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Thermal Coupling in ICs: Applications to the Test and Characterization of Analogue and RF Circuits

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Abstract—In this presentation we cover how to use low frequency or DC temperature measurements to observe figures of merit of high frequency analogue circuits.

I. INTRODUCTION: THERMAL COUPLING

Thermal coupling is defined as the temperature increase at the vicinity of a circuit or device due to its power consumption. Temperature and power dissipation can be related with a linear transfer function behaving as a low pass filter, with a cut-off frequency around 10kHz-1MHz [1,2].

As the dissipated power depends on the voltages and currents driving the circuit, temperature is a signature of its performance and state, being traditionally used to enhance observability in digital circuits.

II. APPLICATIONS TO TEST OF ANALOGUE CIRCUITS

The use of temperature to test analogue circuits is proposed in [3,4]. From Fig. 1 we can see that the temperature is a down converted physical magnitude that contains information of high frequency electrical signals. In this figure, the Joule effect is modeled as a frequency mixer: thanks to its quadratic nature, the spectral components of the power dissipated by a device are frequency shifted from the spectral components of the electrical signals that drive it.

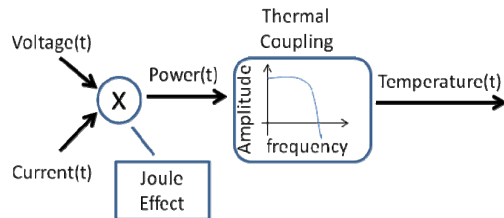


Figure 1. Down conversion from high frequency electrical signals to low frequency temperature increase.

For instance, [3] shows how to stimulate a 2.4GHz narrow band linear amplifier in order to achieve a power dissipation whose spectral component at 1kHz is proportional to the high frequency gain of the amplifier.

III. SENSING TEMPERATURE FOR TEST APPLICATIONS

Several techniques exist to sense this temperature increase, which can be classified as off-chip or embedded [2]. The use of off-chip strategies allow to enhance the observability of blocks in an analogue-RF system whose nodes are not accessible from

input/output pins in a debugging or failure analysis scenario [4,5]. Embedded temperature sensors [6] allow to measure temperature in field application, to either detect faults or to activate self-healing strategies.

IV. CHARACTERIZATION EXAMPLE

Fig. 2 compares the electrical signal measured at the output of an LNA at 800MHz with the amplitude of the spectral component of the temperature increase at 1kHz, when sensed near this device with an embedded temperature sensor [7]. As it can be seen, it is possible to induce the 1dB compression point of this amplifier from temperature measurements.

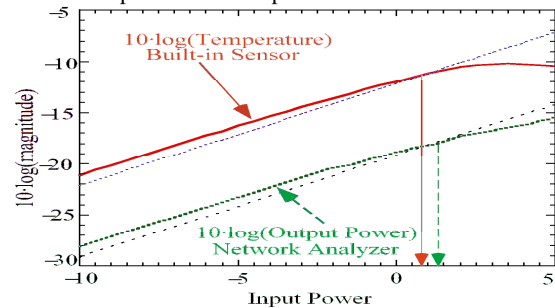


Figure 2. Measurement of the 1dB compression point from high frequency electrical measurements (800MHz) or low frequency temperature measurements (1kHz).

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