode and gain
- Over-circuit & thermal protection
- Fast start-up time: 5ms
- Available in COL1.55x1.55-9L, DFN2x2-8L, MSOP-8L

APPLICATION CIRCUIT

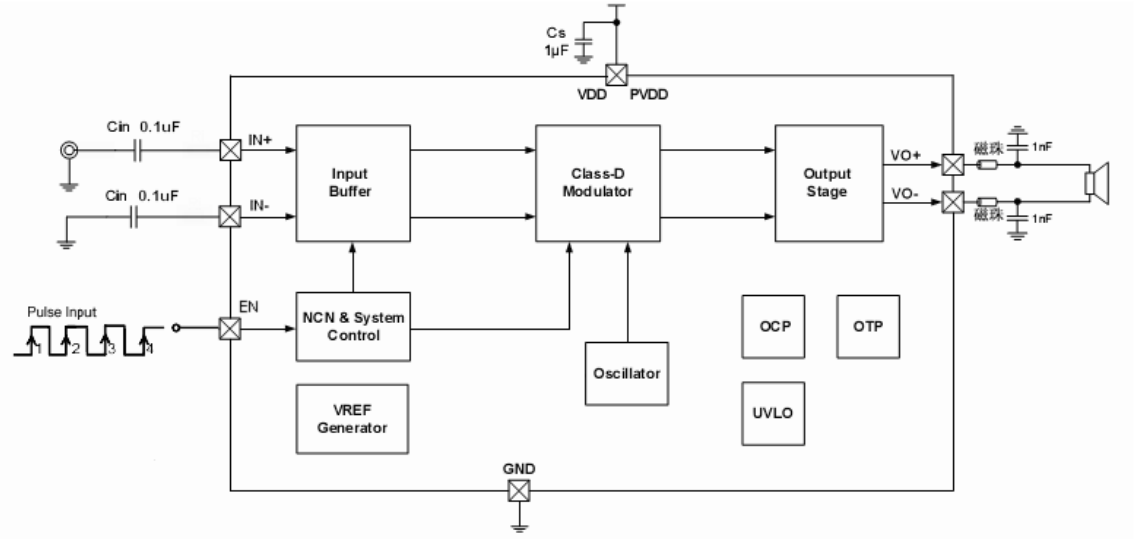
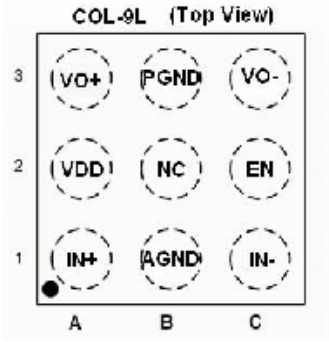
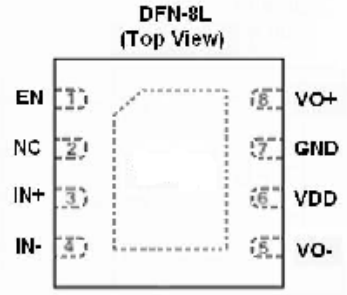


Figure 1: Typical Application Circuit

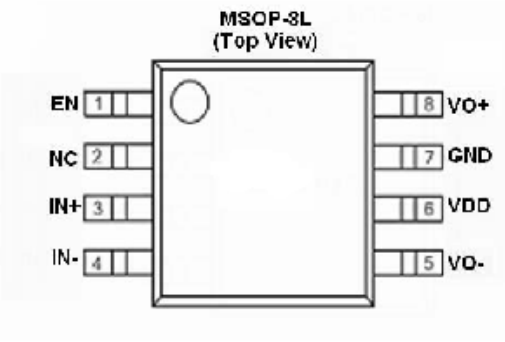
PIN CONGIGURATION AND DESCRIPTION



TCS7191BA (Top View)



TCS7191BN (Top View)



TCS7191B_H (Top View)

PIN NUMBER			SYMBOL	FUNCTION
TCS7191BA	TCS7191BN	TCS7191B_H		
A1	3	3	IN+	Positive input terminal (differential+).
A2	6	6	VDD	Power supply.
A3	8	8	VO+	Positive output terminal (differential+).
B1	7	7	AGND	Ground.
B2	2	2	NC	No connection.
B3	7	7	PGND	Ground.
C1	4	4	IN-	Negative input terminal (differential-).
C2	1	1	EN	Enable terminal (Active High) & one-wire pulse control.
C3	5	5	VO-	Negative output terminal (differential-).

PACKAGE DISSIPATION RATINGS

PACKAGE	PACKAGE DRAWING	Θ_{JC}	Θ_{JA}	UNIT
COL1.55x1.55-9L		NA	150	°C/W
DFN2x2-8L		NA	58	°C/W
MSOP-8L		NA	180	°C/W

ORDERING INFORMATION

PART NUMBER		TEMPERATURE RANGE	PIN-PACKAGE
Lead Free	Green		
TCS7191BA		-40°C to +85°C	COL1.55X1.55-9L
TCS7191BN		-40°C to +85°C	DFN2x2-8L
TCS7191_H		-40°C to +85°C	MSOP-8L

ABSOLUTE MAXIMUM RATINGS

Parameter	Unit
Supply voltage	-0.3V to 6 V
Storage Temperature	−45°C to +150°C
Input Voltage	−0.3V to VDD +0.3V
Power Dissipation (Note 4)	Internally Limited
ESD Susceptibility (Note 5)	2000V
Junction Temperature	150°C
Solder Information	
Vapor Phase (60 sec.)	215°C
Infrared (15 sec.)	220°C

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Supply Voltage (V_{DD})		2.7		5.5	V
Operating Free-air Temperature, TA		-40		85	°C
Speaker Impedance (Rload)		3.2			Ω

ELECTRICAL CHARACTERISTICS

VDD=3.6V, TA=25°C, Cin=0.1μF, A_V=18dB, Mode 1,unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
V_{DD}	Supply Voltage		2.7		5.5	V
V_{UVLU}	Power Up Threshold Voltage	VDD from Low to High		2.2		V
V_{UVLD}	Power Down Threshold Voltage	VDD from High to Low		2.0		V
I_{DD}	Quiescent Power Supply Current	VDD=5V, V_{IN}=0V, 8Ω Load	1.5	2.5	5	mA
		VDD=3.6V, V_{IN}=0V, 8Ω Load	1.2	2.2	4	mA
I_{SD}	Shutdown Current	EN = 0V		0.1		μA
Po	Output Power, Load=8Ω, VDD=5V, NCN Off mode	THD+N=1%; f=1kHz		1.35		W
		THD+N=10%; f=1kHz		1.65		
Po	Output Power, Load=4Ω, VDD=5V, NCN Off mode	THD+N=1%; f=1kHz		2.25		W
		THD+N=10%; f=1kHz		2.8		
Po	Output Power, Load=4Ω, VDD=5V, NCN On mode	Mode 1, Vin=0.4Vrms		2.1		W
Po	Output Power, Load=8Ω, VDD=5V, NCN On mode	Mode 1, Vin=0.4Vrms		1.25		W
Av	Closed-loop Voltage Gain	Mode1, 2		18		dB
		Mode 3, 4		24		dB
THD+N	Total Harmonic Distortion + Noise	Po=0.65W，RL=4Ω，f=1kHz		0.1		%
Vn	Output Voltage Noise	f=20Hz to 20KHz, Inputs AC-Grounded.		85		μVrms
V_{OS}	Output Offset Voltage			10		mV
η	Efficiency	VDD=5V，Po=1W，RL=8Ω+33μH，f=1kHz		90		%
A_{MAX}	Maximum AGC Attenuation			10		dB
SNR	Signal-to-Noise Ratio			85		dB
PSRR	Power Supply Rejection Ratio	f=217Hz		75		dB
CMRR	Common Mode Rejection Ratio	f=1KHz		70		dB
T_{STUP}	Start-up Time			5		ms
V_{IH}	High–level Input Voltage, EN		1.20			V
V_{IL}	Low–level Input Voltage, EN				0.4	V
T_{AT}	AGC Attack Time			45		ms
T_{RL}	AGC Release Time			2		s
f_{PWM}	Switching Frequency			800		KHz
T_{LO}	Time of EN low		0.5		10	μs
T_{HI}	Time of EN high		0.5		--	μs
T_{RST}	Time for Mode Reset, Active Low		100		--	μs
T_{SHDN}	Time of Shutdown			400		μs
T_H	Enter OTP Threshold Temp.	Temp. from Low to High		160		℃
T_L	Exit OTP Threshold Temp.	Temp. from High to Low		140		℃
OCP	Enter OCP Threshold Current	Loading from Low to High		1.6		A

TYPICAL PERFORMANCE CHARACTERISTICS

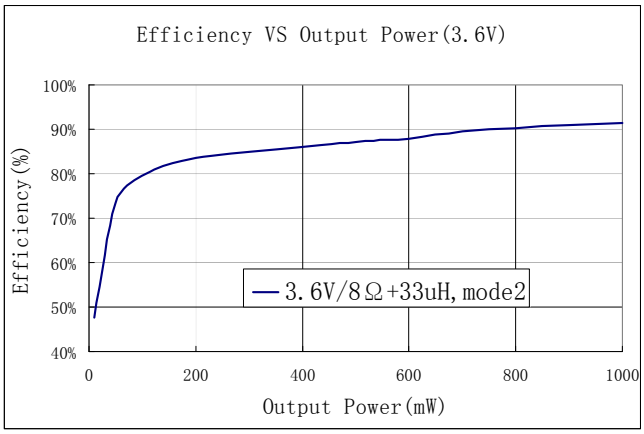


Figure 2: Efficiency vs. Output Power

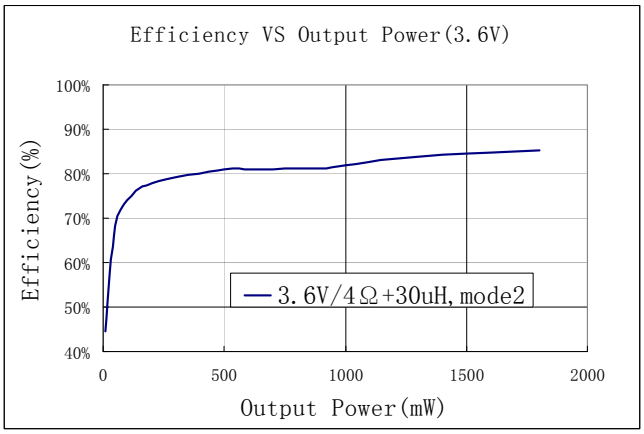


Figure 3: Efficiency vs. Output Power

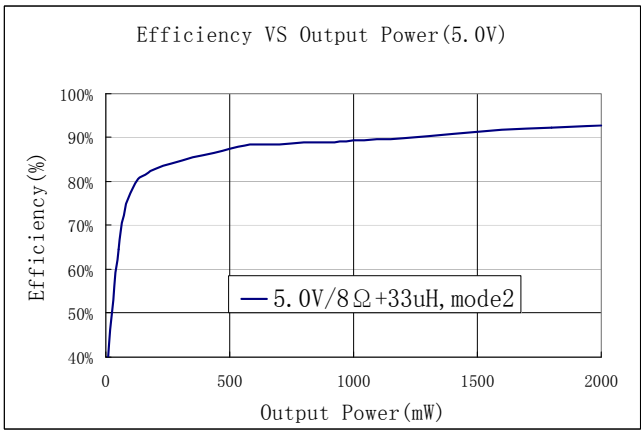


Figure 4: Efficiency vs. Output Power

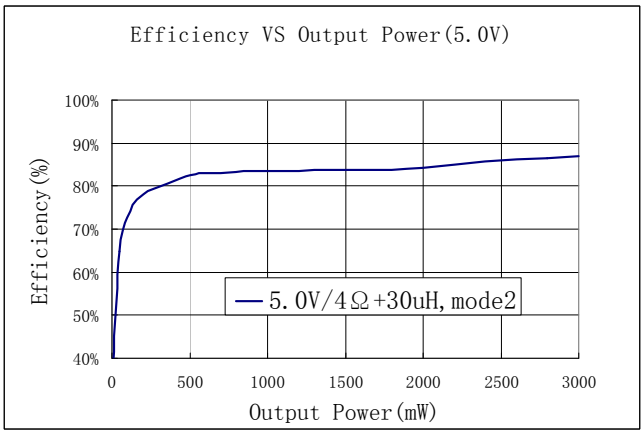


Figure 5: Efficiency vs. Output Power

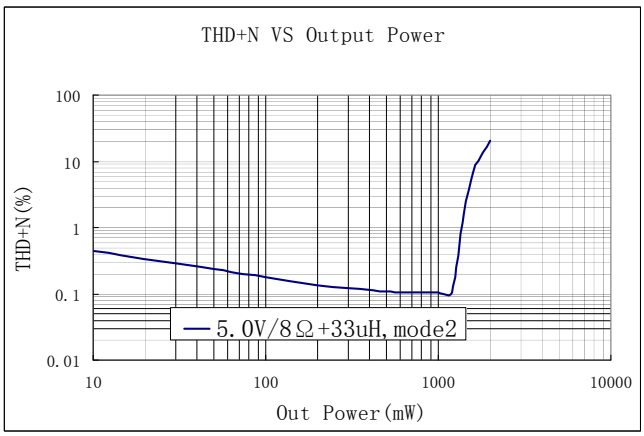


Figure 6: THD+N vs. Output Power

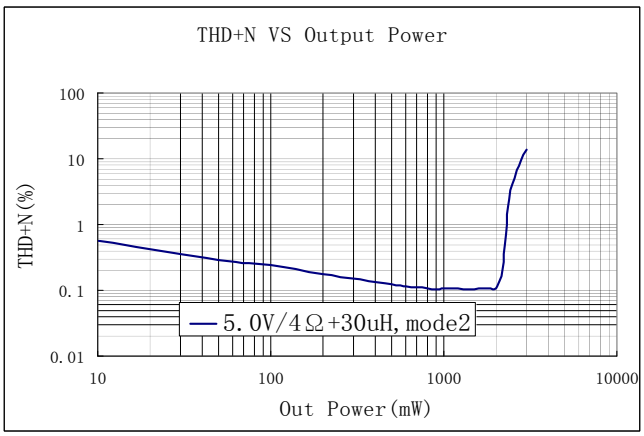


Figure 7: THD+N vs. Output Power

TYPICAL PERFORMANCE CHARACTERISTICS (Cont.)

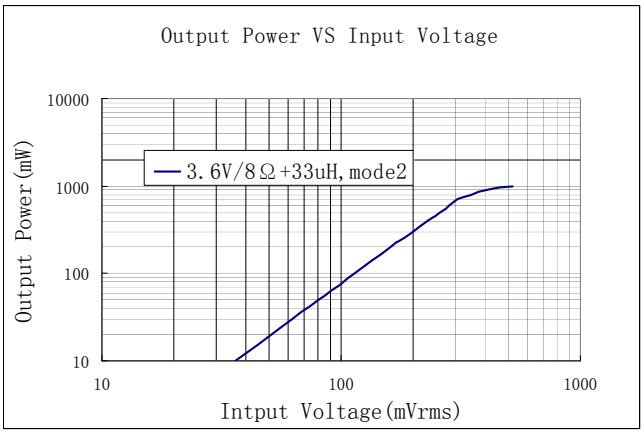


Figure 8: Output Power vs. Input Voltage

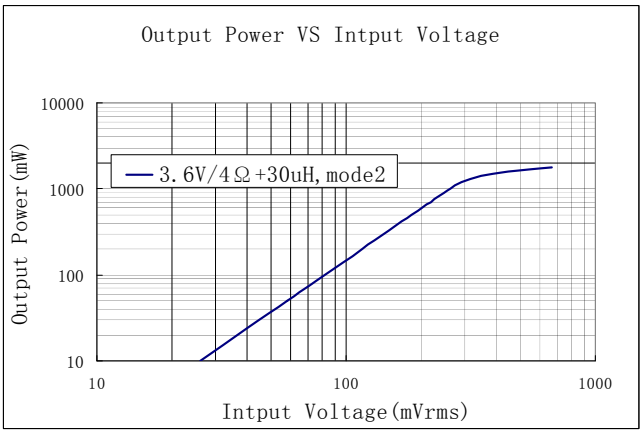


Figure 9: Output Power vs. Input Voltage

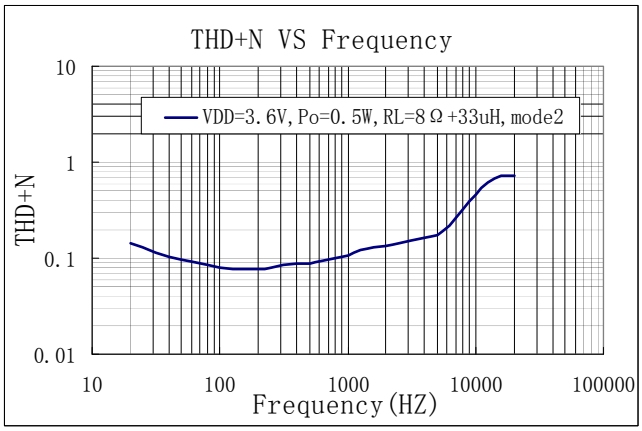


Figure 10: THD+N vs. Frequency

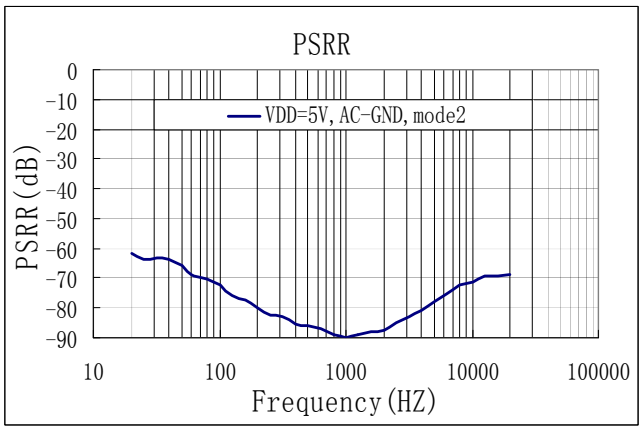


Figure 11: PSRR vs. Frequency

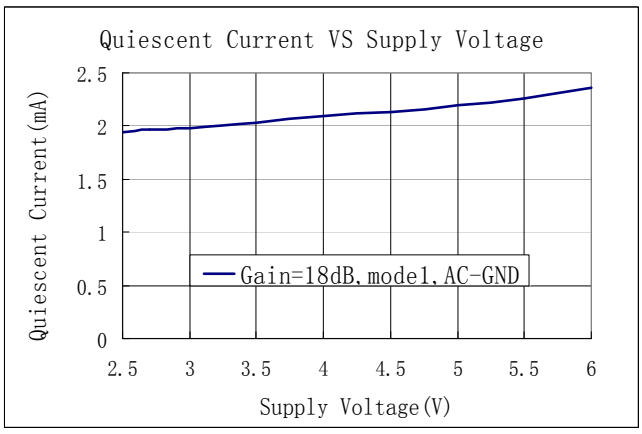


Figure 12: Quiescent Current vs. Supply Voltage

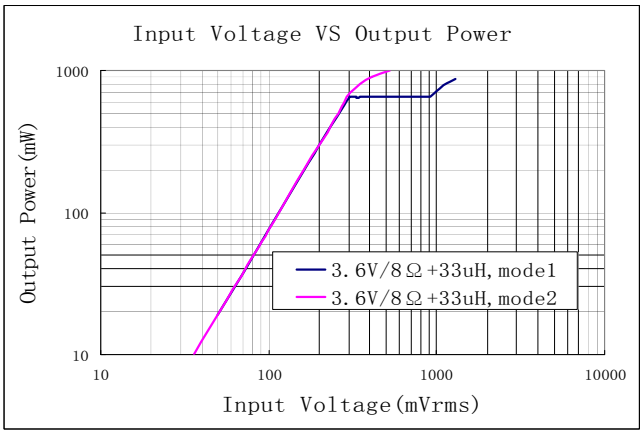


Figure 13: Input Voltage vs. Output Power

APPLICATION INFORMATION

The TCS7191B is a 2.8W high efficiency, non-clip, filterless, Class-D audio power amplifier. It operates from 2.7V to 5.5V supply. When powered with 5V supply voltage, the TCS7191B is capable of delivering 2.8W into 4Ω load or 1.8W into 8Ω load, with THD+D less than 10%.

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As a Class-D power amplifier, the TCS7191B features high efficiency, up to 90%, and high PSRR, 75dB at 217Hz, which make the device ideal for use in battery-powered portable devices. It also features minimized click-and-pop noise during turn-on and turn-off transitions.

As specifically designed for portable applications, the TCS7191B incorporates a shutdown mode to minimize the power consumption by holding the EN pin to ground. It also includes comprehensive protection features against various operating faults such as over-current, Over-circuit, over-temperature, or under-voltage for a safe and reliable operation.

Non-Clip control

The non-clip function is to control the output signal level for a maximum output swing without distortion when an excessive input that may cause output clipping is applied. With the non-clip function, the TCS7191B lowers the gain of the amplifier to an appropriate value such that the clipping at the outputs is eliminated. It also eliminates the clipping of the output signal due to the decrease of the power-supply voltage.

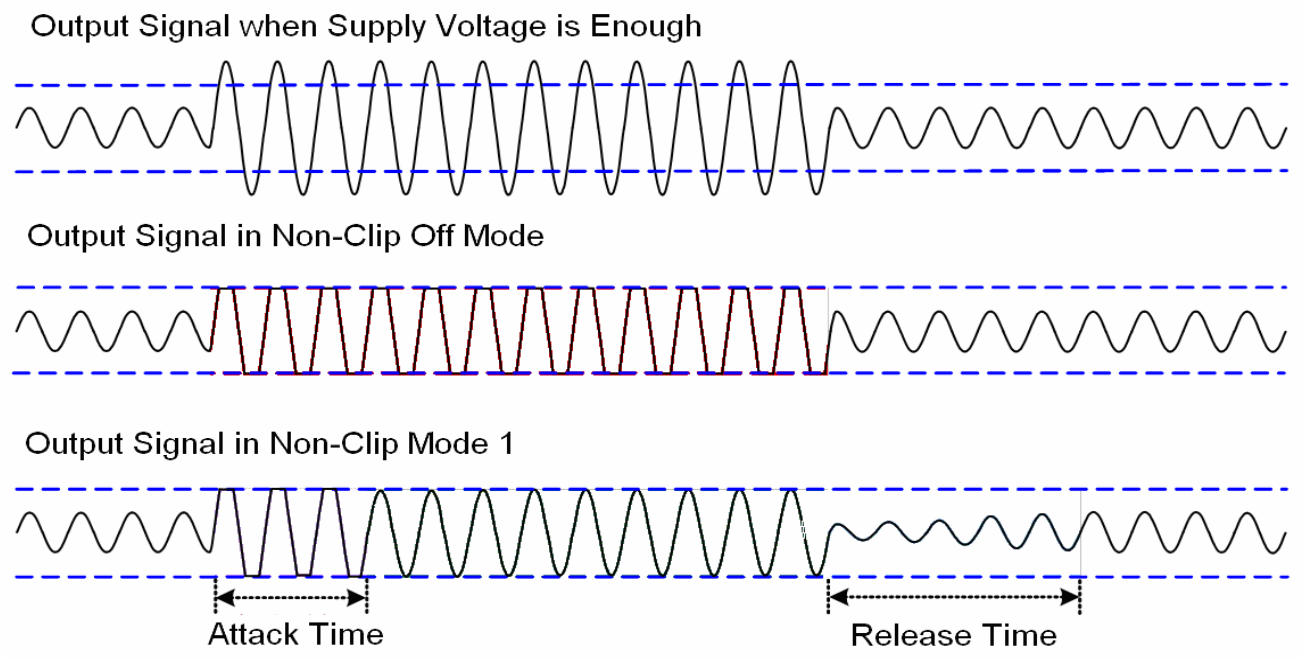


Figure 14: Non-Clip Control Diagram

The attack time is defined as the time interval required for the gain to fall to its steady-state gain less 3dB approximately, assumed that a sufficiently large input signal is applied. The release time is the time interval required for the amplifier to exit out of the present mode of operation. See Table 1.

Attack Time & Release Time

Mode	Attack time (ms)	Release time (s)
Non-Clip On	45	2

Table 1: Attack Time & Release Time

Operating Mode Control and Gain Setting

The TCS7191B implements a one wire pulse control function. Applying pulse signal to EN PIN, users can set operating mode include Gain and Non-Clip On/Off function with the rising edge and numbers of applied pulse signal. The detailed operation of mode control is showed as figure 15.

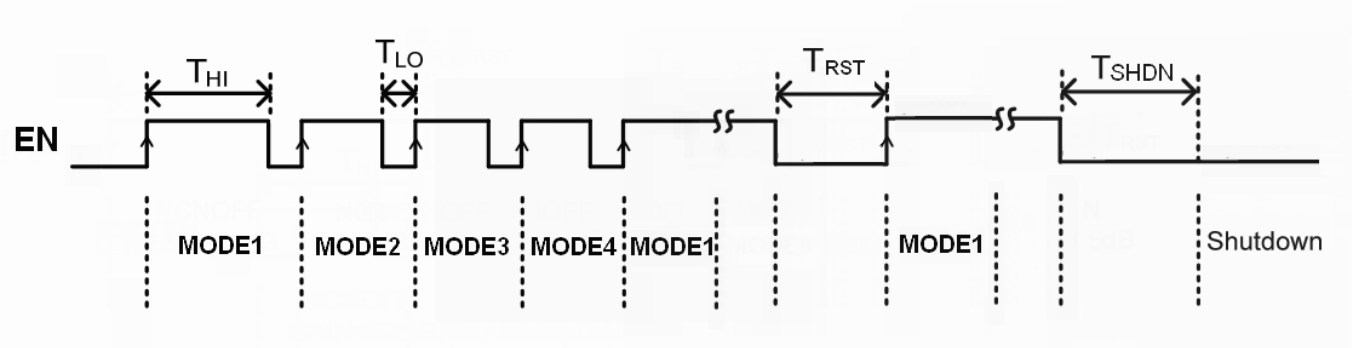


Figure 15. Mode setting pulse

There are four mode settings for TCS7191B gain control. At power-up, the first low-to-high transition at EN pin set the TCS7191B into gain=18dB, Non Clip On mode. The second low-to-high transition at EN pin set theTCS7191B into gain=18dB, Non Clip Off mode. The third low-to-high transition at EN pin set the TCS7191B into gain=24dB, Non Clip On mode. The forth low-to-high transition at EN pin set the TCS7191B into gain=24dB, Non Clip Off mode. The fifth low-to-high transition at EN pin will set the TCS7191B into first mode (gain=18dB, Non Clip On), and so on. Pulses faster than the minimum T_{LO} may be ignored and filtered by the device. Pulses longer than the maximum TSHDN may shutdown the device. When the Pulses is longer than the TRST or TSHDN, the follow low-to-high transition at EN pin will set the TCS7191B into gain=18dB, Non Clip On mode (Mode 1).

Mode	Pules	Gain	AGC
Mode1	1	18dB	On
Mode2	2	18dB	Off
Mode3	3	24dB	On
Mode4	4	24dB	Off

Table 2: Mode setting

Click-and-Pop Suppression

The TCS7191B speaker amplifier features comprehensive click-and-pop suppression. During startup, the click-and-pop suppression circuitry reduces any audible transient sources internal to the device. When entering shutdown, the differential speaker outputs ramp down to Ground quickly and simultaneously.

PROTECTION FEATURES

The TCS7191B incorporates various protection functions against possible operating faults for a safe operation. It includes under-voltage-lock-out (UVLO), Over-circuit protection (OCP), and over-temperature shutdown (OTSD).

Under Voltage Lock-out (UVLO)

The TCS7191B incorporates a circuitry to detect a low supply voltage for a safe and reliable operation. When the supply voltage is first applied, the TCS7191B will remain inactive until t he supply voltage exceeds 2.2V (VUVLU). When the supply voltage is removed and drops below 2.0V (VUVLD), the TCS7191B enters into the shutdown mode immediately.

Over-Circuit Protection (OCP)

When a over-circuit condition is detected at the differential outputs, either to VDD or VSS or to each other, the device enters into the Over-circuit protection mode, where the amplifier output stage is disabled. To release it from the OCP mode, the TCS7191B must undergo the power-up sequence; i.e., pull the EN pin to ground, followed by a sequence of pulses to set the device into the desired operating mode.

Over-Temperature Shutdown (OTSD)

When the die temperature exceeds the preset threshold (160?C), the device enters into the over-temperature shutdown mode, where two differential outputs are pulled to ground through an internal resistor (2KΩ) individually. The device will resume normal operation once the die temperature returns to a temperature, which is about 20 ˚C lower than the threshold.

PSRR enhancement

Compare to conventional class-D amplifiers, the TCS7191B does not require a pin for the common-mode voltage with an external bypass capacitor.

Class D Speaker Amplifier

The TCS7191B filter-less Class-D amplifier offers much higher efficiency than Class AB amplifiers. The high efficiency of a Class D amplifier is due to the switching operation of the output stage transistors. Any power loss associated with the Class D output stage is mostly due to the I2R loss of the MOSFET on-resistance and quiescent current overhead.

Fully Differential Amplifier

The TCS7191B is a fully differential amplifier with different ial inputs and outputs. The fully differential amplifier consists of a differential amplifier and a common-mode amplifier. The differential amplifier ensures that the amplifier outputs a differential voltage on the output that is equal to the differential input times the gain. The common-mode feedback ensures that the common-mode voltage at the output is biased around VDD/2 regardless of the common-mode voltage at the input. The fully differential TCS7191B can still be used with a single-ended input; however, the TCS7191B should be used with differential inputs when in a noisy environment, like a wireless handset, to ensure maximum noise rejection.

Low-EMI Filter-less Output Stage

Traditional Class-D amplifiers require the use of external LC filters, or shielding, to meet EN55022B electromagnetic-interference (EMI) regulation standards. Fangtek use edge-rate control circuitry to reduce EMI emissions, while maintaining up to 90% efficiency (speaker only). Above 10MHz, the wideband spectrum looks like noise for EMI purposes.

Filter-less Design

Traditional Class D amplifiers require an output filter to recover the audio signal from the amplifier's output. The filter adds cost, increases the solution size of the amplifier, and can decrease efficiency and THD+N performance. The traditional PWM scheme uses large differential output swings (2 x supply voltage peak-to-peak) and causes large ripple currents. Any parasitic resistance in the filter components results in a loss of power and lowers the efficiency.

The TCS7191B does not require an output filter. The device relies on the inherent inductance of the speaker coil and the natural filtering of both the speaker and the human ear to recover the audio component of the square-wave output. Eliminate the output filter results in a smaller, less costly, and more efficient solution.

Because the frequency of the TCS7191B output is well beyond the bandwidth of most speakers, voice coil movement due to the square-wave frequency is very small. Although this movement is small, a speaker not designed to handle the additional power can be damaged. For optimum results, use a speaker with a series inductance > 10uH. Typical 8Ω speakers exhibit series inductances in the 20uH to 100uH range.

How to Reduce EMI

Additional EMI suppression can be achieved using a filter constructed from a ferrite bead and a capacitor to ground (Figure 16). Use a ferrite bead with low DC resistance, high-frequency (>100MHz) impedance between 100Ω and 600Ω, and rated for at least 1A. The capacitor value varies based on the ferrite bead chosen and the actual speaker lead length. Select a capacitor less than 1nF based on EMI performance.

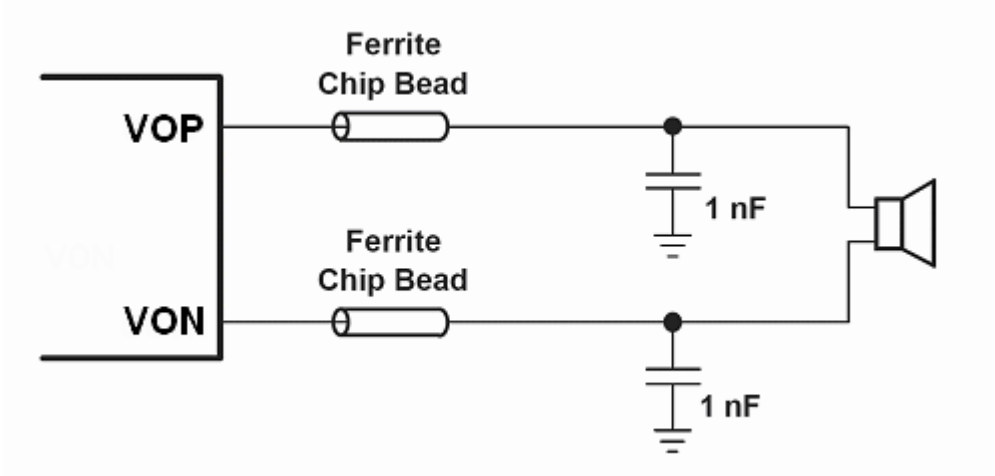


Figure 16: Ferrite Bead Filter to Reduce EMI

Decoupling Capacitor (CS)

The TCS7191B is a high-performance Class-D audio amplifier that requires adequate power supply decoupling. Adequate power supply decoupling to ensures that the efficiency is high and total harmonic distortion (THD) is low.

Place a low equivalent-series-resistance (ESR) ceramic capacitor (X7R or X5R), typically 1μF, within 2mm of the VDD (PVDD) pin. This choice of capacitor and placement helps with higher frequency transients, spikes, or digital hash on the line. Additionally, placing this decoupling capacitor close to the TCS7191B is important, as any parasitic resistance or inductance between the device and the capacitor causes efficiency loss. In addition to the 1μF ceramic capacitor, place a 4.7μF to 22μF capacitor on the VDD (PVDD) supply trace. This larger capacitor acts as a charge reservoir, providing energy faster than the board supply, thus helping to prevent any droop in the supply voltage.

Input Capacitors (Cin)

Input audio DC decoupling capacitors are recommended. The input audio DC decoupling capacitors will remove the DC bias from an incoming analog signal. The input capacitors (Cin) and internal input resistors (Rin) form a high-pass filter with the corner frequency, fc, determined in Equation 1.

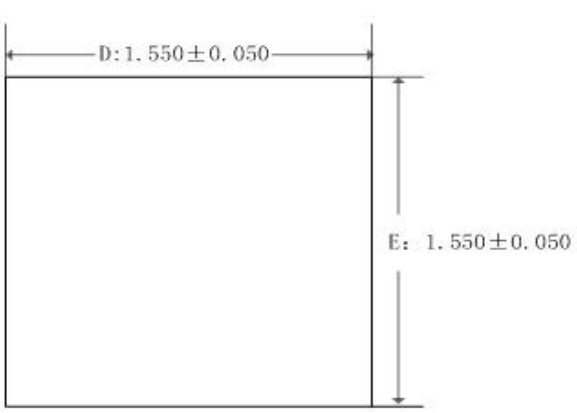
Any mismatch in capacitance between the two inputs will cause a mismatch in the corner frequencies. Severe mismatch may also cause turn-on pop noise, PSRR, CMRR. Choose capacitors with a tolerance of ±5% or better.

$$fc=1/(2 \times \pi \times Rin \times Cin) \qquad (1)$$

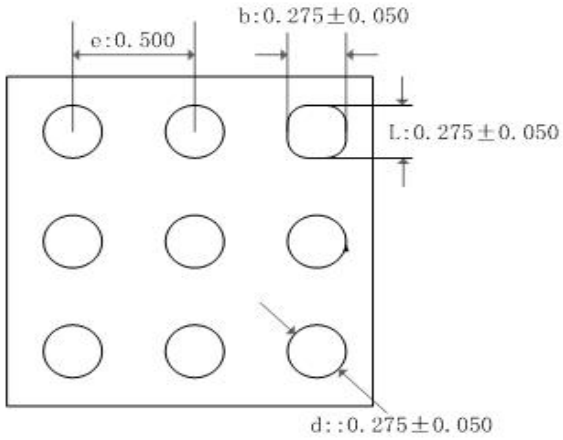
For best audio quality, use capacitors whose dielectrics have low-voltage coefficients, such as tantalum or aluminum electrolytic. Capacitors with high-voltage coefficients, such as ceramics, could result in increased distortion at low frequencies.

PHYSICAL DIMENSION

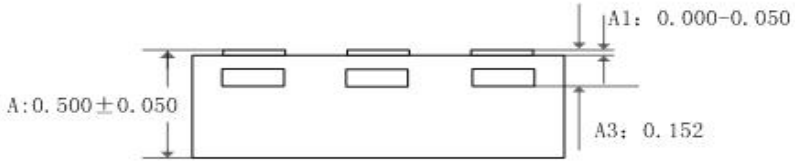
COL1.55X1.55-9L PACKAGE OUTLINE DIMENSIONS



Top View



Bottom View



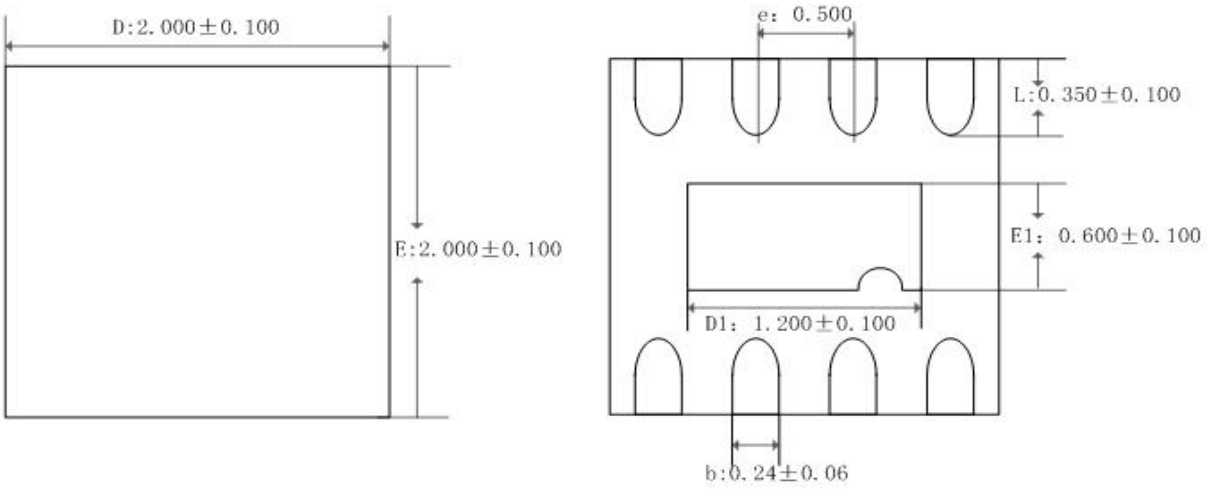
Side View

All dimensions are in millimeters

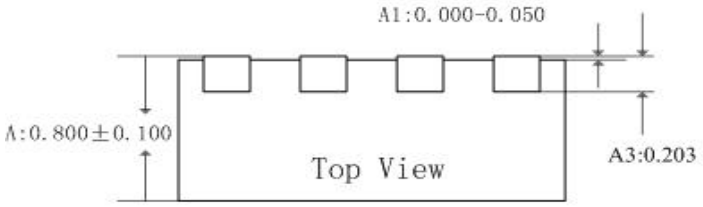
Symbol	Dimensions in Millmeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	0.450	0.550	0.018	0.022
A1	0.000	0.050	0.000	0.002
A3	0.152REF.		0.006REF.	
D	1.500	1.600	0.059	0.063
E	1.500	1.600	0.059	0.063
b	0.225	0.325	0.009	0.013
e	0.500TYP		0.020TRP.	
L	0.225	0.325	0.009	0.013
d	0.225	0.325	0.009	0.013

Unit: millimeters.

DFN2X2-8L PACKAGE OUTLINE DIMENSIONS



Top View Bottom View



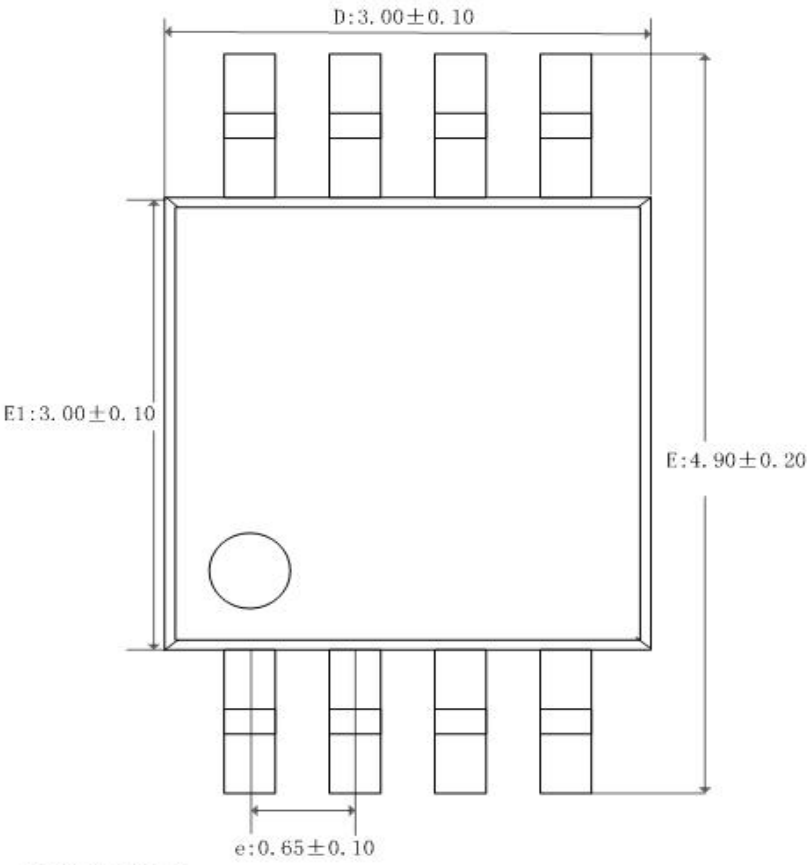
Side View

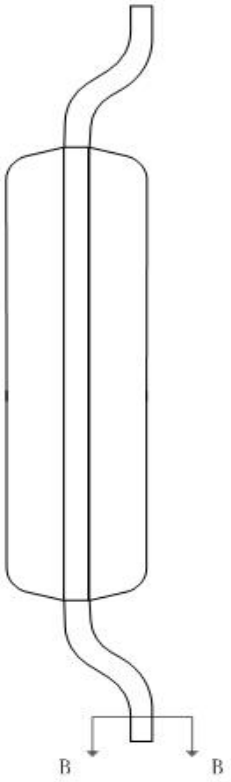
All dimensions are in millimeters

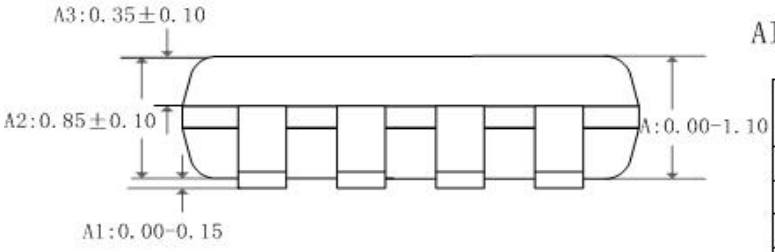
Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF		0.008REF	
D	1.900	2.100	0.075	0.083
E	1.900	2.100	0.075	0.083
D1	1.100	1.300	0.043	0.051
E1	0.500	0.700	0.020	0.028
k	0.200MIN.		0.008MIN.	
b	0.180	0.300	0.007	0.012
e	0.500TYP		0.020TYP.	
L	0.250	0.450	0.010	0.018

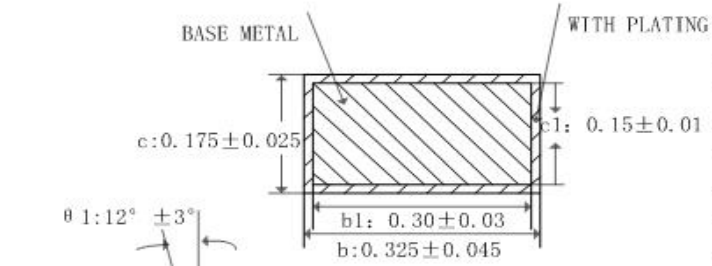
Unit: millimeters.

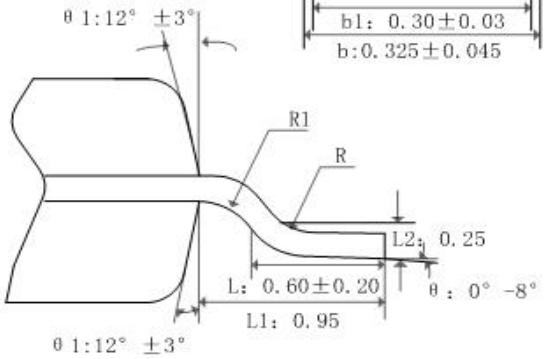
MSOP-8 PACKAGE OUTLINE DIMENSIONS











All dimensions are in millimeters

Symbol	Dimensions in Millimeters	
	Min.	Max.
A	—	1.10
A1	0	0.15
A2	0.75	0.95
A3	0.25	0.39
b	0.28	0.37
b1	0.27	0.33
c	0.15	0.20
c1	0.14	0.16
D	2.90	3.10
E	4.70	5.10
E1	2.90	3.10
e	0.55	0.75
L	0.40	0.80
L1	0.95REF.	
L2	0.25BSC.	
R	0.07	—
R1	0.07	—
θ	0°	8°
θ1	9°	15°

Unit: millimeters.