CHAPTER 9

CONCLUSIONS AND SCOPE FOR FUTURE WORK

In this thesis, some novel waveform generators circuit design, operation and synthesis are presented. All the newly presented circuits in this thesis require a minimum number of active and passive components to generate the waveforms. The proposed sinusoidal oscillators, quadrature sinusoidal oscillators and square waveform generators are simulated using Spectre simulation model parameters and a repetition of them are carried on a laboratory breadboard using commercially available AD 844 AN ICs. All the practical and simulated results are correlated well with the theoretical analysis.

9.1. CONCLUSIONS

Chapter 1 construes the introductory overview of the importance of sinusoidal/ square waveform generators in electronic circuits and the evolution of active devices in waveform generation from voltage mode to the current mode. This chapter also includes the advantages derived by the current mode devices compared to the voltage mode devices.

In chapter 2, the main active device used for the design and implementation of waveform generators is given. The CMOS implementations of the OTRAs given in [32, 33] are used for waveform generation. The CMOS OTRA structures are redesigned using Cadence CMOS gpdk 180 nm technology and simulated using Spectre simulation model parameters. The CMOS transistors W/L ratios are given. The simulated output voltage variation with respect to the input terminal currents is given. The variation of input and output terminal's resistances are also presented in the form of figures. The simulated DC open-loop transresistance gain of the OTRAs is also presented in this chapter. In order to validate the proposed circuits, the OTRA is implemented on laboratory breadboard by using commercially available ICs AD 844 AN. The OTRA implementation using two AD 844 AN ICs and a resistor are given in this chapter.

Chapter 3, mainly focuses on the existing applications and waveform generators have been designed using OTRA. This chapter also provides detailed analysis and important issues involved in the design and implementation of the waveform generators by using OTRA. Each subsection related to the waveform generators by using OTRA also provides intermediate conclusions concerned with the (merits and demerits) advantages and disadvantages posed by the available OTRA based waveform generators in the literature.

Chapter 4-8 presents the main objective of the thesis. Novel active sinusoidal oscillators, quadrature sinusoidal oscillators and square waveform generators are designed in chapter 4. The operation of the proposed waveform generators is discussed in this chapter. Based on the literature survey and the importance of the sinusoidal oscillator in the field of electronics, a generalized configuration using single OTRA with a grounded passive component(s) is proposed in this chapter. Several oscillator circuits can be generated by using the proposed generalized configuration. The minimum passive component sinusoidal oscillator circuit with four passive components is generated by using the generalized configuration. Twelve special case oscillator circuits by using the generalized configuration are presented in this chapter. In these oscillator circuits, seven oscillator circuits are having a single grounded resistance.

The grounded resistance in these oscillator circuits can be replaced with a grounded capacitor. The condition of oscillation and frequency of oscillation can be controlled independently in most of the oscillator circuits realized from the generalized configuration. Two special case oscillator circuits with grounded resistance and capacitance are also presented in this chapter. In these two oscillator circuits, the condition of oscillation and frequency of oscillation are controlled independently. In all the proposed circuits, the grounded resistance/capacitance can be replaced with a JFET to realize a voltage controlled oscillator. Two quadrature sinusoidal oscillator circuits using two OTRAs along with a few passive components are also presented in this chapter. The condition of oscillation and frequency of oscillation can be controlled independently in the proposed quadrature sinusoidal oscillators.

Two square waveform generators are presented in this chapter. The first square waveform generator is designed with one OTRA, two resistors and a capacitor. This square waveform generates fixed and almost equal on-duty and off-duty cycles. The output waveform time period can be varied by any of the passive components connected to the circuit. This circuit makes a linear variation of the time period with respect to the passive components connected to the circuit. The second square waveform generator circuit presented in this chapter can be able to vary both the on-duty and off-duty cycles at a time. This circuit is designed with one OTRA, two diodes and four passive components. By varying the passive component values, the on-duty and off-duty cycles can be adjusted to the required time period. The operation of the square waveform generators to oscillate between the positive saturation to the negative saturation levels is depicted in this chapter.

In chapter 5, the mathematical derivations for the circuits presented in chapter 4 are given. A generalized configuration is implemented to realize ten sinusoidal oscillator circuits presented in chapter 4. From this generalized configuration a generalized characteristic equation is derived by considering the admittances of the passive components connected to the generalized configuration. The characteristic equation for the proposed generalized configuration is derived by considering the ideal behavior of the OTRA. The condition of oscillation and frequency of oscillation for all the newly proposed oscillator circuits can be derived from the generalized characteristic equation.

The characteristic equation can also be derived independently for all the sinusoidal oscillator circuits without depending on the generalized characteristic equation. Similarly, for the two quadrature sinusoidal oscillator circuits presented in chapter 4, the characteristic equation is derived by applying the general network laws to the circuits. The last subsection in this chapter describes the mathematical analysis of the two square waveform generators proposed in chapter 4. By considering the ideal behaviour of the OTRA, the mathematical derivation for the time period of the proposed square waveform generators is carried out. The output waveform of the square waveform generator has two saturation levels. The output waveform changes its state when the inverting input terminal current is more than the non-inverting input terminal current of the OTRA and vice versa.

In chapter 6, the non-ideal analysis of the waveform generators, presented in chapter 4, is described. All the proposed circuits presented in chapter 4 and their derivations for frequency or time period given in chapter 5 is re-analysed by considering the non-ideal model of the OTRA. In OTRA, the output voltage is the difference of two input terminal currents multiplied by the transresistance gain R_m, which is ideally infinite. The inverting and non-inverting input terminals of the OTRA are internally grounded. The parasitic capacitances and resistances (R_p, R_n and R_0) associated with the input and output terminals of the OTRA are very small, grounded and negligible. Thus the most important non-ideality in OTRA is due to the finite transresistance gain R_m. The finite transresistance gain R_m along with the frequency limitations associated with the OTRA must be considered in the analysis of the OTRA based circuits. The equivalent non-ideal model of the OTRA implemented with the ICs AD 844 is also discussed in this chapter. This equivalent OTRA model is redesigned by considering the finite parasitic resistances and non-zero current tracking errors.

In chapter 7, the simulation results for the newly proposed circuits in chapter 4 are given. All the proposed circuits are designed with the CMOS OTRA realization given in chapter 2 along with a few passive components. The proposed circuits in chapter 4 are simulated by using Spectre simulation model parameters with a supply voltage of ± 1.8 V. The sinusoidal oscillator circuits realized from the generalized configuration are designed with appropriate passive component values, to satisfy the condition of oscillation, to produce the sinusoidal output waveform. The simulated output waveforms of the proposed circuits along with passive component values are given to validate the theoretical analysis. Similarly, for the quadrature sinusoidal oscillator circuits the passive components are chosen to produce the oscillations at the output terminals of the OTRAs. All the sinusoidal and quadrature sinusoidal oscillators are tested with different passive component values to satisfy the barkhausen criterion to produce sustained oscillations at the output terminal of the OTRA. The simulated results are in good agreement with the mathematical analysis given in the previous chapter.

Two new square waveform generators are proposed in chapter 4. The first one is the fixed duty cycle square waveform generator, i.e. the on-duty and off-duty cycles are fixed and almost equal with this circuit. The second circuit is able to vary the duty cycles to the required time period. For producing the square waveform in the proposed square waveform generators, the required time period is chosen first. Then the passive component values are arbitrarily determined from the time period equation derived in chapter 5. The capacitor and resistance values can be tuned to select the required time period or frequency. The second square waveform generator is also called as a variable duty cycle waveform generator. In this waveform generator the resistance values are chosen to select the on-duty cycle time period, which is more than the off-duty cycle time period. These resistance values will be reversed if the off-duty cycle time period is more than the on-duty cycle time period. The simulated output waveforms are matched well with the theoretical analysis given in the previous chapter.

This chapter aims at the workability of the new topologies proposed in chapter 4. All the circuits presented in this thesis are experimentally checked for waveform generation using a laboratory breadboard. The prototype OTRA realization by using two AD 844 ICs shown in chapter 2 has been used to validate the theoretical and simulation analysis with the hardware results. The IC AD 844 is a high speed monolithic current feed-back operational amplifier (CFOA). This IC is very popular by its applications in current-mode circuits. The oscillator circuits generated from the generalized configuration are connected on the laboratory breadboard for testing the waveform generation and frequency tuning.

The passive components used for generating sinusoidal oscillations and frequency tuning are given to validate the theoretical analysis. For all measurements on laboratory breadboard the supply voltage of ± 5 V is used. The photographic pictures of the output waveforms on the oscilloscope screen are shown in this chapter. The percentage of errors between the theoretical frequencies and experimental frequencies are given for the oscillator circuits. The circuits having the advantage of tuning independently over the condition of oscillation and frequency of oscillation are tuned with respect to the passive component.

The frequency tuning of such circuits is presented in the form of figures. For frequency tuning, one of the passive components connected to the circuit is varied over a range while the other passive components are kept constant. The comparison of the proposed oscillator circuits realized from the generalized configuration with the existing oscillator circuits from the literature in terms of number of active and passive components, supply voltage and power consumption to produce the waveform is presented in this chapter. Similarly, the quadrature sinusoidal oscillator circuits are also implemented and checked for waveform generation using a laboratory breadboard. The output waveform in the oscilloscope and frequency tuning with respect to the passive components are presented in the form of plots.

For generating the square waveform in the square waveform generators proposed in chapter 4 the required time period is chosen first. Then the passive component values could be calculated from the time period equation shown in chapter 5. The experimental output waveforms of the square waveform generators are shown to validate the mathematical analysis and simulation analysis. The time period tuning with respect to the passive components is presented in the form of plots. From these plots, the time period curve is more linear than the existing OTRA based square waveform generator. The comparison of the proposed square waveform generator with the conventional OTRA based square waveform generator is given in terms of number of active components, number of passive components, maximum frequency range, supply voltage and power consumption to produce the square waveform.

9.2. SCOPE FOR FUTURE WORK

Further work can be done by implementing the OTRA in sub-microvolt region to decrease the supply voltage and power consumption. The OTRA can be implemented using FinFET, TFET and HTFET to achieve the low power consumption with low supply voltage.