4.2W Mono Class-K Audio Amplifier

Features

- Supply voltage range: 2.8 V to 5.5 V
- Static operation current: 3.5mA
- Shutdown current: <1uA
- Loudspeaker peak power from 5V supply:
  - 4.2W @ 4Ω, Po,10% THD+N
  - 3.5W @ 4Ω, Po,1% THD+N
- Loudspeaker peak power from 4.2V supply:
  - 3W @ 4Ω, Po,10% THD+N
  - 2.6W @ 4Ω, Po,1% THD+N
  - 2.9W @ 8Ω, Po,10% THD+N
  - 2.3W @ 8Ω, Po,1% THD+N
- Gain setting: 27.5dB
- Integrated adaptive charge-pump circuit
- Non-Crack-Noise (NCN) Function
- Pop noise and click noise reduction
- Under-Voltage detection
- Short-Circuit protection with auto recovery
- Over temperature protection with auto recovery

Applications

- Portable Multimedia Devices
- Mobile Phones
- GPS
- Handsets

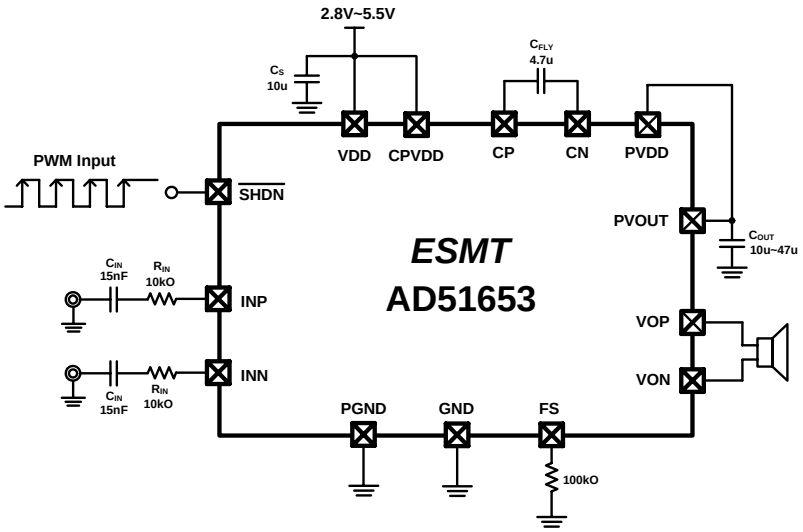
Description

The AD51653 is a mono, class-D audio amplifier with a built-in, adaptive charge pump circuit for better system power efficiency. Due to its design, AD51653 can provide a constant 3W peak output power with 4ohm speaker at 4.2V of battery output voltage. When the amplitude of the input audio signal is below a threshold, AD51653 operates in power-saving mode, which disables the charge-pump circuit to save power, and the amplifier is directly powered by the battery. When the amplitude of the audio signal exceeds the threshold level, AD51653 enables the charge-pump circuit to generate a regulated, 2xVDD (input power) power supply up to 6.5V, to drive the amplifier. Since most of time the audio signal is below the threshold level, this feature prolongs the battery life effectively without sacrificing the output quality.

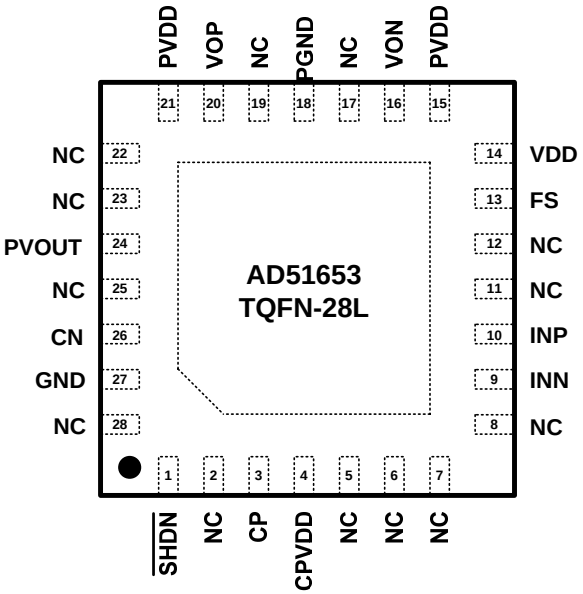
The non-crack-noise (NCN) function is enabled to prevent output signal from distortion when the input signal exceeds a threshold level. All these functions are performed automatically. AD51653 features four control modes, controlled by a one-wire pulse signal, to achieve different NCN mode setting.

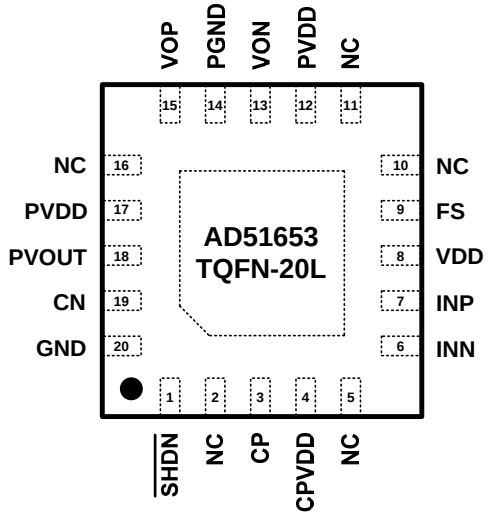
The output short circuit and over temperature protections provide auto-recovery feature. AD51653 is available in TQFN 4x4-28L, TQFN3x3-20L, E-TSSOP-14L and WLCSP-12L packages.

Simplified Application Circuit

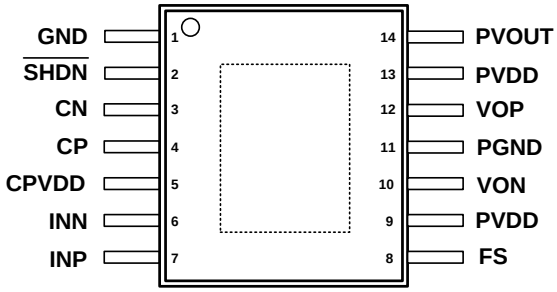


Pin Assignments (Top View)

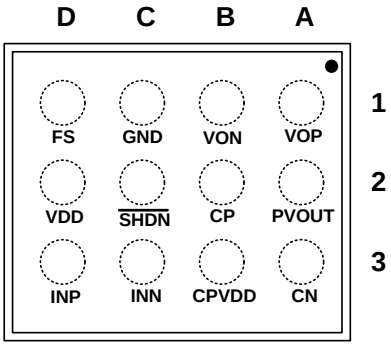




E-TSSOP-14L



AD51653



AD51653
WLCSP-12L

Pin Description

NAME	TQFN-28	TQFN-20	E-TSSOP-14	WLCSP-12	TYP	DESCRIPTION
$\overline{\text{SHDN}}$	1	1	2	C2	I	Shutdown terminal (active low).
NC	2	2	N/A	N/A	N/A	Not connected.
CP	3	3	4	B2	I/O	Charge-pump flying capacitor positive terminal.
CPVDD	4	4	5	B3	P	Charge-pump Supply.
NC	5, 6, 7, 8	5	N/A	N/A	N/A	Not connected.
INN	9	6	6	C3	I	Negative input.
INP	10	7	7	D3	I	Positive input.
NC	11, 12	N/A	N/A	N/A	N/A	Not connected.
FS	13	9	8	D1	I	Back-up pin, connect to GND or NC.
VDD	14	8	9	D2	P	Analog Supply.

PVDD	15	12	N/A	N/A	P	Power Supply, connect to PVOUT.
VON	16	13	10	B1	O	Negative amplifier output.
NC	17	10,11	N/A	N/A	N/A	Not connected.
PGND	18	14	11	N/A	P	Power ground.
NC	19	N/A	N/A	N/A	N/A	Not connected.
VOP	20	15	12	A1	P	Positive amplifier output
PVDD	21	17	13	N/A	P	Power Supply, connect to PVOUT.
NC	22, 23	16	N/A	N/A	N/A	Not connected.
PVOUT	24	18	14	A2	O	Charge-pump output.
NC	25	N/A	N/A	N/A	N/A	Not connected.
CN	26	19	3	A3	I/O	Charge-pump flying capacitor negative terminal.
GND	27	20	1	C1	P	Analog ground.
NC	28	N/A	N/A	N/A	N/A	Not connected.
Thermal pad					P	Must be soldered to PCB's ground plane.

Ordering Information

Product ID	Package	Packing	Comments
AD51653-HI28NRR	TQFN-28L (4mmx4mm)	Tape/Reel 3K Units/Reel	Green
AD51653-HH20NRR	TQFN-20L (3mmx3mm)	Tape/Reel 5K Units/Reel	Green
AD51653-QG14NRR	E-TSSOP-14L	Tape/Reel 2.5K Units/Reel	Green
AD51653-WL12NRR	WLCSP-12L (1.48mmx1.31mm)	Tape/Reel 3K Units/Reel	Green

Available Package

Package Type	Device No.	θ_{JA}(° C/W)	Exposed Thermal Pad
TQFN-28L	AD51653	37(° C/W)	Yes (Note 1)
TQFN-20L		48(° C/W)	Yes (Note 1)
E-TSSOP-14L		38(° C/W)	Yes (Note 1)
WLCSP-12L		128(° C/W)	No

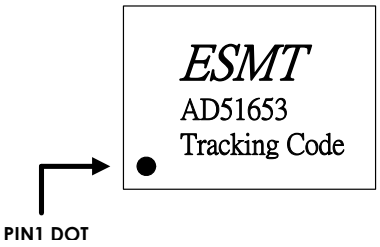
Note1: The thermal pad is at the bottom of package. To optimize the performance of thermal dissipation, solder the thermal pad to PCB's ground plane is suggested.

Marking Information

AD51653

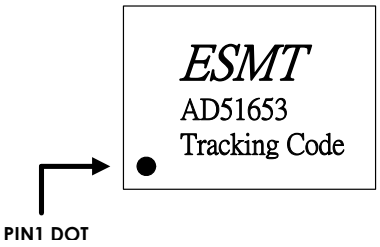
- TQFN-28L and E-TSSOP-14L Package Marking Information

Line 1：LOGO
Line 2：Product No
Line 3：Tracking Code



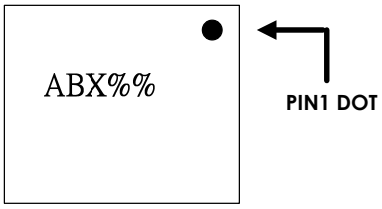
- TQFN-20L Package Marking Information

Line 1：LOGO
Line 2：Product No
Line 3：Tracking Code



- WLCSP-12L Package Marking Information

ABX：Product code
%% ：Tracking Code



Absolute Maximum Ratings

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
VDD	Supply voltage	VDD, CPVDD	-0.3	7	V
V_I	Interface pin voltage	$\overline{SHDN}$, INN, INP	-0.3	VDD+0.3	V
T_A	Operating free-air temperature range		-40	85	°C
T_J	Operating junction temperature range		-40	150	°C
T_{stg}	Storage temperature range		-65	150	°C
ESD	HBM protection voltage		8		kV
Latch-up	+IT		200		mA
	-IT		-200		mA
R_L	Minimum Load Resistance (except WLCSP-12L package)		3.2		Ω
	Minimum Load Resistance for WLCSP-12L package		6.4		Ω

Electrical Characteristics

- T_A=25°C (unless otherwise noted)

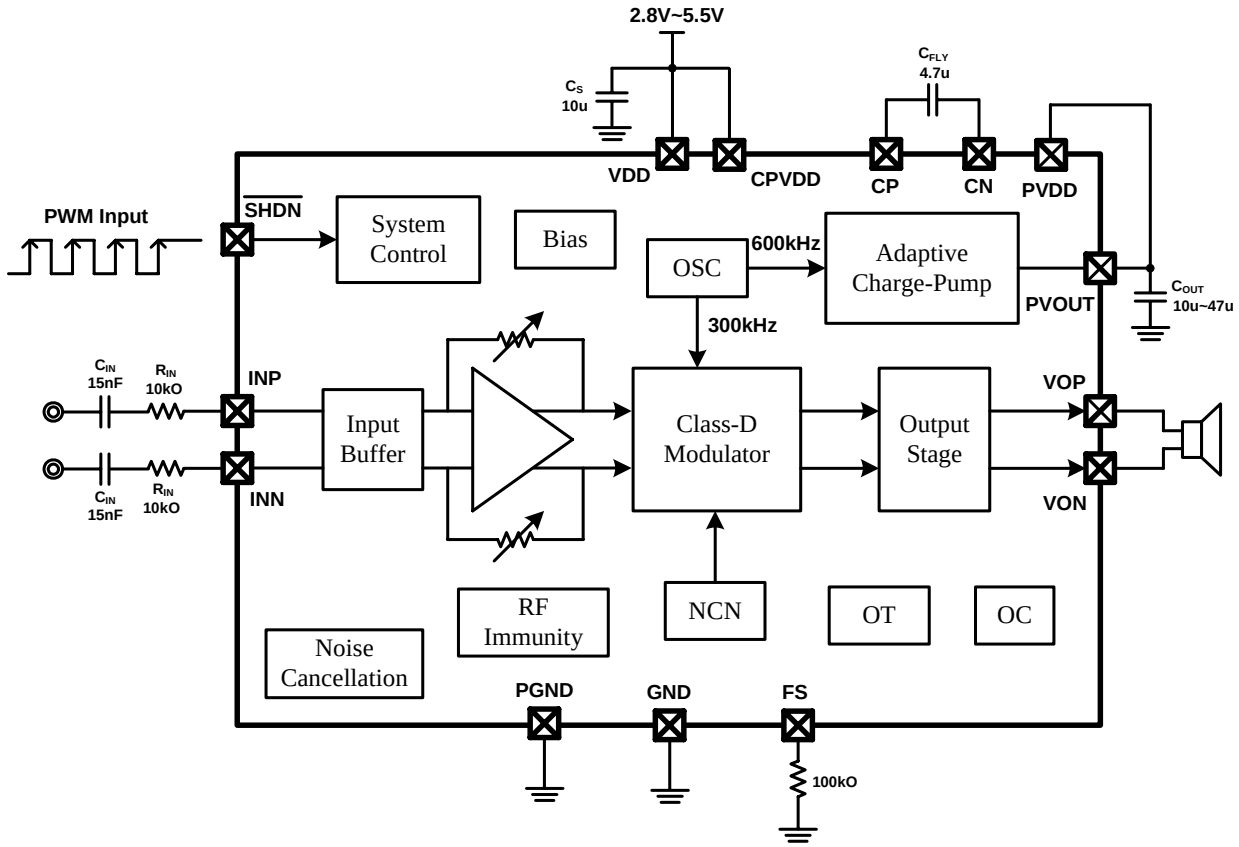
SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
VDD	Supply voltage		2.8		5.5	V
I_Q	Quiescent supply current	VDD=3.6V, no input		3.5	10	mA
I_{SD}	Quiescent supply current in shutdown mode	VDD=3.6V, SHDN=0V		0.1	1	μA
V_{IH}	High-level Input Voltage	SHDN	1.2		VDD	V
V_{IL}	Low-level Input Voltage	SHDN	0		0.35	V
I_{IH}	High-level Input Current	VDD=5.5V, Vi=5.8V			100	μA
I_{IL}	Low-level Input Current	VDD=5.5V, Vi=-0.3V			5	μA
Over temperature protection				160		°C
Hysteresis temperature				135		°C
Vos	Output offset voltage	No load		5	20	mV
R_{IN}	Input Resistance			5		kΩ
f_{PWM}	Modulation Frequency	VDD=2.8V to 5.5V	240	300	360	kHz
PSRR	Power supply rejection ratio	VDD=3.6V, Vpp_sin=0.2V, f=217Hz		-68		dB
		VDD=3.6V, Vpp_sin=0.2V, f=1kHz		-68		dB

Electrical Characteristics(continued)

● T_A=25°C (unless otherwise noted)

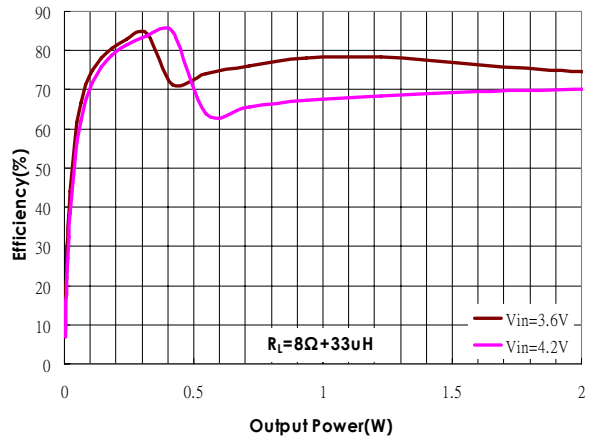
SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
P_O	Output power	THD+N=10%, f=1kHz, R_L=4Ω+33μH, VDD=4.2V		3		W
		THD+N=1%, f=1kHz, R_L=4Ω+33μH, VDD=4.2V		2.6		
		THD+N=10%, f=1kHz, R_L=8Ω+33μH, VDD=4.2V		2.9		
		THD+N=1%, f=1kHz, R_L=8Ω+33μH, VDD=4.2V		2.3		
		THD+N=10%, f=1kHz, R_L=8Ω+33μH, VDD=4V		2.7		
		THD+N=1%, f=1kHz, R_L=8Ω+33μH, VDD=4V		2.3		
THD+N	Total harmonic distortion plus noise	VDD=3.6V, Po=0.3W		0.04		%
		VDD=3.6V, Po=1W		0.04		
Ton	Wake-up time	VDD=2.8V to 5.5V		35	50	ms
V_n	Output integrated noise	VDD=3.6V, Gain=27.5dB, a-weighted filter		130		μV
Charge-pump						
PVOUT	Output voltage	Power-saving mode		VDD		V
		High power mode		6.5V		V
I_{OUT}	Maximum output current				1	A
fcp	Operating frequency	VDD=2.8V to 5.5V	480	600	720	kHz
NCN						
T_{AT}	Attack time	VDD=3.6V		27		ms
T_{RL}	Release time	VDD=3.6V		1.8		s
A_{MAX}	Maximum attenuation gain	NCN enable (Mode 1~3)		-8.7		dB
One wire pulse control						
T_{HI}	Program high time		0.24			μs
T_{LO}	Program low time				240	μs
T_{OFF}	Low time to shutdown		240	300	360	μs

Functional Block Diagram

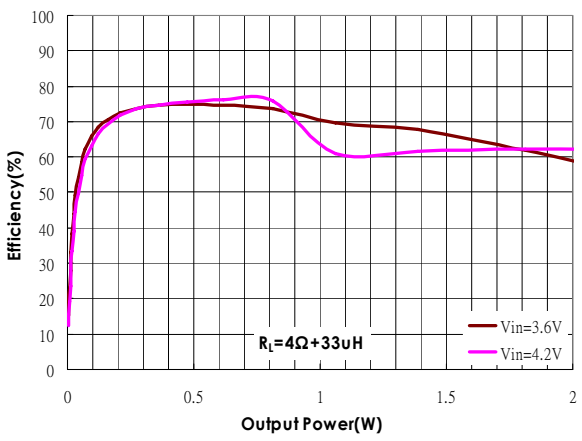


Typical Characteristics

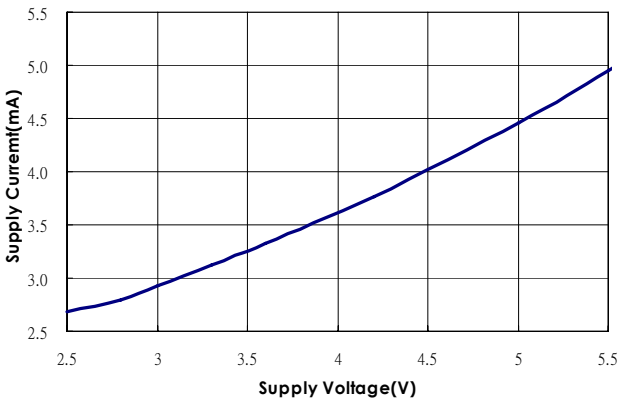
Efficiency vs. Output Power



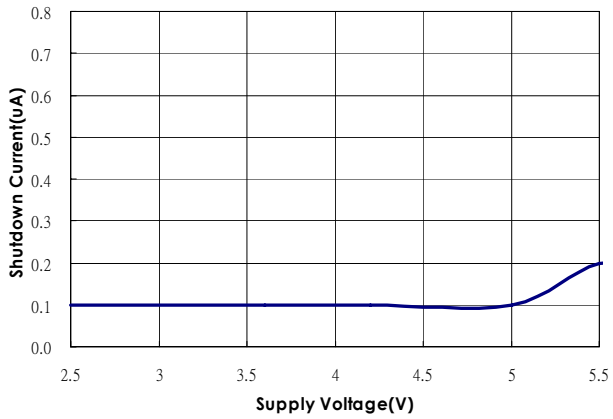
Efficiency vs. Output Power



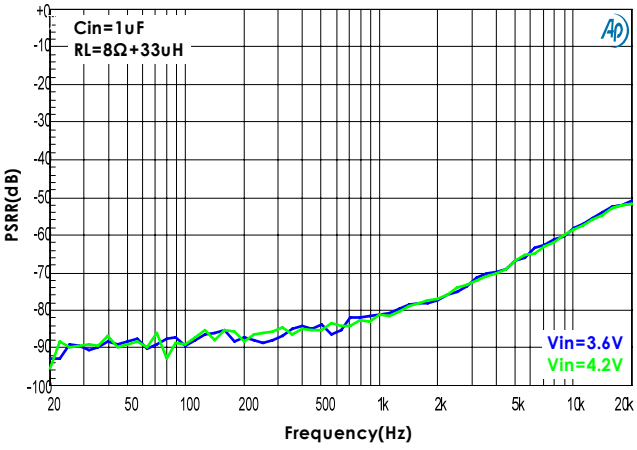
Supply Current vs. Supply Voltage



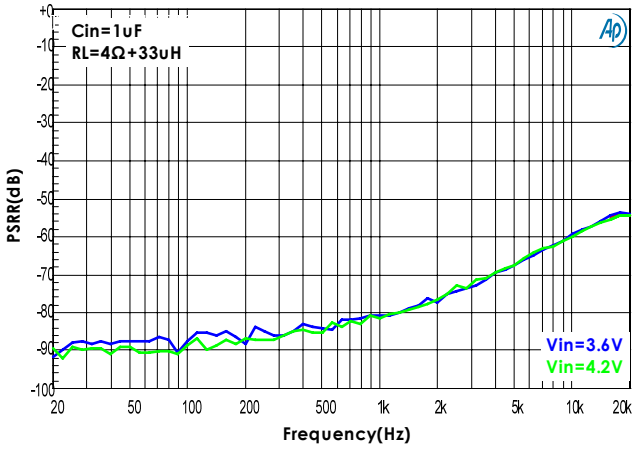
Shutdown Current vs. Supply Voltage



PSRR vs. Frequency

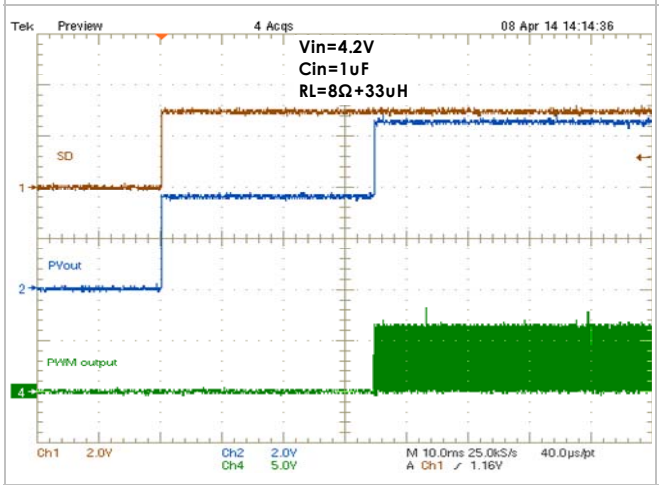


PSRR vs. Frequency

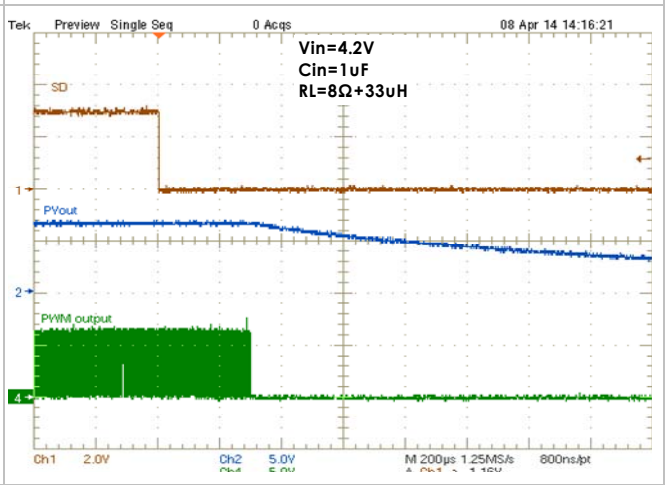


Typical Characteristics

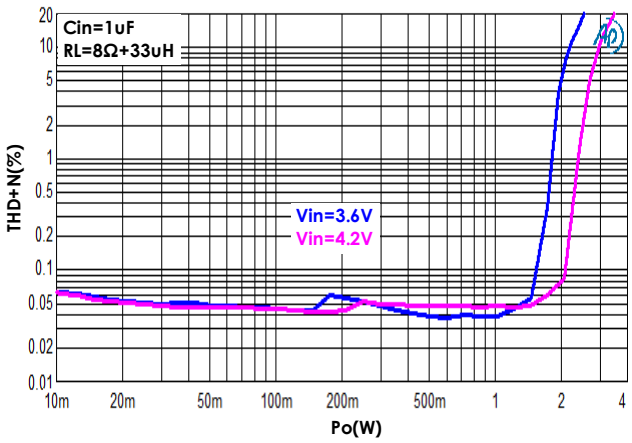
SHDN Response(T_{On})



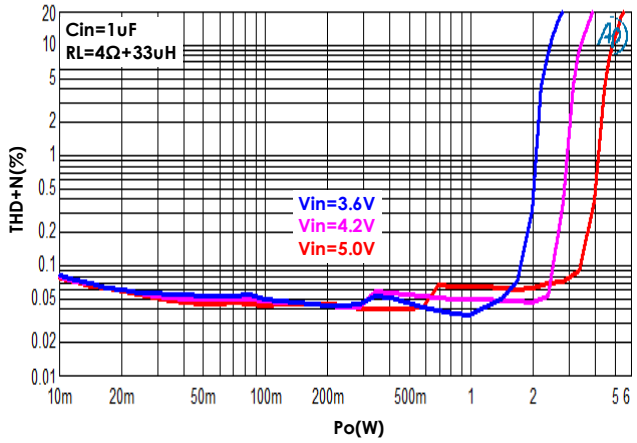
SHDN Response(T_{OFF})



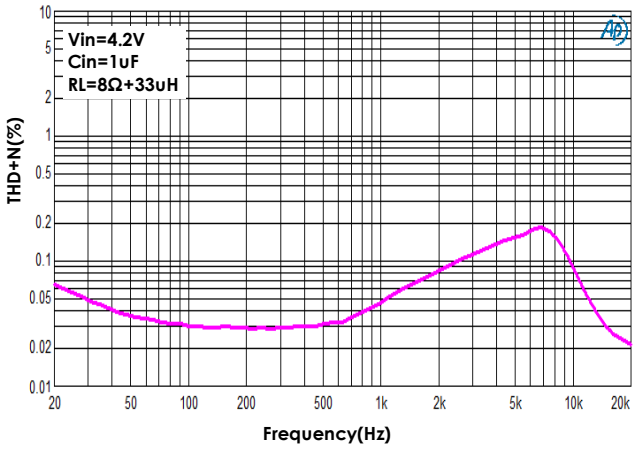
THD+N vs. Output Power(Mode4,NCN OFF)



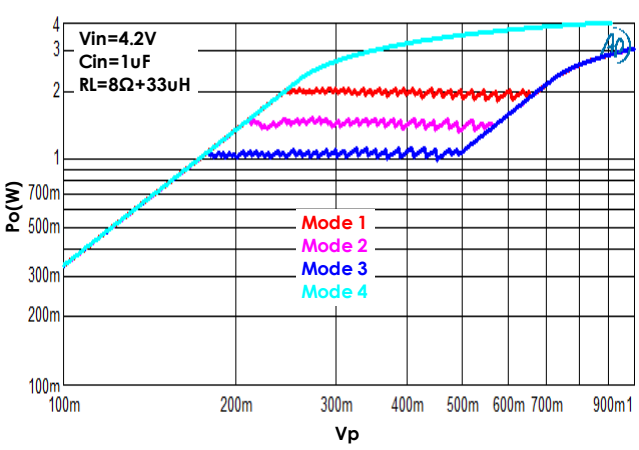
THD+N vs. Output Power(Mode4,NCN OFF)



THD+N vs. Frequency

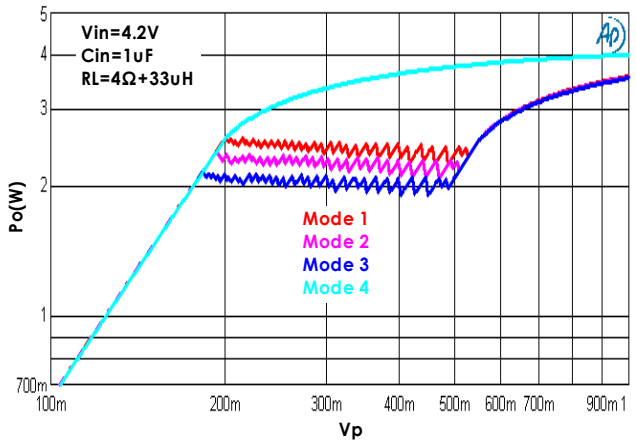


NCN Function

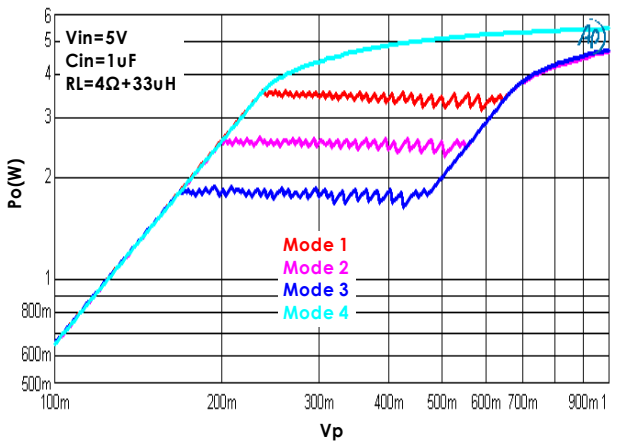


Typical Characteristics

NCN Function



NCN Function



Operation Descriptions

- **Amplifier Function with Charge-Pump**

AD51653 is a class-D power amplifier with an adaptive charge-pump boost circuit. With the help of charge-pump, AD51653 can delivery 2.4W output power at 4V supply. As the amplitude of output signal is smaller than a quarter of VDD, AD51653 works in power-saving mode, the class D amplifier is powered at VDD. As the amplitude of output signal is larger than a quarter of VDD, AD51653 works in high-power mode, and charge-pump output is regulated to 2xVDD or maximum 6.5V. Figure 1 shows the function of adaptive charge-pump circuit operation. When working under high-power mode, once the output signal amplitude drops below a quarter of VDD, the charge-pump circuit returns to power-saving mode after 32ms.

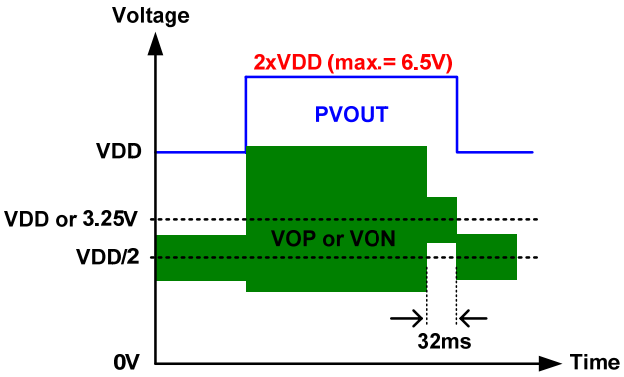


Figure. 1

The soft-start time of charge-pump, output building from 0V to VDD, is about 0.5ms. Under power-saving mode, charge-pump will not function in switching status to save power, and PVOUT will equal to VDD. As charge-pump switch to high-power mode, the power switches are fully turned on to charge output capacitor. Normally, it takes about 20us for charge-pump to build from VDD to 6.5V.

- **NCN Function**

Large input signal or lower supply voltage will easily lead to distortion of output signal. The distortion of crack signal will also cause perpetual damage to the speaker. AD51653 features a non-crack noise (NCN) function to prevent output signal from distortion to provide a better listening experience to user and protect the speaker from overload. NCN function can automatically adjust system gain to let the output signal remain smooth by detecting the distortion level of output signal and keeping the distortion level at NCN limit level with lower THD+N performance.

VDD=4.2V/8ohm load			
Mode	Gain (dB)	NCN Limit Level @Po	NCN Function
1	27.5	2W	ON
2	27.5	1.5W	ON
3	27.5	1W	ON
4	27.5	-	OFF

Figure 2 shows the ideal output waveform without clipping by rail. Figure 3 shows the realistic output signal with clipping by rail. Figure 4 shows the output waveform with NCN function enabled. When output signal is distorted, gain immediately decreases by one step. Then, gain will decrease incrementally every 27ms, which is the attack time. The maximum attenuation of gain is -8.7dB at NCN function enable (mode 1~3). Once the output signal is undistorted, the gain level will remain unchanged until the input signal is lowered. As output is lowered, the attenuated gain steps is released incrementally every 1.8s, which is the release time.

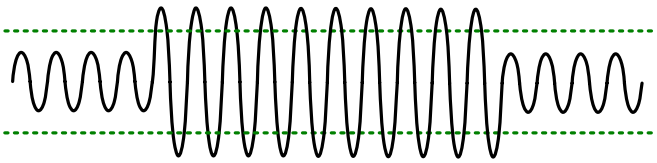


Figure.2 Waveform of output signal without clipping by rail

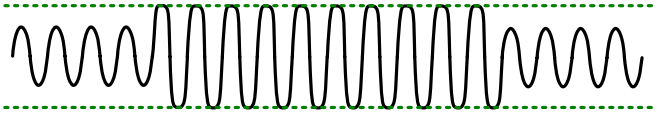


Figure.3 Waveform of output signal with clipping by rail

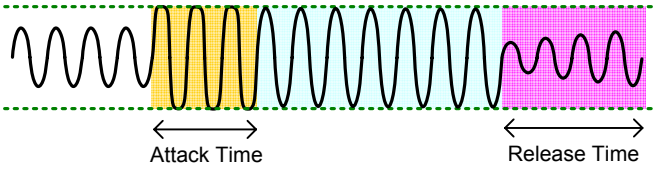


Figure.4 Waveform of output signal with NCN ON

- **Thermal protection**

  If the internal junction temperature is higher than 160°C, the outputs of loudspeaker drivers is disabled and be kept low. The temperature at which the AD51653 returns to normal operation is about 135°C. The variation of protected temperature is about 10%.

- **Short-circuit protection**

  To protect loudspeaker drivers from over-current damage, AD51653 has a built-in short-circuit protection circuit. When the wires connected to loudspeakers are shorted to each other, to GND, or to PVDD, overload detectors may activate. Once one of the positive and negative half bridge overload detectors is activated, the amplifier outputs turns off and the protection latch is engaged. The short circuit protection latch has auto-recovery function every 220ms.

- **Under-voltage detection**

  When the VDD voltage is lower than 2.4V, amplifiers is disabled and the output kept low. Otherwise, AD51653 returns to normal operation.

Operating Mode Selection

AD51653 has four operation modes which can be selected by one-wire control pulse. The chip enters Mode 1 when SHDN/ pin pulled to high. The NCN function to ON and NCN limit level at Po=2W. By continuing to supply low → high at SHDN/ pin, the NCN will be set to ON still and NCN limit level at Po=1.5W. Be mindful of T_{HI} and T_{LOW}, as T_{HI} should not be shorter than 200ns and T_{LOW} should not be longer than 240μs. As a result, given an appropriate pulse at SHDN/ pin, the user can easily choose the operating mode. Note that these four modes will repeat as the pulse at SHDN/ pin continues to give (Mode1 → Mode2 → Mode3 → Mode4 → Mode1 …). Figure 5 shows the one-wire pulse control function.

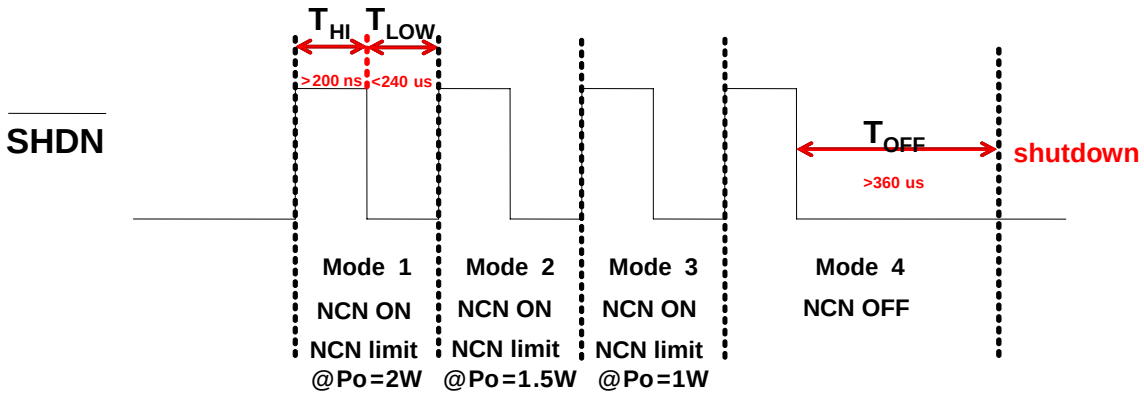


Figure.5 One-Wire Pulse Control

Figure 6 shows an example of entering mode 3. If shutdown is desired, SHDN/ should be pulled to low for more than 300μs, and the chip will enter shutdown mode, resetting mode selection.

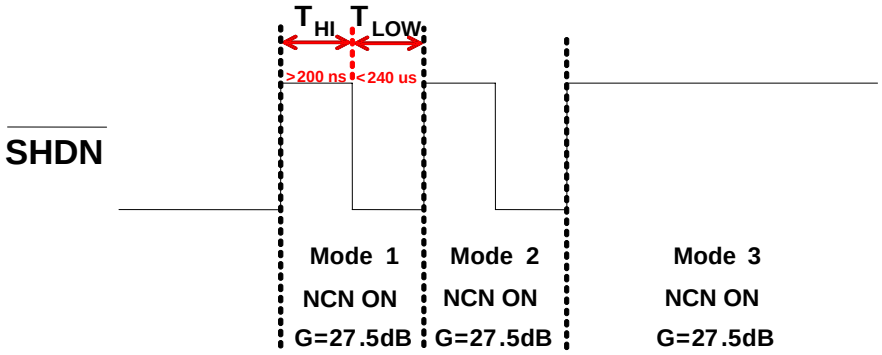


Figure.6 One-Wire Pulse Control Entering Mode 3

Gain Setting

The total gain of the audio amplifier is set by Rin,according to the following equation (a).

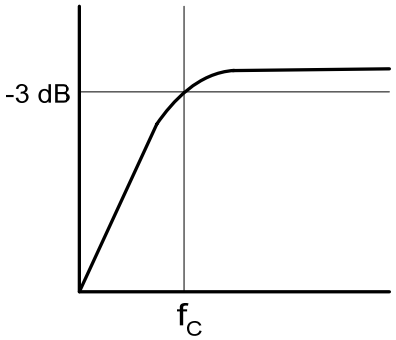
$$Gain = \frac{360k\Omega}{5k + R_{in}} \left(V/V\right) \cdots\cdots\cdots (a)$$

Application information

- **Input capacitors (C_{IN}) and input resistors**

  Performance at low frequency (bass) is affected by the corner frequency (f_c) of the high-pass filter, which consists of an input resistor and an input capacitor (C_{IN}). The resistance of input resistors is different at different gain setting. The respective gain and input resistance are listed in Table 1. For fully differential amplifiers, component matching is important for PSRR, CMRR, and even-order distortion cancellation. It is recommended to use 1% tolerance value of R_{IN} and C_{IN} to get better performance.

$$f_c = \frac{1}{2\pi (R_{IN} + 5k\Omega) C_{in}} \ (Hz)$$



- **Charge-pump capacitors (C_{OUT} and C_{FLY})**

  The capacitance and ESR of C_{OUT} directly affect the charge-pump output voltage ripple, thus affect amplifier's performance. X5R or X7R ceramic type capacitor with capacitance of 10μF and low ESR is recommended for C_{OUT}.

  Flying capacitor directly affects charge-pump's load regulation and output capability. X5R or X7R ceramic type capacitor with capacitance of 4.7μF and low ESR is recommended for C_{FLY}.

- **Ferrite Bead Selection**

  If the traces between AD51653 and speaker are short, the ferrite bead filters can reduce the high frequency emissions to meet FCC requirements. A ferrite bead that has very low impedance at low frequency and high impedance at high frequency (above 1MHz) is recommended. The impedance of the ferrite bead can be used along with a small capacitor with a value around 1000pF to reduce the frequency spectrum of the signal to an acceptable level.

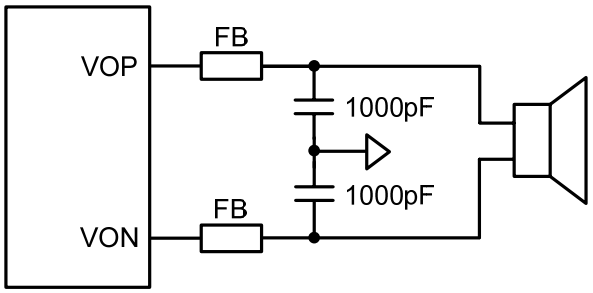
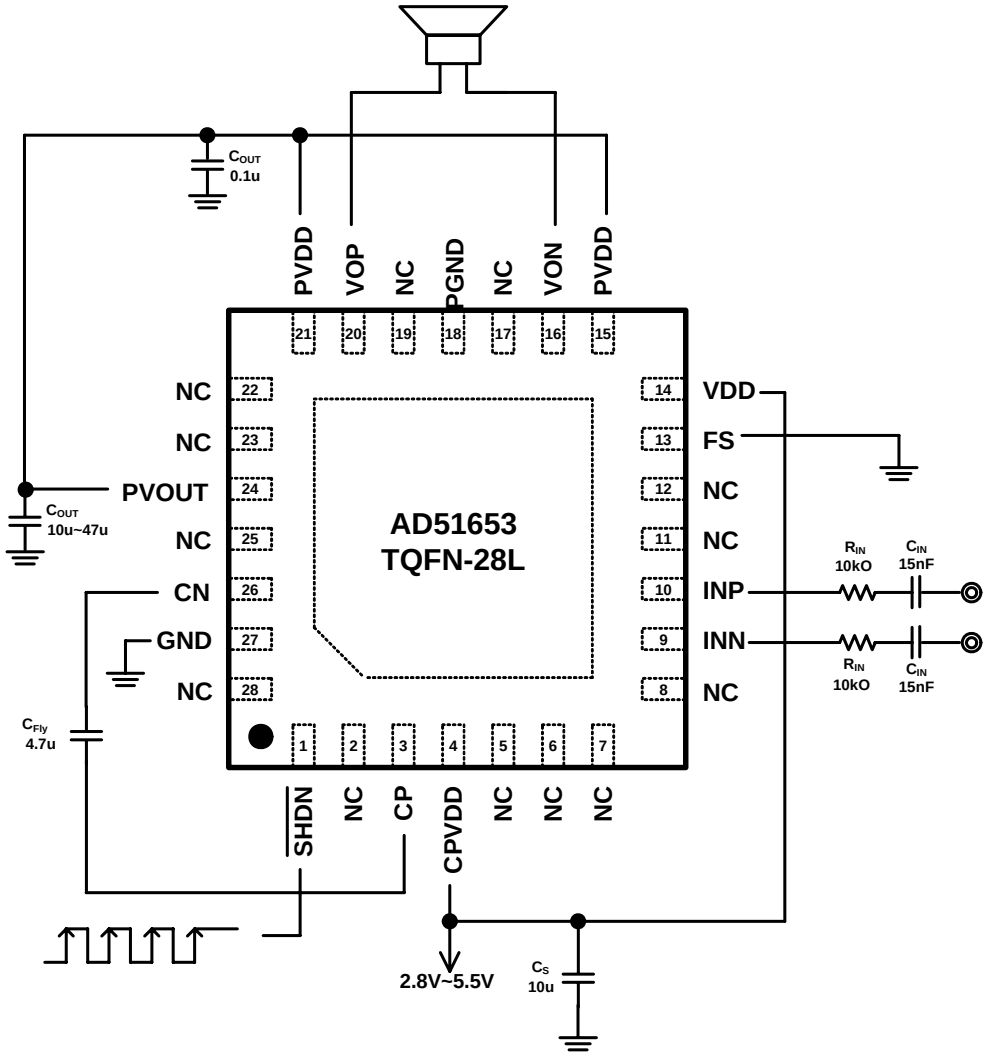


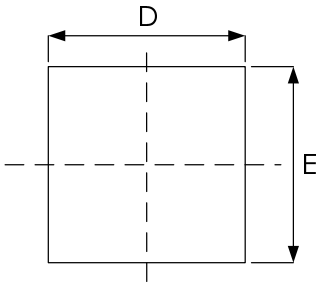
Figure 8. Typical Ferrite Bead Filter

Application Circuit Example

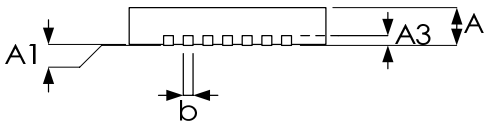


Package Outline Drawing

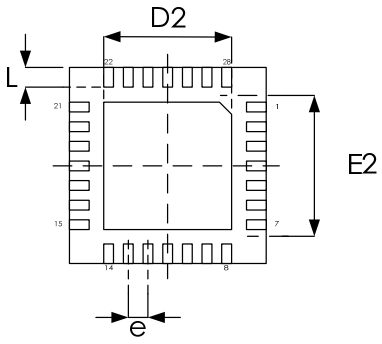
TQFN-28L (4x4 mm)



TOP VIEW



SIDE VIEW



BOTTOM VIEW

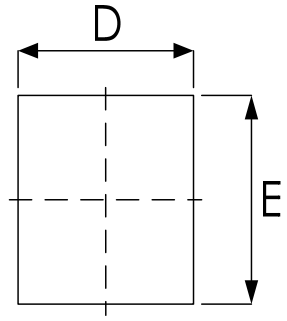
Symbol	Dimension in mm	
	Min	Max
A	0.70	0.80
A1	0.00	0.05
A3	0.20 REF.	
b	0.15	0.25
D	4.00 BSC	
E	4.00 BSC	
e	0.40 BSC	
L	0.30	0.50

Exposed pad

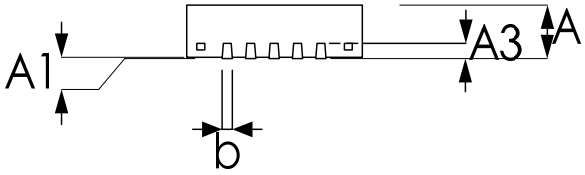
	Dimension in mm	
	Min	Max
D2	2.5	2.65
E2	2.5	2.65

Package Outline Drawing

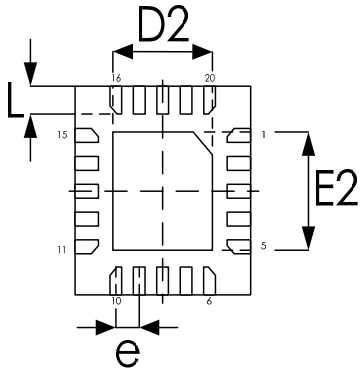
TQFN-20L (3x3 mm)



TOP VIEW



SIDE VIEW



BOTTOM VIEW

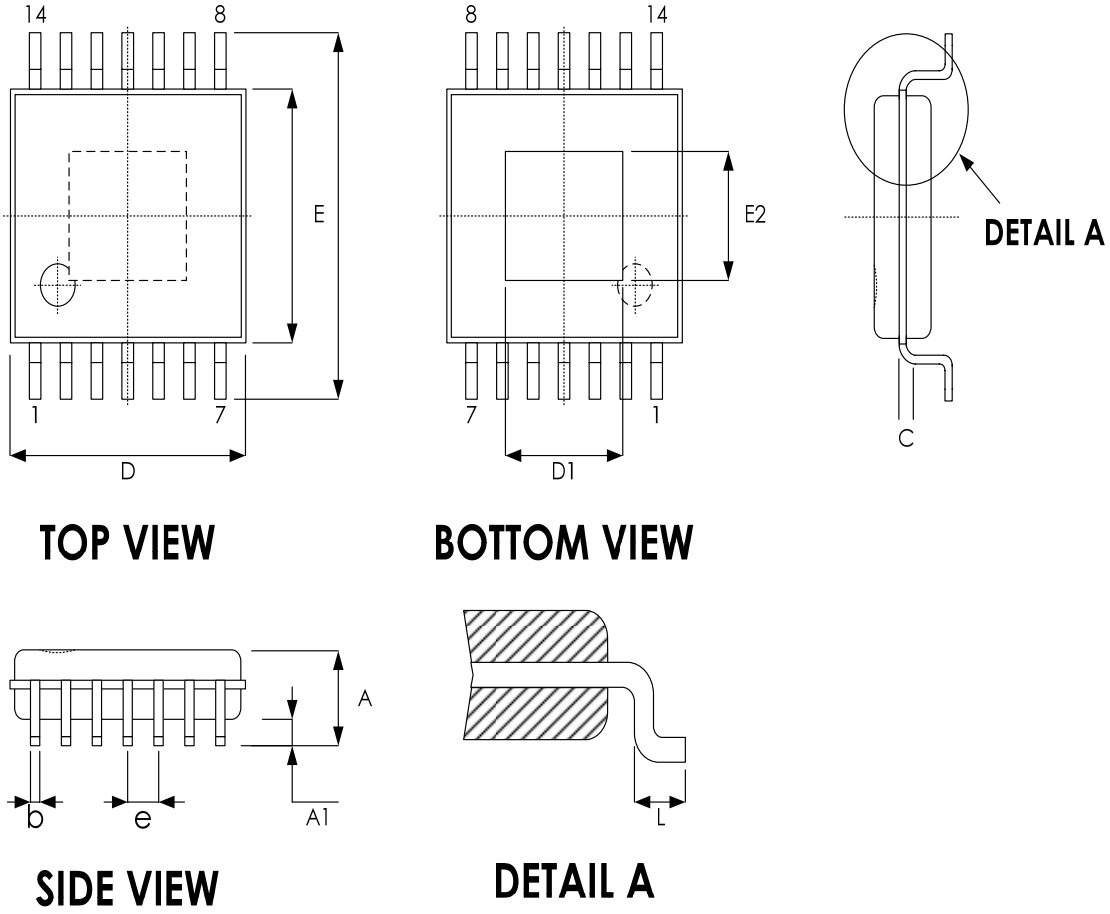
Symbol	Dimension in mm	
	Min	Max
A	0.70	0.85
A1	0.00	0.05
A3	0.20 REF.	
b	0.15	0.25
D	2.924	3.076
E	2.924	3.076
e	0.40 BSC	
L	0.324	0.476

Exposed pad

	Dimension in mm	
	Min	Max
D2	1.40	1.60
E2	1.40	1.60

Package Outline Drawing

E-TSSOP-14L



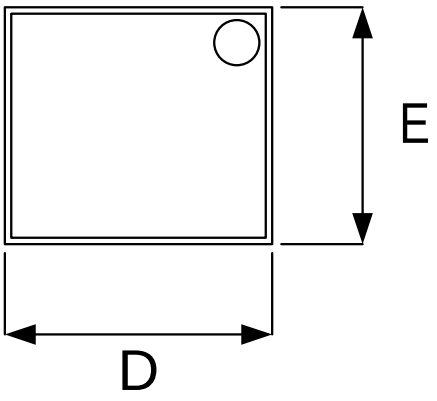
Symbol	Dimension in mm	
	Min	Max
A	--	1.20
A1	0.05	0.15
b	0.19	0.30
D	4.90	5.10
E	4.30	4.50
E1	6.40 BSC	
e	0.65 BSC	
L	0.5	0.75

Exposed pad

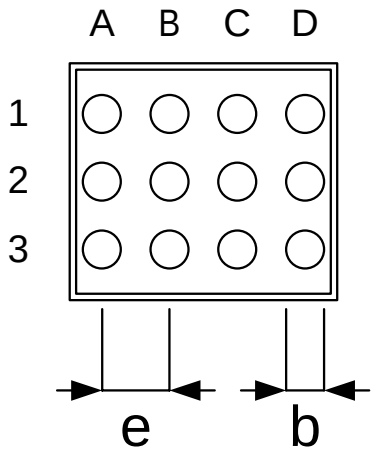
	Dimension in mm	
	Min	Max
D1	1.92	2.54
E2	1.67	2.29

Package Outline Drawing

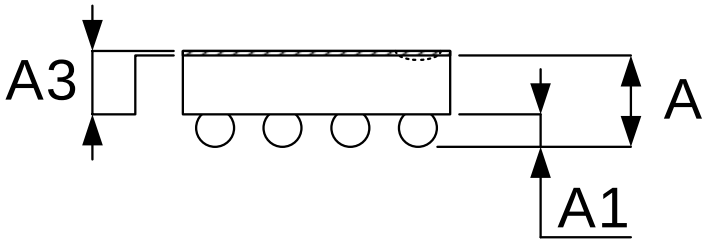
WLCSP-12L (1.48mm x 1.31mm)



TOP VIEW



BOTTOM VIEW



SIDE VIEW

Symbol	Dimension in mm
	Typical
A	0.536
A1	0.16
A3	0.025
b	0.175
D	1.48
E	1.31
e	0.35

Revision History

Revision	Date	Description
0.1	2015.04.02	Preliminary version.
0.2	2015.05.07	Update gain setting in page 13.
0.3	2015.12.24	Update One-Wire Pulse timing
0.4	2016.08.02	Update Application Circuit

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