ft2810

2.4W *Dual-Pump*™ Class-G Audio Power Amplifier

GENERAL DESCRIPTION

The ft2810 is a Class-G audio power amplifier based upon a proprietary ***Dual-Pump***™ topology with battery-tracking AGC technology. It can deliver up to 2.4W into an 8 Ω load with 10% THD+N. Its high efficiency, up to 74%, helps greatly extend battery life for portable applications.

The proprietary ***Dual-Pump***™ topology employed by an internal charge pump generates a 6V supply voltage for the output stage of the Class-G audio amplifier, thus allowing a much higher output power than a conventional stand-alone amplifier directly connected to the battery supply voltage. The AGC technology allows the audio signal to be adaptively amplified for a maximum dynamic range of the output signal without clipping, which might be otherwise resulted from an over-level input signal or a lower supply voltage.

The ft2810 incorporates a low-pass filter (100 KHz) at the inputs to enhance RF rejection and reduce DAC out-of-band noise, therefore greatly improving the signal-to-noise ratio (SNR).

FEATURES

- Wide supply voltage range from 2.7V to 5.5V
- Proprietary ***Dual-Pump***™ topology
- Filterless Class-G operation
- Output power at 4V supply
  - 2.4W (8 load, 10% THD+N)
  - 2.0W (8 load, 1% THD+N)
- Low THD+N: 0.1% (typical) @ 1KHz (VDD=3.6V, RL=8 , P_O=1W)
- High efficiency up to 74%
- Four gain settings: 12/16/24/28dB
- Non-clip control to suppress output clip
- Integrated input low-pass filter for out-of-band noise rejection
- One-wire operating mode and gain control
- Auto-recovering over-current or short-circuit protection
- Low EMI design
- Available in QFN3x3-20L package

QFN-20L

APPLICATIONS

- Cell Phones
- Smart phones
- MP3/4/5
- Portable electronic devices

APPLICATION CIRCUIT

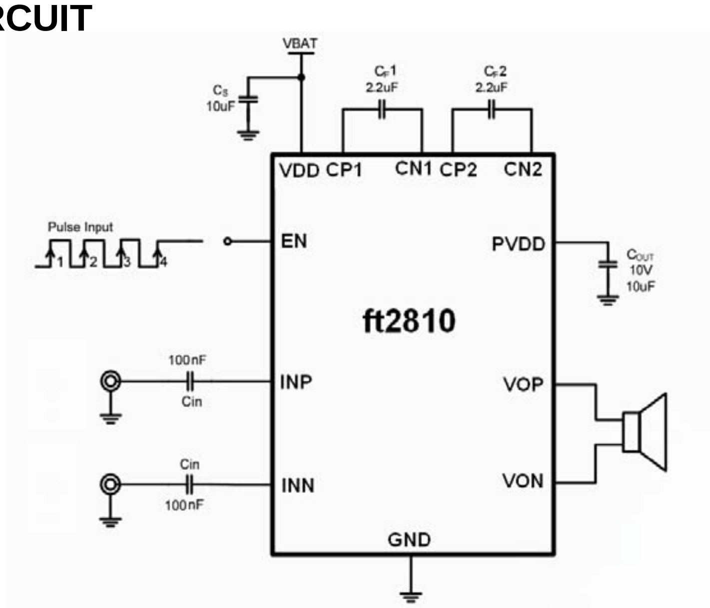
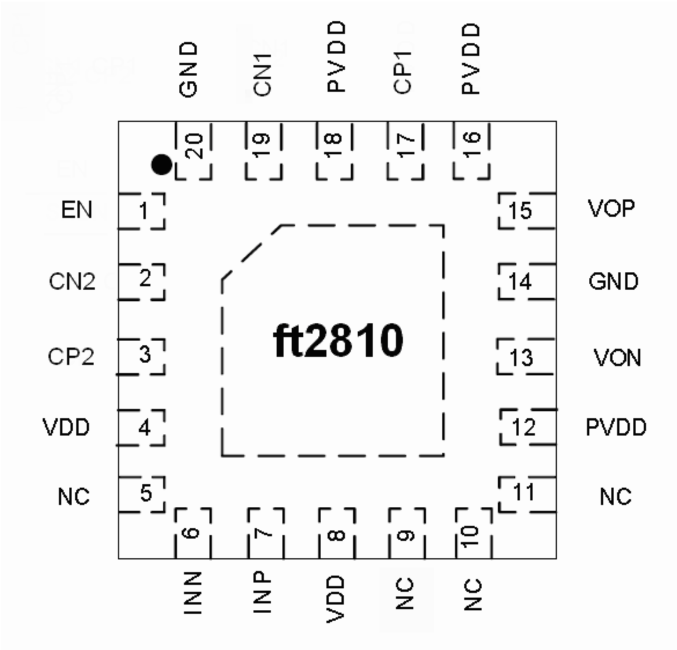


Figure 1: Typical Audio Power Amplifier Application Circuit

PIN CONFIGURATION AND DESCRIPTION



Top View

Symbol	QFN3x3-20	I/O	Description
EN	1	I	Chip enable.
CN2	2	O	Flying capacitor negative terminal 2.
CP2	3	O	Flying capacitor positive terminal 2.
VDD	4	P	Power supply.
NC	5	-	NC.
INN	6	I	Negative audio input terminal (differential -).
INP	7	I	Positive audio input terminal (differential +).
VDD	8	P	Power supply.
NC	9,10,11	-	NC.
PVDD	12	P	Class-G Audio power amplifier voltage supply.
VON	13	O	Negative audio output.
GND	14	G	Ground.
VOP	15	O	Positive audio output.
PVDD	16	P	Class-G Audio power amplifier voltage supply.
CP1	17	O	Flying capacitor positive terminal 1.
PVDD	18	P	Class-G Audio power amplifier voltage supply.
CN1	19	O	Flying capacitor negative terminal 1.
GND	20	G	Ground.

ORDERING INFORMATION

PART NUMBER		TEMPERATURE RANGE	PIN-PACKAGE
Lead Free	Green		
ft2810Q		-40°C to +85°C	QFN3x3-20L

ABSOLUTE MAXIMUM RATINGS

Parameter	Value
Supply voltage, VDD	-0.3V to 6.0 V
Storage Temperature	−65°C to +150°C
Input Voltage EN	−0.3V to VDD+0.3V
Power Dissipation	Internally Limited
ESD Ratings-Human Body Model (HBM)	4000V
Junction Temperature	150°C
θ_{JA} (A)	48°C/W
Maximum Soldering Temperature (@10 sec duration)	260°C

Note 1: Stresses beyond those listed under absolute maximun ratings may cause permanent damage to the device. These are stress ratings only,and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied.Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

Parameter	Conditions	MIN	TYP	MAX	UNIT
Supply voltage，VDD		2.7		5.5	V
Operating free-air temperature, T_A		-40		85	°C
Load impedance, Z_L		6.8	8		

FUNCTIONAL BLOCK DIAGRAM

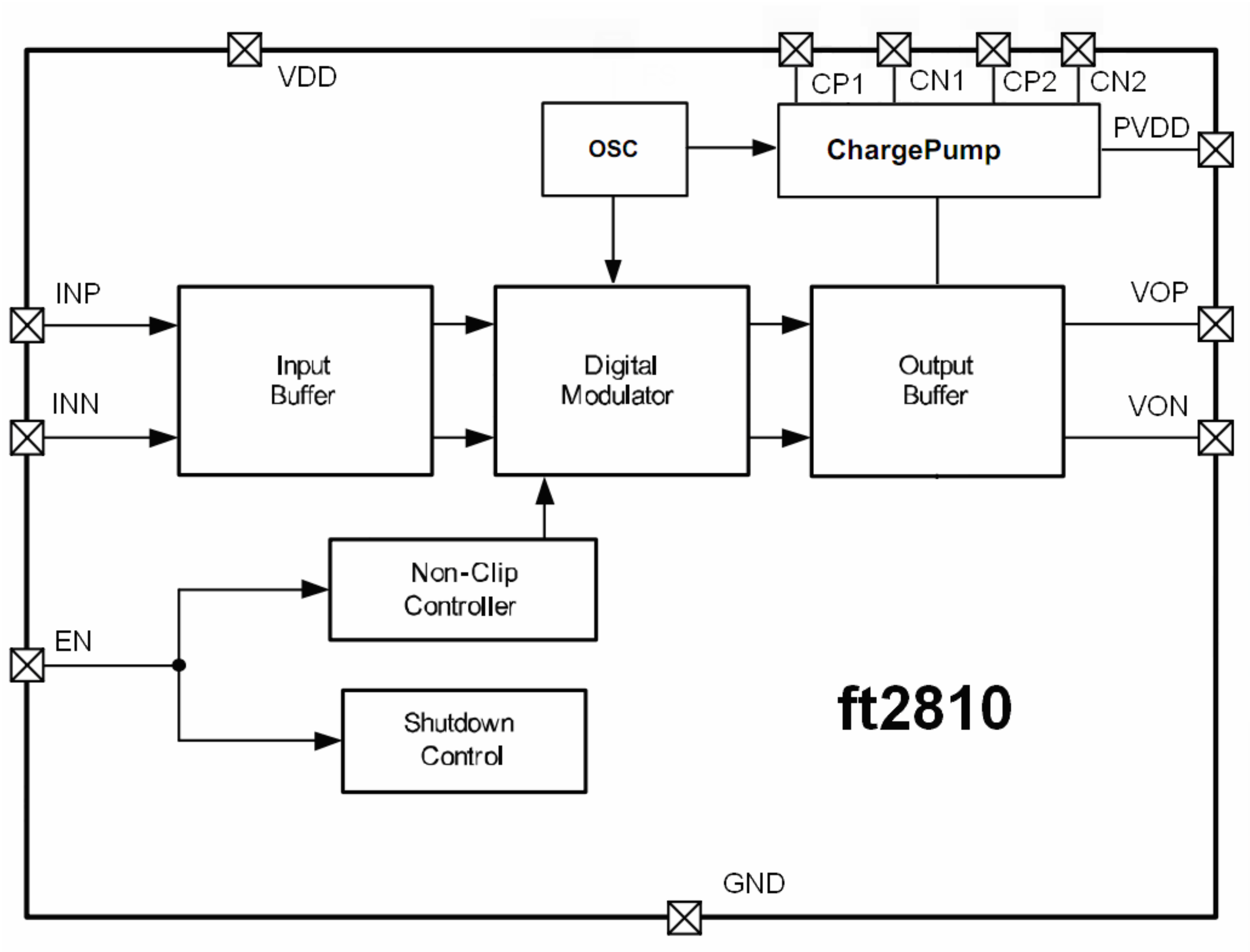


Figure 2: ft2810 Simplified Functional Block Diagram

ELECTRICAL CHARACTERISTICS

VDD = 3.6V, Gain = 12dB, Cs=10μF, COUT=10μF, CF1 = CF2 = 2.2μF, CIN=0.1μF, Load = 8 +33 μH, TA = 25°C, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
VDD	Supply voltage range		2.7		5.5	V
$UVLO_{RISE}$	Under voltage lockout	When VDD rising		2.2		V
$UVLO_{FALL}$	Under voltage lockout	When VDD falling		1.9		V
I_Q	Quiescent current	EN=VDD, Inputs AC-grounded		2.5	5	mA
I_{SD}	Shutdown quiescent current	VDD=2.7V to 5.5V, EN=GND		0.1	1	μA
V_{IH}	High–level input voltage @ EN		1.4			V
V_{IL}	Low–level input voltage @ EN				0.4	V
T_{SD}	Thermal shutdown			160		°C
T_{HYS}	Thermal hysteresis			20		°C
η	Power efficiency	POUT=1W, f=1KHz		74		%
CHARGE PUMP						
PVDD	Charge pump output voltage	I_{PVDD}=500mA	5.7	6.0	6.3	V
I_{OUT}	Max. Output Current			0.7	0.9	A
T_{PRECH}	Pre-charge time	C_{OUT}=10uF		0.4		ms
T_{SS}	Soft-start time	V_{in} from 225mVrms to 450mVrms		0.24		ms
f_{PUMP}	Charge pump switching frequency	VDD=2.7V to 5.5V		800		KHz
CLASS-G AMPLIFIER						
Po	Output power (Non-clip Mode Off)	THD=10%, VBAT=4V, f=1KHz		2.4		W
		THD=1%, VBAT=4V, f=1KHz		2.0		W
	Output power (Non-clip Mode On)	V_{in}=225mVrms, VBAT=4V, f =1KHz		1.9		W
$f_{CLASS-G}$	PWM switching frequency	VDD=2.7V to 5.5V		400		KHz
V_{OS}	Output offset voltage	No load		±10		mV
T_{ON}	Start-up time	VDD=2.7V to 5.5V		10		ms
R_{IN}	Input impedance (Per input pin)	A_V=12dB or 16dB		40		K
		A_V=24dB or 28dB		15		K
V_N	Output voltage noise	f=20Hz~20KHz, Inputs AC-grounded		45		μVrms
ZO	Output impedance in shutdown	EN=0V		3		K
I_{LIMIT}	Over-current limit	VDD=4V, Charge pump inactive		2.5		A
T_{HICCUP}	Over-current recovery time			250		ms
THD+N	THD + Noise	P_O=300mW, f=1KHz		0.08		%
		P_O=1W, f=1KHz		0.08		%
PSRR	Power supply ripple rejection	200mV_{PP} ripple, f=217Hz		75		dB
		200mV_{PP} ripple, f=1KHz		70		dB

AGC						
GAGC	Max AGC attenuation			6		dB
TATTACK	AGC attack time			20		ms
TRELEASE	AGC release time			1.8		s
EN CONTROL						
TLO	Time of EN low		0.5		10	μs
THI	Time of EN high		0.5			μs
TRST	Mode Reset Time			50		μs
TSHDN	Time of shutdown			5		ms

(1) The 1μF input capacitors (CI) were shorted for input common-mode voltage measurements.

(2) A 33mH inductor was placed in series with the load resistor to emulate a small speaker for efficiency measurements.

(3) The 30KHz low-pass filter is required even if the analyzer has an internal low-pass filter. An R-C low pass filter (100 , 47nF) is used on each output for the data sheet graphs.

TYPICAL PERFORMANCE CHARACTERISTICS

VDD = 3.6V, Gain = 12dB, Cs = 10μF, COUT = 10μF, CF1 = CF2 = 2.2μF, CIN=0.1μF, Load = 8 + 33 μH, TA = 25°C, unless otherwise specified.

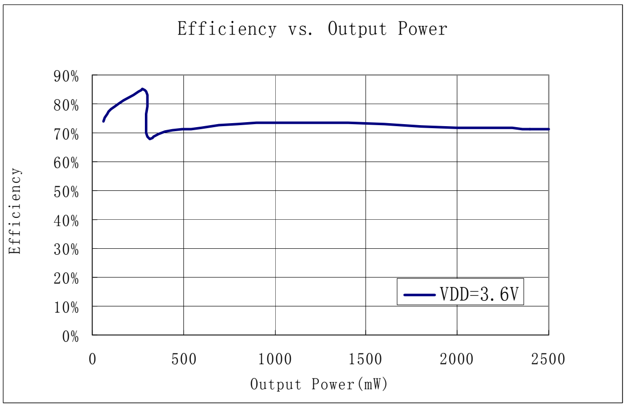


Figure 3: Efficiency vs. Output Power

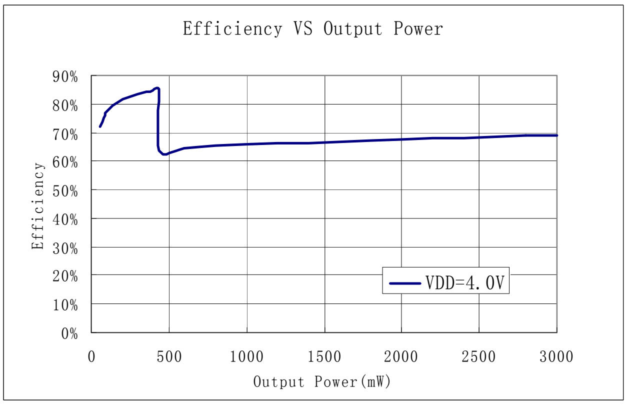


Figure 4: Efficiency vs. Output Power

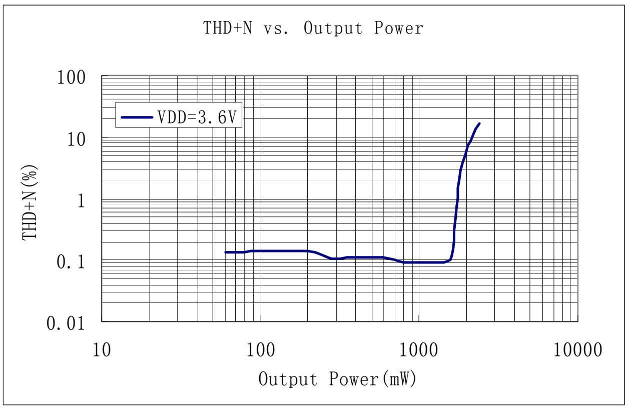


Figure 5: THD+N vs. Output Power

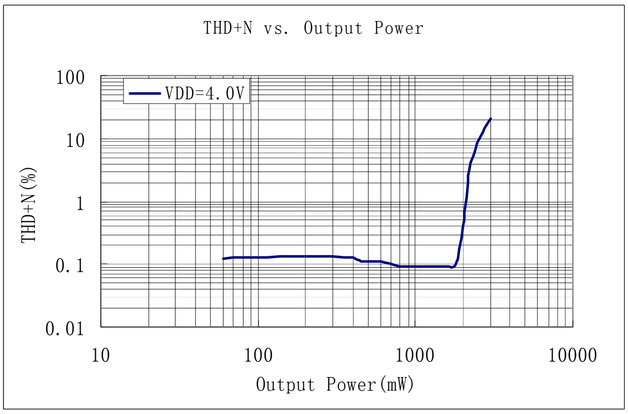


Figure 6: THD+N vs. Output Power

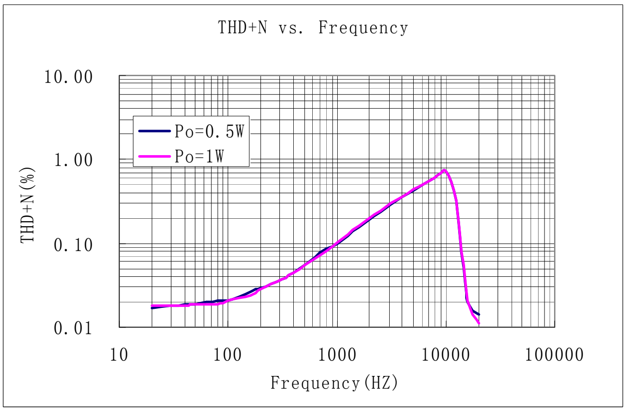


Figure 7: THD+N vs. Frequency

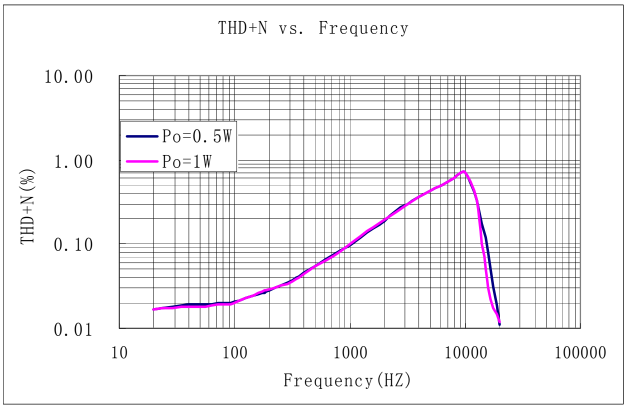


Figure 8: THD+N vs. Frequency

TYPICAL PERFORMANCE CHARACTERISTICS (Cont.)

VDD = 3.6V, Gain = 12dB, Cs = 10μF, C_{OUT} = 10μF, C_{F1} = C_{F2} = 2.2μF, C_{IN}=0.1μF, Load = 8 + 33 μH, TA = 25°C, unless otherwise specified.

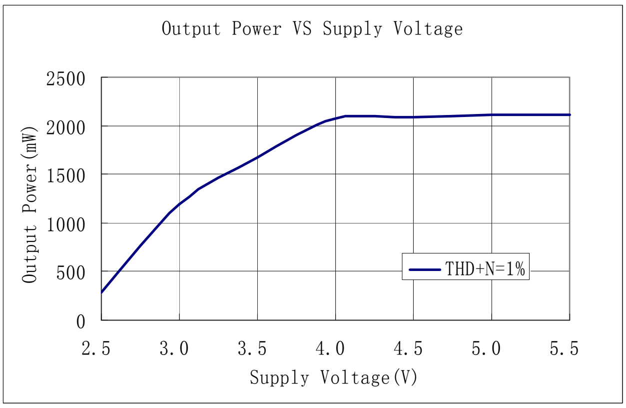


Figure 9: Output Power vs. Supply Voltage

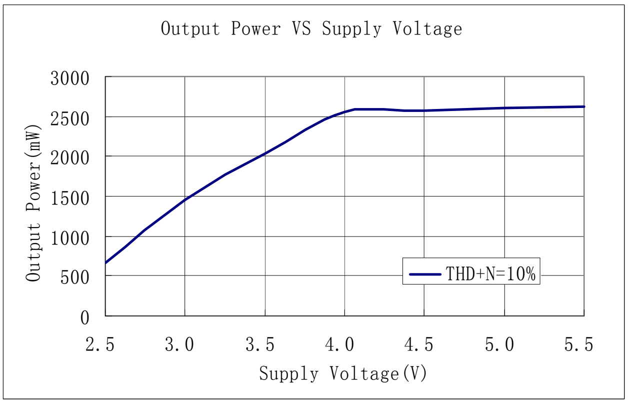


Figure 10: Output Power vs. Supply Voltage

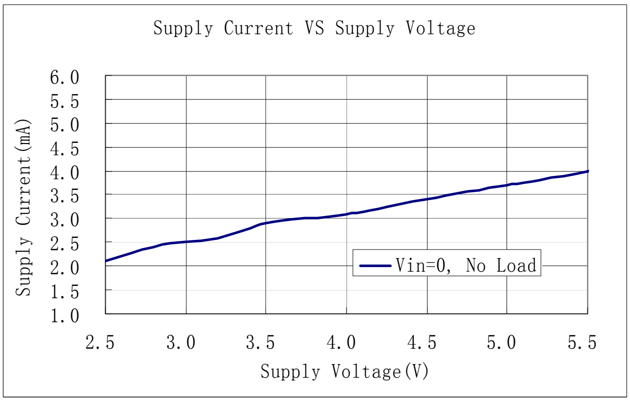


Figure 11: Supply Current vs. Supply Voltage

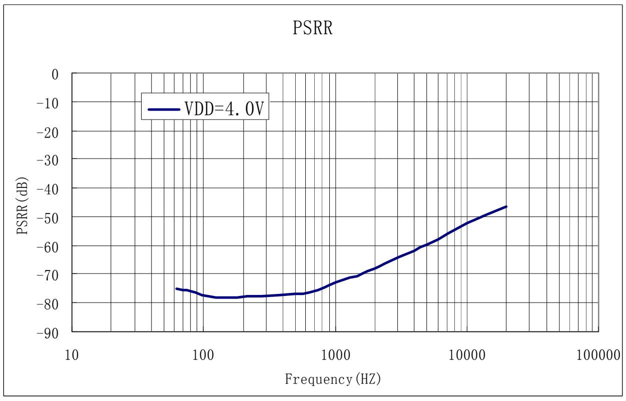


Figure 12: PSRR vs. Frequency

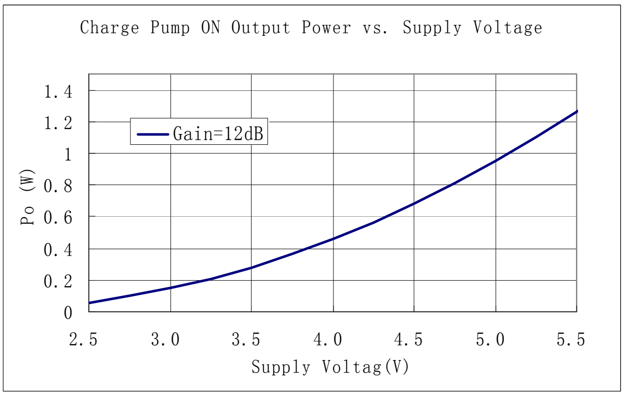


Figure 13: Output Power vs. Supply Voltage (Charge Pump Activated)

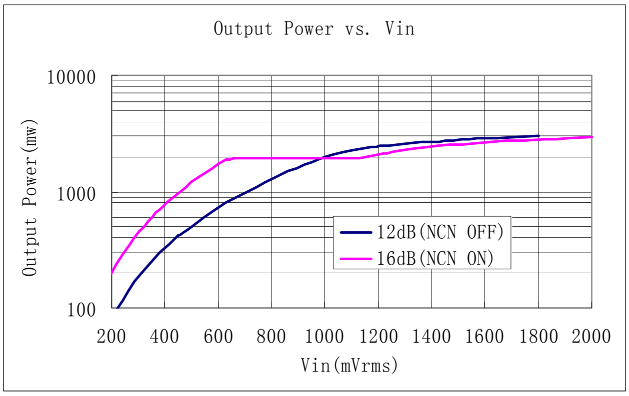


Figure 14: Output Power vs. VIN

APPLICATION INFORMATION

The ft2810 is a Class-G audio power amplifier based upon a proprietary ***Dual-Pump***^{TM} topology with battery tracking AGC technology. It can deliver up to 2.4W power into an 8 load with 10% THD+N. Its high power efficiency, up to 74%, compared with other commercially available parts, helps extend battery life for portable applications.

The proprietary ***Dual-Pump***^{TM} topology employed by the internal charge pump generates a 6V supply voltage for the output stage of the Class-G amplifier, allowing a much higher output power than a conventional stand-alone amplifier directly connected to the battery. The AGC technology allows the audio signal to be adaptively amplified for a maximum dynamic range of the output audio signal without clipping, which might be otherwise resulted from an over-level input signal or a lower power supply voltage.

The ft2810 includes an on-chip low-pass filter (100 KHz) to improve RF rejection and reduce DAC out-of-band noise, greatly enhancing the signal-to-noise ratio (SNR).

Dual-Pump^{TM} Charge Pump

In order to maximize the output power, the ft2810 employs a proprietary ***Dual-Pump***^{TM} topology *for* the internal charge pump with two flying capacitors, to boost the supply voltage to a higher value at 6V. The boosted voltage is regulated internally. To limit the inrush current to an acceptable value when the supply voltage is first applied to the device, the charge pump incorporates soft-start function. Furthermore, when a short-circuit condition at the boosted voltage is detected, the ft2810 limits the charging current to about 100mA for a safe operation.

The start-up of the ***Dual-Pump***^{TM} is composed of three successive stages upon the initial application of the supply voltage. The first operating stage is the pre-charge phase. During this phase, the Class-G amplifier is muted and the ***Dual-Pump***^{TM} charges the output voltage, PVDD, with a constant current at 100mA. Once the output voltage reaches about (VDD-0.2V), the charge pump then transitions into the standby mode. During the standby mode, the Class-G amplifier is enabled, and the PVDD is directly connected to VDD through an internal analog switch. The charge pump will then remain in the standby mode as long as the audio output signal is sufficiently small. The charge pump will exit from the standby mode and enter into the regulation mode once a sufficiently large audio output signal is detected. During the regulation mode, the charge pump output voltage is brought to and regulated at 6V all the time until the audio input returns to a lower value.

Compared with a conventional charge pump topology using a single flying capacitor, the output current capability of the ***Dual-Pump***^{TM} is greatly increased and the output voltage ripple minimized. In this manner, the performance of the Class-G amplifier can be greatly enhanced.

Adaptive *Dual-Pump*^{TM} control

For maximum power efficiency, the ft2810 incorporates an adaptive scheme to choose a proper operating mode of the ***Dual-Pump***^{TM} by detecting and qualifying the amplitude of the audio output signal. Whenever the amplitude of the audio output signal is detected under a pre-set level for more than 128ms, the ***Dual-Pump***^{TM} operates under the standby mode. During this mode, the charge pump is inactive and the Class-G output stage is powered directly from the battery supply voltage through an internal switch. In this case, the power dissipated by the charge pump is eliminated, thus greatly extending battery life for lower audio outputs.

On the other hand, when the amplitude of the audio output signal exceeds the pre-set value for more than 16us, the ***Dual-Pump***^{TM} exits from the standby mode and enters into the regulation mode. During the regulation mode, the PVDD is constantly regulated at 6V, which allows the ft2810 delivering 2.4W into an 8 speaker with 10% THD+N or 2.0W with 1% THD+N.

Operating Mode Control and Gain Setting

The ft2810 incorporates a one-wire control to configure the operating mode and the gain of the amplifier. Users can easily apply a series of pulses onto the EN pin to program the gain and the operating mode of the device. The detailed operation diagram is shown as described in Figure 3.

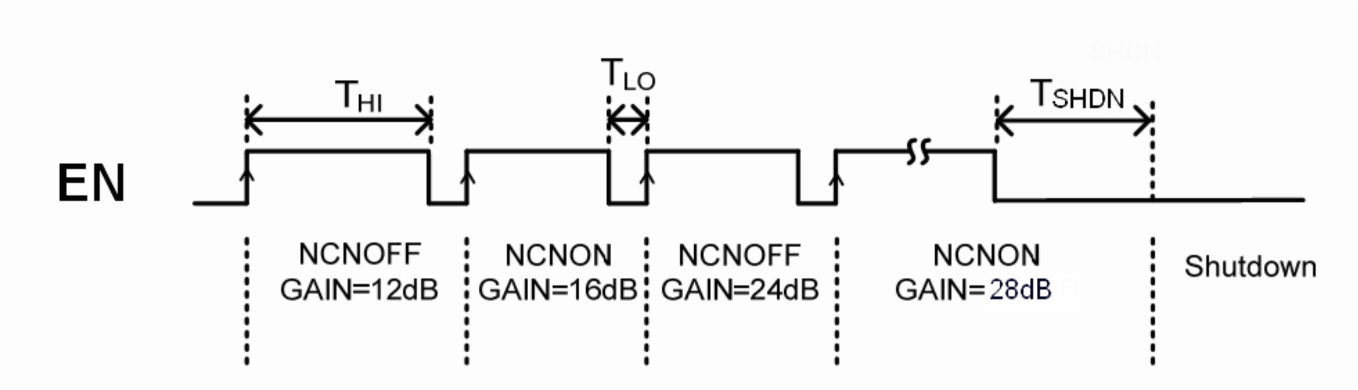


Figure 3: Gain Setting

Operating Mode Reset

When the EN pin is held low for 32μs (typical) or longer, the ft2810's internal state will be reset to its default state, which is Mode1 (GAIN=12dB, NCN OFF) on the next transition from low to high at the EN pin.

Shutdown Mode

When the EN pin is held low for 4ms (typical) or longer, the ft2810 will be forced into the shutdown mode. During the shutdown mode, the supply current will be reduced to less than 1μA.

Non-Clip Control

In the ft2810, the non-clip function may be either enabled or disabled via the one-wire control as shown in Figure 3.

During Non-Clip Off mode, the audio output is equal to the audio input multiplied by the gain defined by the one-wire control. In case where the audio input is sufficiently large, the audio output signal might be clipped, resulting in a severe distortion.

During Non-Clip On mode, with a proprietary AGC circuitry, the ft2810 fully utilizes the boosted voltage supply (PVDD) to obtain a maximum audio output power with much less clip and distortion when an excessive audio input applied to the device.

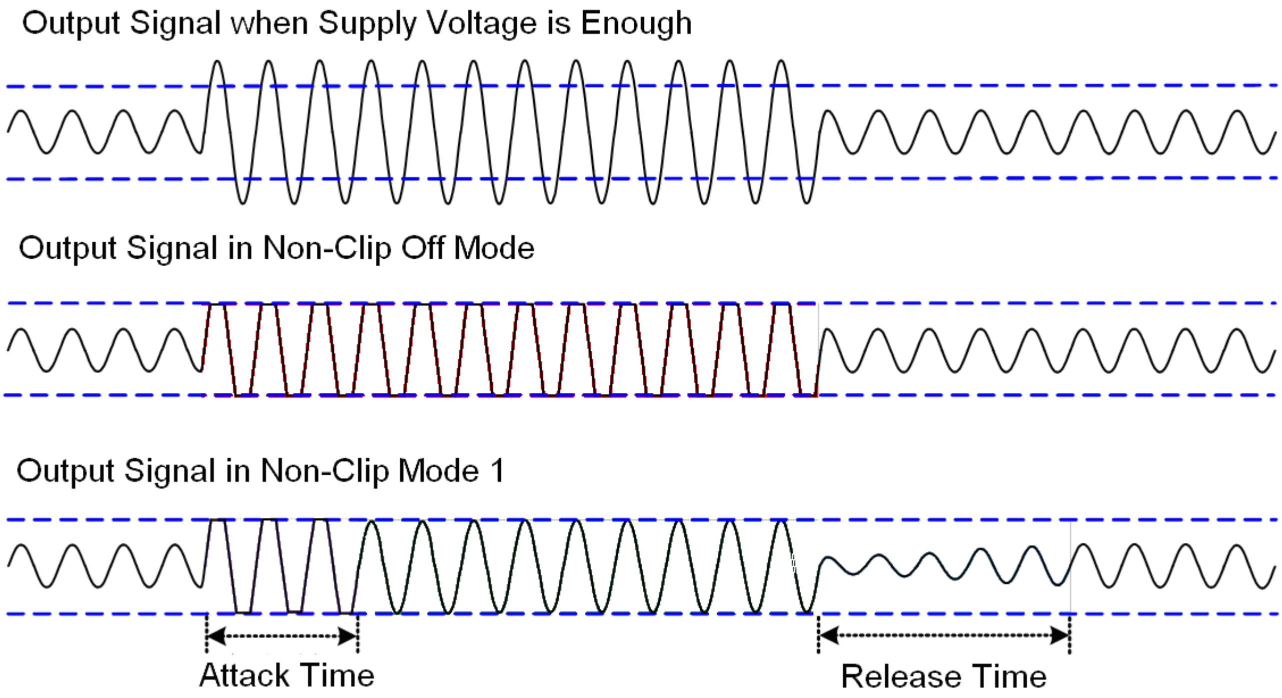


Figure 4: Non-Clip Function Diagram

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.

Click-and-Pop Suppression

The ft2810 audio amplifier includes comprehensive click-and-pop suppression. During startup, the click-and-pop suppression circuitry reduces any audible transients internal to the device. When entering into shutdown, the differential audio outputs ramp down to ground together quickly.

Protection Modes

The ft2810 incorporates various protections against operation faults from over-current (OCP), short-circuited (SCP), thermal-overload (OTP), and under voltage lock-out (UVLO).

Class-G Amplifier Over-Current (OCP) & Short-Circuited (SCP) Protection

During operation, the output of Class-G amplifier constantly monitors for any over-current and/or short-circuit conditions. When a short-circuit condition between two differential outputs, differential output to VDD, PVDD or ground is detected, the output stage of the amplifier is immediately forced into high impedance state. If the fault condition persists over a pre-set period, the ft2810 will enter into the shutdown mode and remain in this mode for about 200ms. During the shutdown, the power switches of the charge pump are also turned off, and the PVDD is discharged through a resistor to ground.

When the shutdown mode times out, the ft2810 will initiate another start-up sequence and then check if the short-circuit condition has been removed. Meanwhile, the charge pump tries to bring PVDD up to the preset voltage again. If the fault condition is still present, the ft2810 will repeat itself for the process of a start-up followed by detection, qualification, and shutdown. It is so-called the hiccup mode of operation. Once the fault condition is removed, the ft2810 automatically restores to its normal mode of operation.

Thermal-Overload Protection (OTP)

This function is to facilitate thermal protection against an excessively high temperature of the die. In the thermal-overload protection mode, the differential outputs become weak low state (a state grounded through high resistivity). When the die temperature returns to a normal value, the ft2810 exits out of such a condition and the protection mode is cancelled.

Under Voltage Lock-Out (UVLO)

To ensure a safe and reliable operation, the ft2810 incorporates a circuitry to detect a low supply voltage. When the supply voltage drops below 1.9V, the ft2810 goes into a state of mute. The device comes out of the mute state and restores to normal function when the power supply voltage is higher than 2.2V.

PSRR Enhancement

By incorporating a proprietary design technique for PSRR enhancement, the ft2810 achieves a high PSRR, 75dB at 217Hz without the need for a dedicated pin for the DC bias and the associated large bypass capacitor.

Class-G Audio Amplifier

The Class-G audio amplifier in the ft2810 operates in much the same way as a Class-D amplifier and similarly offers much higher power efficiency than Class-AB amplifiers. The high efficiency of a Class-G operation is achieved by the switching operation of the output stage of the amplifier. The power loss associated with the output stage is limited to the conduction and switching loss of the power MOSFETs, which are much less than the power loss associated with a linear output stage in Class-AB amplifiers.

Fully Differential Amplifier

The ft2810 is a fully differential amplifier with differential 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 amplifier gain. The common-mode feedback ensures that the common-mode voltage at the output is biased substantially close to VDD/2 regardless of the common-mode voltage of the inputs. Although the ft2810 supports for a single-ended input, differential inputs are recommended for the applications, where the environment can be noisy like a wireless handset, in order to ensure maximum SNR.

Low-EMI Filterless Output Stage

Traditional Class-D amplifiers require for the use of external LC filters, or shielding, to meet EN55022B electromagnetic-interference (EMI) regulation standards. The ft2810 applies an edge-rate control circuitry to reduce EMI emission, while maintaining high power efficiency. Above 10MHz, the wideband spectrum looks like noise for EMI purposes.

Filterless 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 (twice of supply voltage peak-to-peak) and causes large ripple currents. Any parasitic resistance in the filter components results in loss of power and lowers the efficiency.

The ft2810 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. By eliminating the output filter, a smaller, less costly, and more efficient solution can be accomplished.

Because the frequency of the ft2810 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 range from 20uH to 100uH.

EMI Reduction

Additional EMI suppression can be achieved using a filter constructed from a ferrite bead and a capacitor to ground (Figure 5). 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.

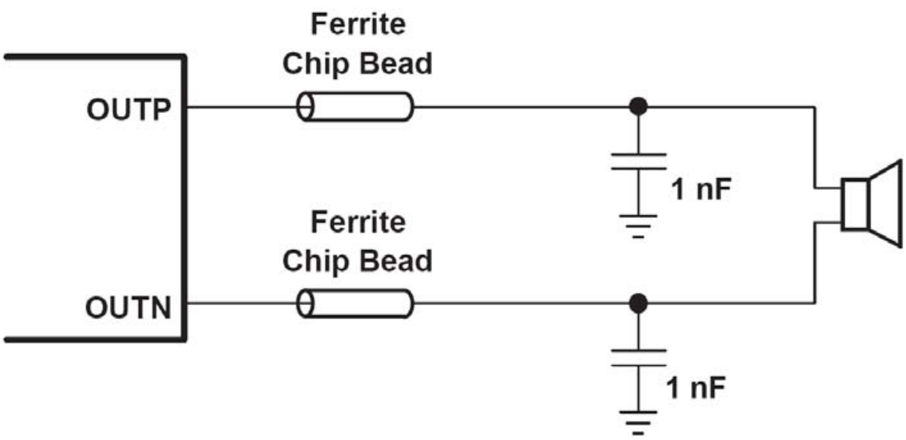


Figure 5: Ferrite Bead Filter to Reduce EMI

Decoupling Capacitor (CS)

The ft2810 is a high-performance Class-G audio power amplifier, which requires adequate power supply decoupling to ensure its high efficiency operation with low total harmonic distortion.

Place a low equivalent-series-resistance (ESR) ceramic capacitor (X7R or X5R), typically 1μF, within 2mm of the VDD pin. This choice of capacitor and placement help reject high frequency transients, spikes, or digital hash on the line. Additionally, placing this decoupling capacitor close to the ft2810 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 10μF to 47μF capacitor on the VDD 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 (C_{IN})

DC decoupling capacitors for audio inputs are recommended. The audio input DC decoupling capacitors will remove the DC bias from an incoming analog signal. The input capacitors (C_{IN}) and input resistors (R_{IN}) form a high-pass filter with the corner frequency, f_C, determined by Equation 1.

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

$$f_C = 1/(2 \times \pi \times R_{IN} \times C_{IN}) \qquad (1)$$

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.

Selection of Flying Capacitors (C_{F1} & C_{F2})

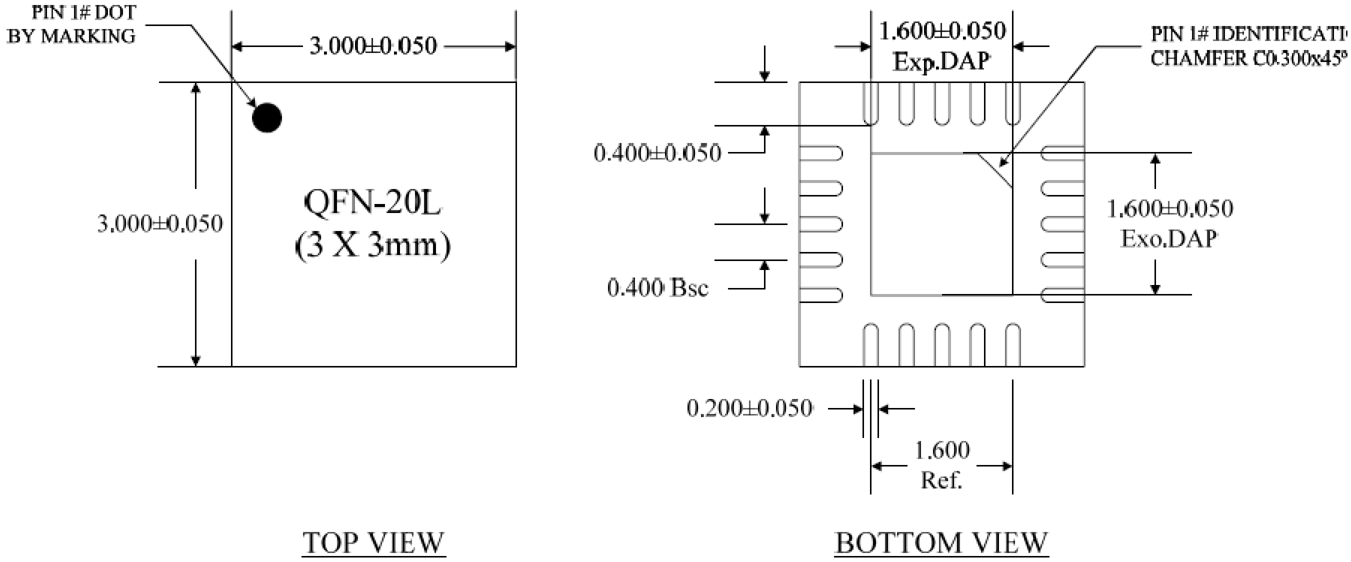
Typically, a capacitor of 2.2μF should be used for flying capacitors (C_{F1} and C_{F2}). Ensure that the same value is selected for C_{F1} and C_{F2}. A low equivalent-series-resistance (ESR) ceramic capacitor, such as X7R or X5R ceramic capacitor is recommended.

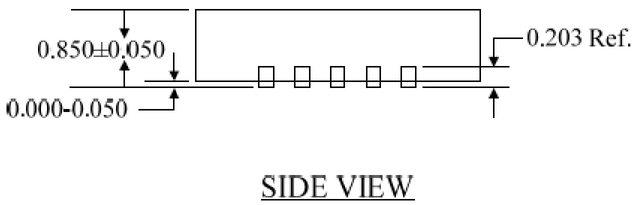
Selection of Output Capacitor (C_{OUT})

Typically, a capacitor of 10μF should be used for C_{OUT}. The X7R or X5R ceramic capacitor is recommended.

PHYSICAL DIMENSIONS

QFN3x3-20L Package





Unit: millimeters.

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