Texas Instruments

Application Report

TAS5825P Hybrid-Pro User Guidance

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ABSTRACT

This document provides guidelines for using the TAS5825P Hybrid-Pro feature by giving an overview of the internal algorithm, external interface architecture, and PPC3 software with test data.

1. Audio Amplifier Evolution

Traditional class-AB audio amplifier are widely used in the past decades, the efficiency only up to 50%, so we will face system thermal challenges and have to use heatsink for cooler amplifier. Using heatsink makes the product size much bigger and higher, which is not friendly for compact system design. The heatsink also acting as a heat source, makes other components work under hotter environment, shorten their lifetime.

Class-D audio amplifier use digital modulation, makes the MOSFET works under fully ON and fully OFF, which means much lower of power dissipation than BJT, hence class-D audio amplifier efficiency can easily higher than 90%, helping the system save a heatsink in middle power application. Depending on these advantages, class-D audio amplifier are widely used in home theater, portable speaker, soundbar, car audio and other audio end equipment, upgrading the traditional class-AB solution.

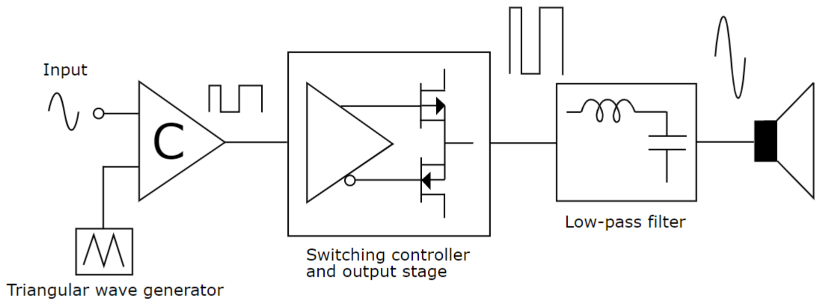


Figure 1. Class-D Architecture

However, even class-D audio amplifier still can't meet the growing efficiency requirement from market. For example, battery life is one of the most important factors in portable speakers, improve the system efficiency will obviously save power consumption and extend battery life. In typical class-D audio speaker system, the supply voltage rail is fixed. To avoid any clipping distortion from audio peaks, a large supply voltage is required for high dynamic range, but the fixed high-voltage supply will decrease the efficiency, compare with using lower voltage supply.

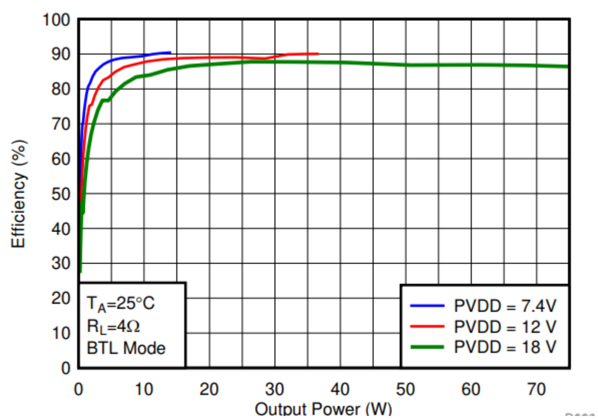


Figure 2.

Actually, using lower PVDD will increase class-D audio amplifier efficiency:

1. The switching interval of MOSFET voltage becomes shorter, means MOSFET switching loss will be smaller, improve the audio amplifier efficiency.

2. In battery application, the PVDD is generated by a boost converter. Lower PVDD will lead to smaller differential voltage between Vin and Vout, also lead to smaller switching loss, improve the boost converter efficiency.

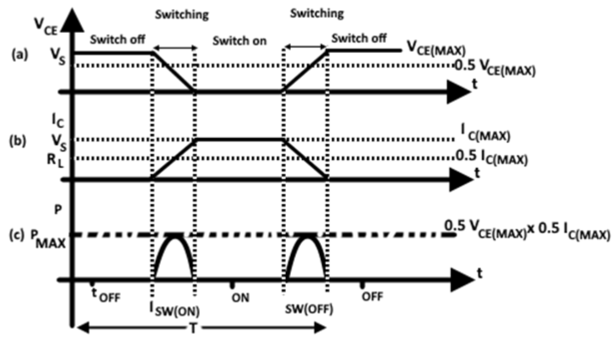


Figure 2. MOSFET Switching Power Loss

Base on these mechanism, class-G and class-H audio amplifier are nominated for high efficiency application. These audio amplifiers dynamically control the supply voltage based on the audio signal level, support audio high dynamic range and improve system efficiency. The difference between class-G and class-H audio amplifier would be power rail levels. Normally class-G audio amplifier only support 2-level power rails while Class-H audio amplifier have much more levels. In other words, class-G architecture is the subset of class-H architecture. Hence class-H audio amplifier have the highest efficiency than others. This architecture also named as audio envelope tracking.

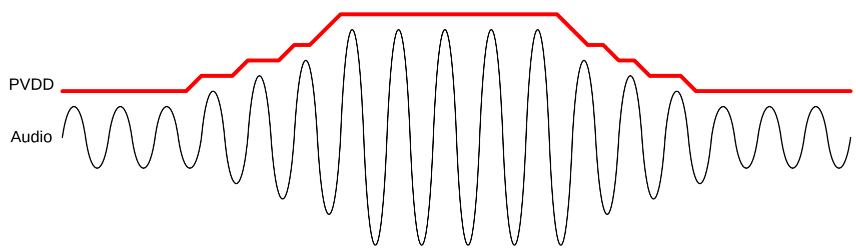


Figure 3. Class-H architecture

2. Analog Envelope Tracking Solution

The popular envelope tracking solution is analog solution, it is finished by discrete component. An example of this implementation can be found in this reference design (**Envelope-tracking power supply reference design for mid-power audio power amplifier applications**). This analog method can improve the system efficiency, especially in small audio condition.

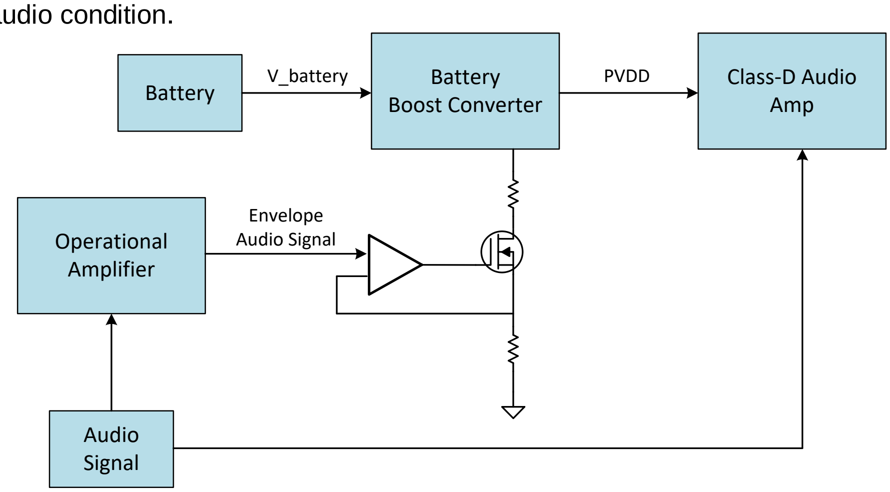


Figure 4. Analog Envelope Tracking Solution

This analog architecture divide the audio into 2 paths:

1. Path A: input the audio signal to amplifier directly.
2. Path B: monitor the analog audio input signal and dynamically control the boost converter output voltage.

Path B need to control FB loop of boost converter, the boost converter also need a raise time to increase the PVDD to target level, hence path B will delay to path A definitely. Once high frequency audio peak signal arrived, the audio amplifier will generate output immediately, but the PVDD still on the way to target level, the clipping distortion occurs at the amplifier output side. This is major drawback of analog envelope tracking system. Except this, too much external component also makes more complex system and bigger PCB size, which is unfriendly to compact system.

3. Customer System Integration Guidance

TI provides one-shop TAS5825P Hybrid-Pro customer system integration, which targets prompt guidance for both hardware schematic design and software algorithm tuning.
This chapter introduces two user integration modes to fit various tuning requirement scenarios: Easy-to-use Mode and Advanced Mode.

	Target Applications	Hybrid-Pro Algorithm
Easy-to-use Mode	• Only one TAS5825P in system. Easy tuning for fast system integration is preferred.	Suggested configurations to meet normal system requirements. Such as max 189 samples delay buffer (~4ms @48kHz).
Advanced Mode	• Only one TAS5825P in system. Needs to fine tune advanced Hybrid-Pro algorithm features. • More than one TAS5825P scenario. Hybrid-Pro feedbacks to same DC-DC to implement enough power rail for all output channels.	Advanced Hybrid-Pro algorithm options for customized envelope tracking behavior.

To get started:
Step1: Hardware – Order TAS5825P Evaluation Module
Step2: Software – Request access to PurePath™ Console and TAS5825P Software

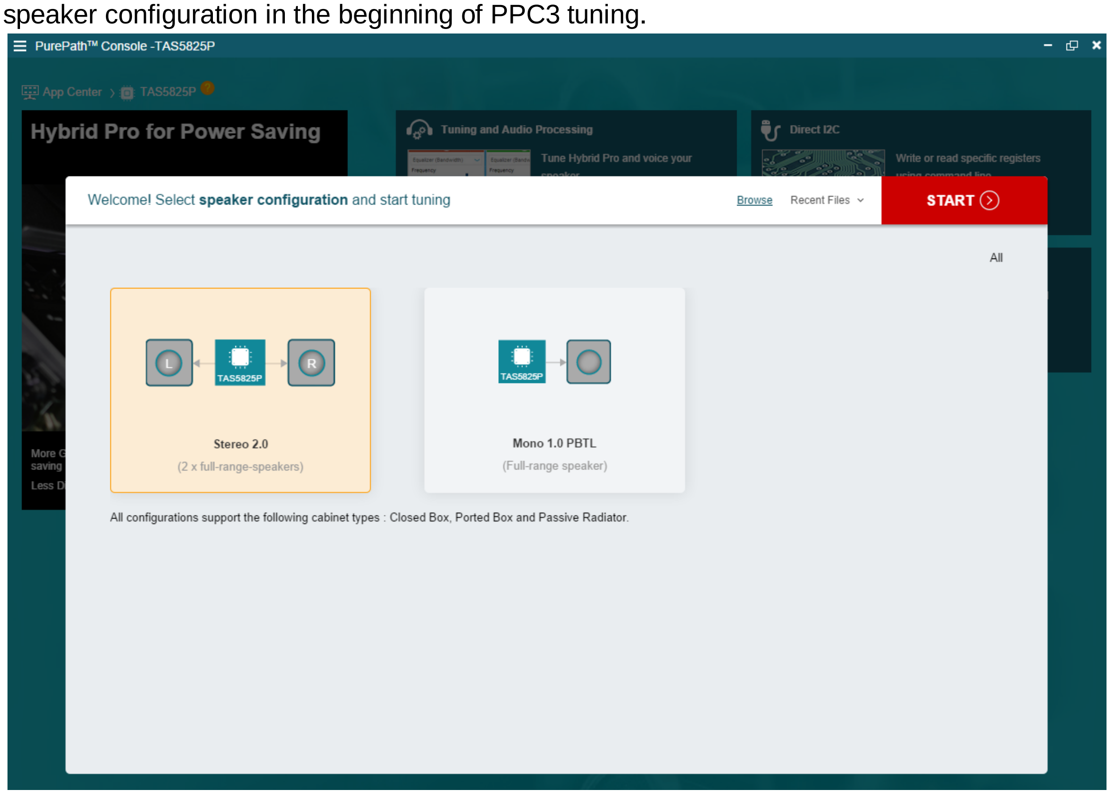
3.1 Easy-to-use Mode

Easy-to-use Mode is targeting for application which only has one TAS5825P in system board to be used as BTL or PBTL mode. It provides fast system integration through recommended Hybrid-Pro algorithm configurations.

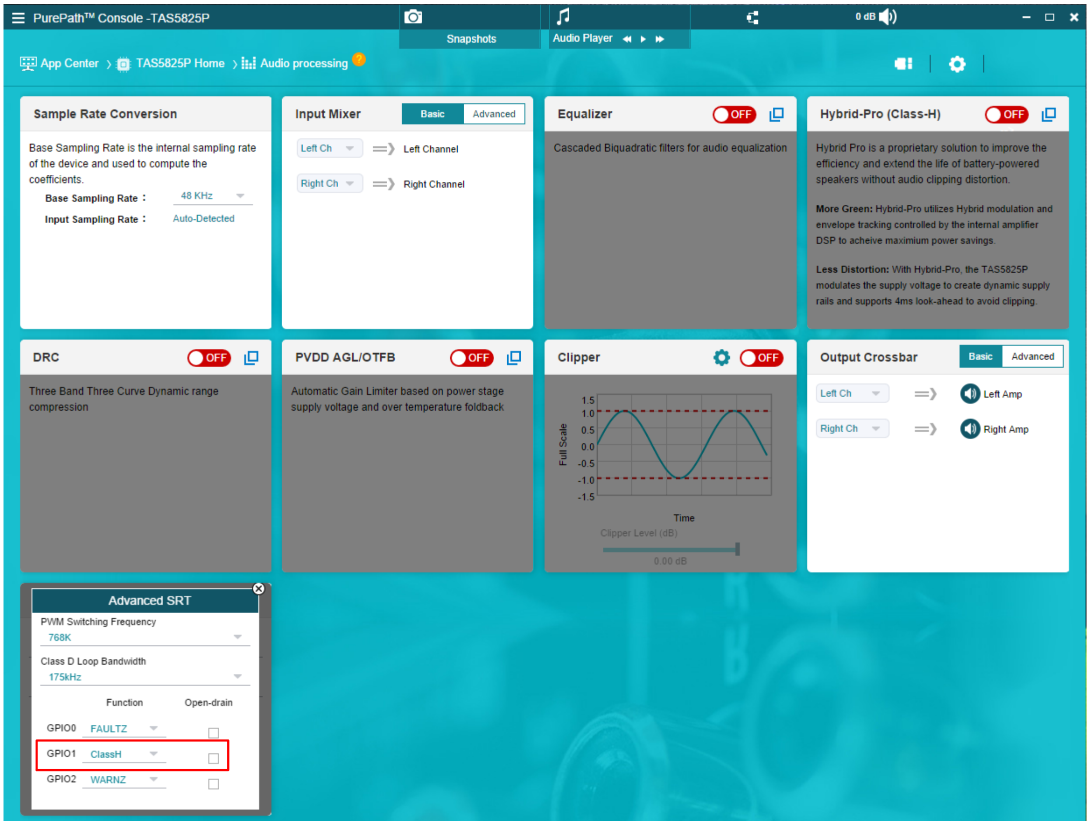
3.1.1 Software Algorithm Tuning

Keep the system requirements in mind, and follow below instructions to finish software scrip generation:

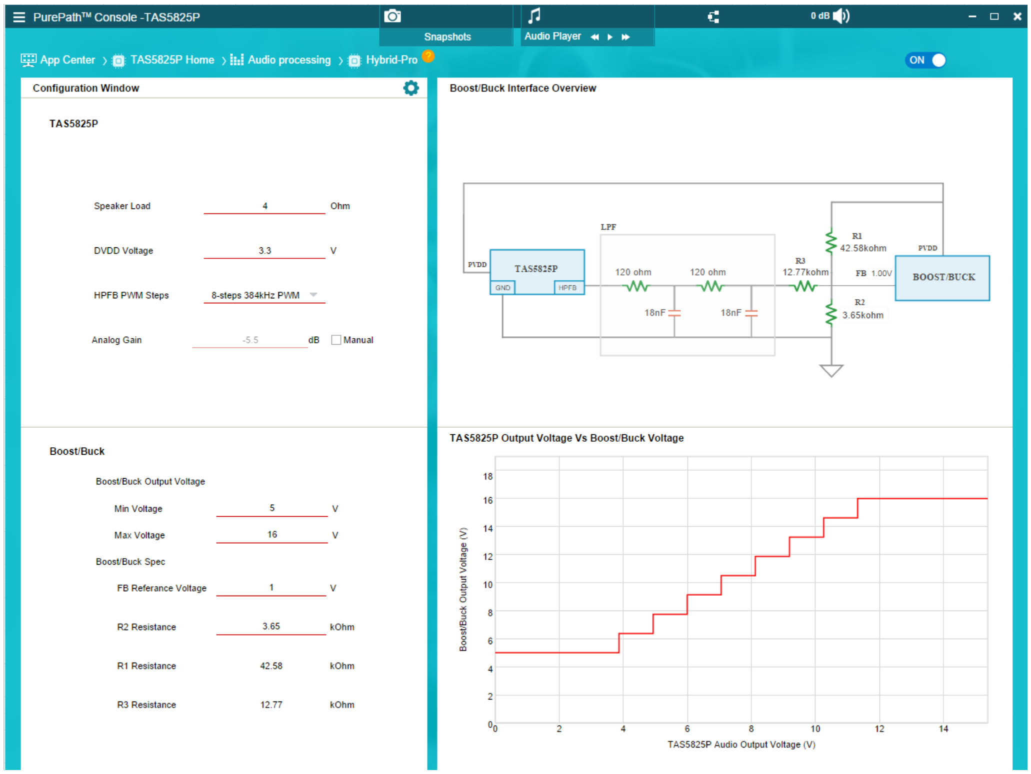
1. BTL or PBTL
   Select speaker configuration in the beginning of PPC3 tuning.



2. One TAS5825P with push-pull Hybrid-Pro GPIO output
   In advanced SRT page of Simple Register Tuning, select ClassH (Hybrid-Pro output) GPIO and uncheck Open-Drain box to configure as push-pull structure.



3. Hybrid-Pro configuration
   Tuning and Audio Processing –> Hybrid-Pro page includes three parts:
   - Configuration Window
     TAS5825P
     Speaker Load: System speaker DC resistance. Set lower one if BTL left and right has different value.
     DVDD Voltage: Optional 3.3V or 1.8V DVDD to TAS5825P.
     HPFB PWM Steps: Hybrid-Pro Feedback PWM waveform format. '16-steps 192kHz PWM' divides 0V to DVDD voltage into 16 steps, and the control frequency is 192 kHz. It could provide smoother DC-DC FB pin control signal, but require lower cutoff frequency of external LPF.
     Analog Gain: ClassD analog gain based on max Voltage of Boost/Buck and full-scale 29.5Vpeak calculation. It could be also set as Manual configuration after click the checkbox.
     Boost/Buck
     Min voltage: Expected boost/buck min output voltage.
     Max voltage: Expected boost/buck max output voltage.
     FB Reference Voltage: Boost/buck FB reference voltage, which is normally listed in datasheet. Such as LM5155 on EVM board lists in Page7 – Error Amplifier – VREF.
     R2 Resistance: Boost/buck FB pull-down resistor value. It will be used to calculate LPF and matching resistors between TAS5825P and boost/buck.
   - Boost/Buck Interface Overview
     This part shows hardware circuit connection between TAS5825P and Boost/Buck. It includes LPF (default 2nd order - 120Ω + 18nF) and matching resistor values, which are calculated based on system configurations. It's highly suggested to follow recommended circuit during schematic design.
   - TAS5825P Output Voltage vs Boost/Buck Voltage
     On account of TAS5825P + Boost/Buck system settings, the audio output amplitude vs Boost/Buck output voltage curve is plotted by PPC3. It can clearly show the relationship between required PVDD voltage and the real Boost/Buck provided.



- Optional 8/16 Steps PWM

TAS5825P Hybrid-Pro can be set to 8 steps 384kHz PWM or 16 steps 192kHz PWM tracking.
The test conditions:

Audio Input: 0dB, 1kHz fade in & fade out burst sinewave as Figure7

Amplifier: TAS5825P EVM with BTL 6ohm load, 5V battery in, default PPC3 with -1dB volume

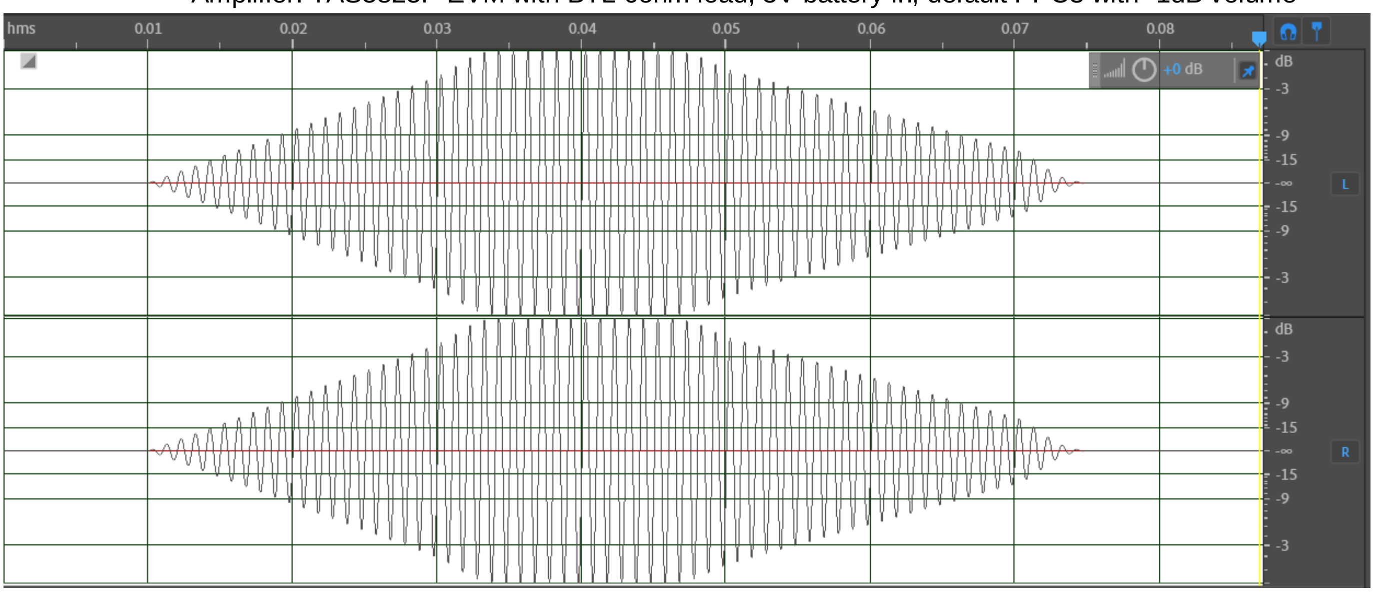


Figure 7. 0dB, 1kHz fade in & fade out burst sinewave

Figure 8/9 shows the waveform of 8/16 steps:

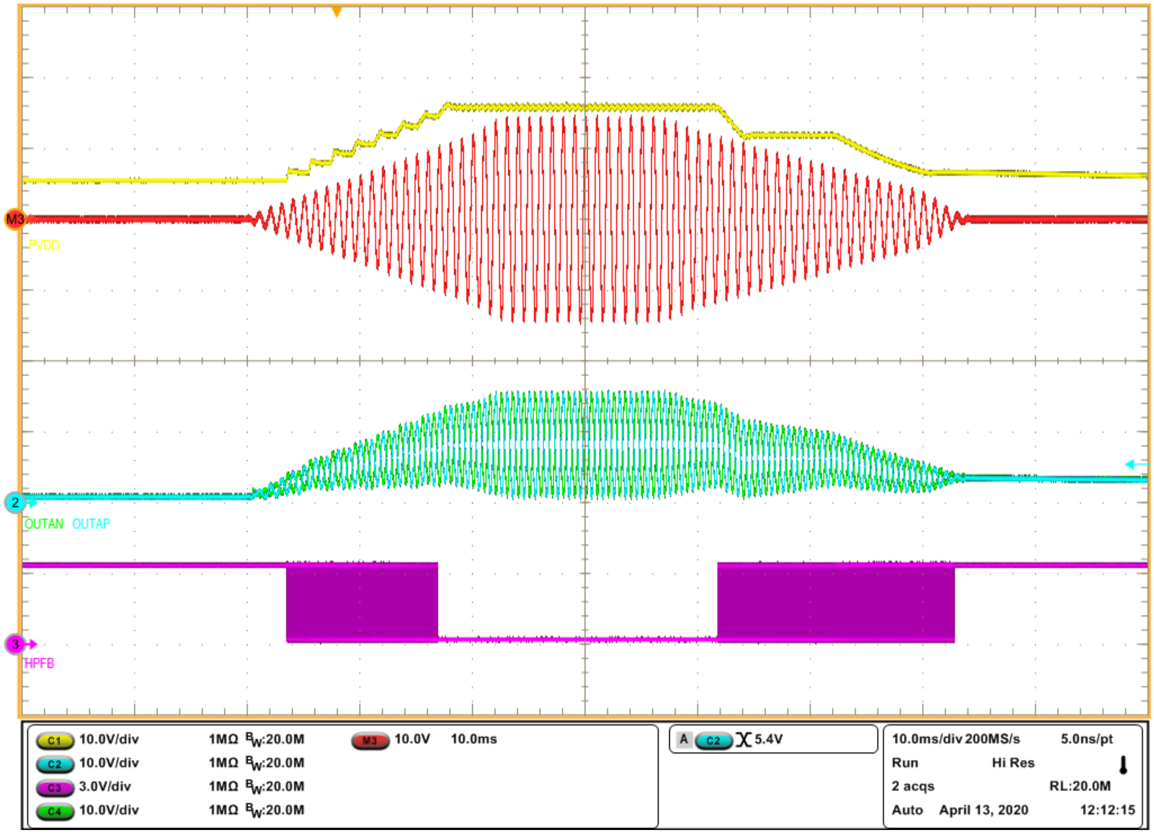


Figure 8. Overall capture of 8 steps HPM tracking
Ch2 OUTPUTA+, Ch4 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output), Ch3 HPFB

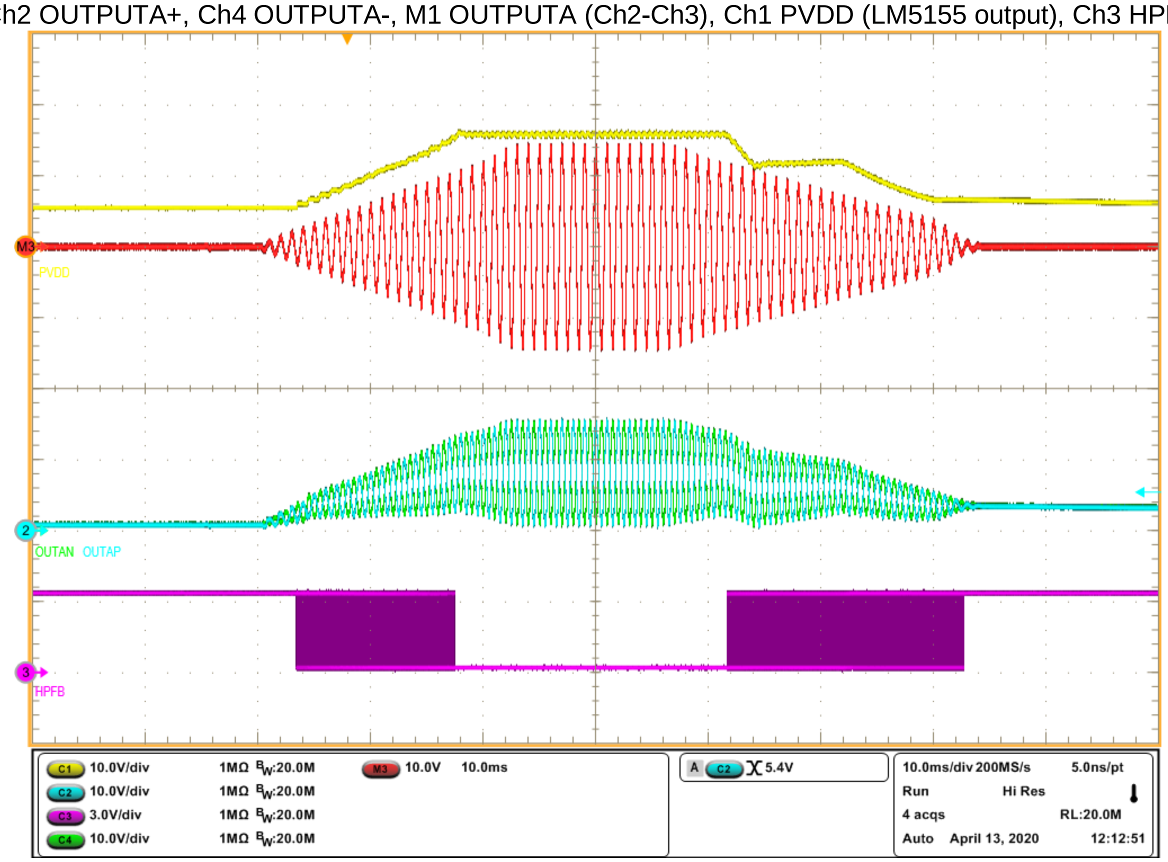
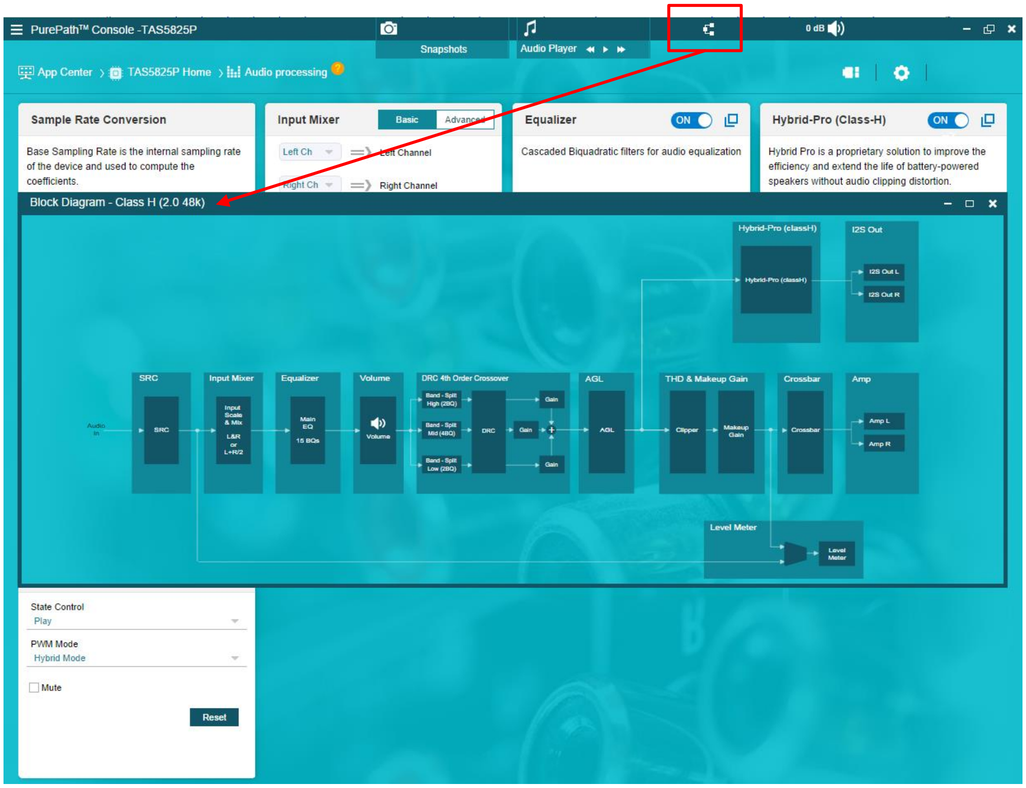


Figure 9. Overall capture of 16 steps HPM tracking
Ch2 OUTPUTA+, Ch4 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output), Ch3 HPFB

4. Other DSP audio processing and dump out header file.
   Following Block Diagram buttons as below, other DSP processing should be well tuned to get final expected audio effect. It includes SRC to accept up to 96kHz audio signal input, input mixer, Equalizer, pop-free volume, 4th order 3 bands DRC, AGL, THD clipper, output crossover and Hybrid-Pro block.
   Final step is to use End System Integration to dump out header file for system driver initialization.



3.1.2 Hardware Schematic Design

It's recommended to follow 3.1.1 Software Algorithm Tuning – 3 Hybrid-Pro configurations Boost/Buck interface overview to design connections circuit between TAS5825P Hybrid-Pro PWM output GPIO and Boost/Buck FB pin.

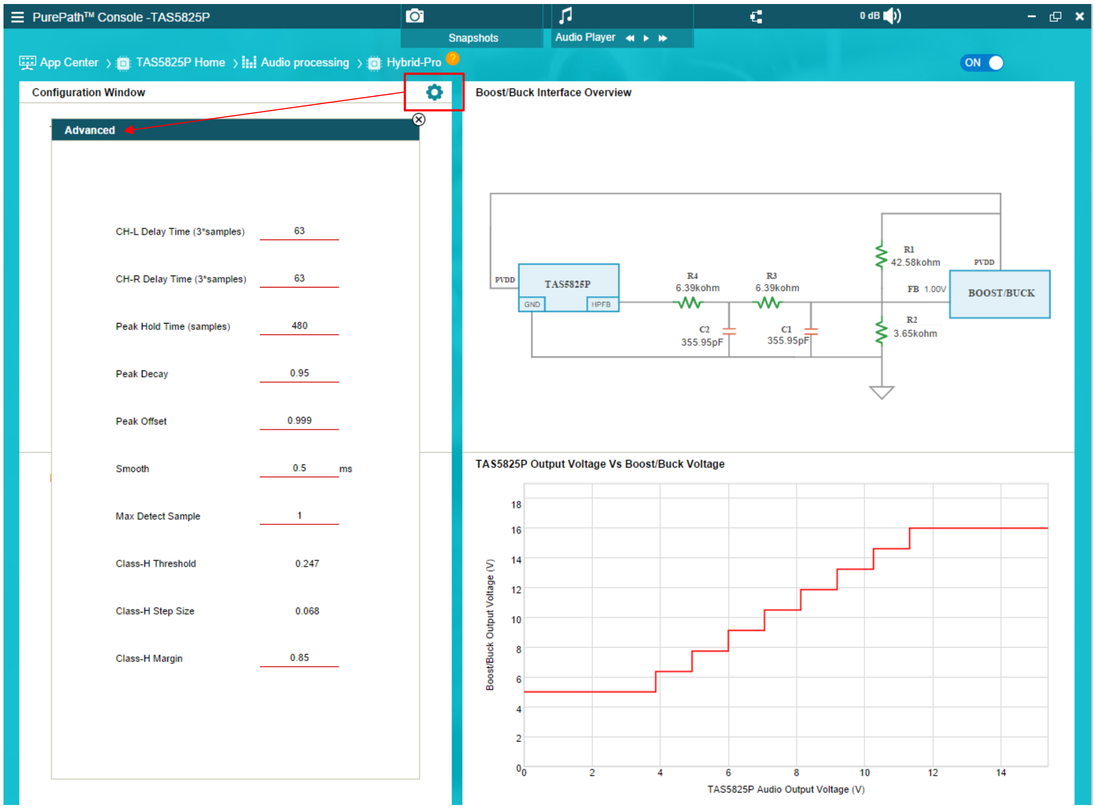
3.2 Advanced Mode

Advanced mode is used when customized Hybid-Pro envelope tracking algorithm is needed or more than one TAS5825P in system, which needs to select open-drain HPFB GPIO structure to implement enough Boost/Buck output power rail for all output channels. It's highly suggested to verify whether 3.1 Easy-to-use Mode could meet system requirements before going into Advanced Mode.

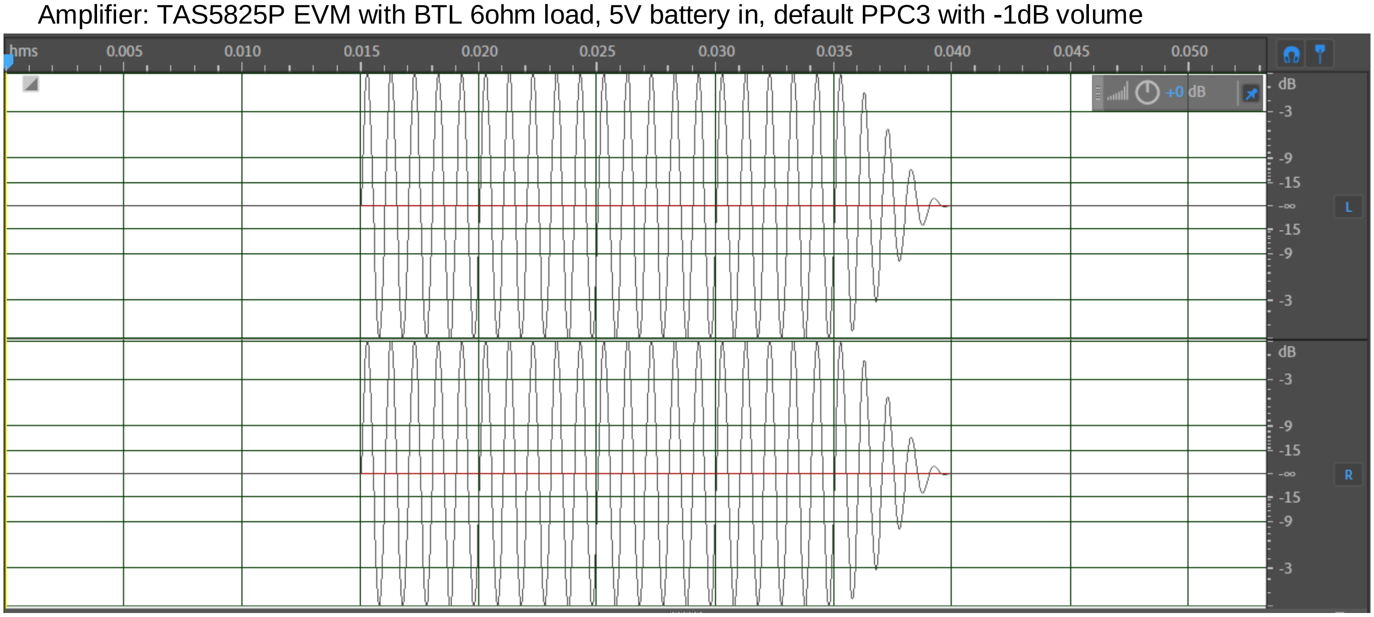
3.2.1 Software Algorithm Tuning

Keep the system requirements in mind, and follow below instructions to finish software scrip generation:

1. BTL or PBTL – same as 3.1 Easy-to-use Mode.
2. TAS5825P HPFB GPIO output
   If there is only one TAS525P enabled Hybrid-Pro in system, then follow 3.1 Easy-to-use Mode to select push-pull output structure for HPFB output.
   Otherwise, system has more than one TAS5825P enabled Hybrid-Pro, and they are used to control the same Boost/Buck to achieve enough power rail for all audio output channels.
   In advanced SRT page of Simple Register Tuning, select ClassH (Hybrid-Pro output) GPIO and check Open-Drain box to configure as open-drain structure.
3. Hybrid-Pro Configuration
   Follow 3.1 Easy-to-use Mode tuning, below advanced page introduces more setting.



- Delay Time Setting
  TAS5825P has max 4ms delay buffer @48kHz (63*3 samples), which needs be configured based on response speed of various DC/DC switching regulators to avoid clipping distortion.
  The test conditions:
  Audio Input: 0dB, 1kHz fade out burst sinewave as below
  Amplifier: TAS5825P EVM with BTL 6ohm load, 5V battery in, default PPC3 with -1dB volume



Compared with Figure 12 default 3×63 samples setting, Figure 13/14 shows 3×0 / 3×40 samples result:

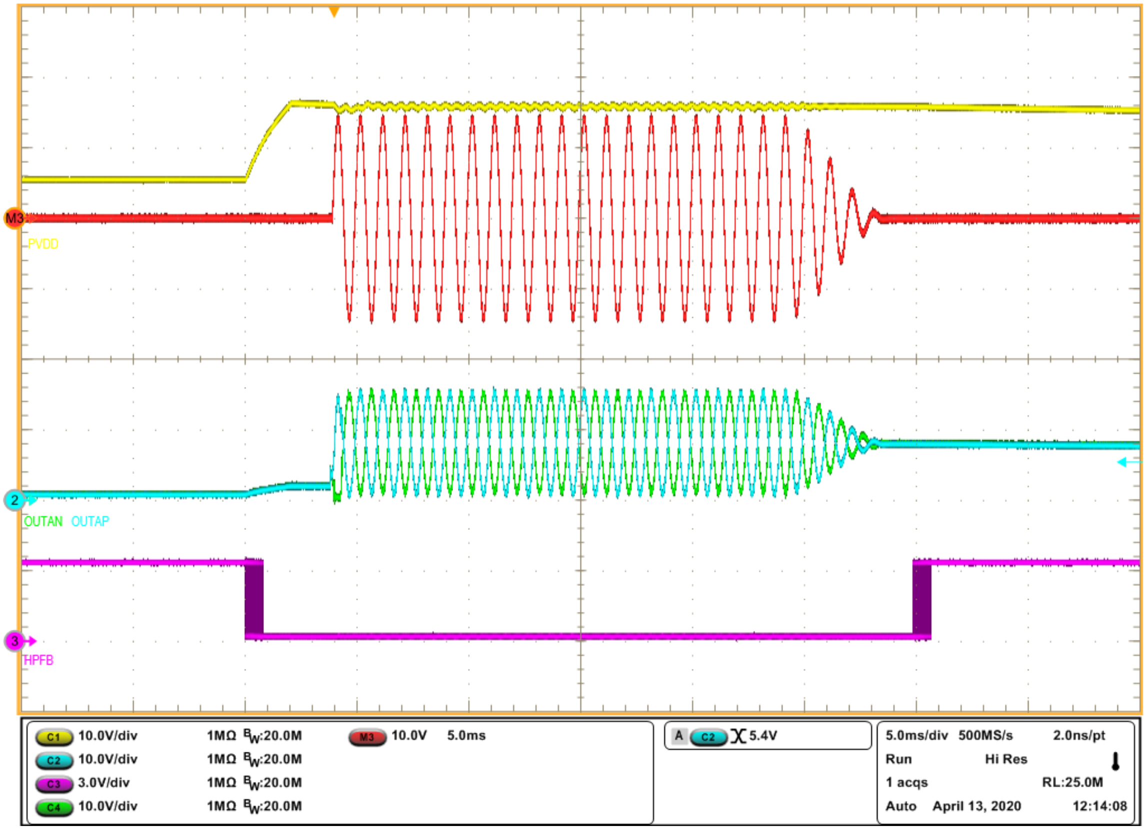


Figure 12. 3×63 delay samples
Ch2 OUTPUTA+, Ch4 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output), Ch3 HPFB

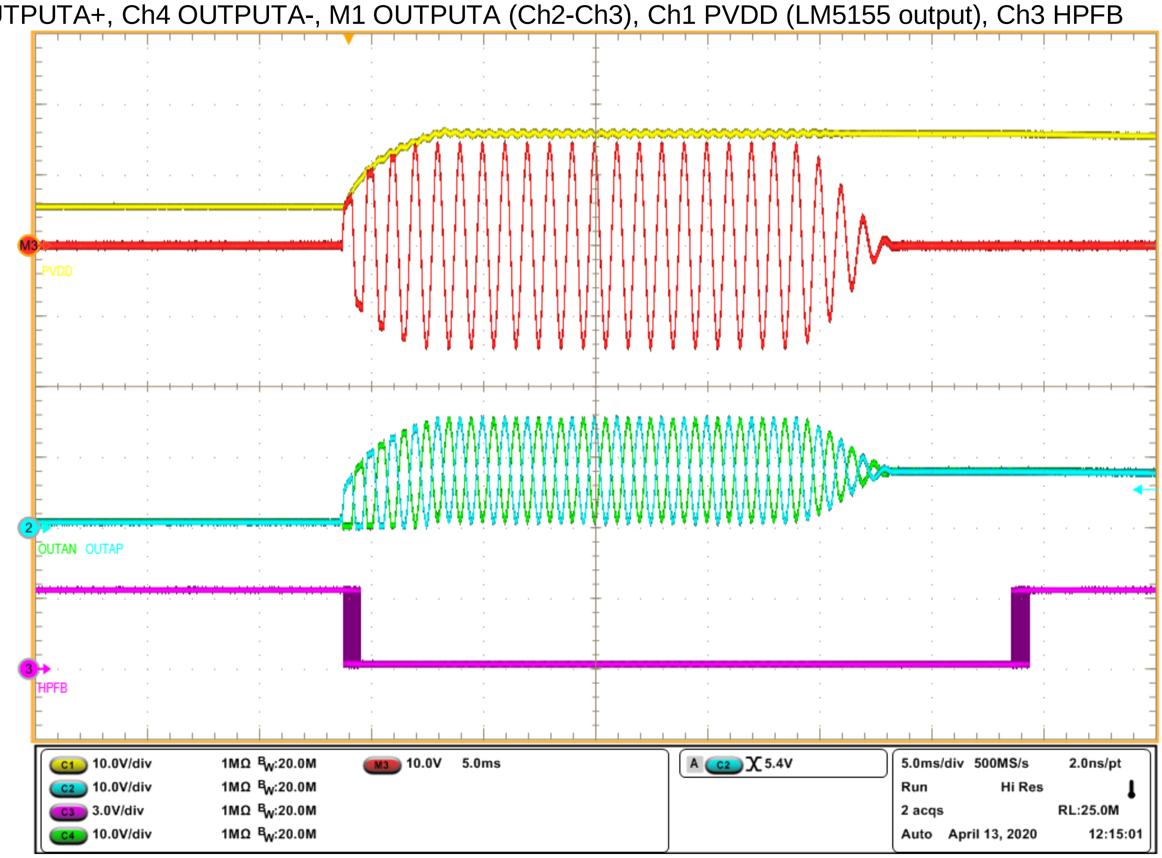


Figure 13. 3×0 delay samples
Ch2 OUTPUTA+, Ch4 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output), Ch3 HPFB

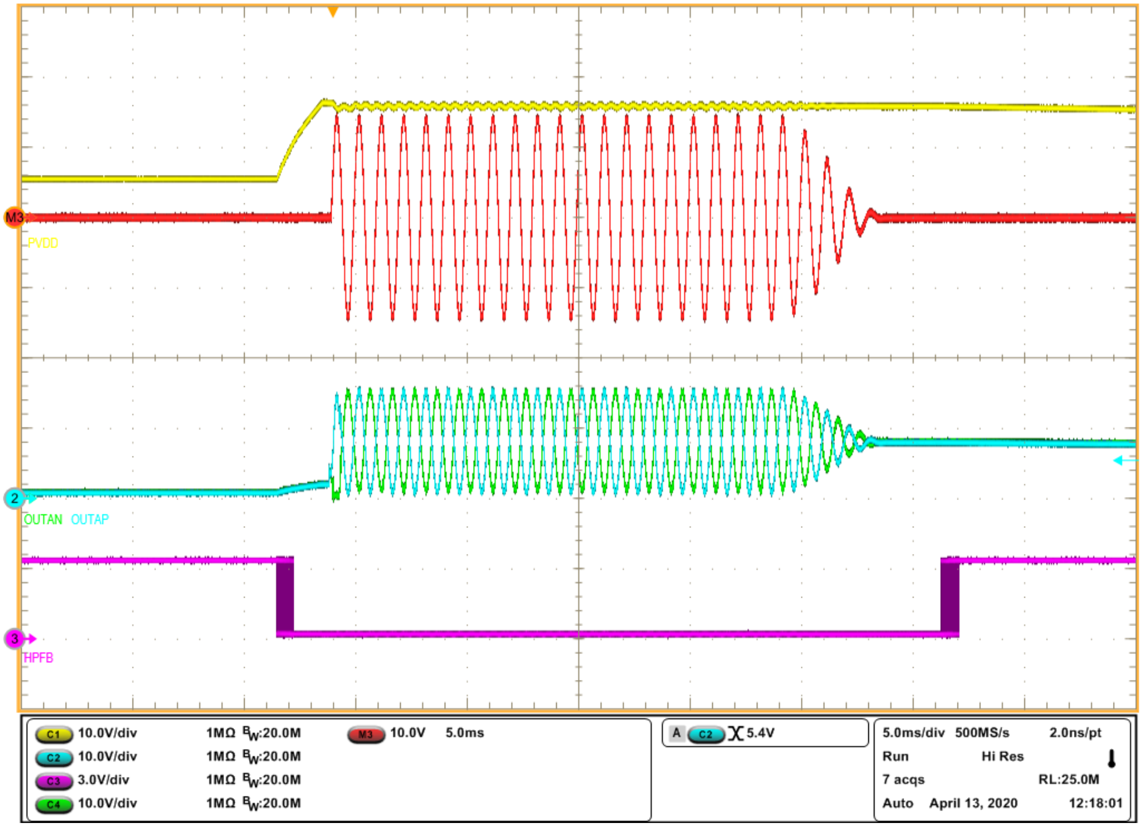


Figure 14. 3×40 delay samples

Ch2 OUTPUTA+, Ch4 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output), Ch3 HPFB

- Class-H Margin

  PPC3 automatically calculates ClassH trigged threshold and steps size based on system configuration. ClassH Margin is used to fine tune threshold and step to leave output margin to avoid music clipping. The tradeoff is too much margin will cause lower battery lifetime extension.

  The test conditions:

  Audio Input: various level, 1kHz fade out burst sinewave as below

  Amplifier: TAS5825P EVM with BTL 6ohm load, 5V battery in, default PPC3 with -1dB volume

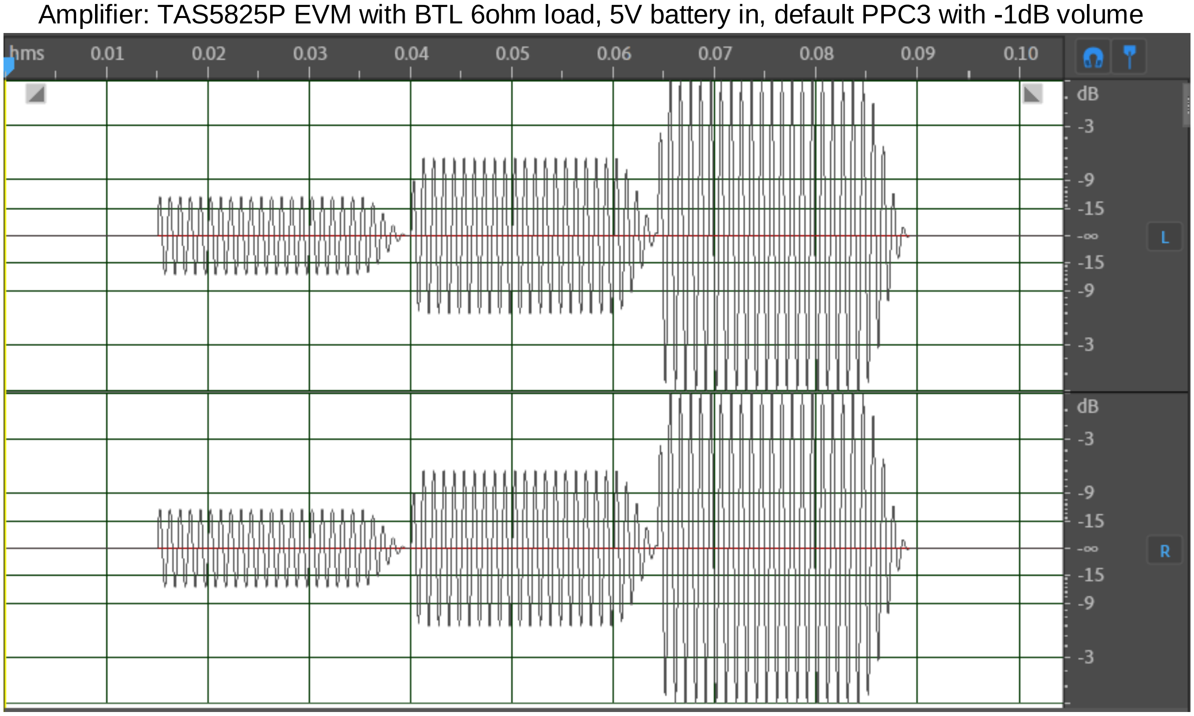


Figure 17/18 shows default 0.85 and 0.75 Margin setting waveforms.

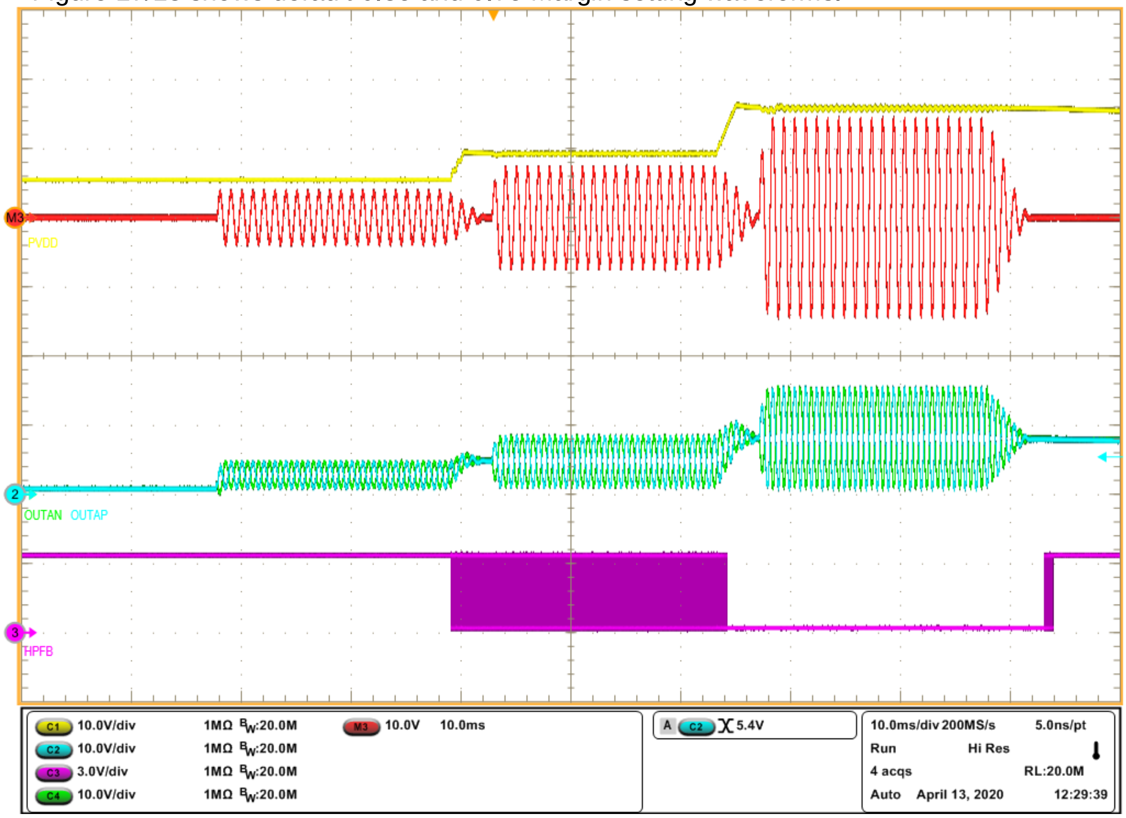


Figure 17. 0.85 ClassH Margin

Ch2 OUTPUTA+, Ch4 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output), Ch3 HPFB

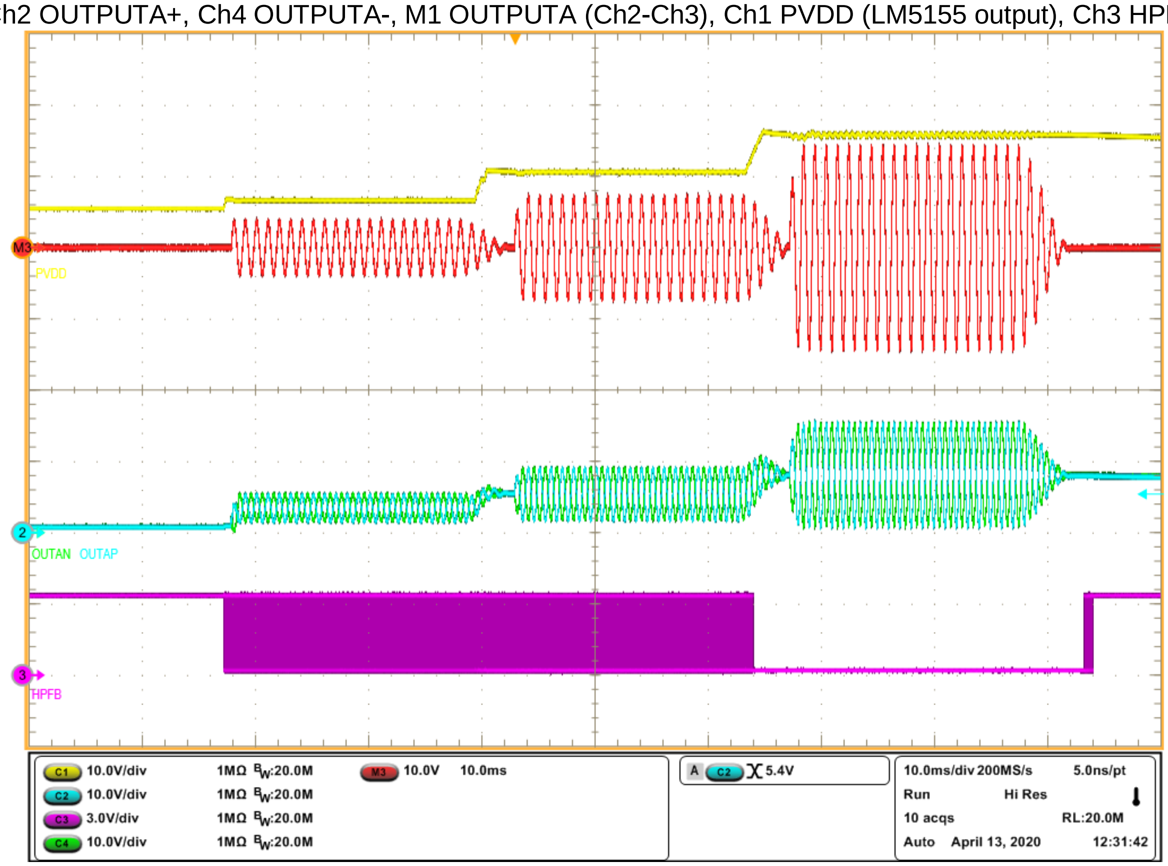


Figure 18. 0.75 ClassH Margin

Ch2 OUTPUTA+, Ch4 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output), Ch3 HPFB

- Peak Hold Time / Peak Decay / Peak Offset
  TAS5825P Hybrid-Pro algorithm provides configurable peak hold option. Keep the same test conditions with Delay Buffer Setting.
  Compared with default 480 samples Peak Hold Time (Figure12), 20/250 samples results are Figure 15/16.

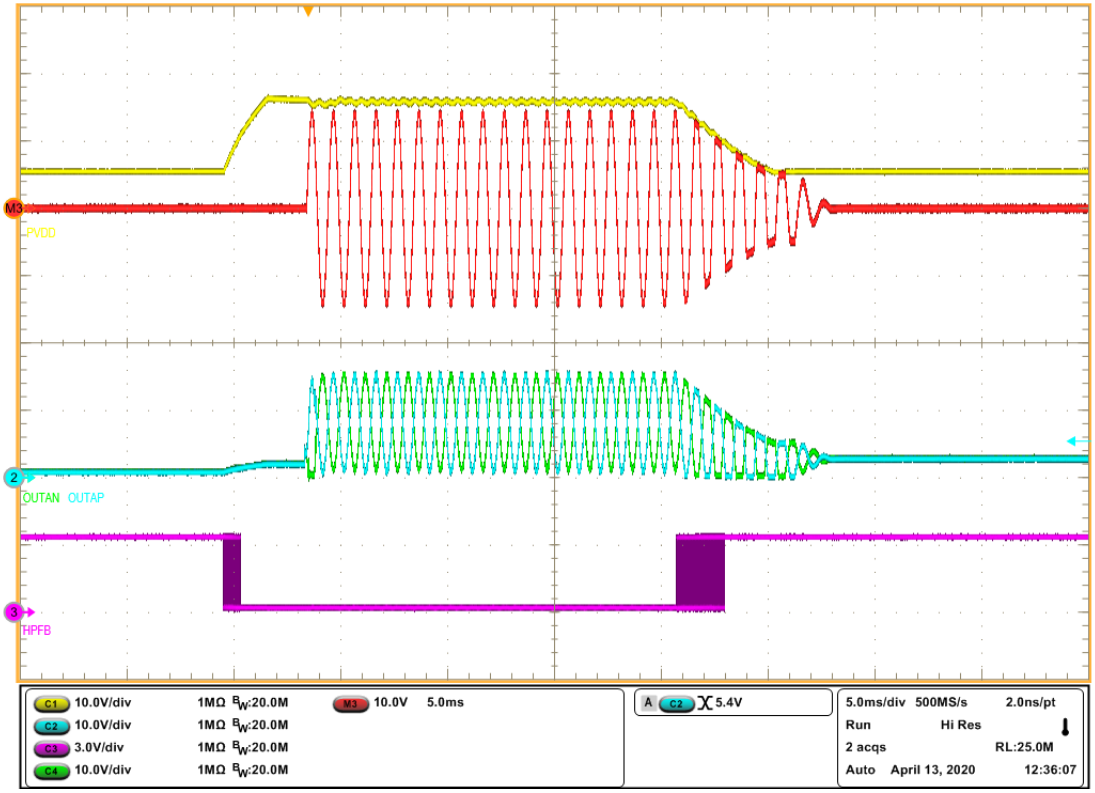


Figure 15. 20 samples Peak Hold Time
Ch2 OUTPUTA+, Ch3 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output)

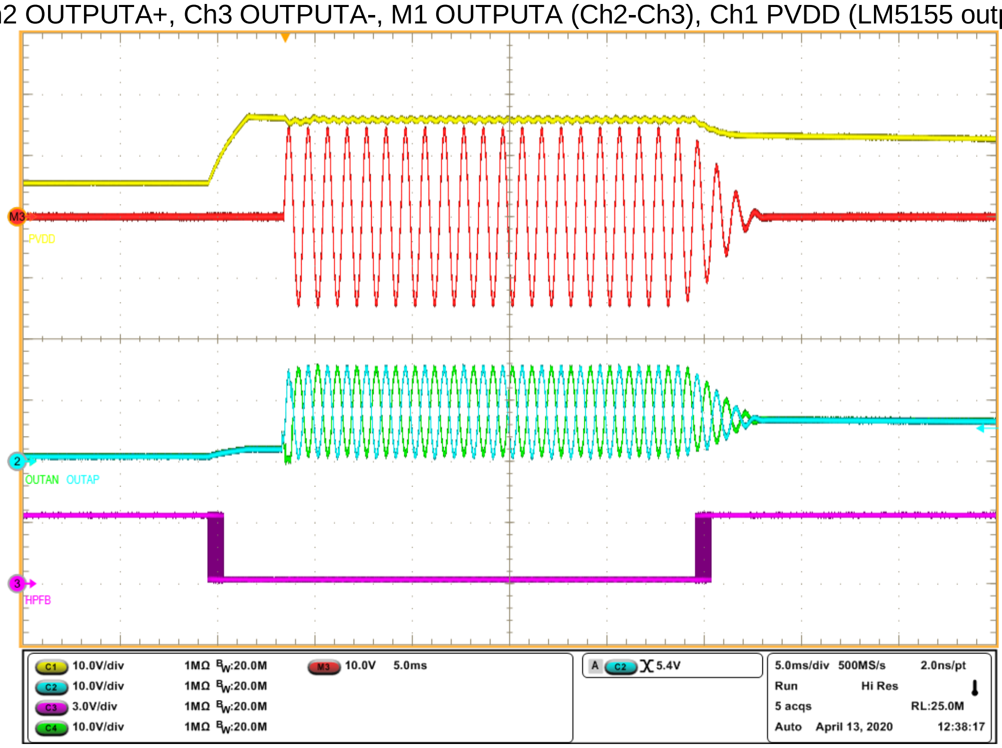


Figure 16. 250 samples Peak Hold Time
Ch2 OUTPUTA+, Ch3 OUTPUTA-, M1 OUTPUTA (Ch2-Ch3), Ch1 PVDD (LM5155 output)

- Smooth / Max Detect Samples
  Smooth time constant is the alpha smooth and Max Detect Samples is the samples used during audio signal level detection. Normally there is no need to change these two parameters.

4. Other DSP audio processing and dump out header file – same as 3.1 Easy-to-use Mode.

3.2.2 Hardware Schematic Design

One TAS5825P in system application keeps the same schematic design with 3.1 Easy-to-use.
As for multiple TAS5825P devices, HPFB GPIOs could be directly tied together with 1kHz pull-up resistor to DVDD. This structure implements ‘AND’ logic to implements enough PVDD power rail based on all channels audio output.