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Modeling of the Seven-Terminal Transformer Implemented in the LTGC-QO[1]

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Abstract—In this paper a seven-terminal transformer has been designed. We have suggested its equivalent-circuit model. This transformer has a primary coil with a center tap and two secondary coils. Based on this transformer, a low-cost transformer-based gate-coupled quadrature oscillator (LTGC-QO) using 0.18 μm CMOS technology has been developed. The LTGC-QO consumes 7 mW at 1 V power supply. The simulated phase noise at 1 MHz offset is –116.3 dBc/Hz. The chip area is 400×500 μm.

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1. INTRODUCTION

The fast development of wireless applications drives the demand for low cost, low power and, in particular, low-phase-noise integrated RF transceivers [1–3]. It is well known that the quadrature oscillator may potentially fulfill all these requirements.

Some circuits and methods used for quadrature signals generation are as follows: poly-phase *RC-CR* filters, ring oscillators, frequency dividers and coupleres. The most commonly implemented topologies are frequency dividers and couplers.

Quadrature oscillators stacked with a divider by two operate at the double frequency [4]. The disadvantages of the transistor-based coupling quadrature oscillators are more power consumption and worse phase noise performance or higher supply voltage [1, 3].

Yi Shen invented a transformer-based coupling quadrature oscillator in order to avoid the drawbacks of the transistor-based coupling quadrature oscillators [2]. However, owing to the application of four transformers, the chip area was increased. In this paper we designed a seven-terminal transformer. Based on this transformer a low-cost transformer-based gate-coupled quadrature oscillator (LTGC-QO) has been developed. Its configuration enables one to decrease the chip area of quadrature oscillators.

2. DESIGN OF THE LTGC-QO

In [2] the authors proposed a transformer-based gate-coupled quadrature voltage controlled oscillator (TGC-QVCO), which consists of two identical crosscoupled LC-VCOs and four transformers T_1, T_2, T_3 and T_4 (Fig. 1). NMOS transistors are used for negative resistance generator and tail current sink. The primary coils $T_{1,p}$, $T_{2,p}$, $T_{3,p}$ and $T_{4,p}$ of the four transformers operate as inductors in the corresponding *LC* resonance circuits. The secondary coils $T_{1,s}$, $T_{2,s}$, $T_{3,s}$ and $T_{4,s}$ of the respective primary coils are connected in series with the gates of transistors M_3, M_4, M_2, and M_1 in the cross-pair, respectively.

The LTGC-QO with two transformers, that is proposed in this paper, is shown in Fig. 2. Only two seven-terminal transformers T_5 and T_6 are used in this quadrature oscillator. The primary coils $T_{5,p}$ and $T_{6,p}$ of the two transformers operate as inductors in the corresponding *LC* resonance circuit. The secondary coils

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