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Software Solutions to Mitigate the Electromagnetic Emissions of Power Inverters

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Nowadays, the switching circuits have become the most used system to convert voltages and currents, in order to supply electrical devices or to drive electrical loads, such as motors. The design of such switching circuits, should take into account not only the power electronics issues, but also the Electromagnetic Compatibility (EMC) ones. Indeed, each electronic system, in order to be sold, should be able to withstand to electromagnetic (EM) disturbances (immunity) as well as to not generate electromagnetic interferences (EMI) over a standard defined limit (emission). The electromagnetic emission, in particular the conducted ones, i.e. the one that propagates in the power supply cables, are usually reduced using power line filters. Such filters are composed by a large inductor, the common mode choke, and some capacitors, in order to confine the generated disturbances at the board power supply input. Such a choke is usually bulky, expensive and heavy. For these reasons, in recent years, the research activity in EMC field has been oriented in developing new techniques to reduce the filter's dimensions or even to remove it. These techniques are mainly software based, such as Spread Spectrum Modulation (SSM) or waveform shaping. However, these approaches present some disadvantages: the first spreads the disturbance signal over a wider frequency band, without reducing its total energy; the latter could reduce the efficiency of the switching circuit, and it requires *ad hoc* gate drivers in order to be implemented.

This work aims to develop and propose a new conducted emission mitigation technique based on software, in order to reduce the power line filter size. Such a technique is applicable whenever a bipolar PWM is used, i.e. the switching circuit should present couples of output nodes switched oppositely. Every time the outputs are switched, during the transition some high frequency current is injected in the parasitic capacitances present between the output switching node and the chassis. This current is defined as common mode conducted emission. If a bipolar PWM is used, such transitions are opposite and synchronized; if the rising and falling times are equal and the parasitic capacitance related to the output nodes have the same value, the disturbance current is internally recovered and it is not measured by the EMI receiver. However, this usually does not occur, since the propagation of the output control signals is affected by a delay, which cannot be determined *a priori*. Due to this delay, the output transitions are not complementary, and some CM current flows in the parasitic capacitances and it is measured by the EMI receiver instrument. From the analytical evaluation of the disturbances, the larger is the delay, the higher are the CM emissions at low frequencies, and therefore the filter needed for the EMI attenuation is larger.

For these reasons, in this work, a closed-loop technique able to compensate the delay, i.e. to align the output waveform transitions, has been developed. The proposed technique exploits a software algorithm, combined with a simple and low-cost sensing circuitry to compensate the delay between the switching circuit outputs. The proposed technique works for bipolar switched circuits. In order to prove its effectiveness, a BLDC motor driver has been designed and prototyped. Using the test bench proposed in the standard CISPR25, the CM emissions have been measured. Two cases have been considered: the first in which a delay is present between the output transitions, approximately equal to 100 ns; the second in which the closed loop delay compensation is active. In the second case the CM EMI spectrum is reduced by 17 dB (best value) with respect to the first case. As found in the analytical evaluation of the delay compensation, the technique is efficient in the lower part of the spectrum; however, in the higher part the emissions are not worsened. The closed-loop delay compensation technique, unlike the SSM technique, reduces the disturbance energy. Since the two EMI reduction techniques work independently, they can be used together in order to obtain a further reduction of the conducted emissions.

If the EMC requirements are still not met, a filter is needed anyway. Unlike the case in which the proposed technique is not implemented, where a classical commercial filter is used, the employment of the delay compensation technique allows the designer to reduce the conducted EMI filter size, gaining a reduction in weight, volume and cost.