Application Note

Y-Bridge in Class-D Amplifiers for Improving Efficiency

Arash Loloee

ABSTRACT

In this application note, one of TI's innovations for reducing the idle power and efficiency at low levels of power in audio amplifiers is discussed. Traditionally, while both PVDD and VBAT (a lower-supply voltage) are connected to audio amplifiers, only PVDD is connected to the amplifier's output stage. With this innovation, called Y-Bridge, both PVDD and VBAT are connected to Class D output stage. Y Bridge automatically switches the output stage from the high-supply voltage, PVDD, to a lower-supply voltage, VBAT, at low input or idle signal levels which results in improved efficiency. When the input signal reaches a predefined programmable threshold, the output stage switches back to PVDD to provide the needed swing at the output.

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1 Introduction

Smart speakers are always-on, waiting for commands and they spend most of their operation time in idle state. When in idle, these speakers are engineered to save system power, but the audio amplifiers used to drive them are usually less than 20% efficient at idle power levels. These amplifies are usually driven by single power level systems, so even while they are not driving a speaker, they are consuming significant power. TI has created an innovative architecture that can reduce not just idle power consumption by 90% but also improve efficiency by 15-20% at low levels of power without affecting the audio performance.

As shown in Figure 1-1, when Y bridge is being used efficiency is significantly improved at low power over the traditional use of PVDD supply.

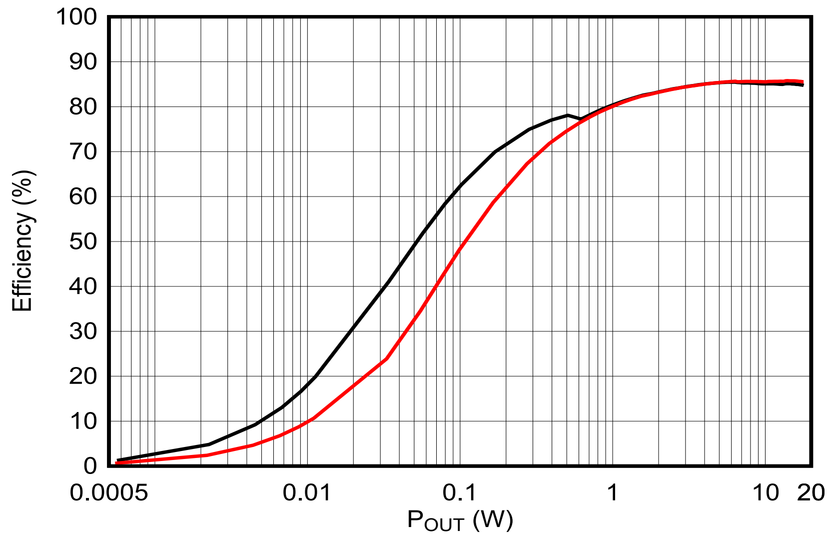

Figure 1-1. Efficiency Improvement by Using Y Bridge

2 Y-Bridge

Traditionally the output stage of Class D amplifier is connected to single power supply, PVDD, which is usually connected to high voltage (2S or 3S battery or an output of boost converter). At low voltage levels of the output signals where headroom needed is much smaller than the available headroom, a lower voltage power supply can be used without degrading the audio performance. Since usually high and low voltages are already available in a system, the Y-Bridge power savings can be achieved without having to change the power architecture of the system. The TI Y-Bridge class D amplifier dynamically shifts between the high voltage (PVDD, for example, 10V-23V) and low voltage (VBAT, for example, 2.7 V - 5 V) rails based on the power needed to deliver the necessary output level. Figure 2-1 shows the functional block diagram of TAS2780.

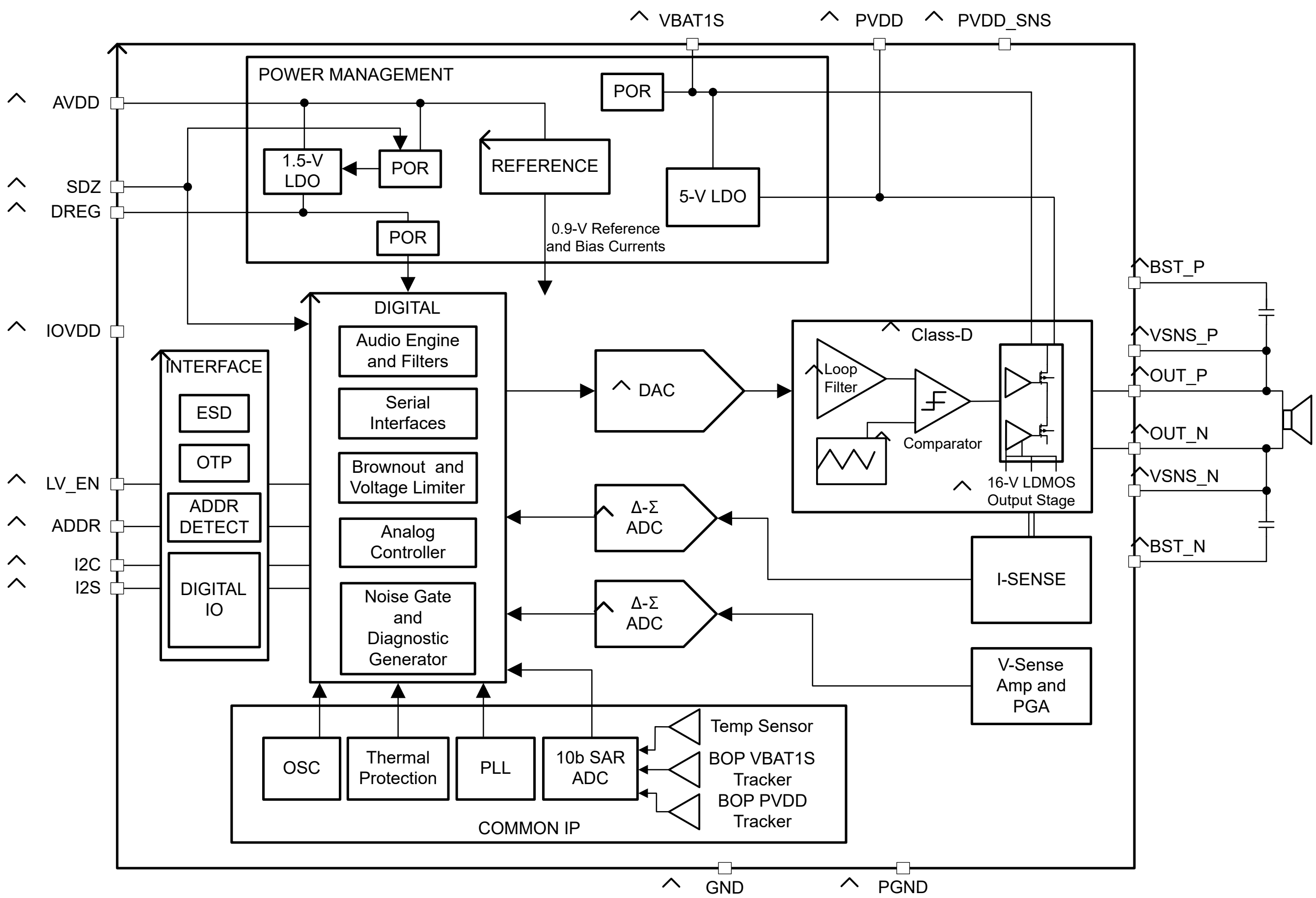

Figure 2-1. Functional Block Diagram

The TAS2780 Class-D output uses a Y-Bridge configuration to improve efficiency during playback. The simplified schematic of Y -Bridge topology is shown in Figure 2-2. As can be seen, both PVDD and VBAT are supplied to the device and connected to Class D output stage. The power supply of output stage is divided into two separate paths, one path connects the output to PVDD and another path connects the output to VBAT. For low and idle level signals, the class D output is connected to the low voltage VBAT rail. This reduces the class-D output swing for small or near Idle signals and thus limits the power consumption of the output stage.

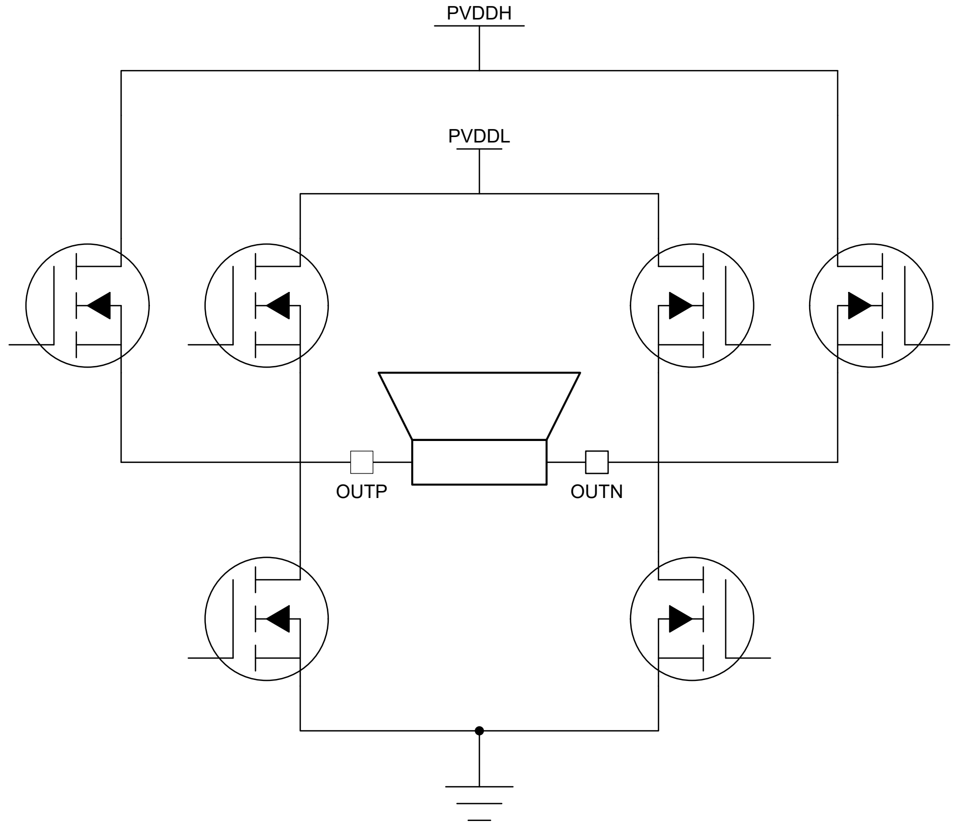

Figure 2-2. Simplified Y-Bridge Schematic

The device can be configured to enable or disable Y-Bridge feature. If Y-bridge mode is disabled, it will only use the selected supply for class-D output. Note clipping can occur if appropriate supply is not selected.

Y-Bridge feature automatically switches between PVDD and VBAT1S. When audio signal increases and crosses a programmed threshold, Class-D output switches over to PVDD supply. When in Y-Bridge mode, if the PVDD falls below a threshold level, the Y-bridge will stop switching between supplies and will remain on the PVDD supply. The threshold for switching between the two supplies is programmable by user.

When voltage levels at OUT_P and OUT_M are switching from 0-V to VBAT1S, the switching losses are much lower when compared to switching between 0-V and PVDD which results in increase in power efficiency.

While switching loses are reduced by using a lower voltage, the conduction losses increases as the VBAT1S path of the output stage usually is designed with higher RDS on to optimize the switching losses. At low output levels, the net power consumption is improved as switching losses are dominant of the two losses.

The TAS2780 can be configured to operate without an external VBAT1S supply, when an internal LDO is used to generate supply voltage at this pin.

3 Modes of Operation and Registry Settings

TAS2780 can have different modes of operation:

- VBAT1S only supply, where the device is forced to work out of a low power rail mode of operation. For example, this can be used for a low power ultrasonic chirp when audio is not played.
- PVDD only supply, where PVDD is the only supply used to deliver output power.
- Y Bridge, where VBAT1S is used to deliver output power based on level and headroom configured. When audio signal crosses a programmed threshold Class-D output is switched over to PVDD.

The mode of operation can be set by setting the power modes registers (address=0x03 and address=0x04)shown in the Table 3-1 and Table 3-2.

Table 3-1. Bridge and Channel Settings (Address 0x03)

Bit	Field	Type	Reset	Description
7-6	CDS_MODE[1:0]	RW	Oh	Class-D switching mode 00b = Y-bridge, high power on VBAT1S 01b = VBAT1S Only Supply of Class D 10b = PVDD Only Supply of Class D 11b=Y-Bridge, lower power on VBAT1S

Table 3-2. Selection of Internal or External VBAT1S (Address 0x04)

Bit	Field	Type	Reset	Description
7	VBAT1S_MODE	RW	Oh	VBAT1S supply 0b = Supplied externally 1b = Internally generated from PVDD

4 Power Threshold for Y Bridge

The level of power where the Y bridge switches from one supply to the other can be programmed by user in to designated registers. LVS threshold is set based on the output signal level and is measured in dBFS.

The LVS threshold can be set as an absolute value with respect to maximum output level or as a relative value with respect to VBAT1S supply.

It is important to know the switching between two supplies does not produce any audio artifact (pop, and so on).

ICs with Y-bridge function, such as TAS2780 and TAS2764, monitor the absolute value of audio signal.

The LVS threshold voltage is set by Low Voltage Signaling (LVS) registers. If the signal level drops below this threshold for longer than the hysteresis time, then the Class-D supply will switch to VBAT1S. The hysteresis time can be also programed in to designated registers. As shown in Figure 4-1, the open-drain BYP_EN pin will be de-asserted (actively pulling the output low) after a delay programmed and thus the Y Bridge will switch from VBAT1S to PVDD after a programmed delay. The LVS threshold can alternately be configured to be a value relative to the VBAT1S voltage.

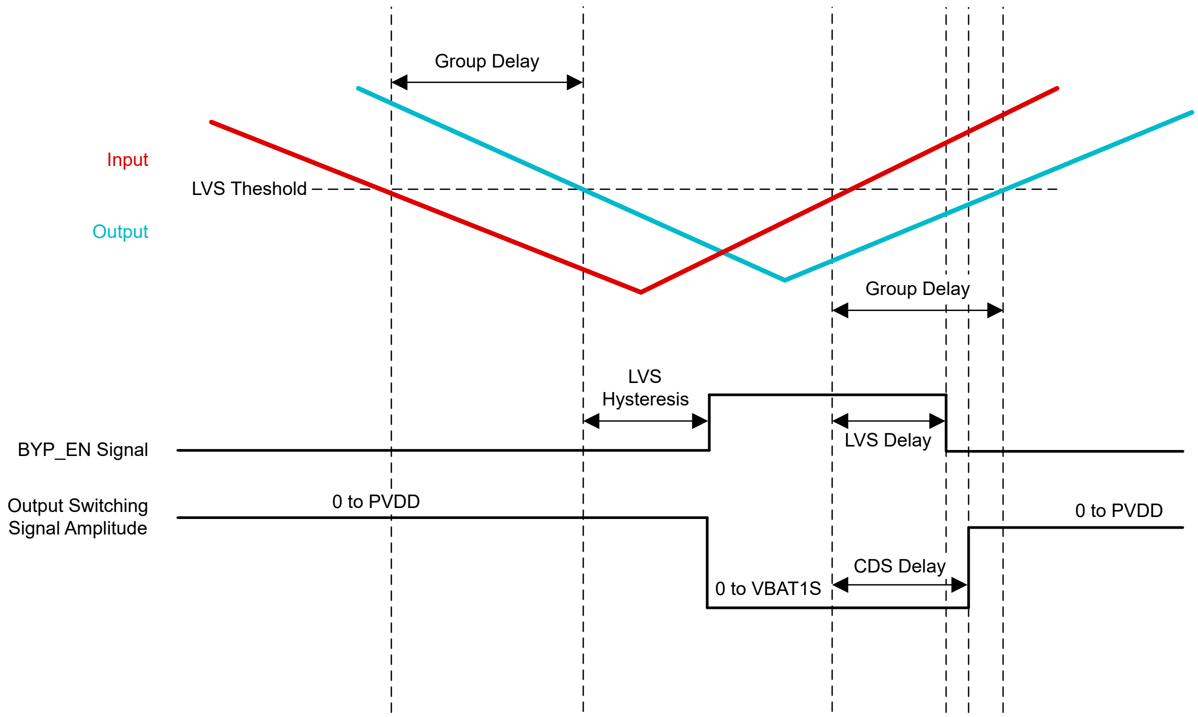

Figure 4-1. Low Voltage Signaling Thresholds and Delays

5 Efficiency Improvement

Figure 5-1 shows the Y-Bridge modulation using Y-Bridge configuration. In battery powered systems, Y-Bridge hardware configuration increases battery life by 20%, without any additional software requirements. Switching to a dual voltage can lower power consumption in wall powered systems and extend the playback time of battery powered systems. Please go to TI.com to learn more about our Y-Bridge audio amplifier portfolio.

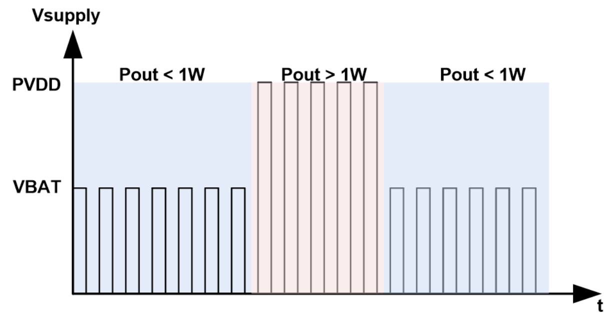

Figure 5-1. Y-Bridge Modulation