Application Report

SLOA216–February 2015

TPA3140D2 Design Considerations for EMC

ABSTRACT

The TPA3140D2 Class D audio power amplifier is the latest TI analog input amplifier that uses advanced PWM switching techniques for reducing electromagnetic interference (EMI) without degrading audio performance. This application note describes the system design and printed circuit board (PCB) guidelines used to maximize the technology employed in the TPA3140D2 device. These techniques include the EMI suppression without the need for expensive inductor filters and the reduction of external component count.

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1 General Overview

The emphasis on green technologies and sleek looking electronics (such as the flat panel TV) has lead manufacturers to produce space-efficient and attractive products without sacrificing performance. The TPA3140D2 mono/stereo Class D audio power amplifier provides Class AB audio performance using only the PC board as heat sink due to its high efficiency. In addition, the TPA3140D2 device has advanced PWM modulation and switching schemes that help reduce EMI while eliminating the need for the traditional Class D output filter. PWM filtering requires only smaller and less expensive RF filter components. No external heat sink and less RF filtering result directly in PC board size reduction.

Discussions in the following sections explain the PC board layout practice and external components selection in order to achieve optimal audio performance and pass electromagnetic compatibility (EMC) specification EN55022.

- Section 2 describes the advanced emission suppression techniques used to combat EMI.
- Section 3 discusses the PC board design guidelines for audio quality and EMC.
- Section 4 shows the EMC results for TPA3140D2 EVM.

2 Advanced Emission Suppression

2.1 Spread Spectrum Modulation

EMI is electromagnetic radiation emitted by electrical systems with fast changing signals that are common to the outputs of a class D audio power amplifier. EMI encompasses two aspects: emission and susceptibility. Emission refers to the generation of unwanted electromagnetic energy by the equipment. Susceptibility, by contrast, refers to the degree in which the equipment is affected by the electromagnetic disturbances. EMC is achieved by addressing both emission and susceptibility issues. The TPA3140D2 device has advanced emission suppression technology which enables the device to run without an LC filter with speaker wires up to one meter long and still meet the EMI regulatory standards such as EN55022, CISPR 22, or FCC Part 15 Class B.

The TPA3140D2 device features an advanced spread spectrum modulation mode with low EMI emission to lower the overall system cost. This reduced system cost is achieved by replacing large expensive LC output filters with small, low-cost ferrite beads filters. The spread spectrum modulation scheme exhibits less EMI by flattening the wideband spectral components from the speaker cables and still retains the high-efficiency feature of a traditional class D amplifier such as the TPA3110D2 device.

Figure 1 shows the topology of a conventional (nonspread-spectrum) BD modulation class D amplifier. The BD switching technique uses an internally generated triangular waveform with a fixed frequency and a complementary signal pair at the input stage. The output PWM changes the duty cycle to generate a moving average of the signal that correspond to the input analog signal. The advantages of PWM switching topology is high efficiency, which provides low power consumption and small thermal design.

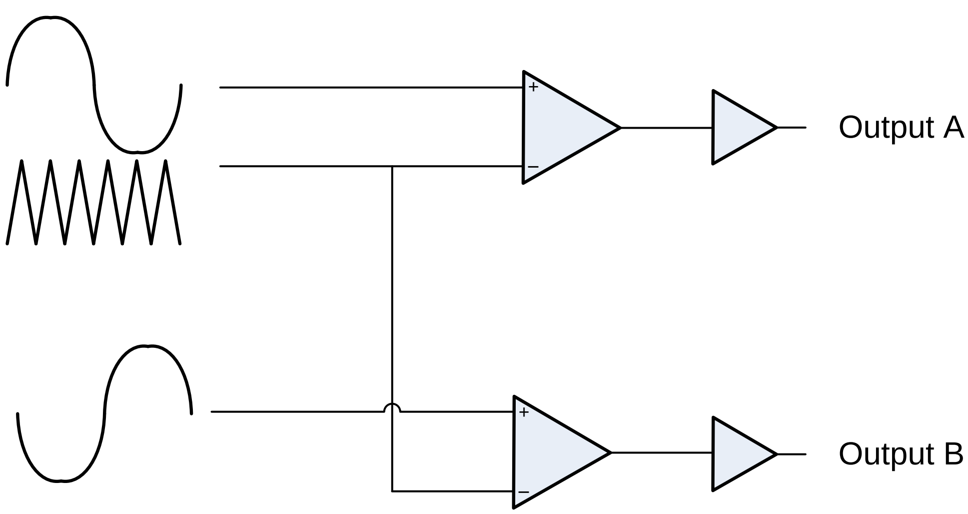

Figure 1. Class D Audio Amplifier

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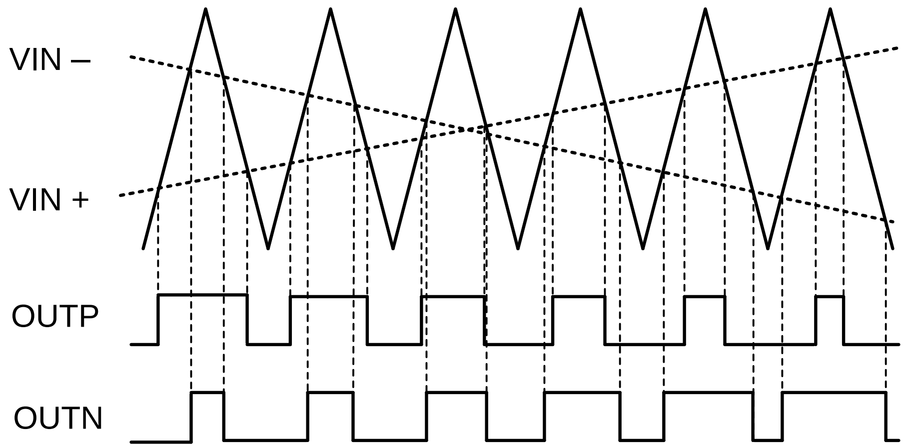

Figure 2. Fixed-Frequency Mode Modulation

The TPA3140D2 device features two modulation modes: fixed-frequency modulation mode (FFM) and spread spectrum modulation (SSM) mode. In the conventional FFM mode (Figure 1) the frequency of the triangular waveform is fixed as shown in Figure 2. In SSM mode, the frequency of the triangular waveform frequency varies by ±10% cycle-to-cycle with a center frequency at about 310 kHz. SSM mode improves EMI emissions radiated by the speaker wires by spreading the energy over a larger bandwidth and reducing the wideband spectral content. On the other hand, FFM produces larger amounts of spectral energy at multiples of the PWM switching frequency. The cycle-to-cycle variation of the switching frequency does not affect the efficiency of the audio amplifier. Figure 3 shows the effects of the frequency variation on the triangular waveform.

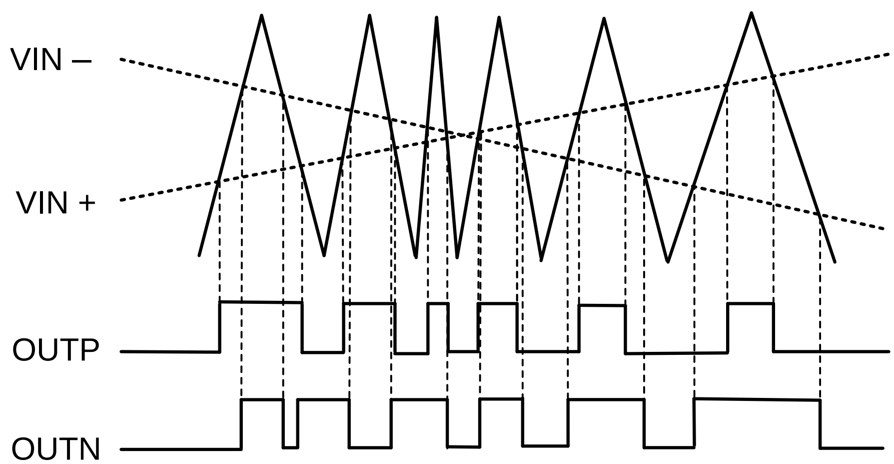

Figure 3. Spread Spectrum Mode Modulation

Compared to traditional FFM class D amplifier, the spread spectrum scheme has reduced the peak energy of the switching frequency and lessens harmonics. shows a comparison of FFM and SSM modulation.

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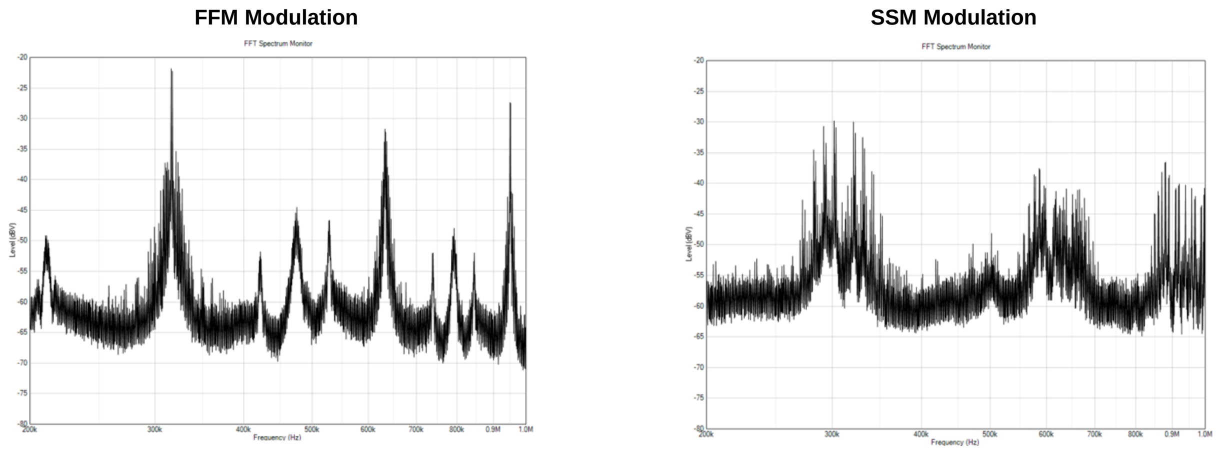

Figure 4. Comparison of FFM and SSM Modulation

2.2 Dephase and Edge Rate Control

In addition to the spread spectrum technology, the TPA3140D2 device employs edge rate control and dephase circuits to further reduce electromagnetic emission without degrading audio performance.

The edge rate control circuit reduces emission by controlling the PWM output FET switching transitions near the rails with as little impact to the efficiency as possible. In this mode, the edge rate is optimized and fixed.

The dephase circuit improves EMI and noise performance by interleaving the switching timing between the two audio channels. This improved EMI and noise performance reduces conducted emission on the PVCC line because the output ripple current of the two audio channels will be out of phase, and the ripple peak current from the PVCC line will thus be reduced to half value.

3 Printed Circuit Board Design for EMC

3.1 Printed Circuit Board Layout

It is necessary to follow recommended PC board guidelines for EMC success. Proper PC board floor planning, component selection, component placement, and routing are all essential to counter EMI. Emissions are exacerbated by improper layout, components, and output trace length causing antenna effect. Practical PC board design guidelines for achieving EMC include:

- Place the high-frequency decoupling capacitors as close to the power pin and ground pin of the device as possible to reduce the parasitic inductance of the trace. To ensure low AC impedance over a wide frequency range for noise reduction, use good quality, low-ESR, 1-nF ceramic capacitors. For mid-frequency noise due to PWM transients, use another good quality 0.1 µF ceramic capacitor placed as close as possible to the PV_{CC} leads.
- Use a continuous ground plane and avoid voltage offset on the ground planes whenever possible.
- Low impedance routing back to source (return signal).
- Power planes should be away from the edges of the PC board.
- Proper filtering of the PC board connectors.
- Place EMC snubbers and ferrite bead filters as close as possible to the IC. Minimize unfiltered loops and trace length as well as stray inductance.
- Keep amplifier output traces to the speaker as short as possible. PC board traces and the speaker wire are the largest sources of emission.

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3.2 Ferrite Bead Filter

Low-cost ferrite bead filters are used to suppress EMI. They are placed close to the amplifier output to minimize loop antennas. At low frequencies, ferrite beads act as 0 Ω resistors with no DC drop. However, the impedance of ferrite bead increases significantly at frequencies above 1 MHz to suppress radiation. Ferrite beads also play a significant role on the THD+N of the system. Examples of ferrite beads which have been tested and worked well with the TPA3140D2 device include the NFZ2MSM series from Murata.

If other ferrite beads are used, the EMC testing must be repeated to ensure compliance.

3.3 Power Supply and Speaker Wires

When performing the conducted emission test, it is essential to keep the AC power cable away from the speaker cables. This prevents stray signals from coupling to power source and other potential unintended radiators or conductors.

4 TPA3140D2 EVM EMI Results

The following sections show the EMI test results from a certified third-party vendor (National Technical Systems) in Plano, TX. The passing margins are greater than 10 dBuV in most cases.

The radiated EMI plots below are taken with standard EVM configuration and BOM components.

The conducted EMI plots are taken using the same EVM configuration but with a TV power supply. The TV is currently available on US consumer market (2015).

4.1 EN55013 Radiated Emission Results

TPA3140D2 EVM, PVCC = 12 V, 8-Ω load, up to 1-meter speaker cable, Spread Spectrum enabled, Po = 1.25 W

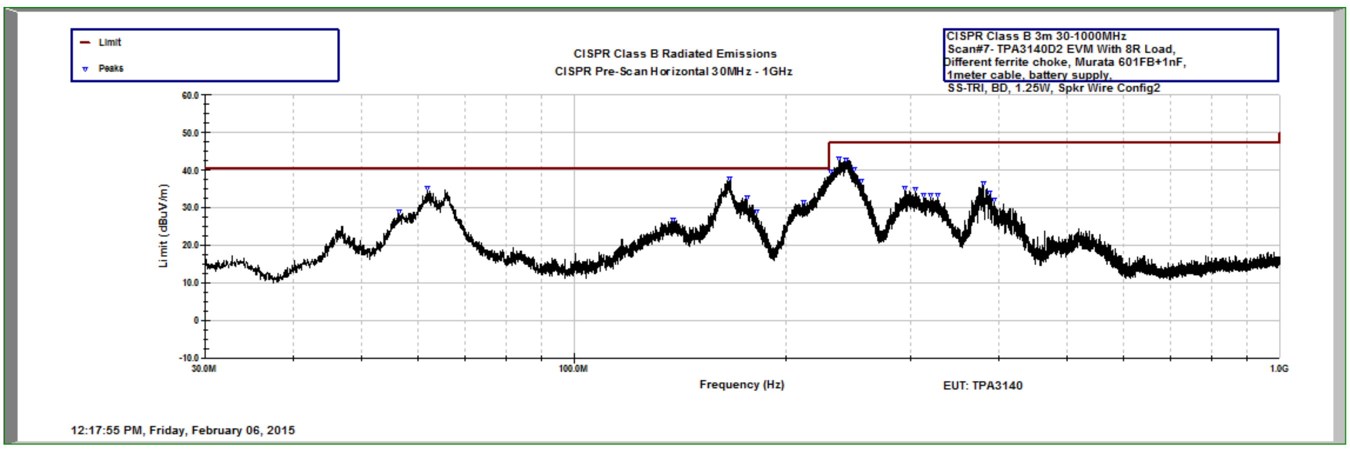

Figure 5. Radiated Emission – Horizontal Pre-Scan

Table 1. Radiated Emission Margins – Horizontal

Frequency MHz	Limit dBuV/m	Peaks dBuV/m	Q-Peak dBuV/m	Margin dB	Turn Table Degrees	Tower cm
166.246	40.457	21.781	21.975	–18.482	44.9	100
237.372	47.457	29.330	29.186	–18.271	326.9	100

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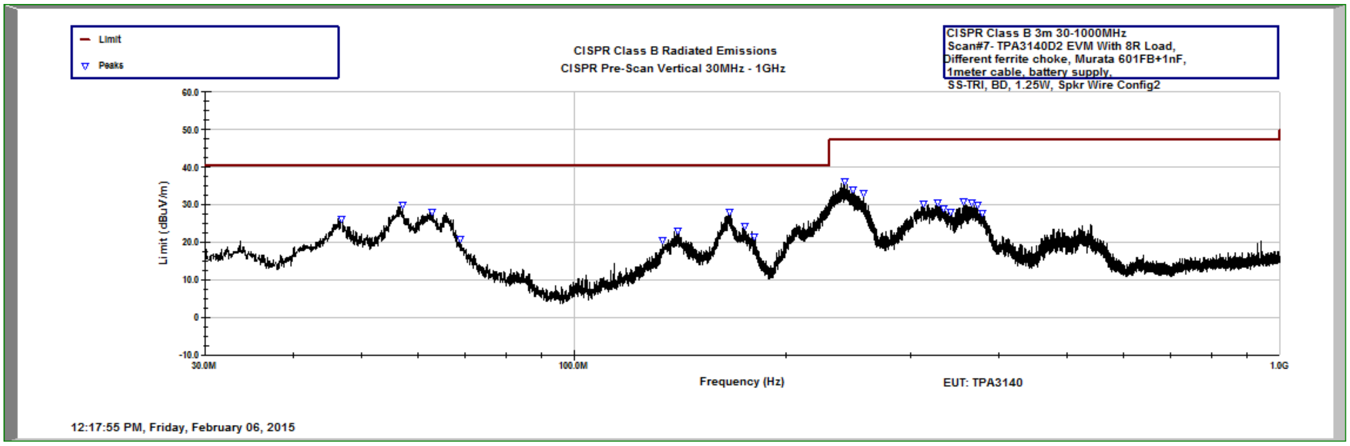

Figure 6. Radiated Emission – Vertical Pre-Scan

Table 2. Radiated Emission Margins – Vertical

Frequency MHz	Limit dBuV/m	Peaks dBuV/m	Q-Peak dBuV/m	Margin dB	Turn Table Degrees	Tower cm
56.841	40.457	26.213	27.058	–13.399	54	100
241.9	47.457	19.429	20.430	–27.027	–0.1	100

4.2 *EN55022 Conducted Emission Results*

TV (40-inch) from the major TV manufacturer, TPA3140D2 EVM, PVCC = 12 V, 8-Ω speakers, Spread Spectrum enabled, Po = 1.25 W

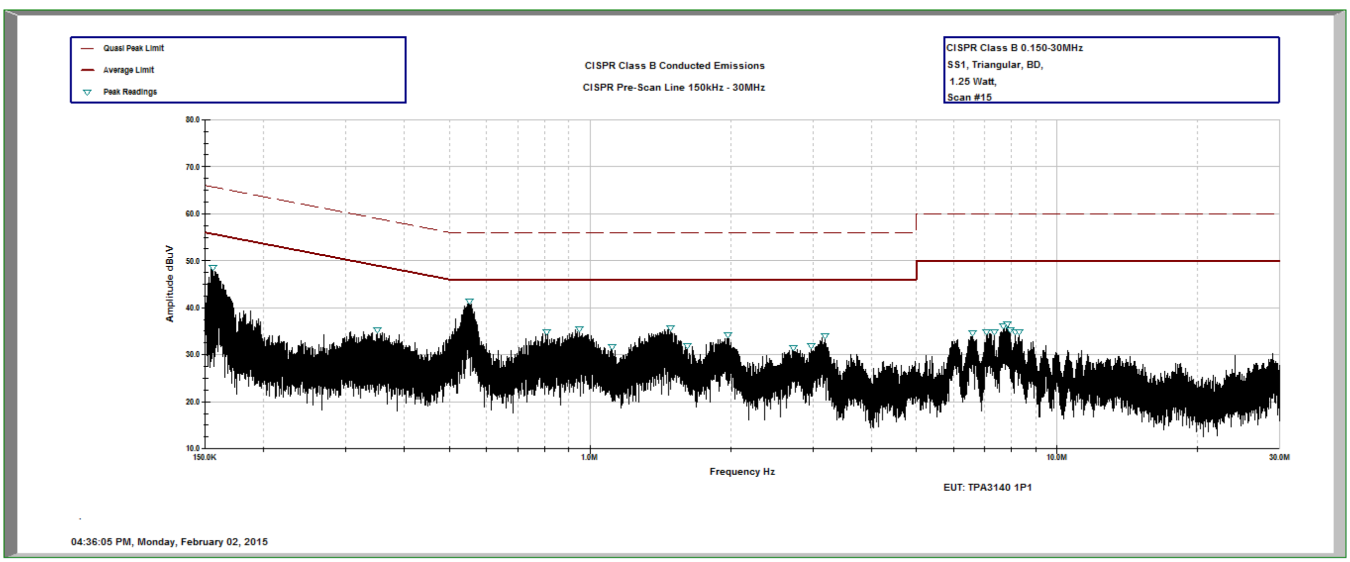

Figure 7. Conducted Emission – Line Pre-Scan

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Table 3. Conducted Emission Margins – Line

Frequency MHz	QP Limit dBuV	AVE Limit dBuV	AVE Readings dBuV	AVE Margin dB	QP Readings dBuV	QP Margin dB
0.156	65.83	55.83	33.774	–22.056	45.956	–19.873
0.552	56	46	28.872	–17.128	39.164	–16.836
0.806	56	46	21.341	–24.659	29.585	–26.415
0.95	56	46	22.678	–23.322	31.471	–24.529
1.485	56	46	22.622	–23.378	31.082	–24.918
1.976	56	46	20.952	–25.048	29.849	–26.151

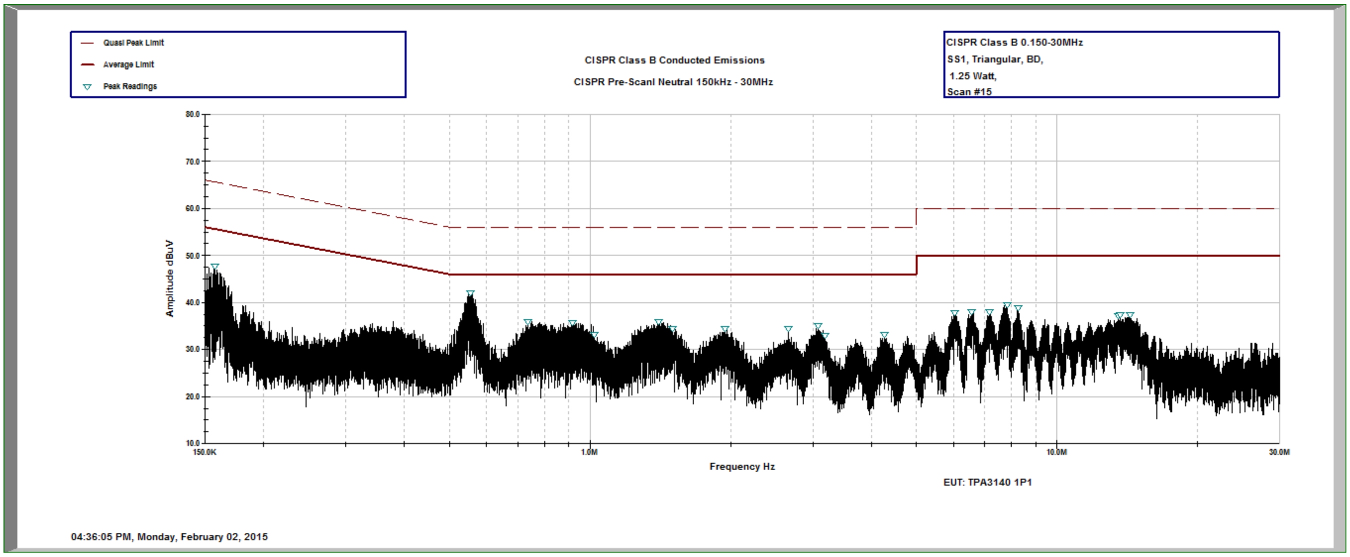

Figure 8. Conducted Emission – Neutral Pre-Scan

Table 4. Conducted Emission Margins – Neutral

Frequency MHz	QP Limit dBuV	AVE Limit dBuV	AVE Readings dBuV	AVE Margin dB	QP Readings dBuV	QP Margin dB
0.158	65.785	55.785	34.022	–21.763	45.398	–20.387
0.554	56	46	29.574	–16.426	40.485	–15.515
0.735	56	46	22.652	–23.348	32.52	–23.48
0.918	56	46	22.699	–23.301	31.849	–24.151
1.402	56	46	23.264	–22.736	32.173	–23.827
7.806	60	50	28.006	–21.994	35.214	–24.786

4.3 Conclusions

The TPA3140D2 device has the proven advanced RF emission suppression technology that helps to design an EMI-compliant audio system without compromising cost and performance. The EVM User's Guide (SLOU405) provides the details of the schematic and BOM. By adhering to the guidelines discussed in this report, EMI requirements are met and costly PC board rework is avoided.

For further questions and discussions on this topic, go to the TI E2E Forums (http://e2e.ti.com/).

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
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