AN2052
Application note

VIPower™: implementing frequency modulation on the VIPer53-E to improve EMI emissions

Introduction

This report describes how the frequency modulation reduces the electromagnetic interference on an SMPS using the VIPer53-E as primary PWM-switch. The comparison of EMI measurement data are presented in the following sections.

Contents

1 Test results

Figure 1. Original, time average at 200 kHz, 53.42 dBuV/m

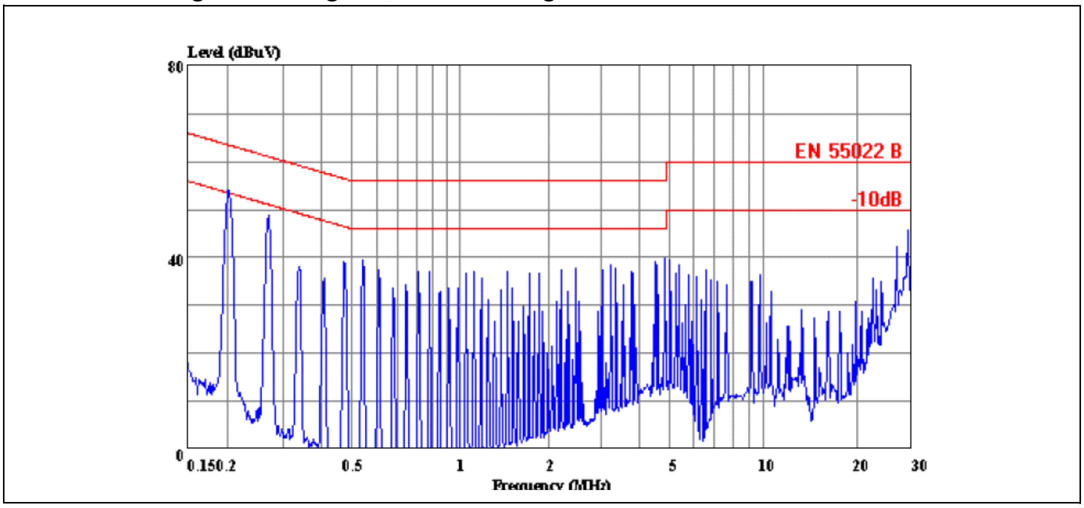


Figure 2. FM configuration “A”, time average at 200 kHz, 48.07 dBuV/m

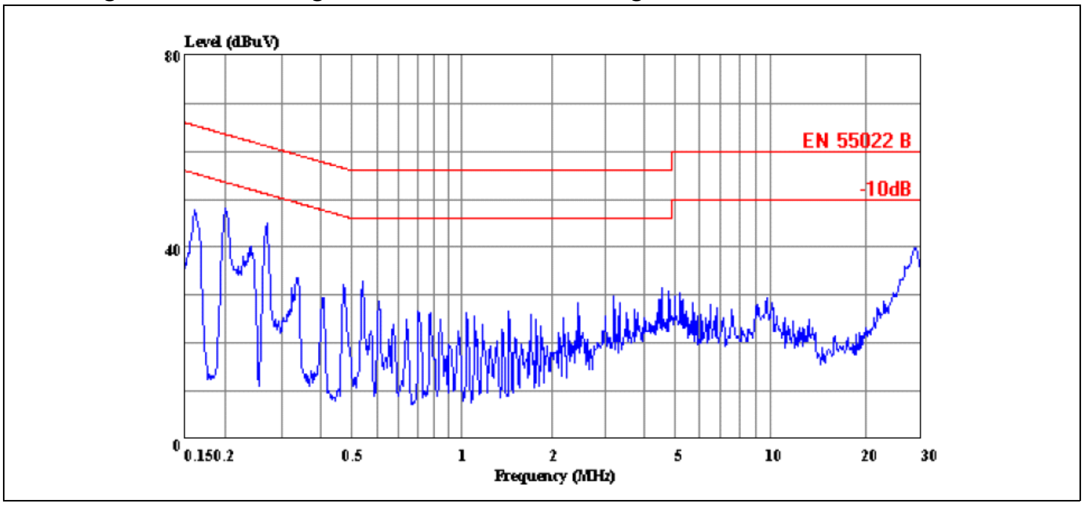
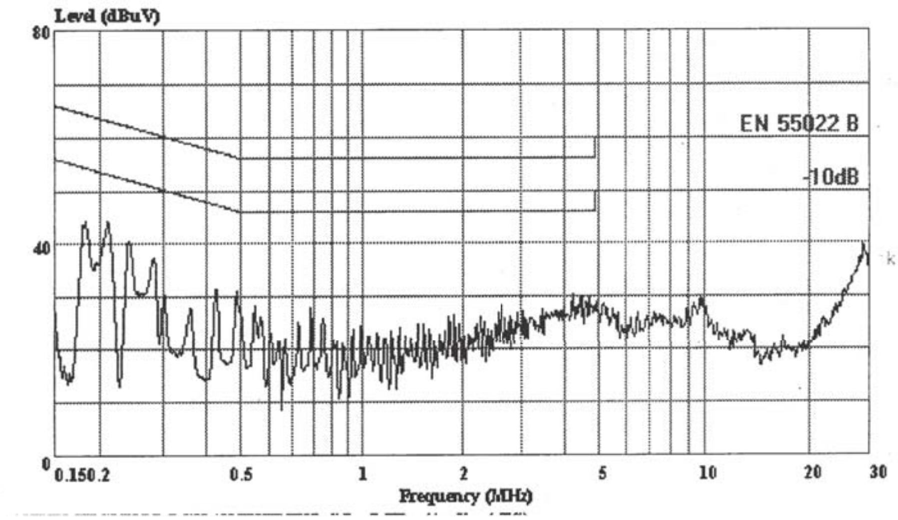


Figure 3. FM configuration “B”, time average at 200 kHz, 43.92 dBuV/m



As shown in *Figure 1*, *2* and *3*, using the FM technique, an improvement is obtained. When frequencies are lower than 1 MHz, the device switching is the primary noise generator. Using the configuration “A” or “B”, a 5 dBuV/m drop is obtained for frequencies lower than 200 kHz.

Between 1 MHz and 10 MHz, both configurations “A” and “B” make a dramatic drop bigger than 15 dBuV/m. Above 10 MHz, FM technique benefits are reduced and capacitive coupling between copper tracks in PCB is dominant.

Table 1. EMI comparison between original “A” and “B” configurations

	<1 MHz	1 MHz to10 MHz	>10 MHz
Original	Marginally pass	Pass	Enough margin
“A”	Pass	More margin	Enough margin
“B”	More margin	More margin	Enough margin

2 Circuit and description of test configurations

Figure 4. Original configuration (fixed frequency at 70 kHz, and no FM)

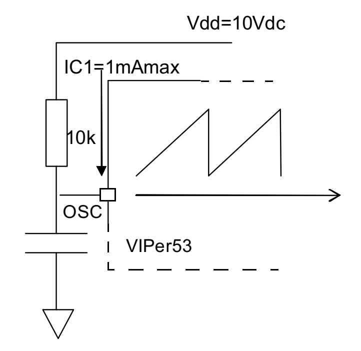


Figure 5. Configuration "A" (switching frequency from 63 kHz to 77 kHz FM cycle 20 ms, 50 Hz)

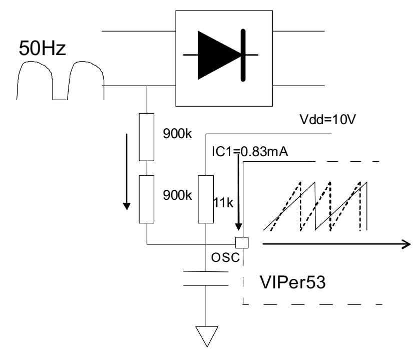
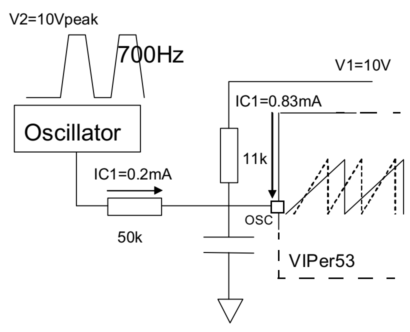


Figure 6. Configuration "B" (frequency from 63 kHz to 77 kHz, FM cycle 1.4 ms, 700 Hz)



By changing the resistor value between VDD and OSC pin, the frequency oscillator (capacitor value is fixed at 220 nF) can be modified. In this way the FM percentage can be set. The target FM percentage is +/-10%. In the original circuit a 10 kohm resistor is used, obtaining a switching frequency of 70 kHz. This resistor value gives a charging current capacitor of 1 mA max.

The external circuit works to increase the switching frequency. Therefore, the resistor value should be changed between VDD and OSC pin in order to reduce the minimum switching frequency to 66 kHz. As a result the new resistor value is 11 kohm, obtaining a charging current of 0.9 mA when the external voltage is 0 V. The switching frequency variation depends on the charging current capacitor, therefore it is proportional to the external voltage. Maximum value of the switching frequency is 77 kHz: it is obtained when the charging current is 1.1 mA where 0.9 mA is given by V_{DD} and 0.2 mA is supplied from the external circuit.

Below, the design of the resistor value, between OSC pin and the oscillator, is explained:

– in configuration “A”, maximum voltage is 374 V, so the resistance is R = 373 V/0.2 mA = 1.8 Mohm
– in configuration “B”, the maximum voltage is 10 V, so the resistance is R = 10 V/0.2 mA = 50 kohm

It is important to verify the frequency obtained using the oscilloscope. This frequency value has to be tuned to the desired value. In *Figure 7*, *8*, *9* and *10* the typical clock signal is shown.

Figure 7. Configuration “A”: AC signal (50 Hz oscillator)

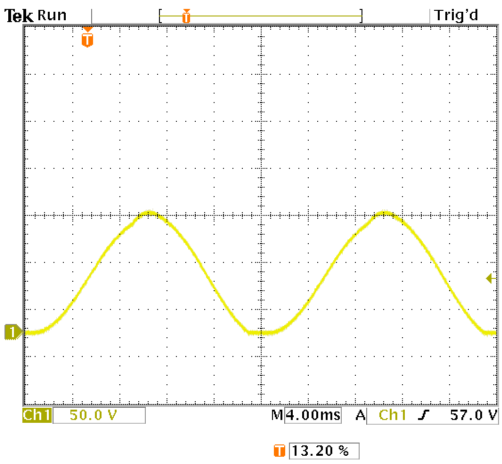


Figure 8. Configuration “A”: PWM ramp signal

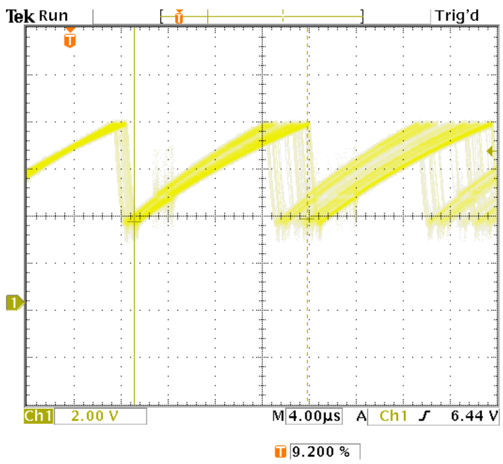


Figure 9. Configuration “B”: oscillator signal (700 Hz oscillator)

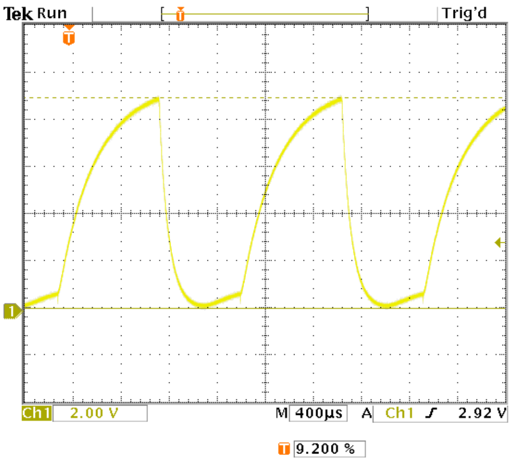
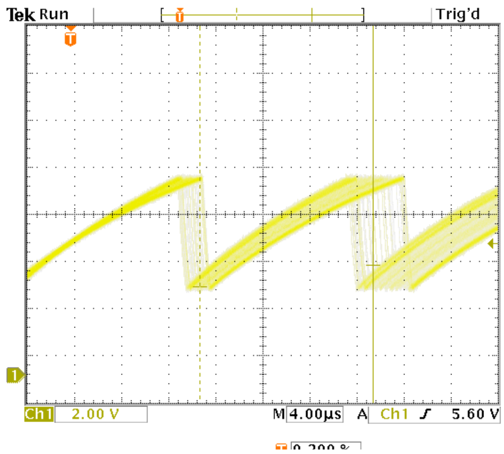


Figure 10. Configuration “B”: PWM ramp signal



3 Analysis and possible further development

In *Figure 11*, *12* and *13* the peak value data of the three tested configurations are shown.

Figure 11. Original peak

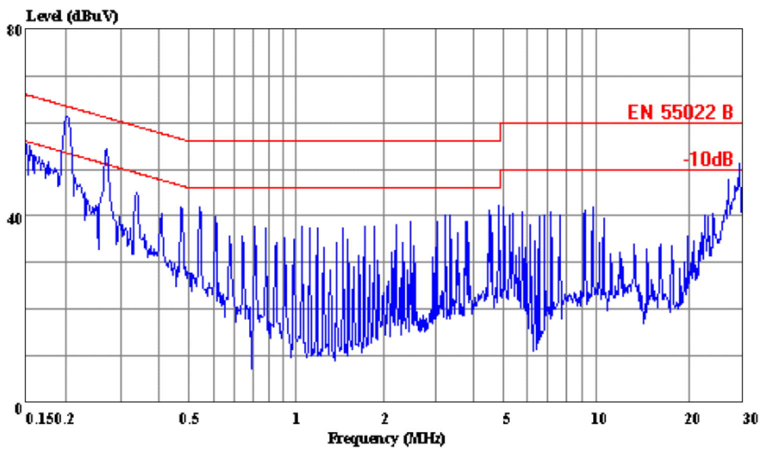


Figure 12. Configuration “A” peak

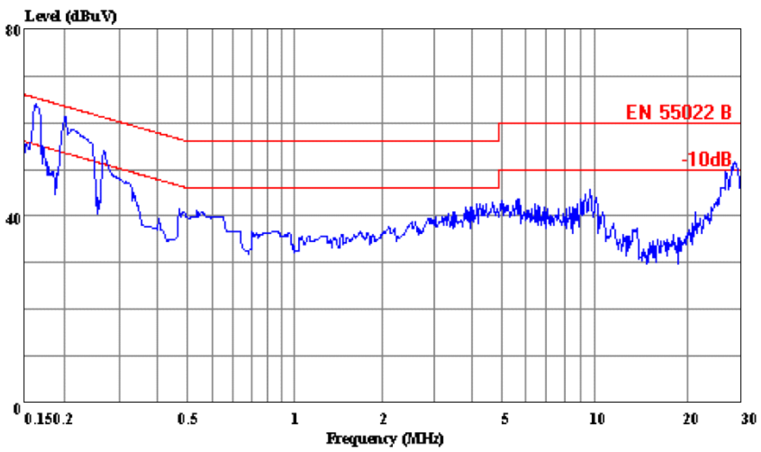
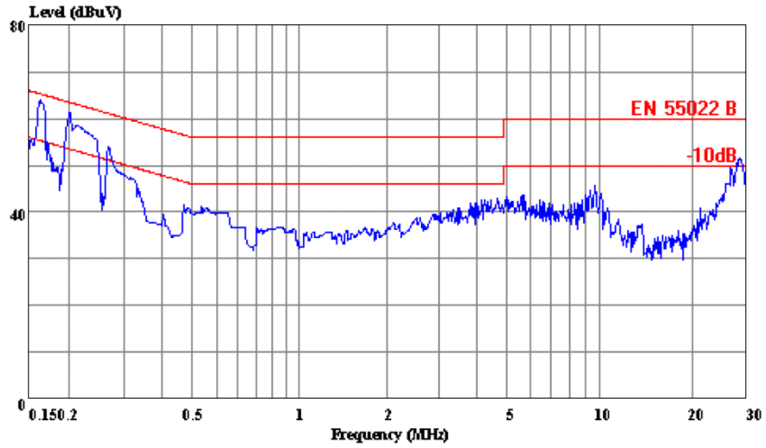


Figure 13. Configuration “B” peak



One remarkable point is that the peak value of the three tested configurations is almost the same. The major difference between peak and average measurement is in the filter and in the measurement time. Wide-band filter and short measurement time are used to capture the peak value; while narrow-band filter and relatively long measurement time are used to capture the average value. Through web search engines it is possible to find the definitions for the terms “peak” and “average” as “spectrum peak” and “spectrum average”, respectively. These definitions are different from the “time-peak” and “time-average” defined in this report. Instead, the term “frequency modulation” can be found on the web as “spread spectrum”. The spectrum peak is the highest component of the frequency spectrum. In EMI test data of SMPS, it corresponds to a low frequency.

The spectrum average is the average noise over the whole frequency spectrum. The time peak is the “peak” data measured by most EMI test lab. Noise, in terms of dBuV/m, is measured through a wide-band filter within a short period of time. Analysing such measurements, the fact that FM does not bring benefit is highlighted. The measurements obtained are very similar to the spectrum envelope of *Figure 11*.

The time average is the “average” data measured by EMI test lab. Noises are measured through a narrow-band filter, over a relatively long period of time.

Note that there is no regulation on the measurement average time.

4 Optimization of external oscillator

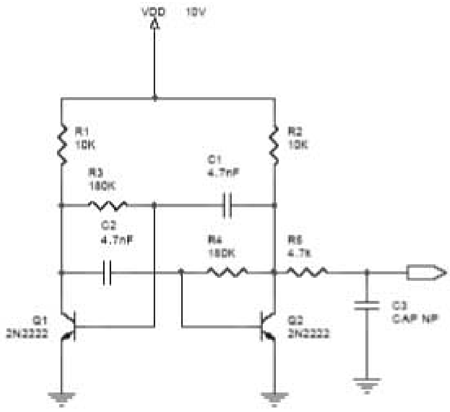
Targeted to lower down the average value of EMI noise, the PWM must go through the whole frequency range within the testing time. In other words, the FM cycle is as short as possible. On the other hand, since the PWM signal is modulated by the FM cycle and switching cycle, to avoid audible noise, FM frequency should be lower than 2 kHz.

In fact the average data of configuration "B", 700 Hz oscillator, are lower than the configuration "A", 50 Hz oscillator.

Another drawback of configuration "A" is the dependency on AC mains, which can be an issue in the transformer design.

5 Reference

Figure 14. Oscillator with 2 BJTs, low cost and start-up voltage down to 3 V



6 Revision history

Table 2. Document revision history

Date	Revision	Changes
12-Nov-2014	2	Updated the title in cover page. Content reworked to improve readability, no technical changes.