Chapter 4

EMI Resisting Analog Output Circuits

Electromagnetic effects can cause impressive disasters that urge us to control the problem. One example is the catastrophe with H.M.S. Sheffield during the Falkland crisis. An Exocet missile hit this frigate because its search radar was switched off. It was switched off because it was known that the satellite communication system was interfered with by this radar. At the time of the disaster some officers used this communication link to talk with their prime minister. [...] The ‘disaster philosophy’ is already known to many EMC engineers who every now and then make use of a disaster to get new budgets.

—Quoted from [Gro02]

1 Introduction

There are numerous integrated output circuits, and an attempt to study all of them at the same time in view of understanding and improving their susceptibility to EMI would quickly prove to be a futile effort. However, under the assumption that similar output structures experience the same type of EMC issues, it is not too farfetched to claim that the same solutions which can be applied to one type of circuit may improve the EMC behavior of a related topology. After all, as was indicated in Chap. 3, although EMC problems originate almost in any type circuit – basically, they are spawned by the accumulation of a nonlinear signal – their effect is usually limited to signal distortion and DC shift: the latter is particularly harmful since it tinkers with the circuit’s operating point, alters its bias currents and depending on the strength of the interfering signal even possibly debiases the full circuit completely.

To this end, this chapter classifies and characterizes the electromagnetic susceptibility of CMOS analog integrated output structures in a general way. Applying the observations established in Chap. 3 on more complex (output) circuits, the originating EMC problems are identified using small signal approximations in order to detect the appearing EMC effects. The advantage of
using small signal approximations to do so resides in the fact that the mathematical complexity is greatly reduced, since a purely linear analysis is required to detect the appearing EMI issues [Red07b]. However, as has been illustrated anteriorly, small signal analyses are not sufficient by themselves to quantize and appreciate the full impact of EMI on a given circuit. Therefore, the output circuit characterizations are equally conducted from a large signal perspective, in order to check at which point the circuit is interfered with by strong nonlinear distortions using anhysteretic power series. This approach is valid in the event that the power series converges, which is the case as long as the active devices are not pulled out of their operating region by large EMI signals [Wam98]. Taking the previous comments into account, it is shown further on that CMOS analog integrated output structures can be distictively grouped into two major categories, namely the output circuits driving the load at the transistor source (common-drain type of circuits), and those driving the load at the transistor drain (common-source type of circuits). The major properties of both circuit types are derived mathematically, and compared to each other. As illustrated, common-source circuits exhibit a much higher immunity to EMI which is injected into their output terminals compared to their common-drain counterparts. After developing this theoretical foundation, two case study examples are studied and evaluated in detail, namely:

- **Case study 1: an EMI resisting integrated DC current regulator using an external trimming resistor.** This case study concentrates on improving the EMC behavior of an externally trimmed DC current regulator. Being originally designed as a common-drain output type, the appearing EMI problems are identified and matched to the theoretical observations. An EMI resisting current regulator structure with a rerouted feedback loop using a common-source output type is introduced and described: the resulting high immunity to EMI of this improved design is confirmed with measurements of a test-IC.

- **Case study 2: an EMI resisting integrated Local Interconnect Network (LIN) driver.** Although the classic LIN driver design is a common-source output type, a high capacitive coupling is essentially responsible for a low EMI immunity. As a consequence, the EMI disturbances injected in the output of this circuit easily propagate to the gate of the output driving transistor, hereby irrevocably distorting the output signal. Using the general derived observations in order to improve the robustness of the original design, a much higher immunity to EMI can be achieved. Two test-IC’s are presented in this case study. The first test-IC shows how the appearing EMC problems are solved using a modified design concept, however, at the cost of a large and continuous power consumption as well as a mediocre behavior of the output signal slopes. Both issues are dealt with and solved