Adaptive Ring Oscillator Design for 20MHz HIFU Ultrasound Sensor Applications

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1. Introduction

High-Intensity Focused Ultrasound (HIFU) technology has garnered significant attention as a non-invasive therapeutic tool for dermatological applications, including correcting pigmentation disorders and tattoo removal. A key challenge within HIFU systems lies in maintaining a stable, resonant frequency (20 MHz) over extended operational periods. Environmental factors and the effects of aging can lead to deviations in a transducer's performance. Traditional frequency stabilization methods often require frequent recalibration or hardware modifications, which can hinder system efficiency and longevity. To tackle these challenges, this research introduces a manually tunable ring oscillator-based frequency control circuit designed to actively compensate for resonance drift actively, ensuring precise and sustained ultrasonic wave generation. This circuit improves the operational reliability of HIFU transducers by allowing real-time frequency adjustments, which decreases the need for periodic recalibration.

2. Structural and operating characteristics of the proposed frequency control circuit

2.1 Architecture of the Control Circuit Based on a Ring Oscillator

The proposed design employs a ring oscillator architecture, where inverters drive the ultrasound transducer to generate the high-frequency oscillations essential for High-Intensity Focused Ultrasound (HIFU) applications[1]. However, traditional ring oscillators are prone to frequency drift resulting from aging and thermal variations, which can negatively impact the efficiency of ultrasonic wave transmission.

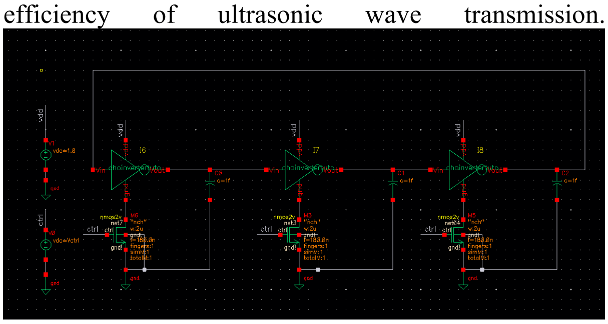

Fig. 1. Schematic of the proposed ring oscillator-based frequency control circuit.

An additional NMOS transistor is integrated beneath each inverter stage to address this issue, allowing manual control over the oscillation frequency. The frequency tuning mechanism is achieved by applying an external control signal to the gate voltage of the NMOS transistor[2]. By varying this gate voltage, we can finely adjust the effective capacitance and propagation delay within the inverter chain, allowing for precise tuning of the oscillation frequency.

2.2 Frequency stabilization and performance optimization

Integrating a tunable NMOS transistor ensures that the HIFU transducer consistently operates at 20MHz, even in the face of resonance deviations caused by environmental factors or aging. In contrast to conventional fixed-frequency drivers, which require periodic calibration or component replacement, the proposed architecture offers a dynamic, real-time compensation mechanism that significantly enhances operational stability.

Future research will include an Automatic Gain Control (AGC) circuit to automatically adjust the signal amplitude. This adjustment will optimize ultrasound power output without the need for manual intervention. This enhancement is expected to significantly improve the efficiency and adaptability of High-Intensity Focused Ultrasound (HIFU) devices in clinical applications.

3. Conclusion

This research introduces an innovative ring oscillator-based frequency control circuit to sustain stable 20MHz operation in HIFU ultrasound transducers.

The proposed method effectively compensates for frequency drift by employing an NMOS-transistor-based tuning mechanism, eliminating the need for frequent recalibrations or hardware modifications. The dynamic stabilization of resonant frequency is expected to greatly improve the efficiency, reliability, and lifespan of next-generation High-Intensity Focused Ultrasound (HIFU) systems. Future research will concentrate on integrating an Automatic Gain Control (AGC) system to optimize the delivery of ultrasound power, improving the adaptability of HIFU technology for medical applications. More comprehensive results and performance evaluations will be shared at the upcoming conference.

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