Impact of Temperature on the Electromagnetic Susceptibility of Operational Amplifiers

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Abstract— In this paper, the impact of temperature on the electromagnetic susceptibility of operational amplifiers at different frequencies is presented. The IEC 62132-4 direct power injection standard has been used with several commercials operational amplifiers in a printed circuit board specifically fabricated. The results show that the susceptibility of the operationals amplifier is reduced with the temperature.

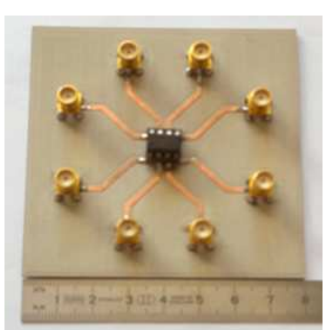
1. INTRODUCTION

Over recent years, due to the increasing demand for wireless operation electronic devices, a severe and complex electromagnetic pollution environment has been created. Therefore, the susceptibility to Radiofrequency Interference (RFI) has become a more important constraint for integrated circuit designers, particularly for analogue integrated circuits (ICs), which are the most sensitive circuits to RFI [1]. In order to characterize the IC susceptibility different standards have been proposed and the IEC 62132-4 Direct Power Injection (DPI) is one of the most extensively used [2]. In this work, the IEC 62132-4 standard has been used in order to characterize the most widely known analog device, the operational amplifier (OpAmp). In this case, unlike others works, where the operational amplifier susceptibility is evaluated [3, 4], the temperature has been taking into account. The impact of the temperature can be critical in a lot of safety application, i.e., automotive, where the electronic equipments located near the engine should resist, under normal operation conditions, temperatures about 100°C.

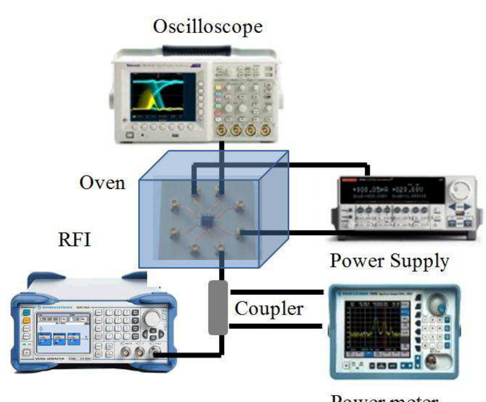
2. EXPERIMENTAL

Figure 1(a) shows the experimental fabricated PCB. The PCB dimensions are $8 \times 8\,\text{cm}^2$ and as it can be observed a symmetrical microstrip layout with same electrical length traces and characteristic impedance, $Z_0 = 50\,\Omega$, has been used. With this layout, all the injection ports present identical behavior. In order to investigate the operational amplifier susceptibility, a follower topology has been selected, as a worst EMI case [3]. Moreover, all the devices under test are mounted on a DIP-8 package in combination with an 8 pin dual in line IC socket. The prototype has been fabricated on the commercial *Rogers RO3010* substrate (dielectric constant $\varepsilon_r = 10.2$, thickness $h = 1.27\,\text{mm}$, $\tan\delta = 0.0023$) in order to have high performance above 1 GHz.

The susceptibility to electromagnetic interference has been evaluated under the standard IEC 62132-4 DPI [2] which is a very popular and efficient method to apply a conducted interference disturbance to a component. Fig. 1(b) describes the DPI setup. It consists of a RF signal generator



(a)



(b)

Figure 1: (a) PCB specifically designed for this experiment. (b) Experimental setup.

(providing the RFI disturbance) directly connected to a directional coupler in order to measure the actual level of power injected into the DUT with a power meter. A power supply provides the DC voltage to the integrated circuit and an oscilloscope is used to measure the OpAmps offset voltage due to RFI. Notice that the PCB is located in an oven in order to control the temperature of the devices under test. The RF interference has been swept from 10 MHz to 1 GHz with a input power forward level up to 10 dBm, at three temperatures: 25°C, 50°C and 75°C. The experiments have been performed for two types of operational amplifiers, the well-known LM741 operational amplifier and the TL081, which is wide bandwidth JFET input operational amplifier.

3. RESULTS

Figure 2 shows the frequency dependency of the offset voltage when a power level of 0 dBm is injected into the operational amplifier non-inverter input at room temperature (25°C). The results are shown for two different integrated circuits, LM741 and TL081. It is observed that the offset voltage of LM741 reach a value about 300 mV, meanwhile the TL081 reach a voltage offset below 40 mV.

In order to evaluate the impact of the temperature, both operational amplifiers have been subjected at different temperatures. The results are shown in Fig. 3. It both cases the offset voltage is reduced when the temperature is increased. For instance, for a RFI interference of 100 MHz the offset voltage drops from 360 mV at 25°C to 328 mV at 75°C for the LM741, which represents a reduction 8.9%. At the same frequency, the reduction of TL081 offset voltage drops from 22.3 mV to 13.8 mV, which corresponds to a 38% offset voltage reduction.

Notice that, although the absolute offset voltage reduction is higher in case of LM741, the relative reduction is lower than in case of TL081 due to the high offset voltage at room temperature. Fig. 4 details the offset voltage temperature dependence in case of 100 MHz RFI with three different RFI power levels, −20 dBm, −10 dBm and 0 dBm for LM741 and −10 dBm, 0 dBm and 10 dBm for TL081.

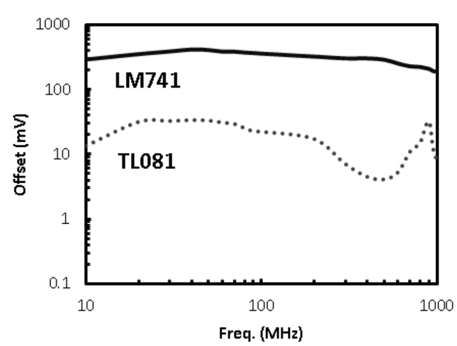


Figure 2: Operational amplifier offset voltage when a RFI interference of 0 dBm is injected at the inverter input at room temperature.

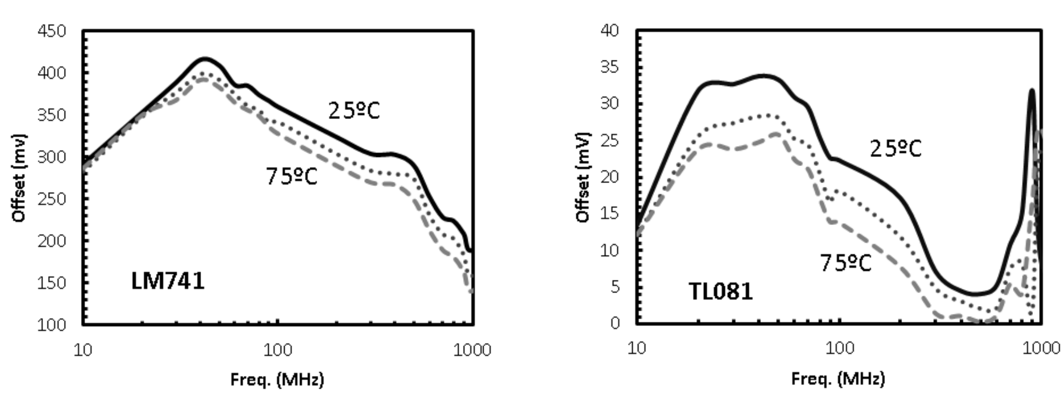


Figure 3: Operational amplifier offset voltage when a RFI interference of 0 dBm is injected at the inverter input ($f = 100$ MHz). The results are shown for three temperatures: 25°C, 50°C and 75°C.

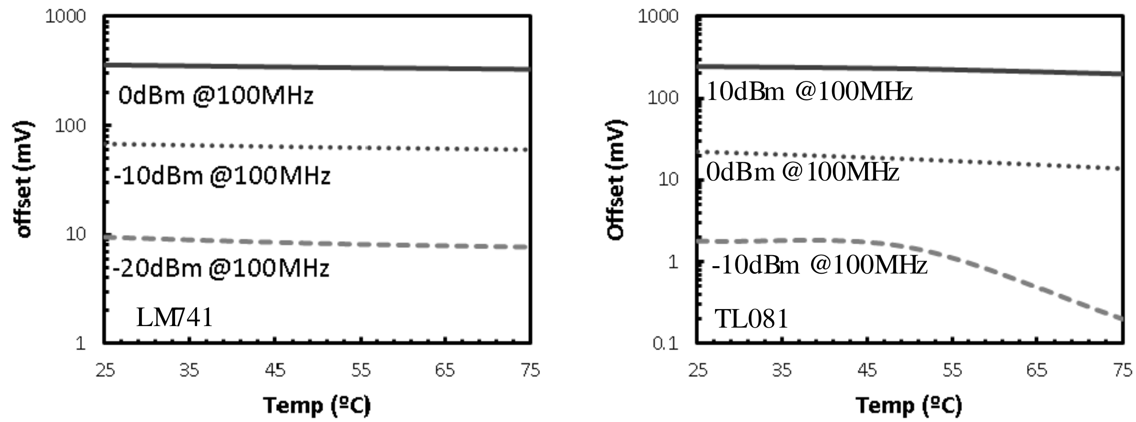


Figure 4: Operational amplifier offset voltage temperature dependence. The results are show for three different RFI power injection levels.

As in Fig. 2, the offset voltage of LM741 is about one order of magnitude worse than TL081. In order to achieve similar offset voltage in both integrated circuits, the power injection level of TL081 should be increased 10 dBm. The experimental results of Fig. 4 confirm the voltage reduction trend when the temperature is increased. A deeply investigation should be done in order to explain the physical reason of this behavior. However, one brief explanation can be the improvement of the non-linearity behavior of the transistor at high temperatures.

4. CONCLUSIONS

In this paper, the impact of temperature on the electromagnetic susceptibility performance of operational amplifiers has been experimentally evaluated. Specifically, the offset voltage of the operational amplifiers in a follower topology has been evaluated when a conducted RF interference from 10 MHz to 1 GHz is introduced into the non-inverter input at different temperatures. The experiments have been developed in two different commercial devices, the LM741 and the TL081. The results show that in both cases the offset voltage is reduced when the temperature is increased. Although a deeply investigation should be done in order to know the physical reason of this offset reduction, the improvement of the non-linearity performance of transistor could be a reason.

ACKNOWLEDGMENT

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