TRANSFORMER-COUPLED VOLTAGE CONTROLLED OSILLATOR

Seok-Ju Yun, and Sang-Gug Lee
School of Engineering, INFORMATION AND COMMUNICATIONS UNIVERSITY
58-4 Munji-dong, Yuseong-gu, Daejeon in Korea, 305-732
stoneju@icu.ac.kr, sglee@icu.ac.kr

INTRODUCTION

In CMOS wire/wireless transceiver, the design of high performance voltage controlled oscillator (VCO) is not easy due to the low quality factor (Q-factor) of an on-chip resonator. In order to achieve better performance of the VCO, it is desirable to utilize high Q-factor transformer as a resonator. In conventional transformer-based VCO, only one port of transformer is connected to oscillation node [1] or feedback scheme by using asymmetric transformer (not 1:1 turn ratio) is used [2]. However, through these methods, the Q-factor of transformer-based resonator cannot be maximized due to less mutual inductance and different impedances of the primary and secondary ports at the oscillation frequency. This paper presents a transformer-coupled VCO using symmetric transformer which adopts cross-coupled transistors at both side of it. To verify proposed VCO's superiority, measurement results are suggested with the comparison of conventional transformer adoption [1]

TANSFORMER-COUPLED VOLTAGE CONTROLLED OSCILLATOR

Using a transformer-based resonator is a better choice to improve the VCO performance due to high Q-factor. In addition, as transformer is more symmetric, more increased Q-factor is probable due to large mutual coupling. Fig.1 shows the proposed transformer-coupled VCO using symmetric transformer (L_1=L_2). To establish highest Q-factor of the transformer resonator, the resonant frequencies at primary and secondary ports should be same [1]. Considering that transistors for negative impedance, used to travel through the triode, saturation and cut-off region, large oscillation signal gives an additional capacitance to the resonator [3]. Moreover, if amount of the current flowing through both side of transformer is different, same resonant frequency is difficult to obtain at the two ports of the transformer. As shown in the Fig.1, the proposed VCO adopts cross-connected transistors at both side of transformer-based resonator.

Therefore, with symmetric transformer, equivalent active circuits at both side of transformer enable resonation frequencies same while keeping same capacitance at two oscillation ports. (C_{a1}=C_{a2}, where I_{bias1}= I_{bias2}, V_{B1}=V_{B2} and V_{dd1}, V_{dd2}). Fig.2 shows simulated impedance values at primary/secondary ports of an ideal transformer-based resonator (here L1=L2=7.5nH, C1=C2/Kc=0.5pF) and its quality factors with various capacitance ratios of C1 to C2, Kc and coupling coefficient k. As shown in the Fig.2, the oscillation impedances (Zo1 and Zo2) of the resonators are a maximum near at point where two resonant frequencies are same (L_1=L_2, C_1=C_2) and it implies that at this point, lowest power consumption can be achieved. In addition, as shown in the Fig.2, the quality factor of resonator is also highest value with the same resonant frequencies of both side of transformer. Therefore, the proposed transformer-coupled oscillator which adopts symmetric transformer and equivalent active circuit at both side of it, is expected to have improved performance in aspect with power consumption and low phase noise.

MEASUREMENT RESULTS

The proposed VCO circuit is implemented with CMOS 0.13 μm technology. Fig. 3 shows the measured phase noise and output spectrum of the proposed VCO. In order to compare

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with conventional transformer-based VCO [1], VCO in Fig.1 is also measured with the turn-off of one side active circuit (conventional mode: OSC_1 turn-on and OSC_2 turn-off, proposed mode: OSC_1 and OSC_2 turn-on).The measurement results show oscillation frequency 6.57GHz and phase noise -108dBc/Hz at 1MHz offset frequency, which is almost 6 dB improvements compared with the conventional mode.

It is interesting to investigate output power at two different modes, the conventional and proposed modes, as increasing DC power consumption of oscillators. The measured output power with DC power increase is shown in Fig. 4. The output power is measured with the power down of output buffer to check power difference between two modes, exactly. Noticeably, as shown in the Fig. 4, the output power of the proposed VCO exceeds about 2dB than that of conventional mode while consuming same DC power. These results are mentioning that the proposed mode is more effective way to obtain high output power at given amount of DC power dissipation, or reduce DC power dissipation in the transformer-based VCO. Fig.5 shows tuning characteristic and phase noise through whole tuning voltage of the proposed VCO. Fig. 6 show the photograph of fabricated chip and performance comparison of conventional and proposed VCO is shown in Table 1.

Table 1 Summarized performances comparison of VCOs

	Conventional mode	Proposed mode
Oscillation range [GHz]	6.56~6.89	6.54~6.86
Phase noise [dBc/Hz] 1MHz offset	-102	-108
Power consumption [mW]	1.3	1.26
Power consumption minimum[mW]	0.238	0.153
Technology[μm]	CMOS/0.13	CMOS/0.13
FOM	177.5	183.6

CONCLUSIONS

This paper presents transformer-coupled VCO using symmetric transformer. By adopting cross-coupled transistors at both side of transformer, phase noise performance is improved by 6dB compared with conventional VCO. The proposed VCO has been fabricated in CMOS 0.13μm technology. Measured results show -108dBc/Hz phase noise at 1MHz offset and frequency range 6.54~6.86GHz while dissipating 2.1mA from a 0.6V supply.

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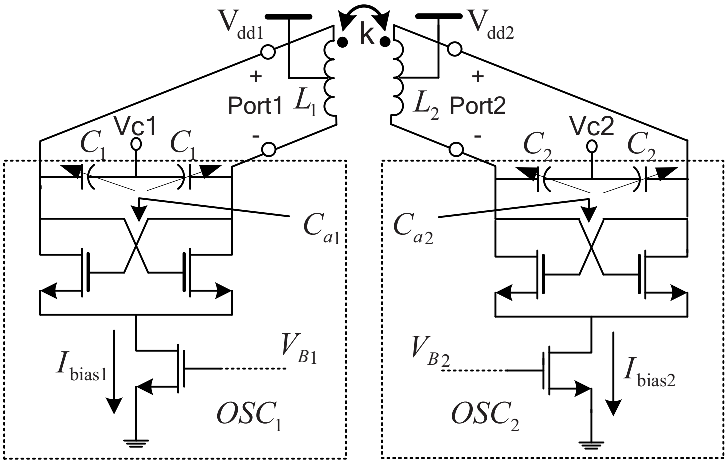

Figure 1. Transformer-coupled VCO using symmetric transformer

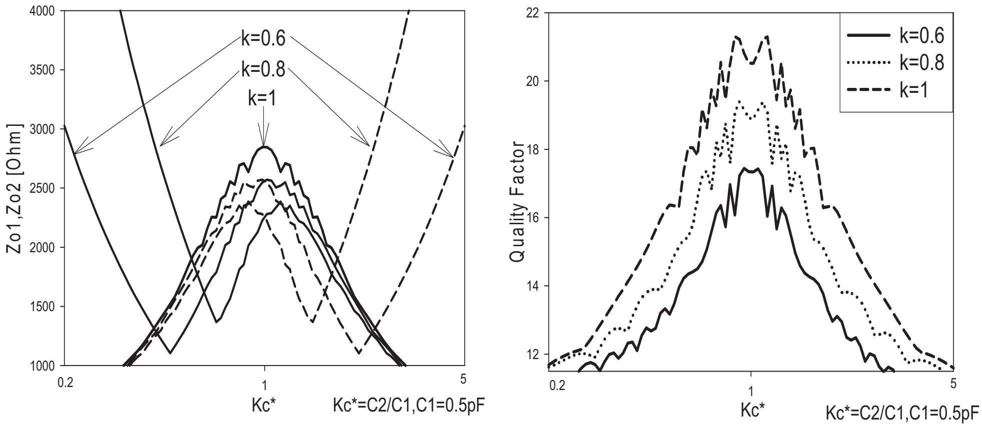

Figure 2. Simulated primary/secondary impedance at the oscillation and quality factor of the transformer

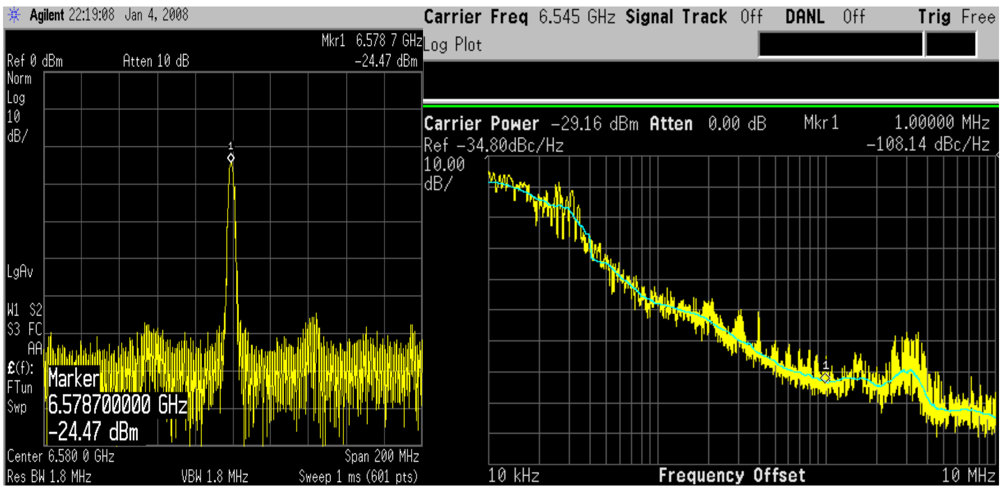

Figure 3. Spectrum and phase noise of the proposed VCO

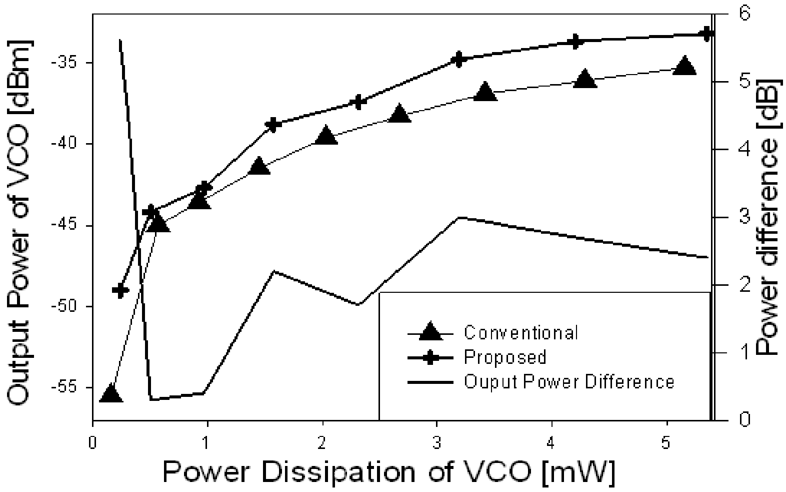

Figure 4. Output power with increasing DC power dissipation

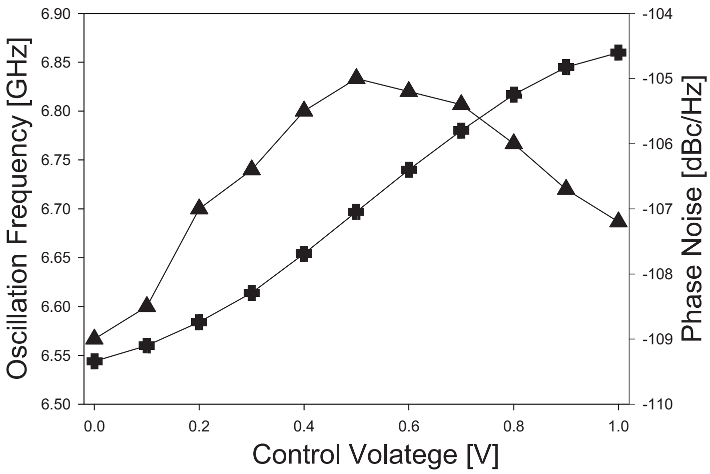

Figure 5. oscillation frequency and phase noise versus control voltage

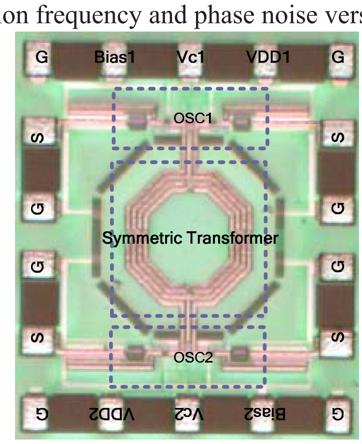

Figure 6. Chip photograph of the proposed VCO