Application Report
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Power Rating in Audio Amplifiers

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ABSTRACT

Average consumers often weigh heavily on cost versus power rating of audio amplifiers as their basis for purchasing one. Depending on the marketing strategy, the power rating methodology for audio amplifiers can vary from manufacturer to manufacturer. The purpose of this document is to clarify three commonly used power ratings: average power, peak power, and PMPO. The following Texas Instruments PurePath Digital™ power stages will be used for power measurement:

- TAS5142 – 4 half-bridges (2 BTL channels or 4 single-ended [SE] channels)
- TAS5152 – 4 half-bridges (2 BTL channels or 4 single-ended [SE] channels)
- TAS5186 – 6 half-bridges (6 single-ended [SE] channels)

1 Introduction

1.1 Power-Rating References and Basic Definitions

There are a few standards that describe the power rating of an audio amplifier. The Federal Trade Commission (FTC) establishes fair advertisement practices for home audio power ratings. This is described in the FTC document 63FR37233, 16 CFR, Chapter 1, Part 432. Another standard is the Electronic Industries Association (EIA) SE-101-A. For the car audio industry, some manufacturers accept the Consumer Electronics Association CEA-2006-A standard. It defines how the amplifier should be tested for power and signal distortion.

How can one tell a good power rating from a bad one? For a good power rating, all the specified reference points are measurable.

Ohm's law establishes the relationship of voltage, current and load, i.e., $V = I \times R$, where V = voltage, I = current in amperes and R = load resistance in ohms.

Power is energy per time and is derived as $P = V \times I = V^2/R = I^2 \times R$.

For an audio signal, the voltage is in Vrms (root-mean-square), the power is referenced to a frequency of 1,000 Hz, and the load is usually referenced to a resistive load. Thus, the power obtained is the average power that the amplifier can sustain. The FTC requires further that the amplifier be pre-conditioned at one-eighth of rated total power output (for a multiple-output system, all channels are on) for one hour using a sinusoidal wave at a frequency of 1,000 Hz. The power spectrum measurement is then collected with two channels at maximum rated power over the audio frequency range of 20 to 20,000 Hz, in ambient still air of not less than 25°C, for the duration of not less than 5 minutes.

Some manufacturers use an average power rating, but at a higher distortion ratio obtained by amplifying the original input signal to a level where clipping occurs. At 10% THD+N, the average power rating is higher than at 1% THD+N. For Texas Instruments PurePath Digital power-stage data sheets, both unclipped and clipped power ratings are measured.

1.2 Extended Power Ratings

PMPO stands for peak music power output or peak momentary performance output. These terms are used interchangeably and have approximately the same meaning. PMPO has no well-defined standard of measurement and is not generally used in high-fidelity audio as a performance measurement. In actuality, when manufacturers quote a PMPO number, it is often based on a theoretical calculation. A PMPO power rating has no reference point. The power supply used for a class-AB audio amplifier is much different than that for a digital audio amplifier (see Reference 1). For a class-AB audio power amplifier, PMPO can be quoted much higher than for a digital audio amplifier because of the physical properties of the analog components. The instantaneous voltage at start-up delivered by the power supply for a class-AB audio power amplifier can be many times higher, thus producing a much higher power spike at start-up. PMPO is often quoted using this instantaneous start-up voltage. PMPO is a great marketing tool, because the customers are usually looking for a higher power rating with lower-cost audio amplifiers.

Peak power ratings are obtained by using peak voltage. Peak power rating is sometimes referred to as music power. This music power is the dynamic headroom of the audio power amplifier which it can deliver when music transients occur. If the dynamic headroom of an audio amplifier is specified at 3 dB, then the amplifier can deliver two times its average power; e.g., if the amplifier is rated for 200 W average power, then the peak power is 400 W. For some high-end audio amplifiers, the dynamic headroom is lower because they have good power supplies that can deliver equally high power in any music dynamics.

The following paragraphs define and derive two power ratings, namely, *peak power* and *instantaneous peak power*. These two power ratings can be used as PMPO figures in cases where power ratings exceeding the standard rms power are needed in order to promote certain amplifier products in specific markets or regions. Both power ratings are measurable on actual hardware as opposed to more theoretically based PMPO definitions. Test setups and test procedures are described and performed on three different Texas Instruments power stages. For completeness, the rms power for the same power stages is also derived.

The devices used as power stages in the following measurements are Texas Instruments TAS5142, TAS5152, and TAS5186.

2 Test Setup

Instruments:

- System Two™-2322 audio measurement system (AP) by Audio Precision™
- Lab power supplies – HP6024A, HPE3610A, HPE3616A, Sorensen DLM 60-10
- Oscilloscope – Tektronix TDS784A
- Current probe – Tektronix TCP202
- Voltage probe – Tektronix P6139A
- Loads – DALE rated at 200 W, various resistance values
- Reference design boards – DAVREF635 and DAVREF636

Instrument setup:

1. Power supplies are connected to the reference design board.
2. Resistive load is connected to the output of the power stage under test.
3. Current probe is connected to the output of the power stage under test.
4. Voltage probe is connected to the output of the power stage under test.
5. AP is connected to the output of the power stage under test.

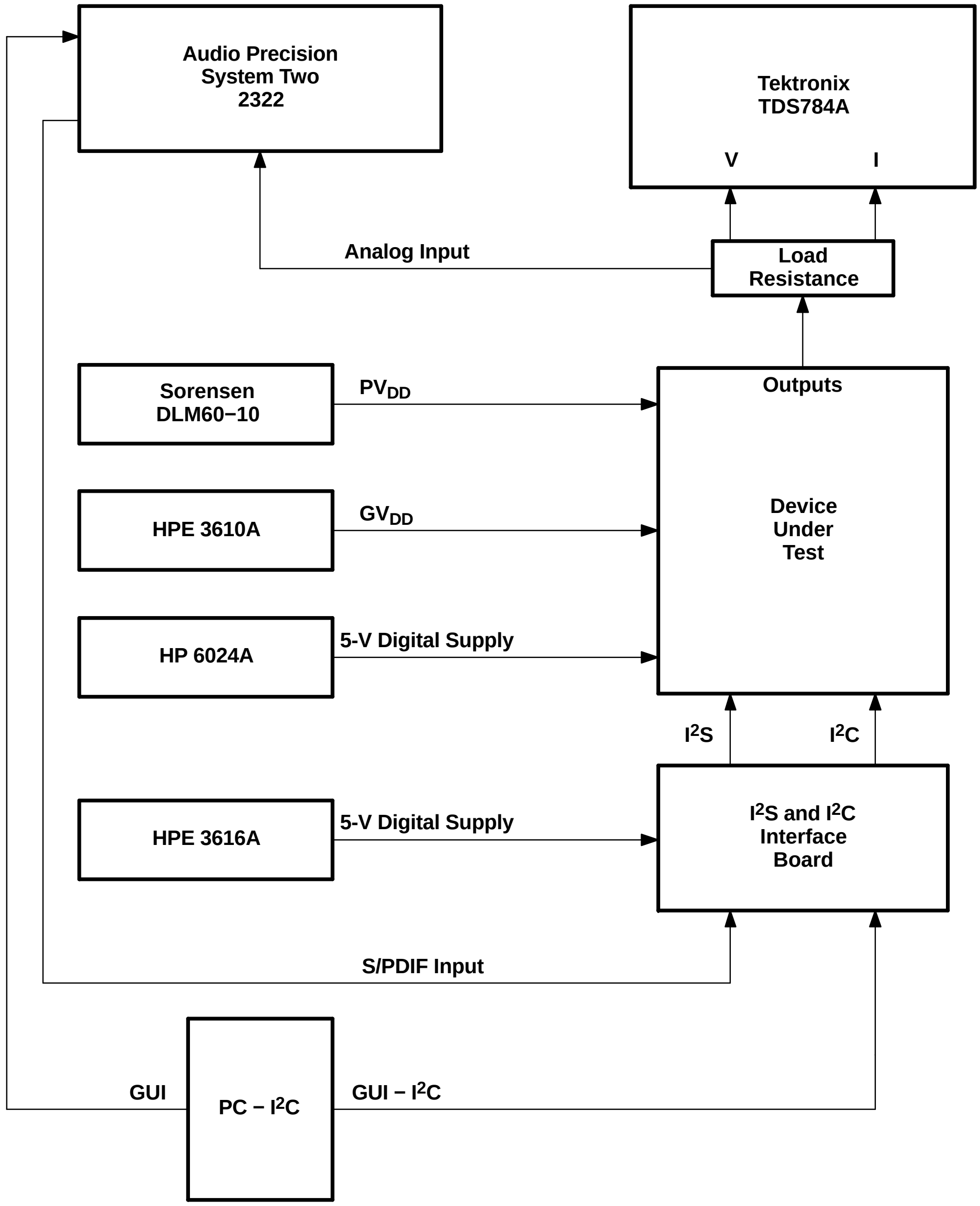

Figure 1. Test Setup Block Diagram

3 Power Measurements

3.1 RMS Power

Description:

1. Use the typical operating voltage as specified in the data sheet for each device to set the voltage level for PV_{DD} (MOSFET voltage).
2. On the AP, generate a 1-kHz sine wave continuously at 0 dBFS.
3. Use the typical resistive load as specified in the data sheet for each device.
4. Set the modulator gain at 0 dB.
5. Set up the current probe to capture the output current waveform.
6. Set up the voltage probe to capture the output voltage waveform.

Discussion:

The average power can be calculated from the power equation as previously described in the introduction section:

$$P_{RMS} = \frac{V^2}{R} = I^2 \times R$$

Using parameters from the voltage or current trace captured by the oscilloscope (see the notes in Table 1):

$$P_{RMS} = \left[\frac{I_{PP}}{2} \div \sqrt{2}\right]^2 \times R,\ \text{where } I_{PP} = \text{peak-to-peak current},\ R = \text{load resistance}$$

Note: The preceding equation applies to 0 dB (unclipped) input. For clipped input (10% THS+N), this equation does not apply.

The result can be correlated with a power measurement captured using the AP with the same exact test conditions. The AP captures the Vrms value at the given load impedance using a high-precision meter. The values are then plotted using AP Windows™ software. See the power vs frequency graphs in Appendix B.

Table 1. RMS Power – Unclipped

DEVICE	CONFIGURATION	CURRENT (I_{pp})	LOAD RESISTANCE	POWER
TAS5142	BTL(1)	13.2 A	4 Ω	87 W
	SE(2)	7.12 A	4 Ω	25 W
TAS5152	BTL(3)	14.24 A	4 Ω	101 W
	SE(4)	7.68 A	4 Ω	29.5 W
TAS5186	SE satellite(5)	5.60 A	6 Ω	23.5 W
	SE subwoofer(6)	11.04 A	3 Ω	45.7 W

(1) See Appendix A, Figure 1. For correlation with the AP measurement, see Appendix B, Figure 1.
(2) See Appendix A, Figure 2. For correlation with the AP measurement, see Appendix B, Figure 3.
(3) See Appendix A, Figure 3. For correlation with the AP measurement, see Appendix B, Figure 5.
(4) See Appendix A, Figure 4. For correlation with the AP measurement, see Appendix B, Figure 7.
(5) See Appendix A, Figure 5. For correlation with the AP measurement, see Appendix B, Figure 9.
(6) See Appendix A, Figure 6. For correlation with the AP measurement, see Appendix B, Figure 11.

Texas Instruments (TI) also provides RMS power measurement with digital gain so that the THD+N is ≤ 10%. The digital gain is accomplished by using a TI modulator, e.g., TAS5508 or TAS5086. The average power at 10% THD+N is higher than the normal FTC-quoted power of <1% THD+N. The following power table is the average power at 10% THD+N. See Appendix B for the AP power vs frequency graphs.

Table 2. RMS Power at 10% THD+N

DEVICE	CONFIGURATION	Average Power at 1 kHz and 10% THD+N
TAS5142	BTL(1)	108. 5 W
	SE(2)	31.6 W
TAS515	BTL(3)	126.4 W
	SE(4)	37.6 W
TAS5186	SE satellite(5)	30 W
	SE subwoofer(6)	58 W

(1) See Appendix B, Figure 2.
(2) See Appendix B, Figure 4.
(3) See Appendix B, Figure 6.
(4) See Appendix B, Figure 8.
(5) See Appendix B, Figure 10.
(6) See Appendix B, Figure 12.

3.2 Peak Power

Description:

1. Use the typical operating voltage as specified in the data sheet for each device to set the voltage level for PV_{DD} (MOSFET voltage).
2. On the AP, generate a 1-kHz sine wave continuously at 0 dBFS.
3. Use typical resistive loads as specified in the data sheet for each device.
4. Set the modulator gain at 0 dB.
5. Set up the current probe to capture the output current waveform.
6. Set up the voltage probe to capture the output voltage waveform.

The peak power is measured at the peak of the current or voltage delivered into the load impedance. Thus, deriving from the power equation we have peak power as follows:

$$P_{PK} = \frac{V^2}{R} = I^2 \times R$$

Using parameters from voltage or current traces captured from oscilloscope (see the notes in Table 3):

$$P_{PK} = \left[\frac{I_{PP}}{2}\right]^2 \times R,\ \text{where } I_{PP} = \text{peak–to–peak current},\ R = \text{load resistance}$$

Table 3. Peak Power

DEVICE	CONFIGURATION	CURRENT (I_{pp})	LOAD RESISTANCE	POWER
TAS5142	BTL(1)	13.2 A	4 Ω	174 W
	SE(2)	7.12 A	4 Ω	51 W
TAS5152	BTL(3)	14.24 A	4 Ω	203 W
	SE(4)	7.68 A	4 Ω	59 W
TAS5186	SE satellite(5)	5.60 A	6 Ω	47 W
	SE2 subwoofer(6)	11.04 A	3 Ω	91 W

(1) See Appendix A, Figure 1.
(2) See Appendix A, Figure 2.
(3) See Appendix A, Figure 3.
(4) See Appendix A, Figure 4.
(5) See Appendix A, Figure 5.
(6) See Appendix A, Figure 6.

TI does not publish the peak power for PurePath Digital power stages in the data sheets (see *Conclusion*, Section 4). The peak power can vary from system to system, and thus the system configuration limits the maximum peak power.

3.3 Instantaneous Peak Power

Description:

1. Use the maximum operating voltage specified in the data sheet for each device to set the voltage level for PVDD (MOSFET voltage), i.e., TAS5142 = 34 V; TAS5152 = 37 V; TAS5186 = 39 V.
2. On the AP, generate 1-kHz sine-wave bursts at 0 dBFS.
3. Use various resistive loads in combination with the following step to determine the lowest resistance value before the device is shut down.
4. Set the device for maximum digital gain without the device shutting down. This step is performed in combination with the previous step. The gain is adjusted until one complete sine wave is captured on the oscilloscope.
5. Set up the current probe to capture the peak-to-peak current delivered into the load.
6. Set up the voltage probe to capture the peak-to-peak voltage waveform.

Discussion:

The instantaneous peak power can be calculated using the parameters captured from the traces in Appendix C.

Table 4. Instantaneous Peak Power

DEVICE	CONFIGURATION	CURRENT (I_{pp})	LOAD RESISTANCE	Instantaneous Peak Power
TAS5142	BTL(1)	25.2 A	2 Ω	318 W
	SE(2)	24.5 A	1 Ω	150 W
TAS5152	BTL(3)	26.9 A	2 Ω	362 W
	SE(4)	24.8 A	1 Ω	154 W
TAS5186	SE satellite(5)	10 A	3.5 Ω	88 W
	SE subwoofer(6)	15 A	2.5 Ω	141 W

(1) See Appendix C, Figure 1.
(2) See Appendix C, Figure 2.
(3) See Appendix C, Figure 3.
(4) See Appendix C, Figure 4.
(5) See Appendix C, Figure 5.
(6) See Appendix C, Figure 6.

TI does not publish the instantaneous peak power for PurePath Digital power stages in the data sheet (see *Conclusion*, Section 4). As mentioned in the introduction, the instantaneous peak power does not have any standard. The instantaneous peak power depends on the system and test setup configurations.

4 Conclusion

Texas Instruments (TI) PurePath Digital audio devices deliver world-class performance. TI always strives to maintain the highest standards and integrity in the products that are sold, including the supporting documentation, e.g., data sheets, application notes, etc. TI power stages are tested using proper engineering techniques so that accurate measurements can be obtained (see Reference 2). Audio performance published in the data sheets is collected using AP test equipment. This data, including the power rating, is traceable and reproducible using the TI evaluation board (EVM). The power rating in the data sheet for each power stage is the average power that the device can deliver continuously.

The need for attractive marketing strategies requires TI customers to devise creative ways to use power rating for advertisements. This paper assists TI customers in determining the suitable power rating to be used in the advertisement of their products. TI supports customers internationally and understands that each region of the world requires different marketing strategies.

While the power rating for the US market is dictated by the FTC, other countries may not be restricted to such requirements. In those cases, TI customers are open to choose the acceptable power rating for advertisement. As mentioned in the introduction, PMPO generally is not well-defined and accepted as an audio performance measurement. It is used mostly for advertisements.

The instantaneous measurement data detailed previously indicate the peak-to-peak current that a device can deliver to the specified load. These data can be used for traceable and reproducible PMPO ratings for a given Texas Instruments PurePath Digital application.

5 References

1. *Power Supply Considerations for AV Receivers* (SLEA028)
2. *Digital Audio Measurements* (SLAA114)
3. 3. FTC 16 CFR, Chapter I, Part 432

Appendix A Voltage and Current Traces

A.1 TAS5142

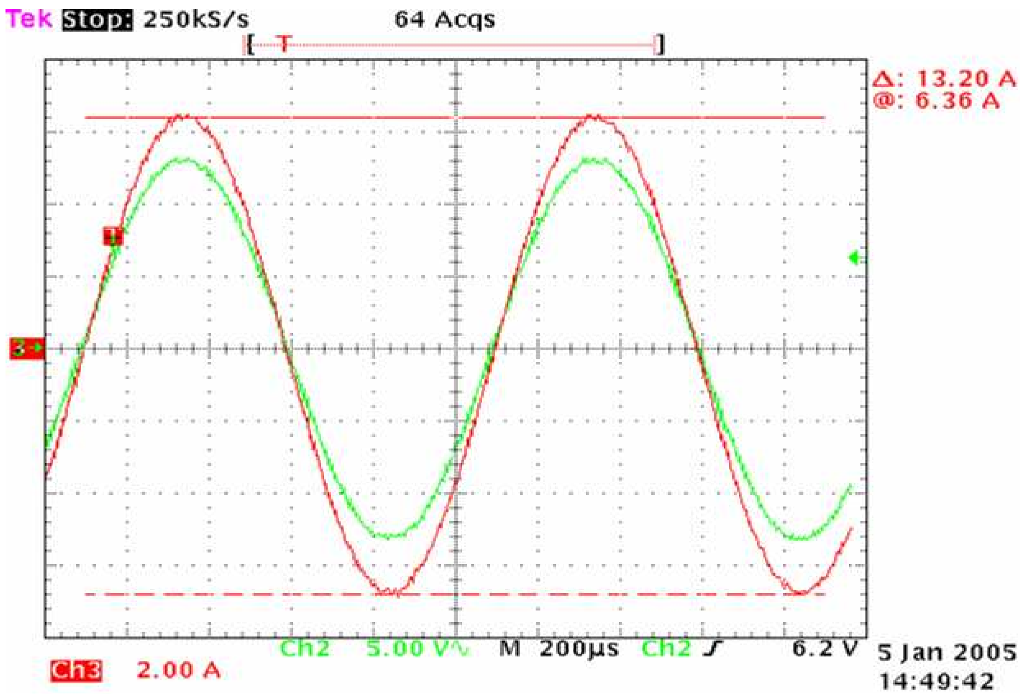

Figure A-1. TAS5142 - BTL

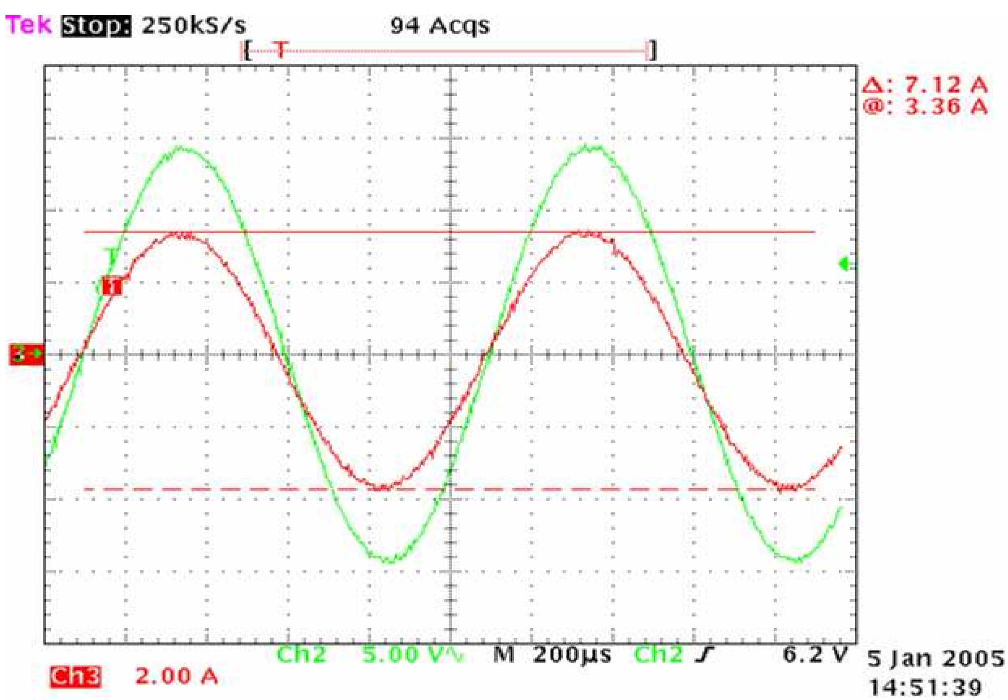

Figure A-2. TAS5142 - SE

A.2 TAS5152

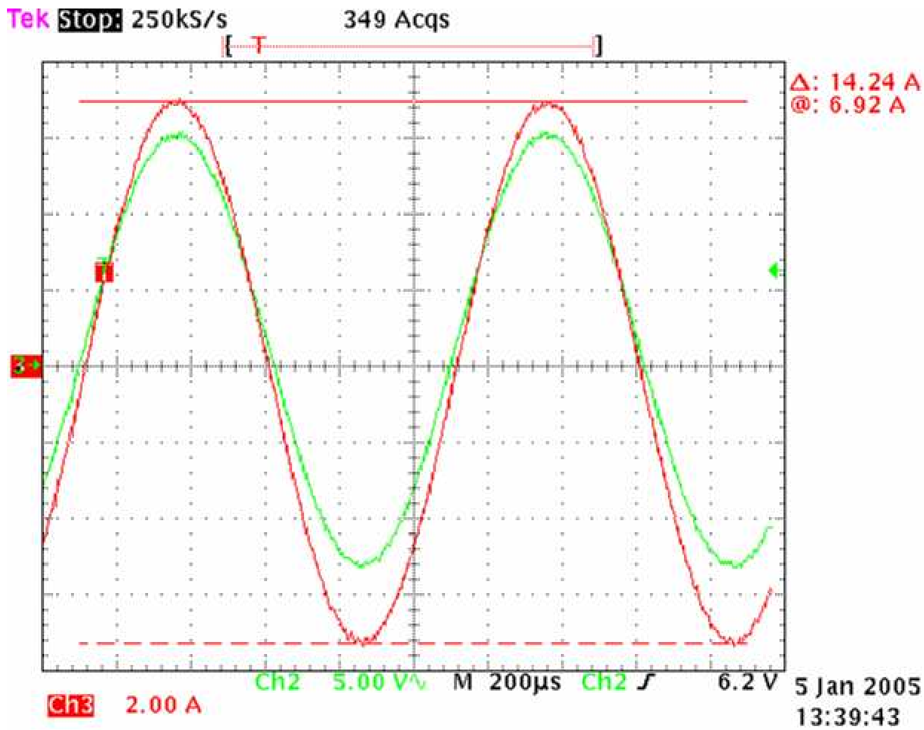

Figure A-3. TAS5152 - BTL

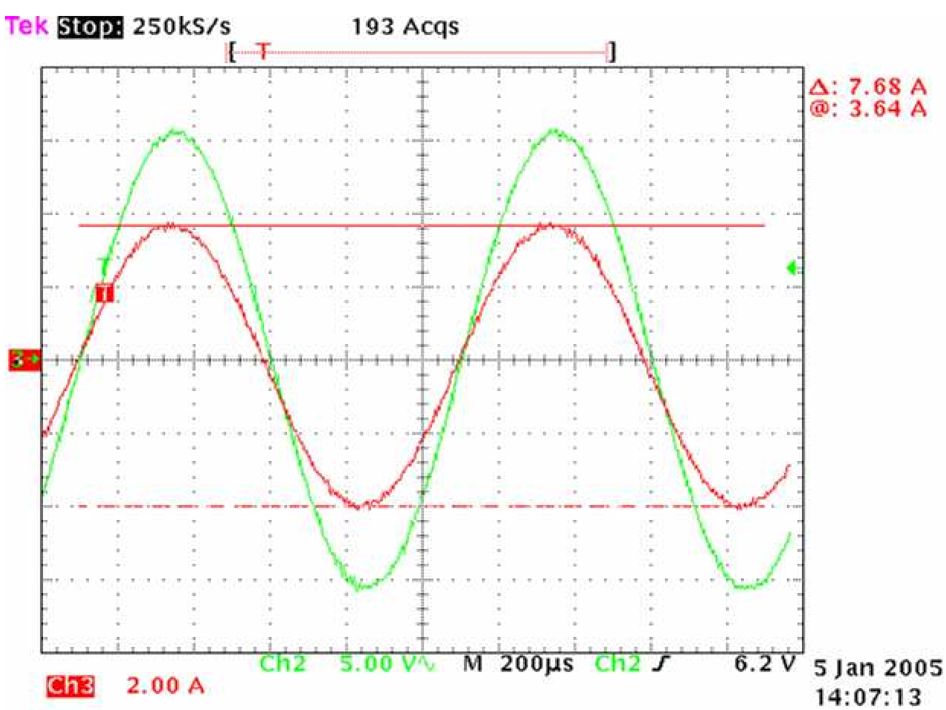

Figure A-4. TAS5152 - SE

A.3 TAS5186

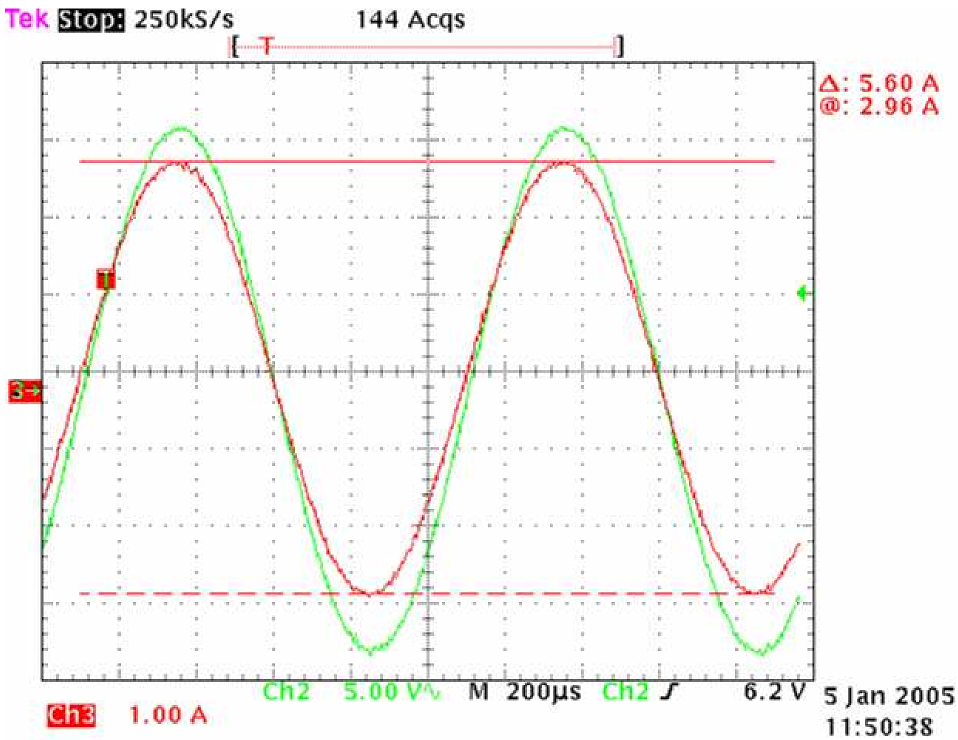

Figure A-5. TAS5186 - SE Satellite

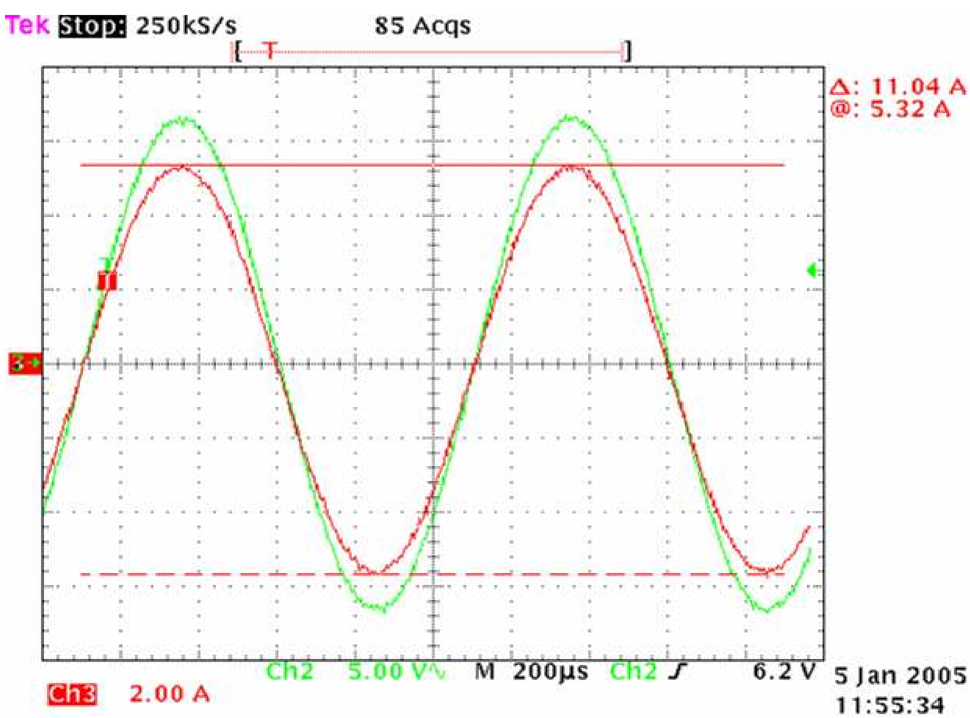

Figure A-6. TAS5186 - SE Subwoofer

Appendix B Audio Precision Power Graphs

B.1 TAS5142

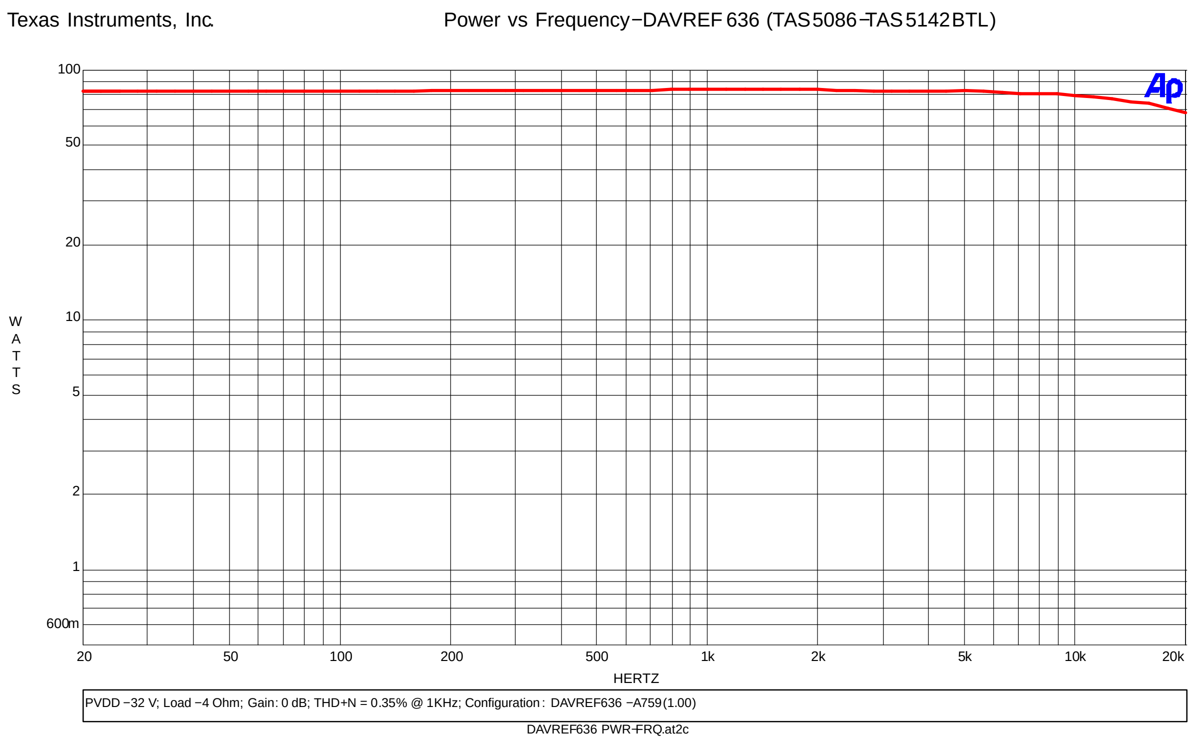

Figure B-1. TAS5142 - BTL

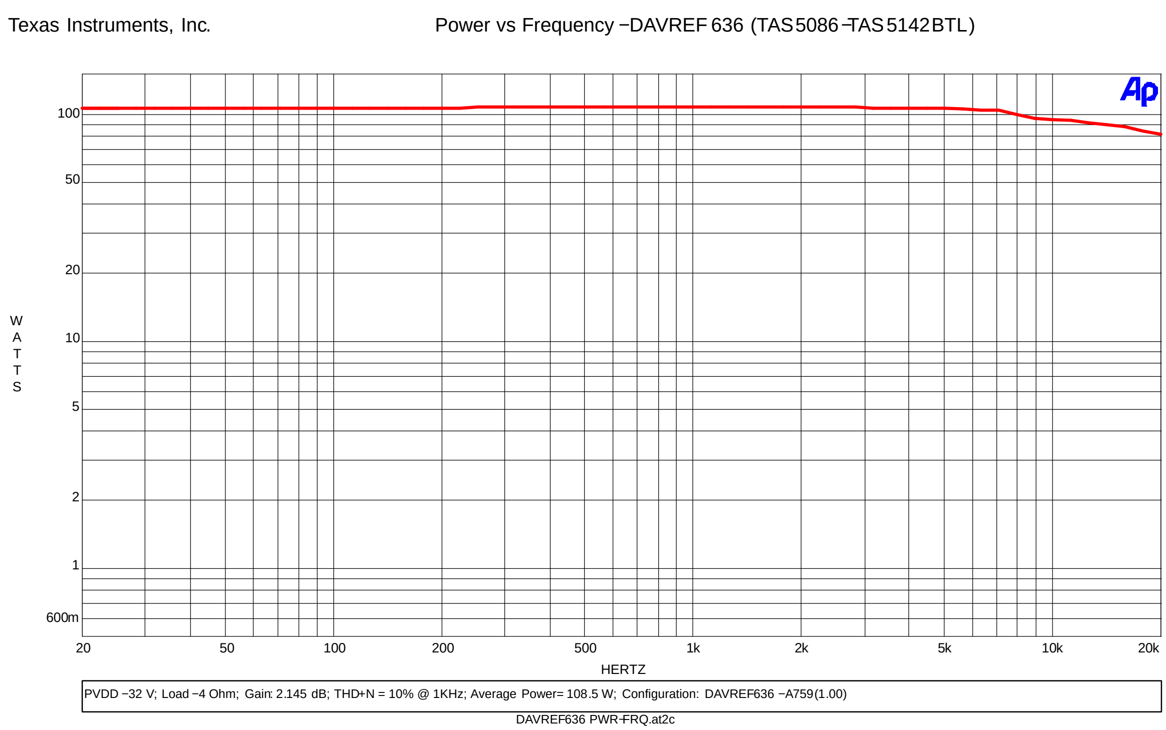

Figure B-2. TAS5142 - BTL (10% THD+N)

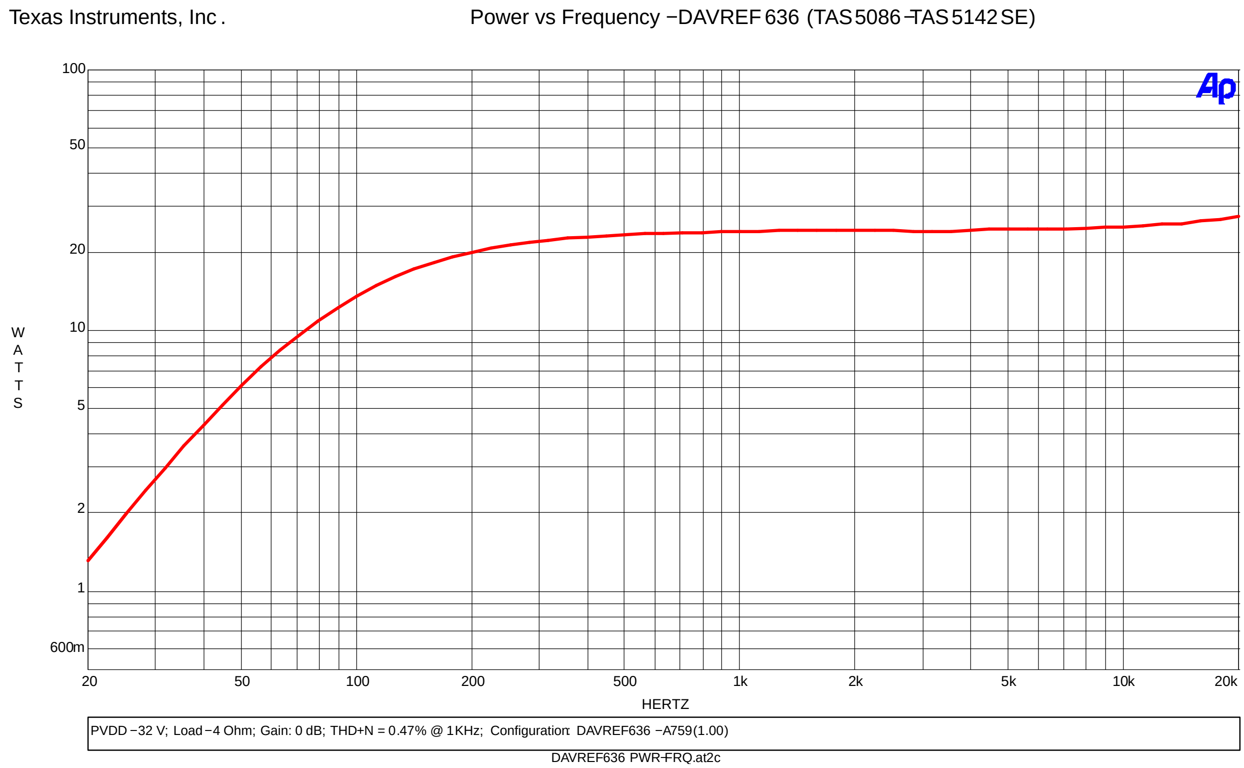

Figure B-3. TAS5142 - SE

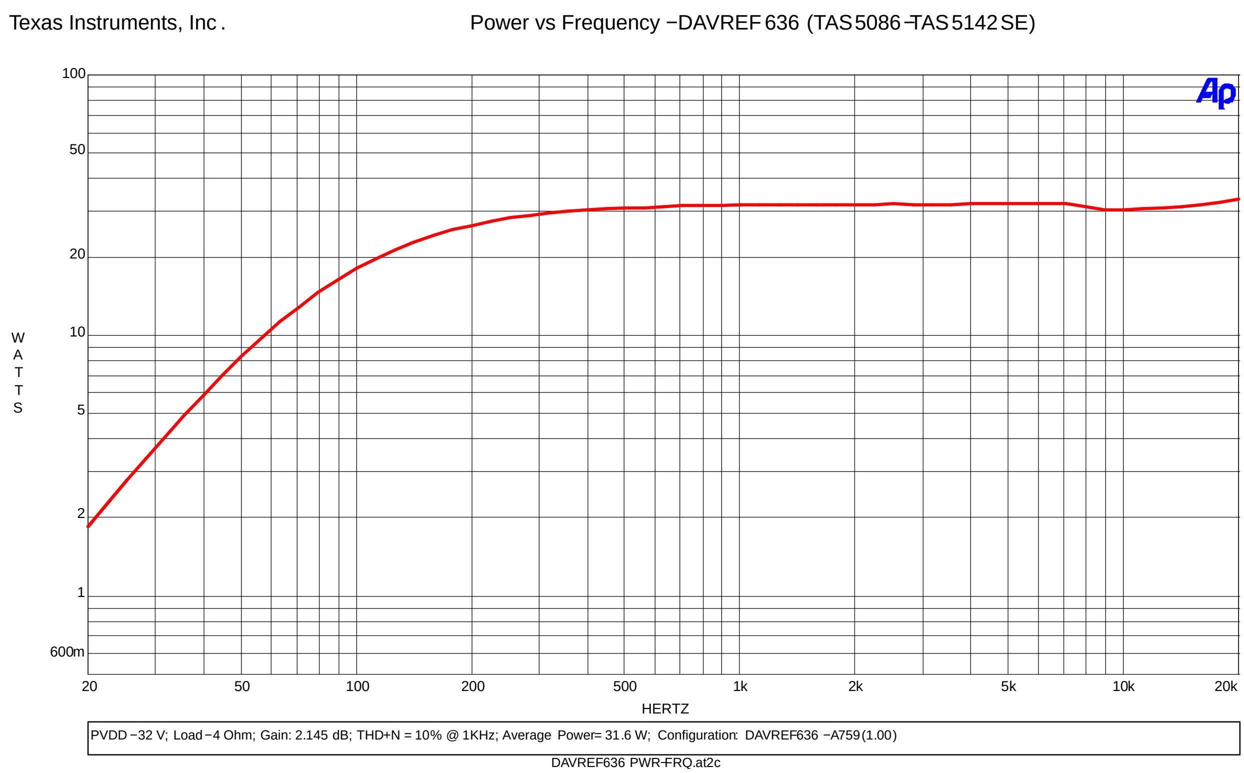

Figure B-4. TAS5142 - SE (10% THD+N)

B.2 TAS5152

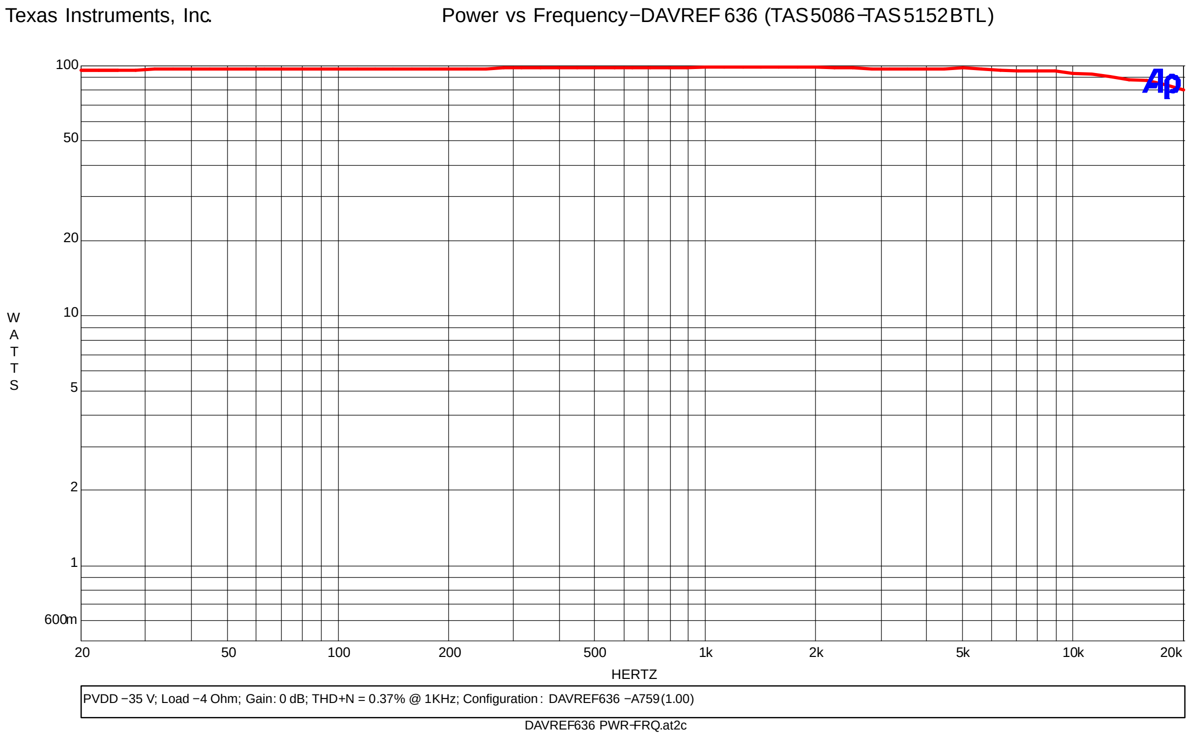

Figure B-5. TAS5152 - BTL

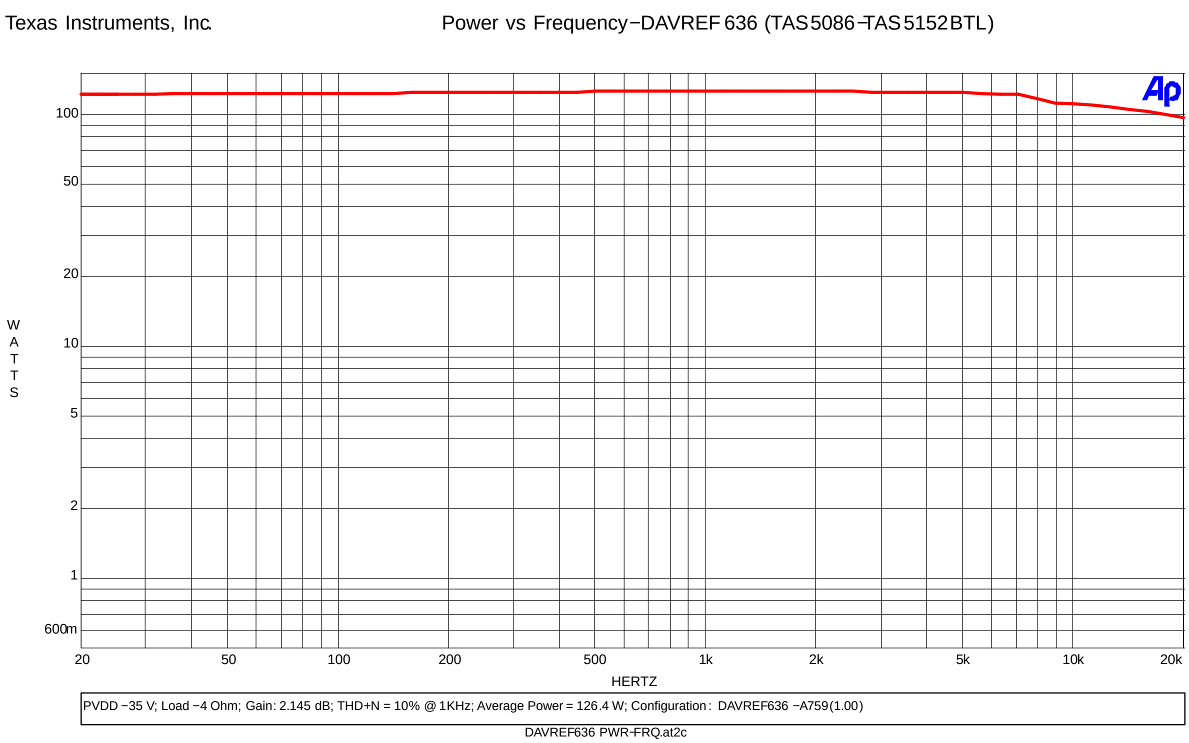

Figure B-6. TAS5152 - SE (10% THD+N)

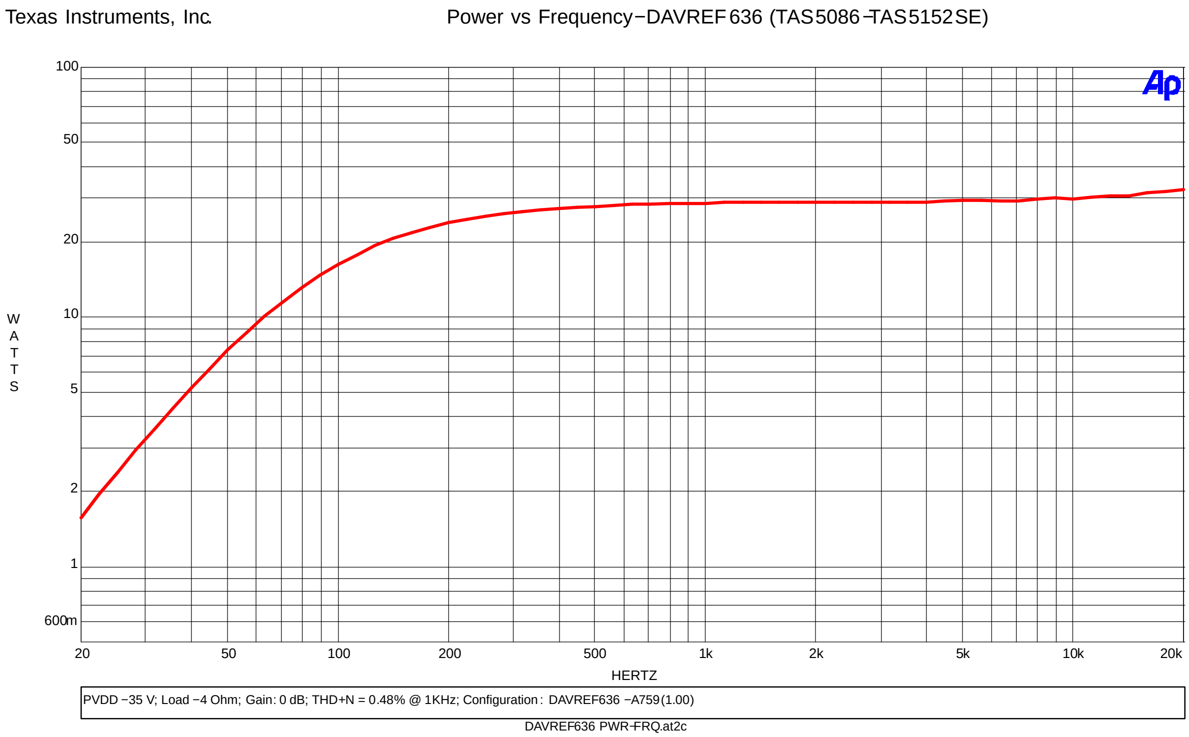

Figure B-7. TAS5152 - BTL

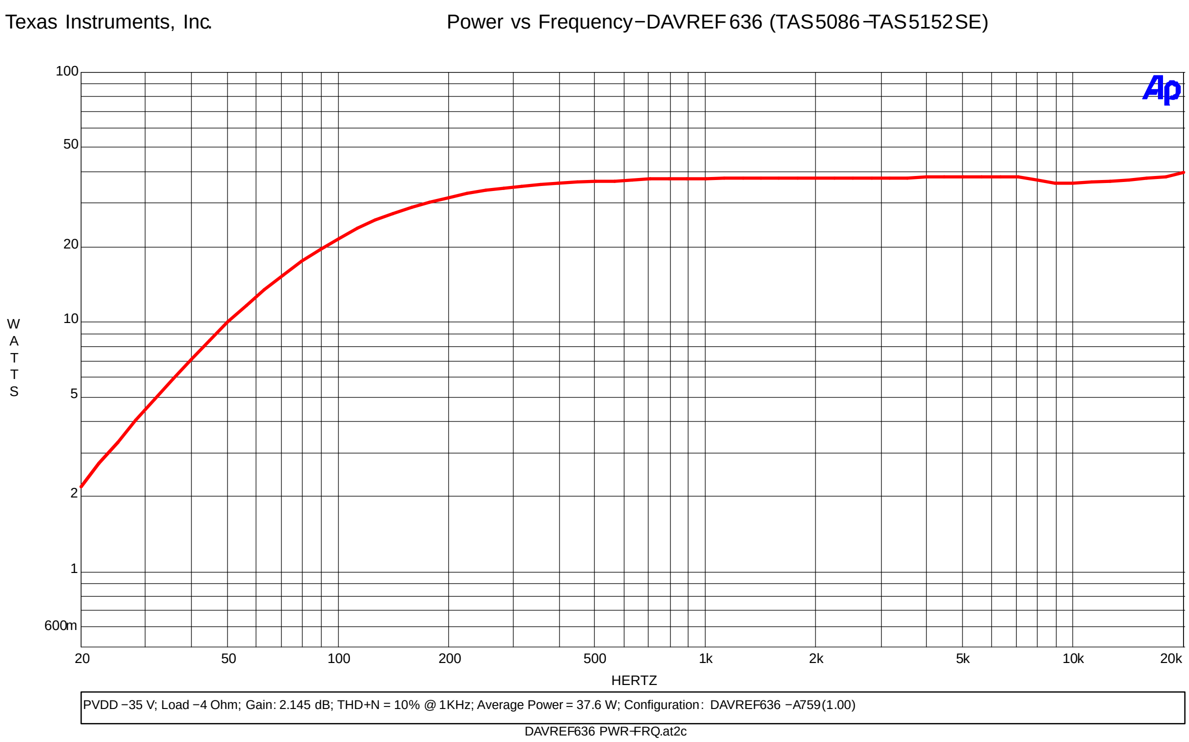

Figure B-8. TAS5152 - SE (10% THD+N)

B.3 TAS5186

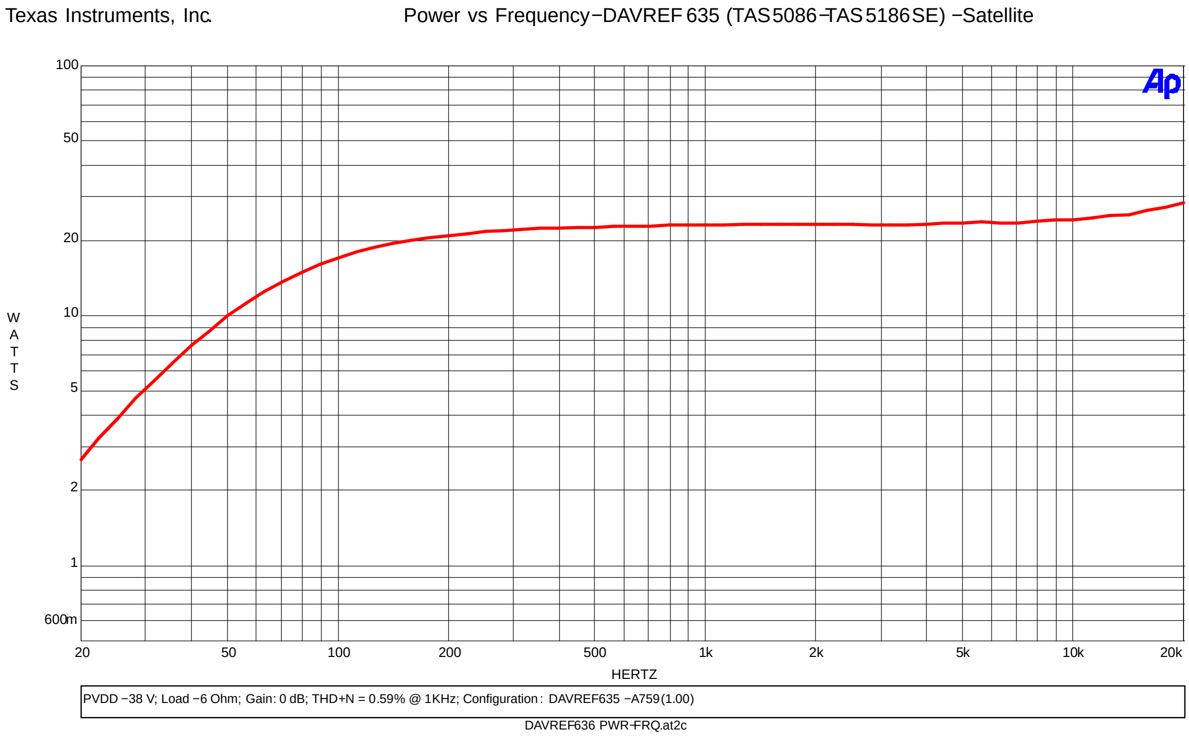

Figure B-9. TAS5186 - SE Satellite

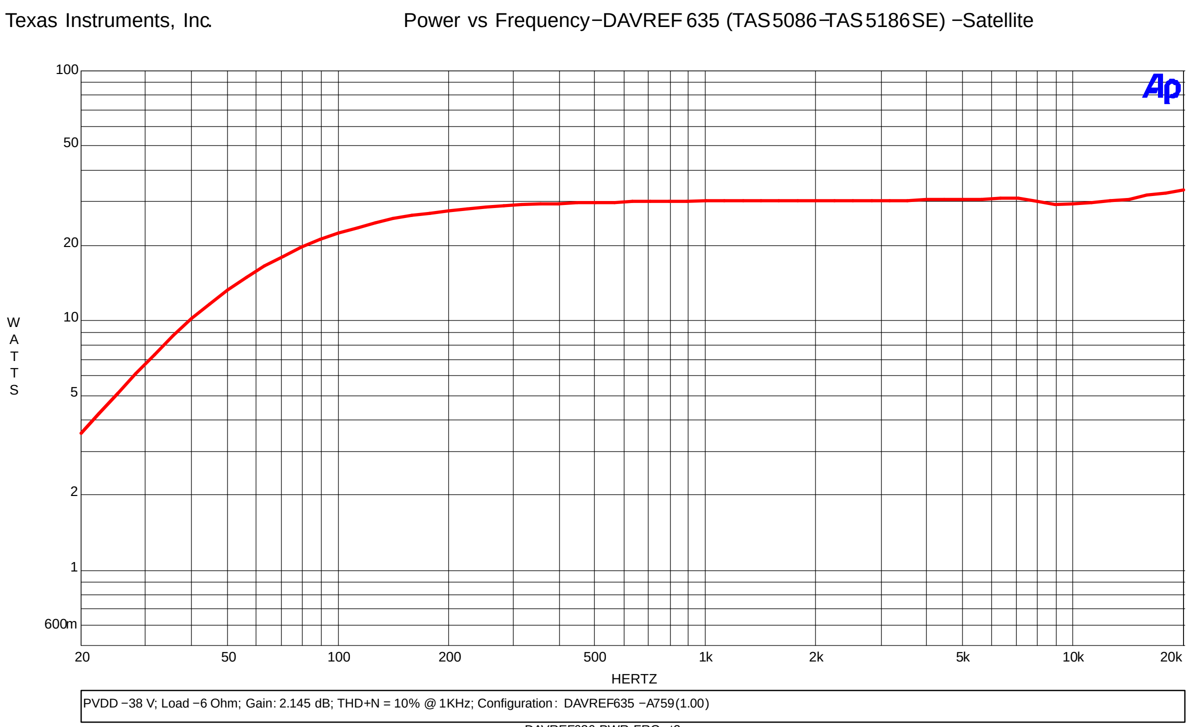

Figure B-10. TAS5186 - SE Satellite (10% THD+N)

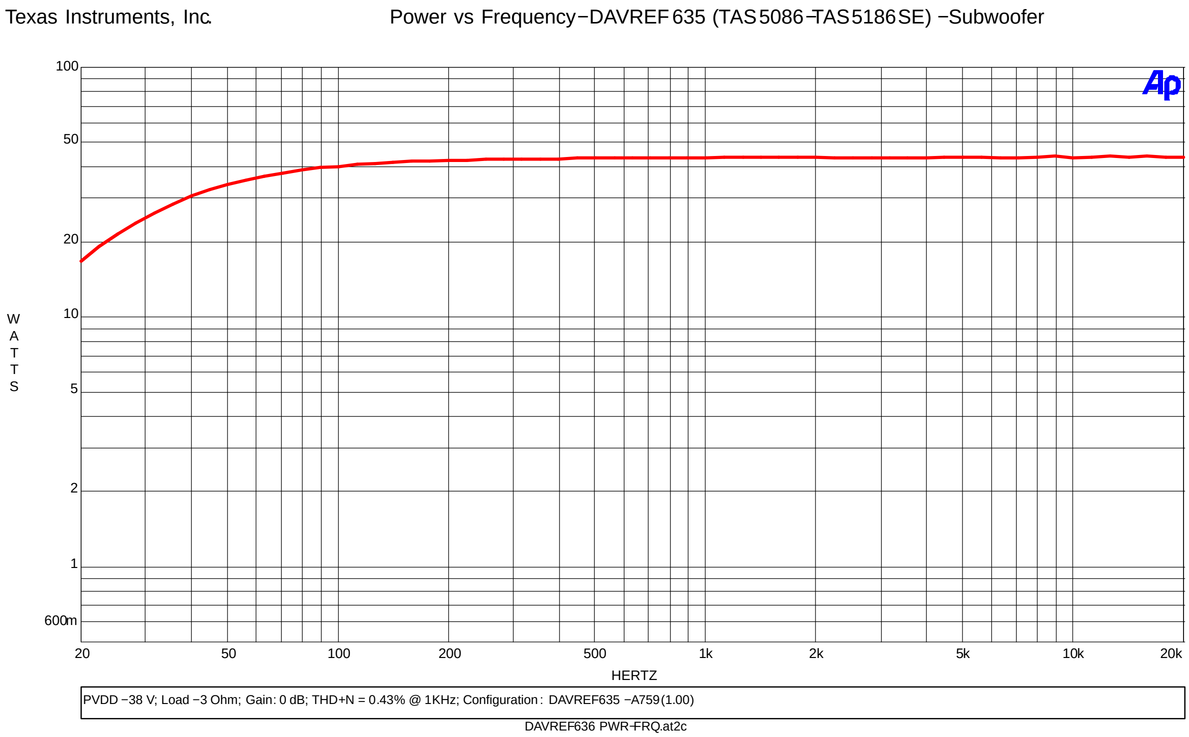

Figure B-11. TAS5186 - SE Subwoofer

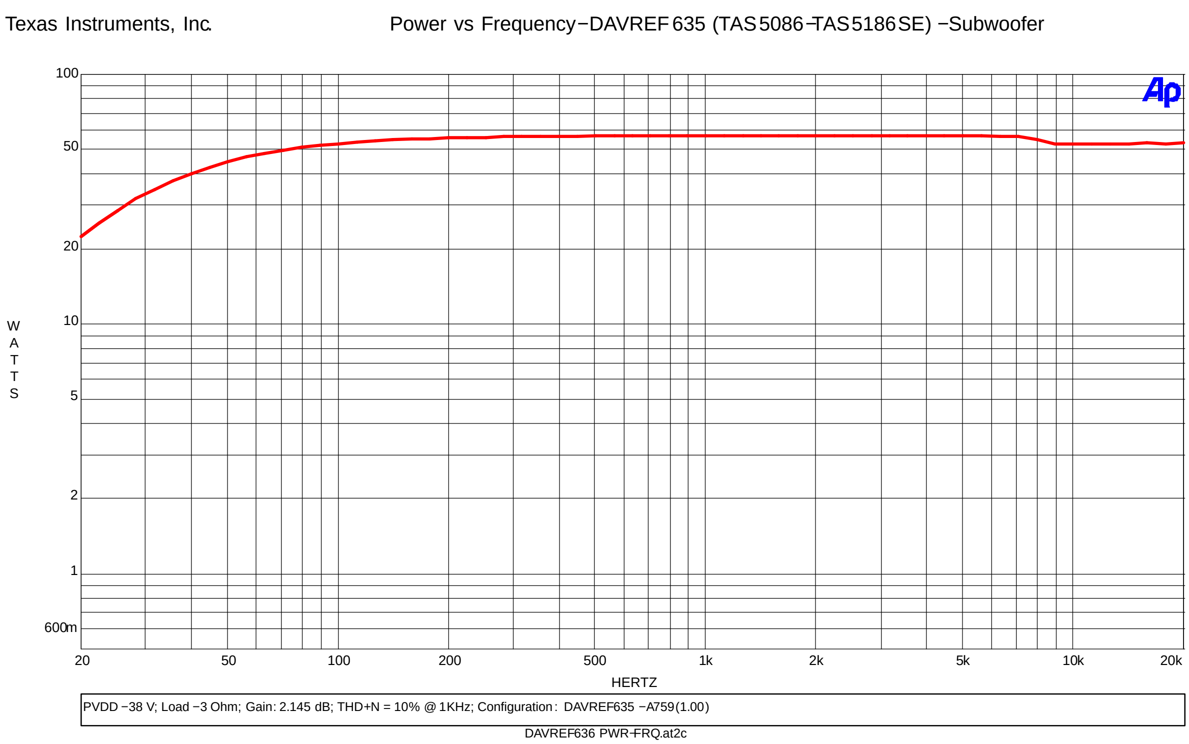

Figure B-12. TAS5186 - SE Subwoofer (10% THD+N)

Appendix C Instantaneous Voltage and Current Traces

C.1 TAS5142

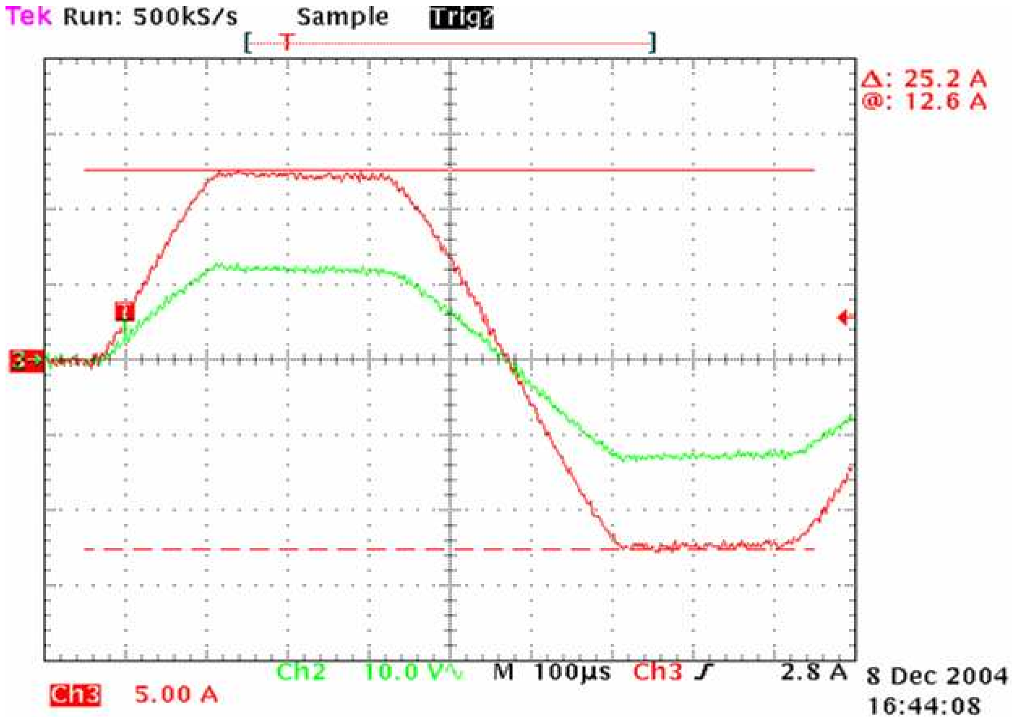

Figure C-1. TAS5142 - BTL

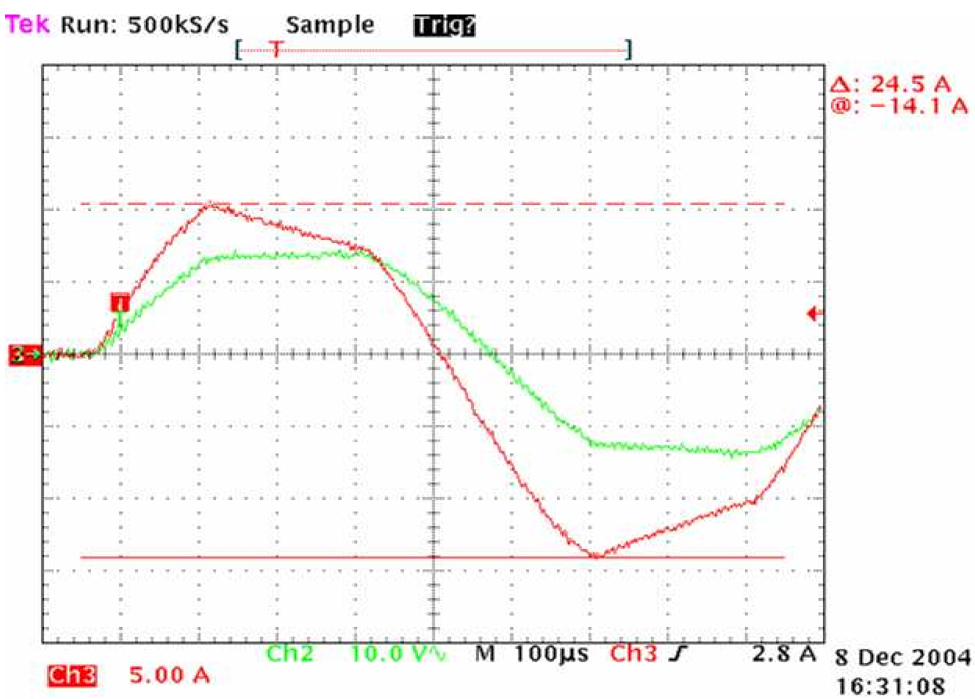

Figure C-2. TAS5142 - SE

C.2 TAS5152

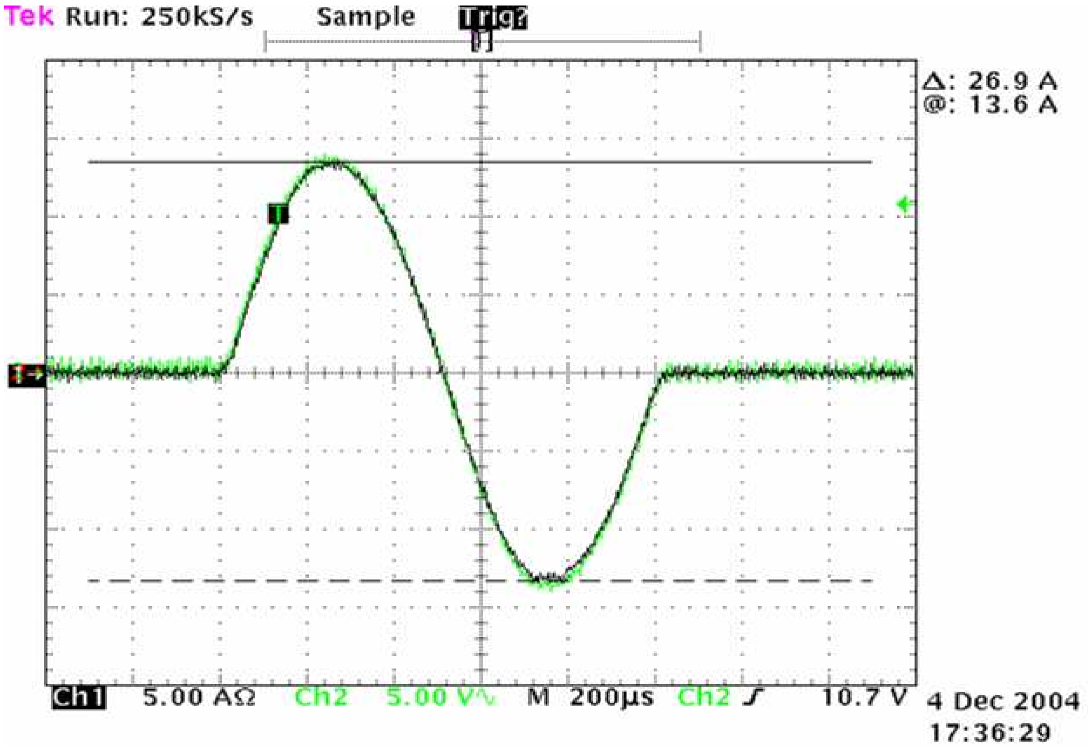

Figure C-3. TAS5152 - BTL

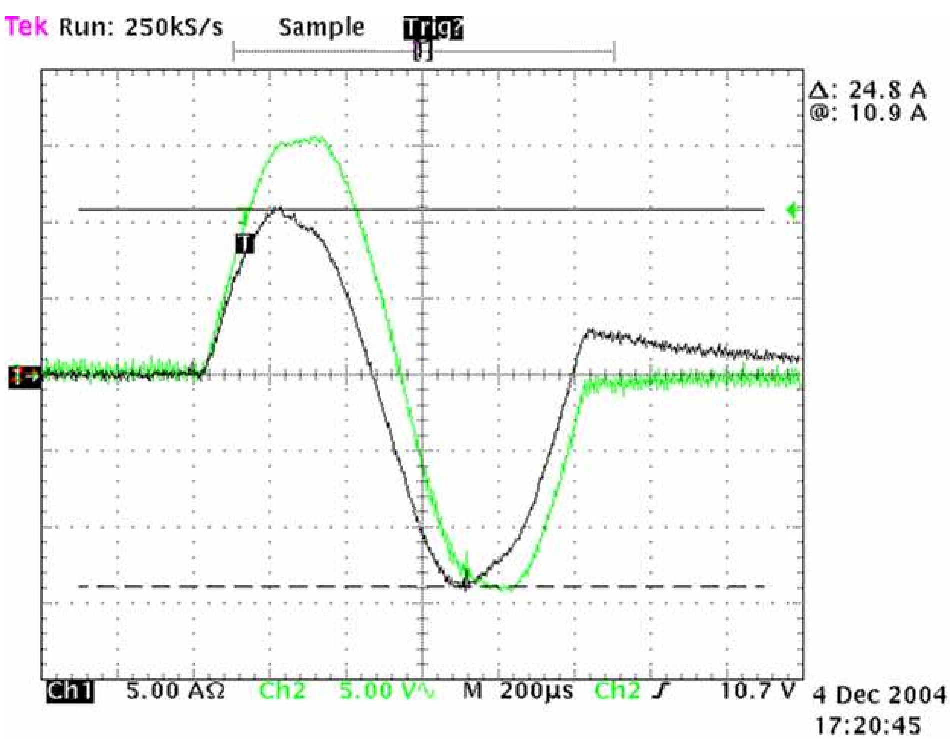

Figure C-4. TAS5152 - SE

C.3 TAS5186

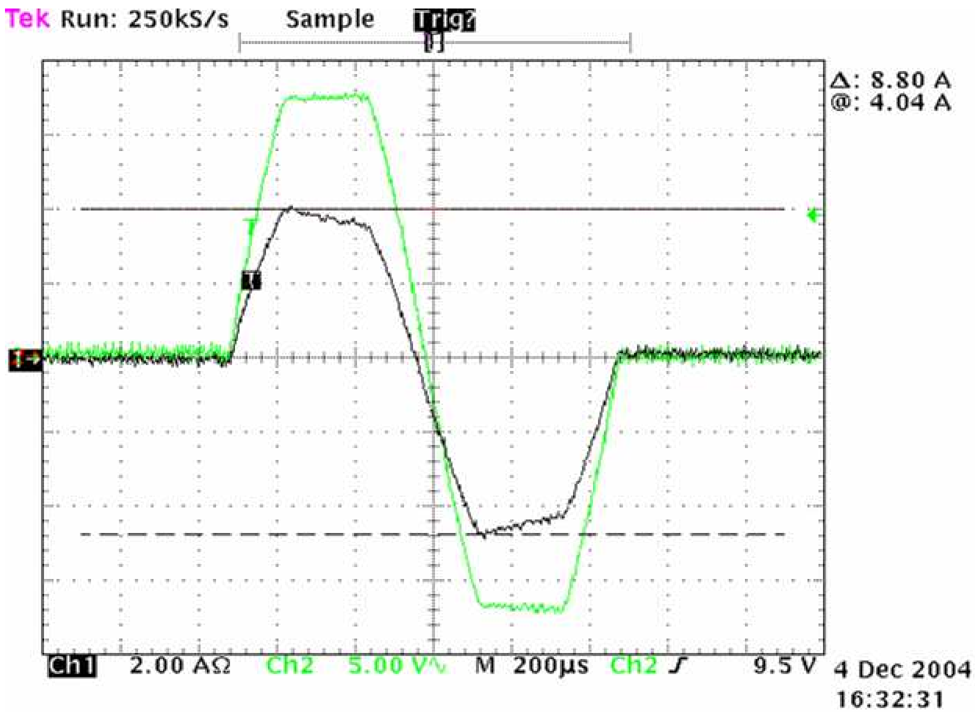

Figure C-5. TAS5186 - SE Satellite

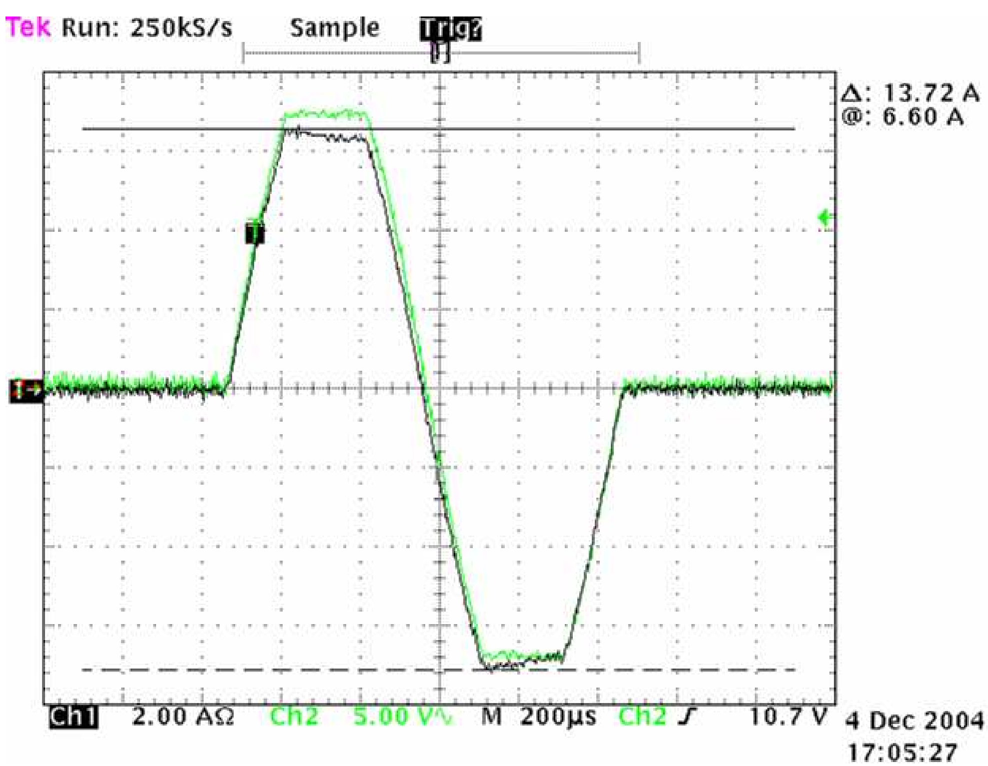

Figure C-6. TAS5186 - SE Subwoofer

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