

MP1720
2.7W Mono Class D Low-EMI High-
Efficiency Audio Amplifier

Application Note

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ABSTRACT

Compared with the linear audio amplifiers, high efficiency is the most noticeable advantage for the class D amplifier in portable devices. However, there are some drawbacks for the conventional class D amplifiers, such as the requirement of the output low-pass filter and the potential EMI problem. The new developed class D audio amplifiers, such as the MPS audio product MP1720, can eliminate the output filter and still keep low EMI. All these advantages make MP1720 ideal for portable and compact system application.

1 INTRODUCTION

The MP1720 utilizes a full bridge output structure and it is capable of delivering 2.7W into 4Ω speaker under 5V power supply. This device exhibits as high fidelity as a class AB amplifier with 90% efficiency. Compare with traditional class D amplifier, the most notable advantages are filterless operation and low EMI performance.

In this application note, the MP1720 modulation scheme is analyzed first in section 2. In section 3, how the MP1720 external output LC filter can be eliminated is explained, and the possible problems for filterless operation are introduced. In section 4, the reason why MP1720 can keep low EMI even though there is no output LC filter is discussed, and the attentions for emission are introduced.

2 MODULATION SCHEME

The MP1720 is a fully differential amplifier with differential inputs and outputs. This device can also be used with a single-ended input. The MP1720 block diagram of the audio signal path is shown in figure 1.

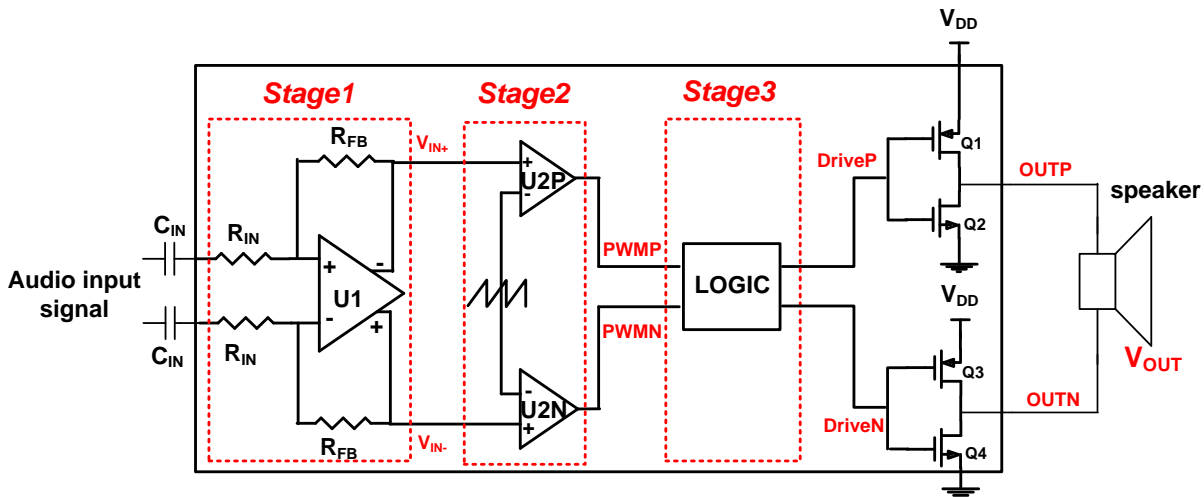


Figure 1—MP1720 functional block diagram of the audio signal path

At stage1, the amplifier U1 is a differential output amplifier. No matter if the input signal is single-ended or differential, the amplifier U1 transfers the input signal into differential signals (V_{IN+} and V_{IN-}). The differential signals are biased with the DC bias voltage, and amplified with the gain R_{FB}/R_{IN} .

At stage 2, there are two individual comparators (U2P and U2N) for each half bridge. PWM is generated by comparing the differential audio signal with a high frequency sawtooth waveform (the sawtooth frequency is detailed in the section 4.1.2). For example, the outputs of both comparators (PWMP and PWMN) switch low when the magnitude of the sawtooth waveform exceeds the corresponding input voltage (V_{IN+} or V_{IN-}).

At stage 3, there is a specific LOGIC block. If both LOGIC inputs (PWMP and PWMN) are low, the timer in the LOGIC function is triggered. At the end of the fixed delay time $T_{min}(on)$, both LOGIC outputs (DriveP and DriveN) are pulled high if both inputs (PWMP and PWMN) are still low. At any time,

once the inputs (PWMP and PWMN) are not both low, the output DriveP follows the input PWMP, and the output DriveN follows the input PWMN. For MP1720, this delay time $T_{min(on)}$ is about 240ns. After the output power stage, the output switching signals OUTP and OUTN can directly drive the speaker without the output low pass filter.

The detailed operation waveform is shown in the followed figure 2.

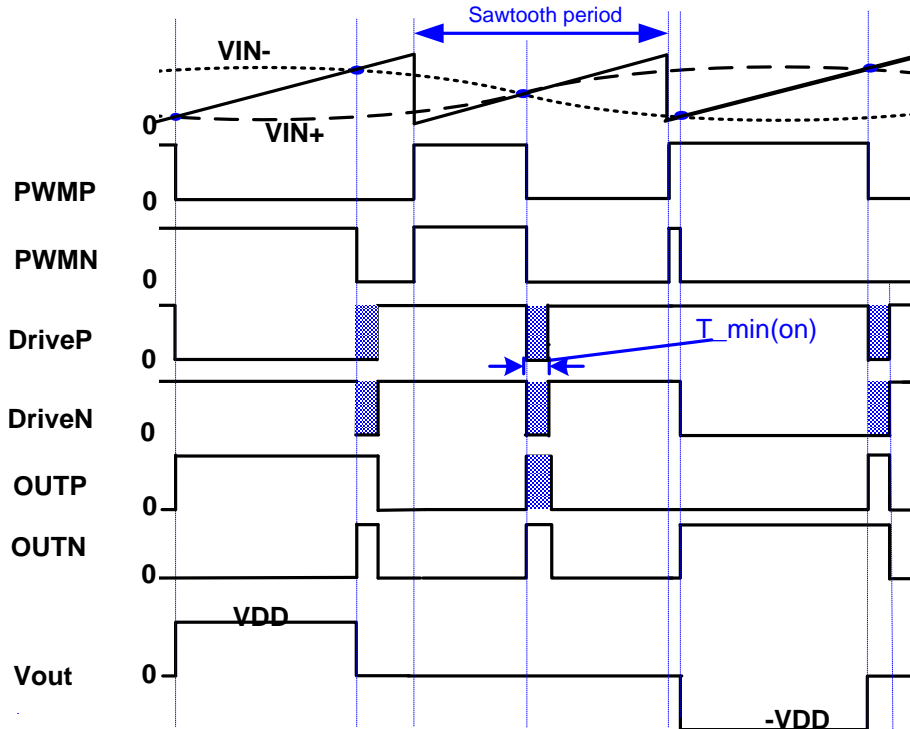


Figure 2- MP1720 operation diagram (with input signal) (not to scale)

3 FILTERLESS OPERATION PRINCIPLE

The requirement of the external output LC filter is one of the major drawbacks of the traditional class D amplifier. For a portable system, the filter may introduce additional distortion due to filter component nonlinearities, and cause additional cost and larger board-space. The MP1720 eliminates the requirement of an output LC filter for the BTL output configuration.

3.1 THE REASON FOR FILTERLESS

3.1.1 The Traditional Class D BTL Output

Figure 3(a) is the output stage block for one kind of traditional full-bridge class D. The outputs of two half bridges are antiphase, which means both outputs are 180 degrees out of phase. Thus the differential output voltage (OUTP-OUTN) always varies between positive VDD and negative VDD whether there is the input signal or not. Take the setup with no input signal for example, the operation waveform is shown in figure 3(b). Although the average voltage across the load is 0V, the differential voltage forces large output current through the load which means large losses and severe EMI issues. So an external LC filter is required before the speaker to prevent high-frequency energy from being dissipated in the load.

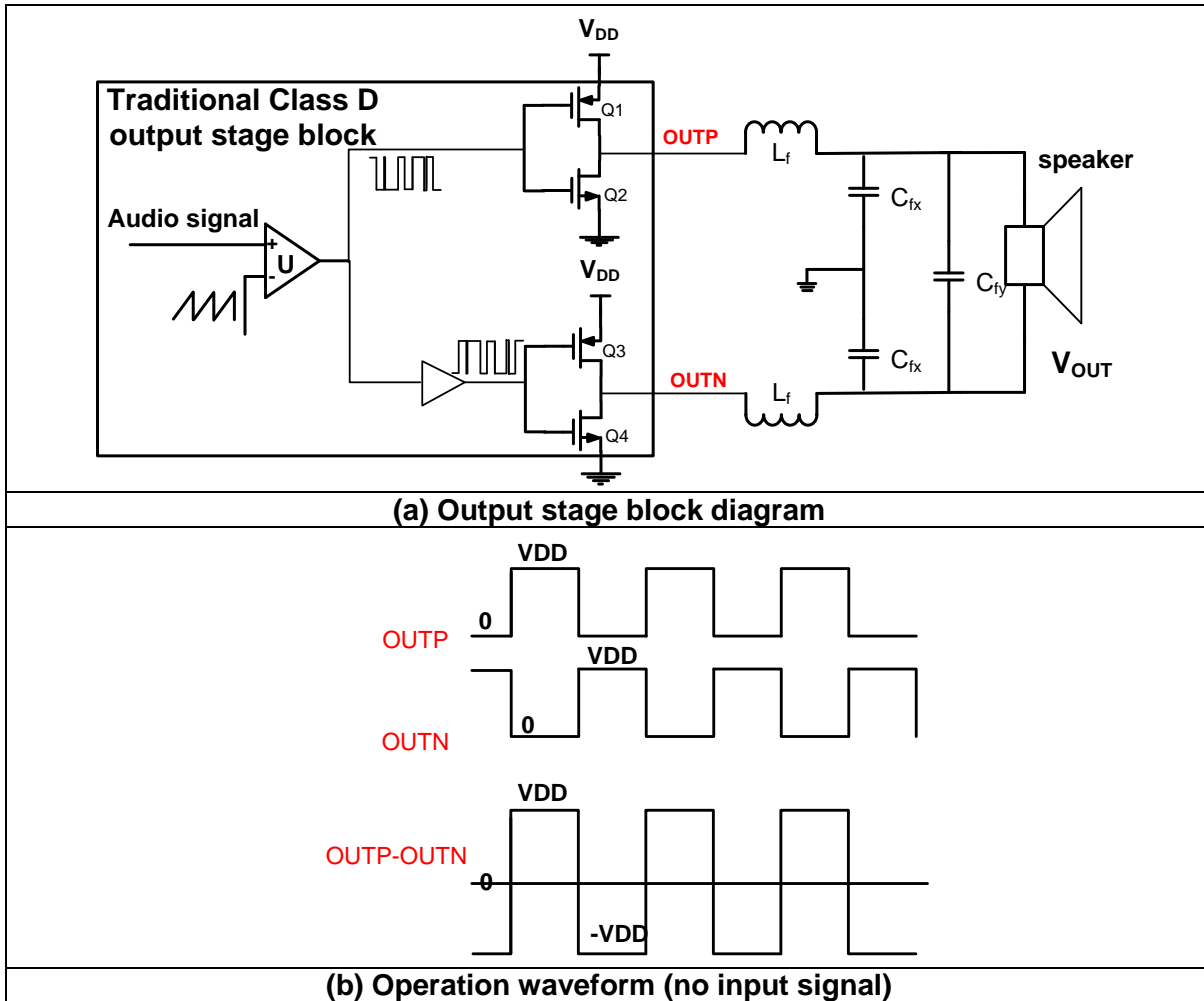


Figure 3, A traditional BTL Class D

3.1.2 The MP1720 BTL Output

The MP1720 outputs of two half bridge OUTP and OUTN are inphase instead of antiphase with each other as in the traditional BTL class D amplifier. Figure 1 illustrates the MP1720 output stage block diagram. The detailed operation principle is already introduced in the section 2.

When the input signal is zero, the operation waveform is shown in figure 4(a), the outputs of both half bridge, OUTP and OUTN, are pulses with a fixed turn on time, $T_{\min}(\text{on})$. The differential voltage across the load (OUTP-OUTN) is zero instead of varying between positive V_{DD} and negative V_{DD} , which greatly lowers the loss and EMI.

When there is a positive input signal, the duty of OUTP output is larger than $T_{\min}(\text{on})$ while the duty of OUTN remains fixed at $T_{\min}(\text{on})$ or less. The larger the positive input signal is, the larger the OUTP duty is (max duty is 100%), and the smaller the OUTN duty is (min duty is 0%). So the large positive output voltage is from the difference of two channels (OUTP-OUTN) and the output voltage (OUTP-OUTN) varies between V_{DD} and 0. There is the opposite duty adjustment for each half bridge output voltage when the signal is negative. The output waveform with input signal is shown in figure 4(b).

The output voltage (OUTP-OUTN) swing is only between V_{DD} and 0V, not between V_{DD} and $-V_{DD}$. It is evident that the power consumption in the speaker with MP1720 is minimized compared with traditional BTL class D amplifier. No extra external LC filter is required for most of applications.

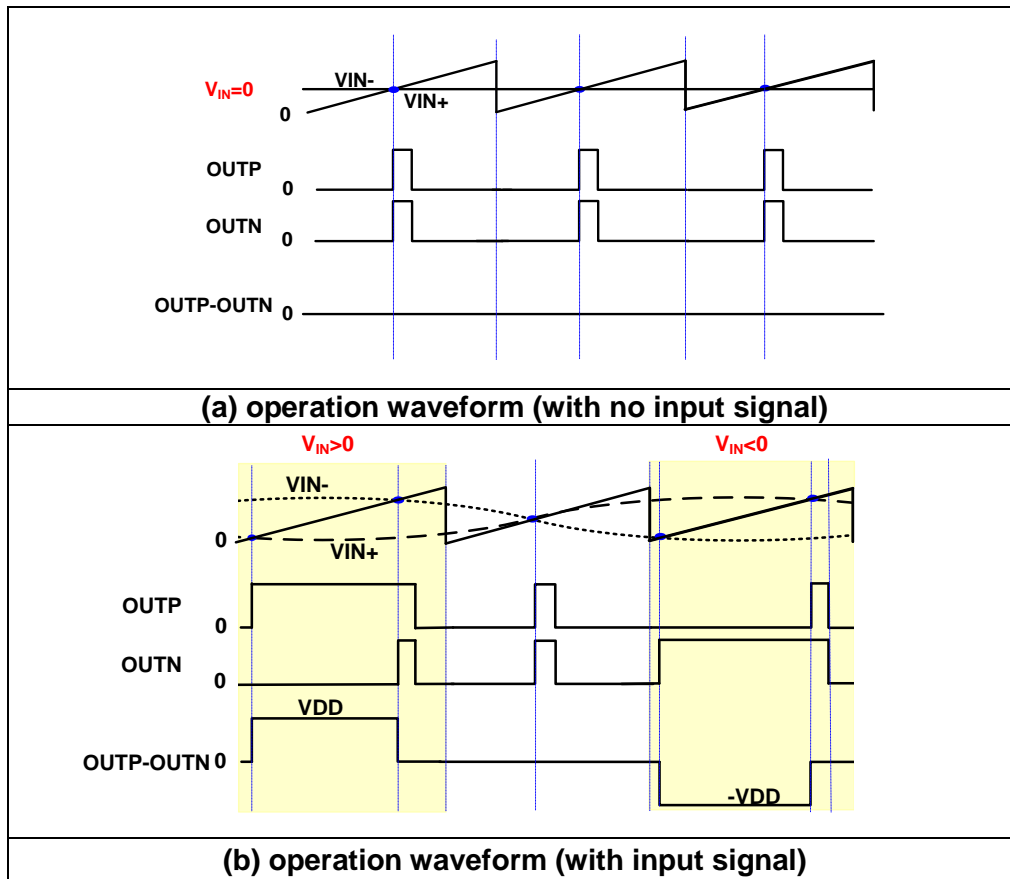


Figure 4, MP1720 BTL output operation waveform

3.2 TWO PROBLEMS OF FILTERLESS CLASS D AMPLIFIER

3.2.1 EMI

For the filterless class D amplifier, the EMI problem can be challenging. However, excellent EMI performance is one of the MP1720 outstanding features. The detailed operation principle for low EMI is introduced in the section 4

3.2.2 Switching Frequency Noise

The other possible problem is that the output signal includes the audio signal components and the high frequency components if the output is filterless. In fact, this switching frequency noise is not the issue. The inherent inductance and resistance of the speaker form a 1st-order low pass filter to pass the audio signal and help to prevent the high frequency switching energy from being dissipated in the speaker. Here is the formula of the low pass filter corner frequency.

$$F_c = 1 / (2 * \pi * L_s / R_s) \quad (1)$$

L_s : the equivalent inductance of the speaker load

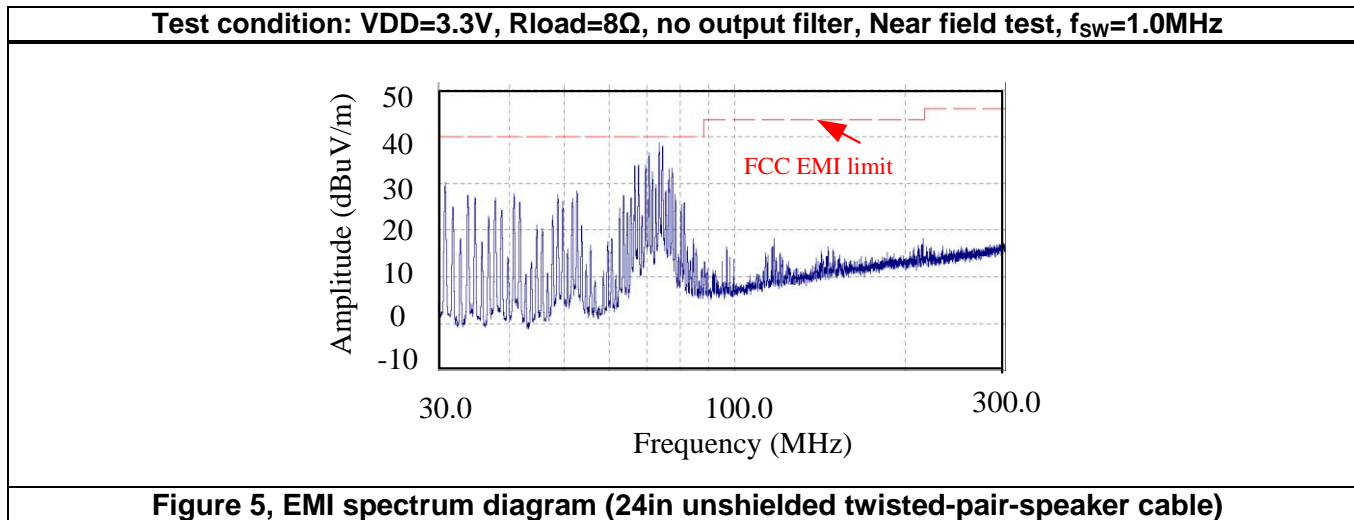
R_s : the speaker resistance

Furthermore, the switching frequency component is well above the audible frequency range for human beings (20Hz to 20kHz) which are inaudible and does not deteriorate the performance. So even though the inductance is not large enough to filter out all the high frequency signals, it is also OK.

4 LOW EMI PRINCIPLE

Electromagnetic Interference (EMI) is a common problem in modern electronic systems, and it is the main challenge for the filterless class D amplifier.

The MP1720 can pass the FCC Class B limit with up to 24 inches of unshielded, twisted-pair speaker cable with at least 2dB margin, as shown in figure 5.



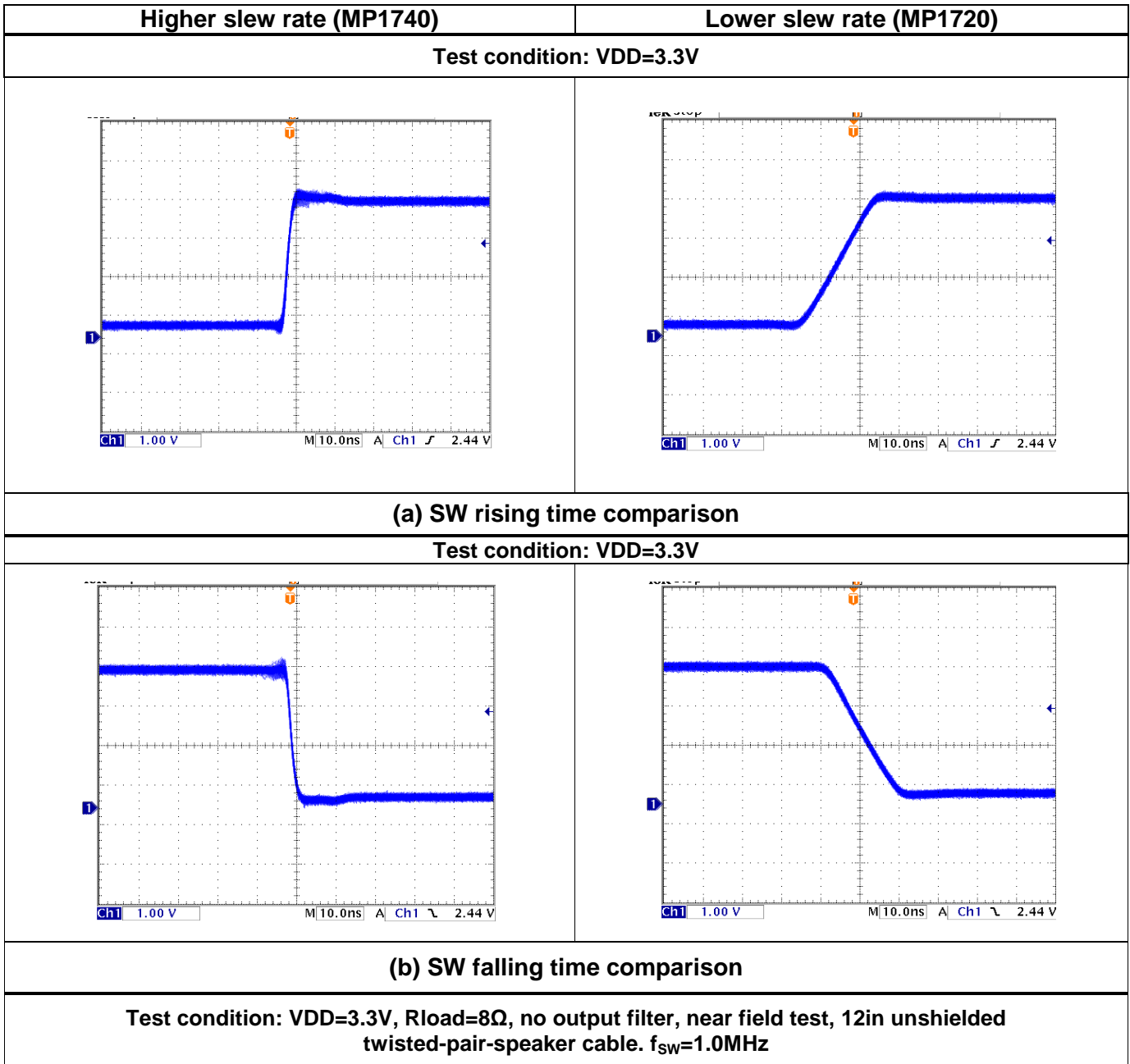
4.1 TWO IMPORTANT FACTORS OF LOW EMI

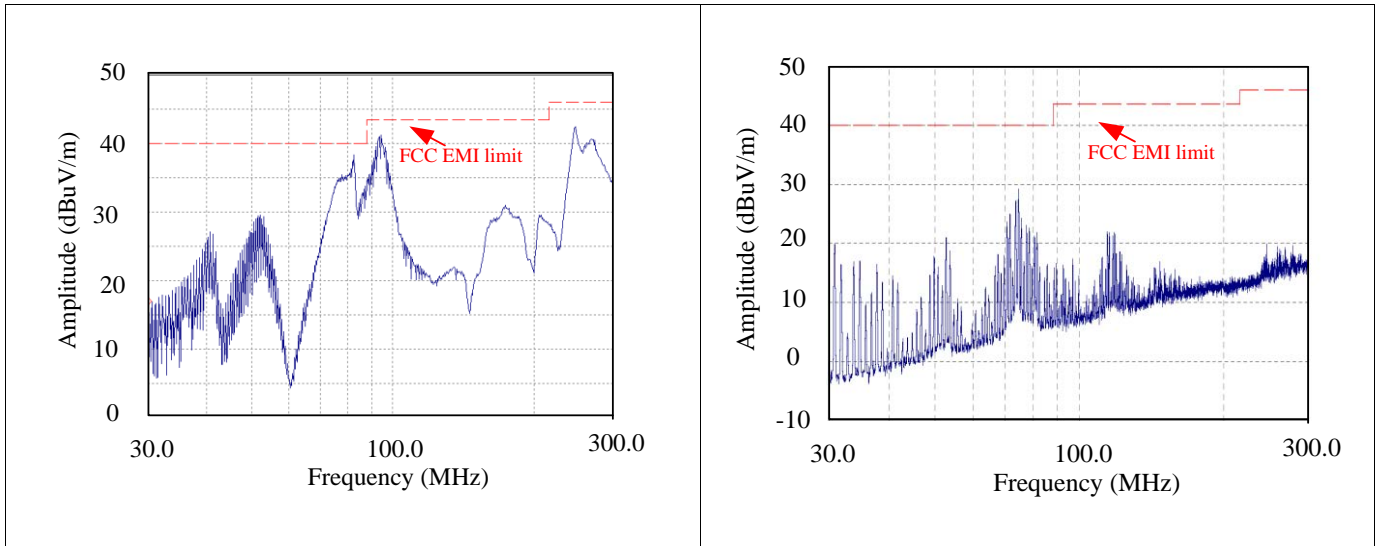
4.1.1 Appropriate Slew Rate

For all class D amplifiers, the high frequency switching transition of the output MOSFETs causes emissions. The higher the slew rate of gate transition is, the larger the emission energy of the high frequency band is. Figure 6 (a)~(c) illustrate the different rising/falling rate comparison and the corresponding EMI comparison. All the left figures (with cyan background color) belong to the higher slew rate part, and the right figures (with yellow background color) belong to the lower slew rate part. It is clear that the slew rate of MP1720 is lower and the EMI performance is better.

However, decreasing the slew rate of output gate transition increases the loss during the switching time and has negative effect on the Class D amplifier's efficiency. Thus, it is a trade off between power losses and EMI to determine the suitable switching transition time. As shown in figure 6(d), the MP1720 can achieve an efficiency up to 90% under 5V VDD with 8ohm load, although the efficiency is a little lower at low output power.

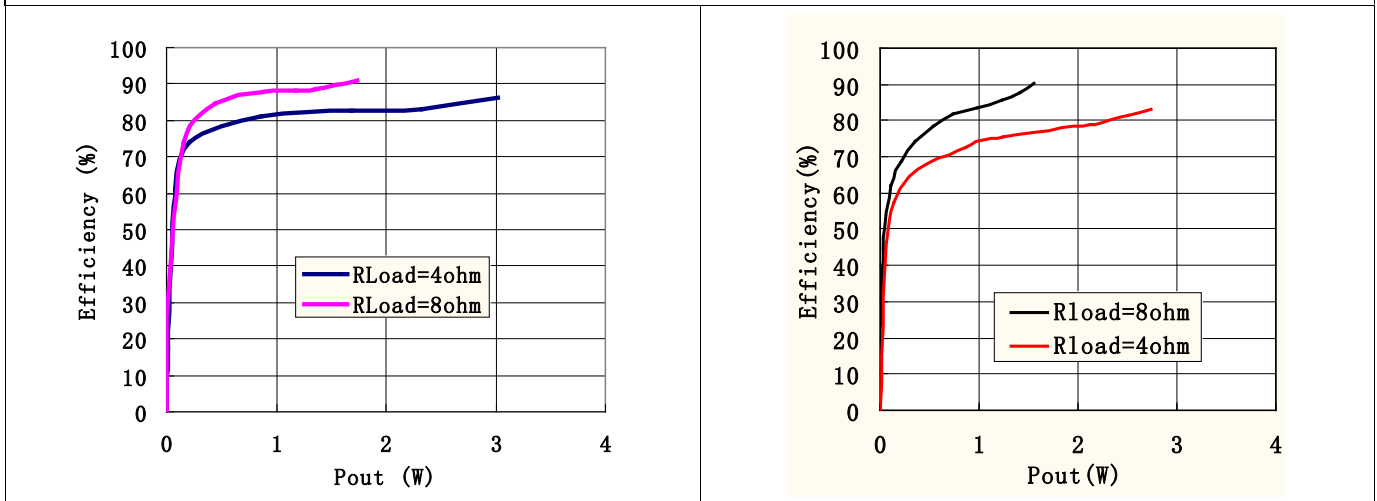
So with appropriately rising/falling rate of each gate transition, MP1720 can effectively minimize the radiated emissions without degrading efficiency much.





(c) EMI performance comparison

Test condition: VDD=5V



(d) Efficiency comparison

Figure 6, the different slew rate and corresponding performances comparison

4.1.2 Flexible Switching Frequency

MP1720 offer flexible switching frequency selection, as shown in the figure 7. There are two kinds of operating frequency solution: an internal fixed clock (1.0MHz or 1.3MHz), or an external clock (the frequency range can be 0.5MHz ~ 1.4MHz). This allows the customers to manually adjust the switching frequency and avoid the noise in sensitive frequency bands. Table 1 shows the detailed setup and selected switching frequency.

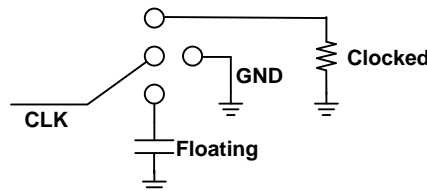


Figure 7, MP1720 frequency select circuit

Table 1 MP1720 switching frequency vs. CLK mode

| CLK pin voltage | Switching frequency |
|-----------------|---|
| CLK=GND | f _{sw} =1.0MHz |
| CLK=Floating | f _{sw} =1.3MHz |
| CLK=Clocked | f _{sw} =external clock frequency (0.5MHz ~ 1.4MHz) |

4.2 TWO ATTENTIONS FOR EMISSION

1. The speaker cable act as an antenna, so the longer speaker cable, the more severe radiated emissions. In common application, the output ferrite bead and capacitor filters are enough. If a device fails in radiated-emissions tests due to long speaker cables, an external output filter is needed to provide additional attenuation of the high-frequency components.
2. EMI performance is also very sensitive to the layout, so the proper PCB layout guidelines should be strictly followed to guarantee compliance with applicable FCC and CE regulations.

5 CONCLUSION

1. The MP1720 can eliminate the requirement of the LC output filter, because the output differential voltage swing is just V_{DD} or even 0V for the MP1720 modulation scheme, not $2 \cdot V_{DD}$ as the traditional class D amplifier. This greatly lowers the losses and emissions.
2. With the internal EMI reduction scheme and flexible switching frequency, the MP1720 passes emission standards without a filter and with 24in cable. The MP1720 adopts the appropriate slew rate of the output MOSFET gate transitions to effectively minimize radiated emissions and does not affect the efficiency much.
3. The MP1720 integrates the input resistors which minimizes the external component count. Combined with the class D amplifier inherent high efficiency advantage, the MP1720 can provide high fidelity, low EMI, require only 3 external components and extend battery life with high efficiency. These advantages are very attractive for a space-saving, low cost solution, which make the MP1720 ideal for cell-phone, MP3, PDA, and notebook applications.

6 REFERENCES:

- [1]. Svetoslav Cvetanov Ivanov and Elena Krusteva Kostanova, "Active gate drivers for MOSFETs with circuit for dv/dt control", Electronic'2004.
- [2]. Johnson, Howard W./ Graham, Martin "High-Speed Digital Design", June 2005.

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