Application Report

Current and Voltage Sensing Accuracy and Linearity

Texas Instruments

ABSTRACT

Current and Voltage sense (IV sense) tracking is critical to the speaker protection algorithm in a smart audio amplifier. When IV Sense data is both accurate and responds linearly, then the speaker load resistance calculation will improve and allow the most power to be delivered into the speaker without damaging it. The speaker protection algorithm relies on this accurate sensing of current and voltage.

In order to characterize the electrical performance and ensuing accurate speaker protection algorithm can be built around the device, it is necessary to measure IV sense accuracy reliably and precisely. This article focuses on how to measure IVsense accuracy and linearity/gain error of pilot tone across audio signal power level and audio signal frequency using industry accepted instruments.

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1 Equipment Setup

Typically bench measurements are performed using Audio Precision Analyzers. In the case of the AP2700 family of analyzers, there will be a Programmable Serial Interface Adapter (PSIA) which is used to drive and receive I^2S data. When monitoring the Class-D outputs of audio amplifiers, it is also necessary to use a filter to assist the analyzer by resolving the output switching waveform.

When selecting a load, it is critical to use a resistor capable of easily handling the full-scale output voltage of the amplifier. Any changes in nominal resistance due to heating will reduce measurement accuracy. Additionally, wires used to connect the load need to be selected to minimize resistive losses at high output power.

Please refer to Figure 1-1 for a typical hardware setup:

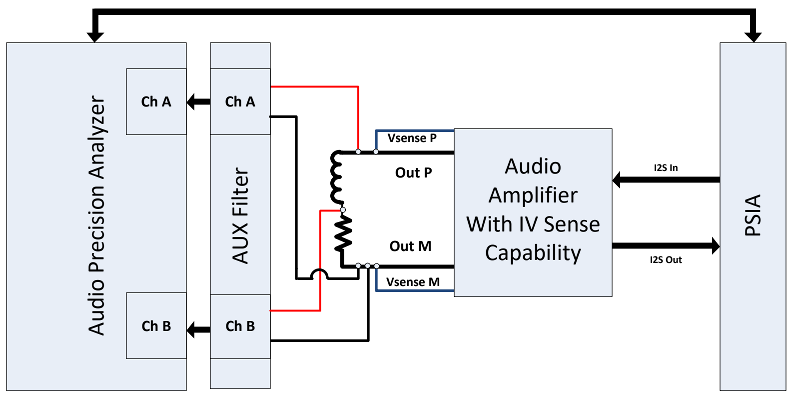

Figure 1-1. Typical Hardware Setup

After connecting the AP analyzer as shown above, configure the analyzer software to use the following settings:

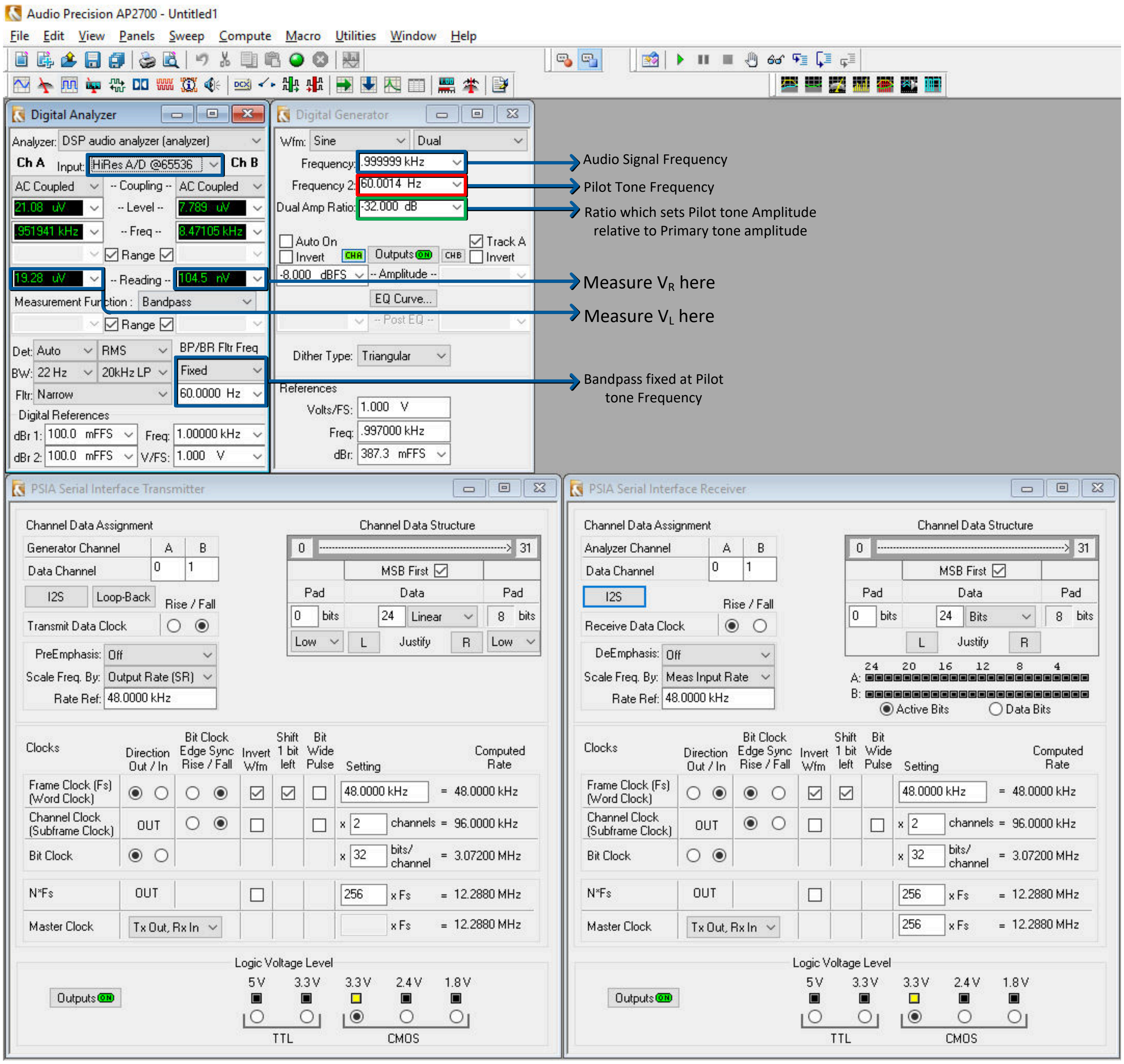

Figure 1-2. AP2700 Series Configuration

Once the analyzer is setup, configure the amplifier to generate IV sense data. This requires you to enable IV sense and then configure the I^{2}S outputs to transmit both Isense and Vsense data. This can be easily done using the Pure Path Console 3 software associated with the EVM.

Figure 1-3. Enable IV Sense Functions - Pure Path Console 3

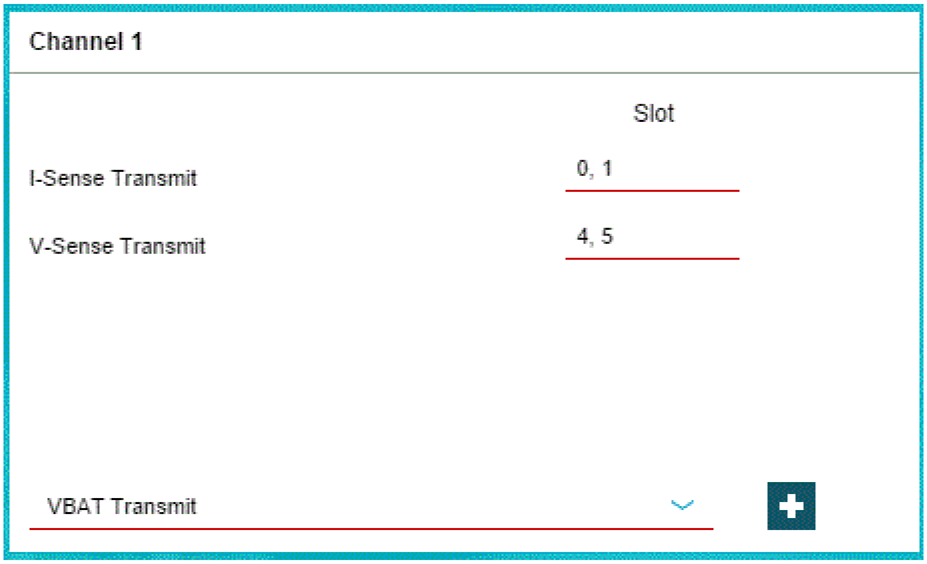

Figure 1-4. Transmit IV Sense Data - Pure Path Console 3

2 Perform Measurements

It is critical to the reliability of this test that the load resistance be a known calibrated value. It is best to measure this using a 4-wire connection for the most accurate value. Several calculations will depend on the accuracy of this value.

The test will proceed in a stepwise manner across output power. At each power level of concern, the following data should be recorded:

$$V_R = \text{Voltage across the Resistor Only (CH B)} V_L = \text{Voltage across the complete R+L Load (CH A)} V_{dig} = \text{Voltage Sense Digital Value (CH B)} I_{dig} = \text{Current Sense Digital Value (CH A)} R = \text{Calibrated Resistance} \tag{1}$$

Measuring both Voltages and Digital inputs require changing the AP Input source between the HiRes A/D Converter and the Digital inputs.

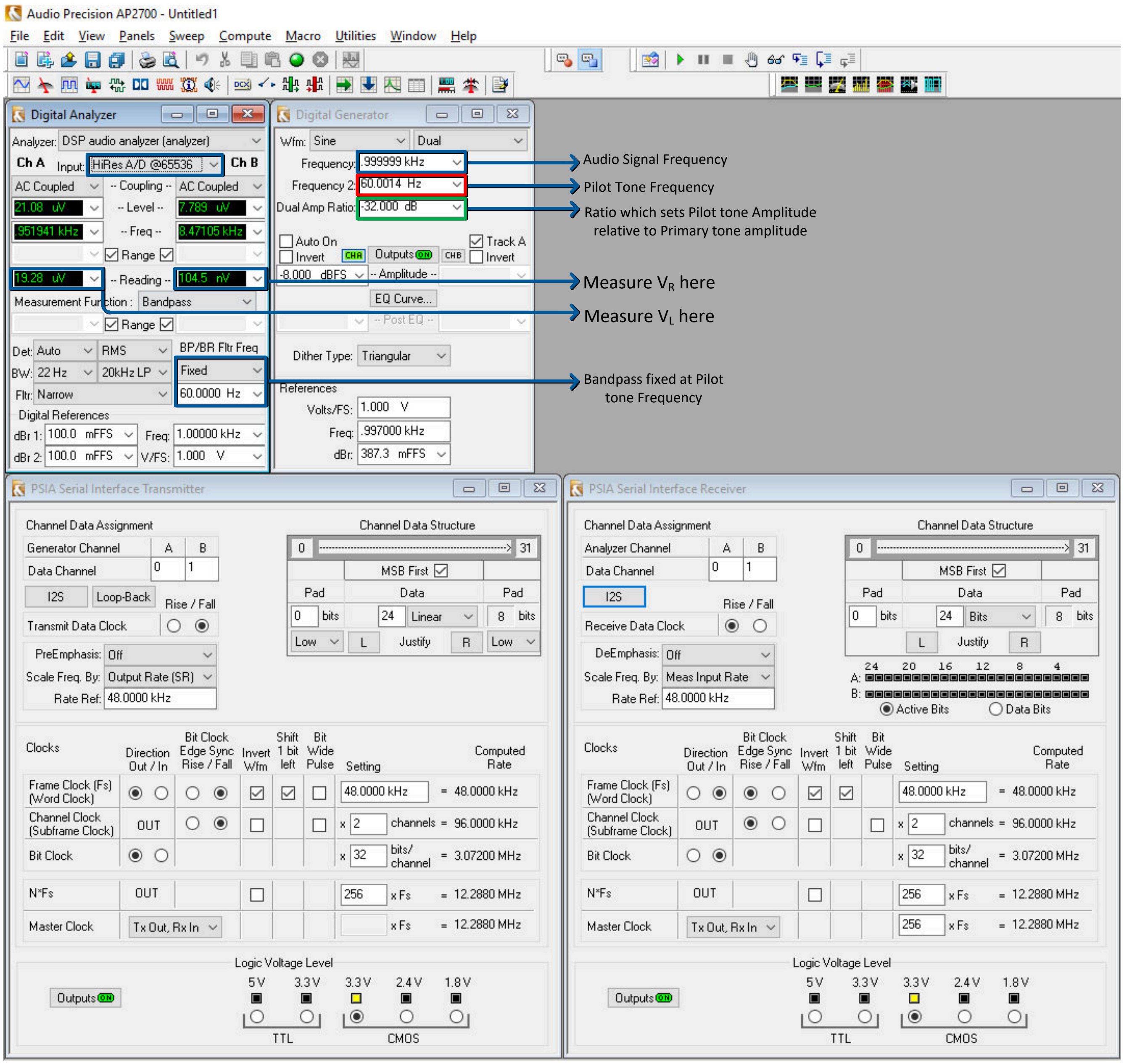

Figure 2-1. Measuring Analog Voltages - Use HiRes A/D

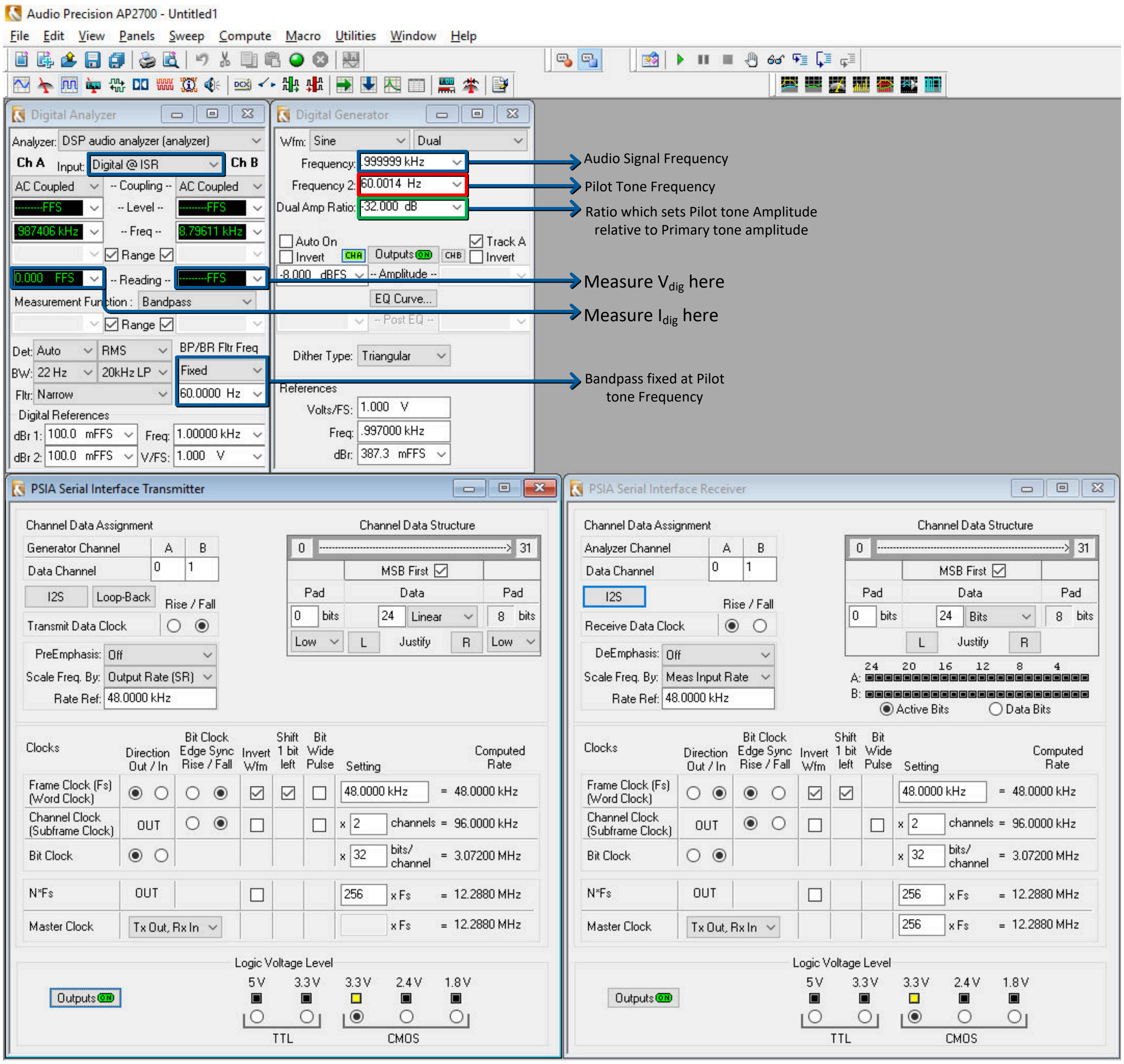

Figure 2-2. Measuring Digital Outputs - Use Digital Interface

Proceed to capture each of the above values, step the output power to the next amplitude, and repeat until the full output range under test is captured. However, in this configuration, the pilot tone amplitude is a scalar ratio of the fundamental. You only want to increase the magnitude of the fundamental, so this ratio will require adjustment at each step. Setting the ratio and the amplitude in units of dB will allow for easy adjustments. As long as the sum of the ratio and amplitude is kept constant, the pilot tone amplitude should remain fixed.

Once data collection is complete, you can perform calculations for each output level to determine accuracy.

$$V_{FS} = \text{Full Scale Voltage} \quad I_{FS} = \text{Full Scale Current} \quad I_{actual} = \frac{V_R}{R} \quad V_S = \frac{V_{dig} * V_{FS}}{2} \quad I_S = \frac{I_{dig} * I_{FS}}{2} \tag{2}$$

$$V_{accuracy(\%)} = \frac{(V_S - V_L) * 100}{V_L} \quad I_{accuracy(\%)} = \frac{(I_S - I_{actual}) * 100}{I_{actual}} \quad Load_{accuracy(\%)} = \frac{\left(\frac{V_S}{I_S} - \frac{V_L}{I_{actual}}\right) * 100}{\frac{V_L}{I_{actual}}}$$

It is necessary to determine the full scale voltage and current values from the data sheet of the amplifier being used. For example, you can pull this information for TAS2562 in Figure 2-3:

CURRENT SENSE						
DNR	Dynamic range	Un-Weighted, Relative to 0 dBFS		69		dB
THD+N	Total harmonic distortion + noise	R_L = 8 Ω + 33 µH, f_{in} = 1 kHz, P_{OUT} = 1 W		-56		dB
		R_L = 4 Ω + 33 µH, f_{in} = 1 kHz, P_{OUT} = 1 W		-57		dB
	Full-scale input current			2.0		A
	Current-sense accuracy	R_L = 8 Ω + 33 µH, I_{OUT} = 354 mA_{RMS} (P_{OUT} = 1 W @ 1kHz)		±1		%
	Current-sense gain error over temperature	0°C to 70°C, 8 Ω, using a 60Hz -40dB pilot tone		±1		%
	Current-sense gain error over output power	50mW to 0.1 % THD+N level, f_{in} = 1 kHz, 8 Ω, using a 60Hz -40dB pilot tone		±1.5		%
	LPF passband corner	fs = 8 kHz to 48 kHz		0.417		fs
		fs = 96 kHz		0.208		fs
		fs = 192 kHz		0.104		fs
	LPF passband ripple		-0.05		0.05	dB
	LPF stopband attenuation	0.55 fs		60		dB
	LPF group delay	DC to 0.417 fs			5.7	1/fs
VOLTAGE SENSE						
DNR	Dynamic range	Un-Weighted, Relative 0 dBFS		69		dB
THD+N	Total harmonic distortion + noise	R_L = 8 Ω + 33 µH, f_{in} = 1 kHz, P_{OUT} = 1W		-60		dB
		R_L = 4 Ω + 33 µH, f_{in} = 1 kHz, P_{OUT} = 1W		-60		dB
	Full-scale input voltage			14		V_{PK}
	Voltage-sense accuracy	R_L = 8 Ω + 33 µH, I_{OUT} = 354 mA_{RMS} (P_{OUT} = 1 W)		±0.5%		
	Voltage-sense gain error over temperature	0°C to 70°C, 8 Ω, using a 60Hz -40dB pilot tone		±0.5%		

Figure 2-3. TAS2562 Full Scale Values

3 Linearity Calculations

Linearity, or Gain Error, can be easily calculated for each accuracy measurement in *Section 2*. To do this, a reference value should be selected from the set of data. It is typical to use the condition of 1 W, 1 kHz, and 25°C. Linearity for each data point is then the difference from its respective reference value.

$$I_{linearity} = I_{accuracy} - I_{ref} V_{linearity} = V_{accuracy} - V_{ref} Load_{linearity} = Load_{accuracy} - Load_{ref} \quad (3)$$

These values can then be plotted to show the changes in accuracy relative to the reference for each calculation. Fixed offsets to this data can be calculated out easily, but it is most desirable to see this line be flat and centered at zero for the best speaker protection performance. Figure 3-1 sample plot.

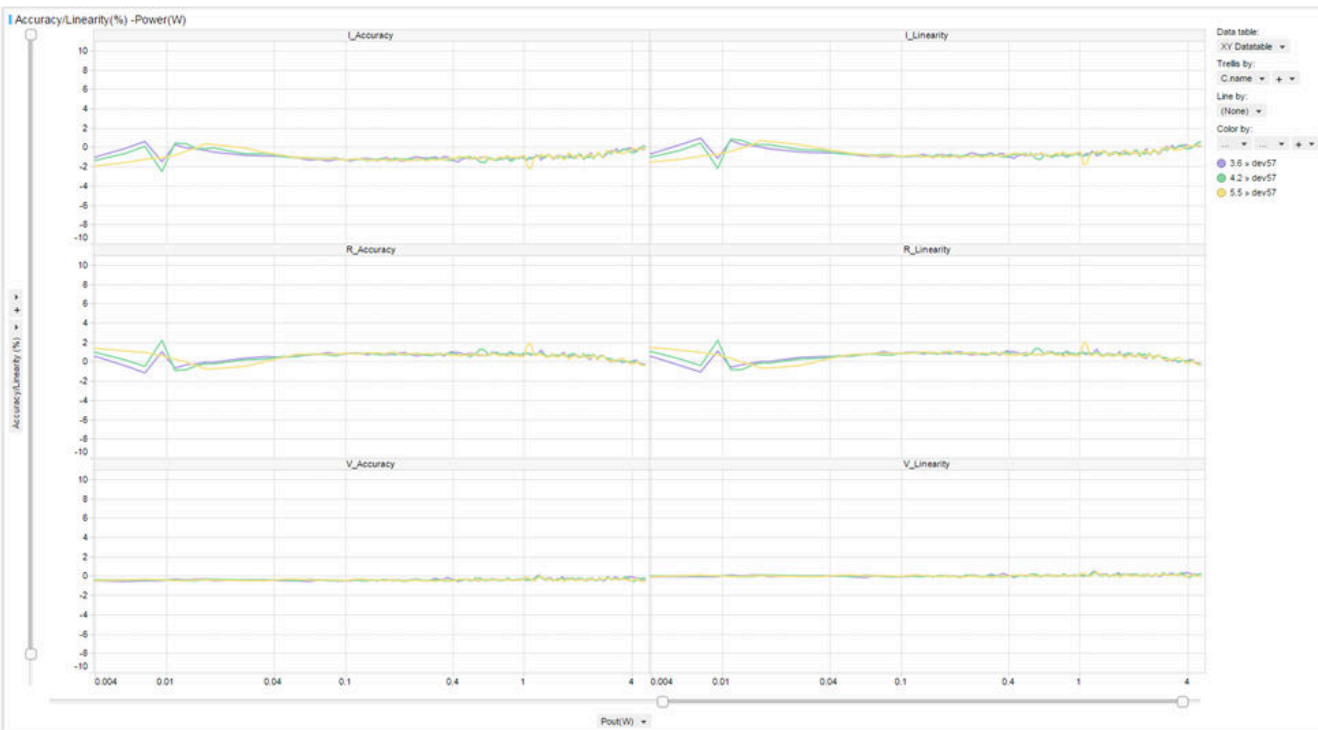

Figure 3-1. Sample Plot

4 Summary

The test flow for evaluating IV Sense linearity and accuracy is a typical part of the design validation and characterization. It is helpful to know the overall expected accuracy. Many devices available from TI.com such as TAS2562, TAS2563, TAS2564, and TAS2770 are able to meet 1% accuracy or better across power and temperature. This allows the SmartAmp algorithm to provide superior speaker protection while maximizing output power into small speakers.

5 References

- *TAS2562 Digital Input Mono Class-D Audio Amplifier with Speaker IV Sense Data Sheet*
- *TAS2563 6.1-W Boosted Class-D Audio Amplifier with Integrated DSP and IV Sense Data Sheet*
- *TAS2564 7-W Boosted Class-D Audio Amplifier with <10 µV Noise and IV Sense Data Sheet*
- *TAS2770 20-W Digital Input Mono Class-D Audio Amplifier with Speaker IV Sense Data Sheet*

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