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論 文

Wien-Bridge발진기에 대한 주파수대역 개선과 SC회로 실현

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The Frequency Range Improvement and Realization of SC Circuits for the Wien-Bridge Oscillator

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要 約 본 논문에서는 발진주파수 대역을 확장하기 위하여 3개의 연산증폭기로 구성된 RC형 Wien-Bridge 발진기를 제시하였으며, 이 발진기를 LSI화 할 수 있도록 Forward Z 변환법에 의하여 새로운 SC형 발진기로 실현하였다. 실현된 SC형 발진기는 Reddy, Budak과 Nay가 제시한 발진기보다 주파수대역이 확장되었음을 발진주파수 함수 f_0의근궤적 해석 방법을 이용하여 확인하였으며, 또한 발진조건에 충분히 만족됨을 개방 루프 측정에 의하여 확인하였다.

ABSTRACT In this paper, we have proposed the RC Wien-Bridge oscillator consisting of three operational amplifiers in order to improve the frequency range, and the proposed oscillator has been realized a new SC Wien-Bridge oscillator for LSI realization by the forward Z transform method. The realized SC oscilltor has been affirmed that the frequency range has been improved more than Reddy's. Budak and Nay's by the analysis of pole loci as a frequency function f_0. Also, it has been confirmed that the designed SC oscillator has been satisfied substantially the oscillated condition by the open-loop measurements.

I. INTRODUCTION

To extend the useful frequency range of the Wien-Bridge oscillator, Reddy designed the oscillator consisting of two operational amplifiers (OAs)[1]. After that, Budak and Nay recommended the oscillator with the developed frequency range by the improved Reddy's circuits[2]. However, Budak and Nay's oscillator has many problems such as narrow frequency range and the realization of LSI.

An important consideration in the design of variable frequency oscillators is how to keep the

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poles on the imaginary axis as the frequency of operation is increased. This problem can be solved by the circuit, of which amplifier gain is constant value of 3 and phase is 0 [2,3]. Therefore, we studied about the RC oscillator consisting of the above circuits [3]. The technique we used, had many problems due to resistor as follows: unaccurated RC product, poor linearity and temperature characteristics of the integrated resistors, large areas of the integrated circuits, etc.

Therefore, we have realized the Vien-Bridge oscillator consisting of a new switched capacitor (SC) circuits in order to avoid the above problems. It has also shown that the SC oscillator has the same frequency characteristics with the designed 3 OA's oscillator [3], which has extended the useful operating frequency range.

II. SC CIRCUITS OF FREQUENCY SELECTOR

Z transformations for realization of continuous resistors using switched capacitor(SC) circuits are forward, backward and bilinear methods.

We are used the forward Z transform that analog active-RC circuits can be transformed into SC circuits. The Z domain transfer function is

$$S \rightarrow (Z-1)/T \tag{1}$$

where T is sampling period.

The resistance R for transforming a RC circuits into an equivalent SC circuits is [6]

$$R = T/C \tag{2}$$

The Wien-Bridge oscillator circuits are shown in Fig.1, where the RC circuits and the SC circuits are frequency selectors and the gain amplifier

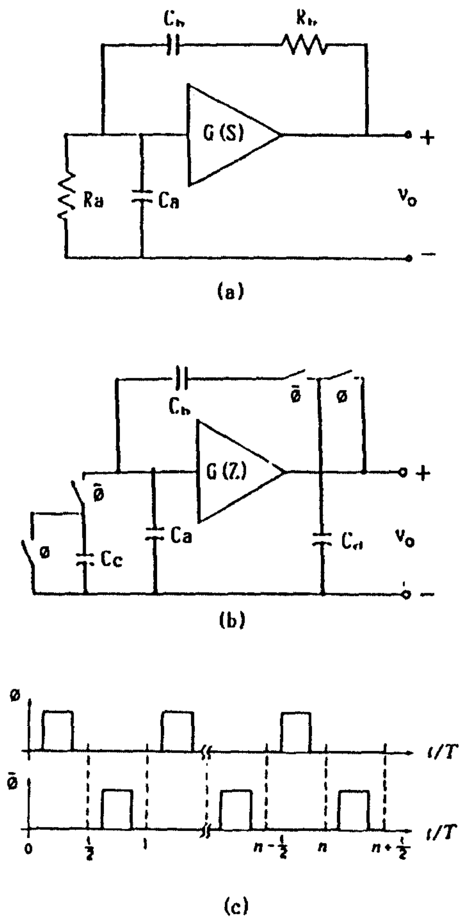


Fig. 1 Wien-Bridge oscillator
(a) RC type, (b) SC type.
(c) clock phasing.

are designated by G(S) and G(Z).

Fig.1(a) can be transformed into the SC oscilitor such as Fig.1(b) by the forward Z transform. The switches turn on and off according to the rise and fall of clocks ϕ and ϕ in Fig.1(c), respectively. The odd clocks are defined a two-phase clock to be the period of time where

$$(n+i) \leqq t/T < (n+i+1/2)$$

and the even clocks ϕ are defined a two-phase clock to be the period of time where

$$(n+i+1/2) \leq t/T < (n+i+1)$$

where i={- - -, -2,-1,0,1,2,- - - } corresponds to the ith clock period.

By Eq.(2), Cc and Ca in the circuits become

$$Cc = T/Ra, \quad Cd = T/Rd. \tag{3}$$

If Ca=Cb and Cc=Cd, then transfer function of the frequency selector B(S) is

$$B(S) = \frac{\omega_0 S}{S^2 + 3\omega_0 S + \omega_0^2} \tag{4}$$

where the circuit oscillates with

$$\omega_0 = Ca/TCc,$$
$$Q = 1/3.$$

By substituting Eq.(1) into Eq.(4), the transfer function B(Z) are obtained;

$$B(Z) = \frac{T\omega_0 (Z-1)}{Z^2 + Z(3\omega_0 T - 2) + 1 - 3\omega_0 T + \omega_0^2 T^2} \tag{5}$$

where the sampling period T is 1/100KHz.
Also, the magnitude and phase of B(Z) are plotted in Fig.2. Notethat at $\omega = \omega_0$

$$B(e^{j\omega_0}) = 1/3, \quad \theta(e^{j\omega_0}) = 0^\circ \tag{6}$$

From the result of Fig.2, the magnitude and phase of B(Z) have the same frequency characteristics with the designed 3 OA's RC oscillator in[3].

The loop gain LG of the oscillator is given by

$$LG(Z) = B(Z) \cdot G(Z) \tag{7}$$

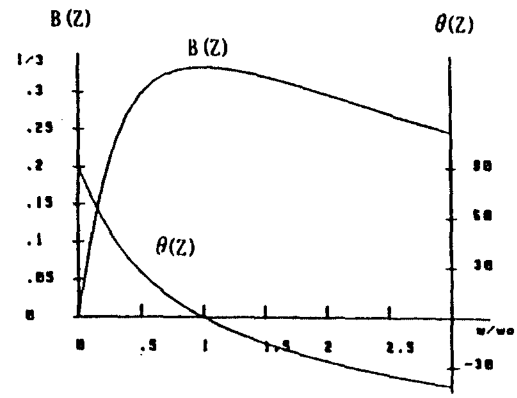


Fig. 2 Magnitude and phase characteristics of SC frequency selector.

Using Eq.(7) in 1-LG(Z)=0, results in the characteristic equation

$$s^2 + s\omega_0 [3 - |G(Z)|] + \omega_0^2 = 0 \tag{8}$$

If it were possible to design an ideal amplifier, G(Z) would be constant, G(Z)=Go, and the poles could be placed on the imaginary axis by making Go=3. The circuits would then oscillate at the frequency ω_0 At this frequency, the loop gain has a magnitude of 1 and phase of 0 which are the required criteria for oscillation.

In reality, however, G(Z) is a function of frequency and, therefore, the gain can be maintained at the constant value of 3 only at dc or at very low frequencies. Hence, as ω_0 is made higher by lowering the SC product, the poles will eventually move away from the imaginary axis. Obviously, the nature of G(Z) determines the frequency at wjich this departure occurs.

In order to socillate, the gain and phase must be maintained at the constant value as following;

$$G(Z) = 3 / 0^\circ \tag{9}$$

In the actual case, the gain A(S) of OA can be modeled by

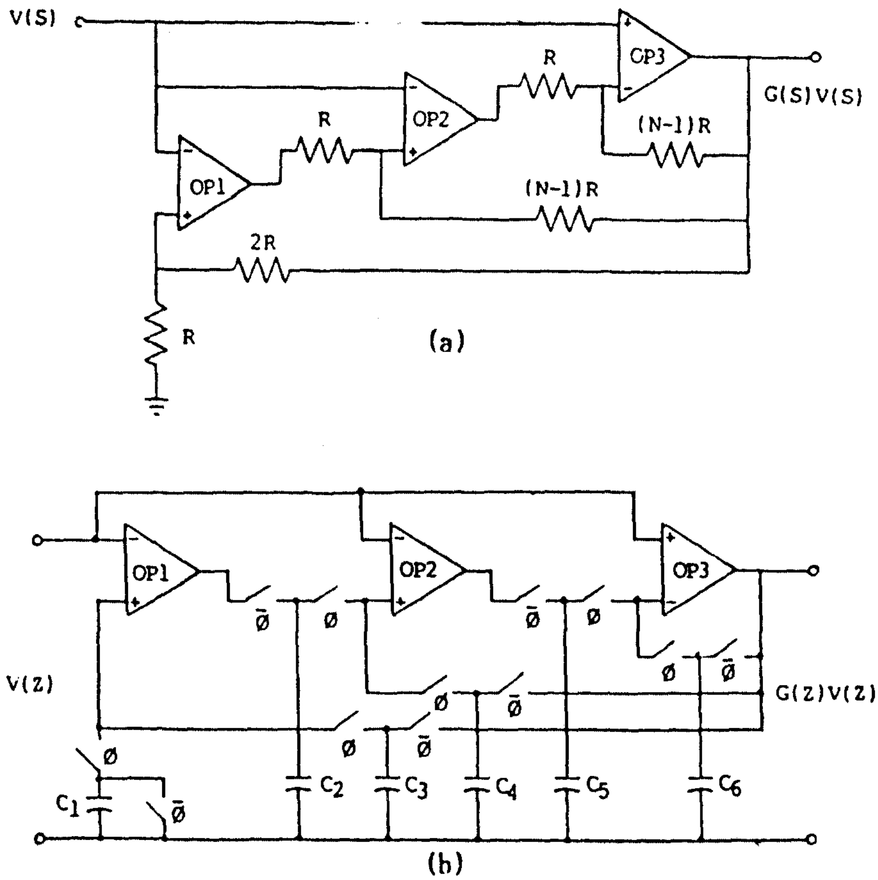


Fig. 3 (a) The advanced 3 OA's circuits.
(b) A new SC circuits of gain amplifier.

$$A(S) = GB/S = 1/S\tau \tag{10}$$

where GN is the gain-bandwidth product and τ is the time constant of the OA. Because of the above problems, the frequency range is confined.

III. A New SC Circuits of Gain Amplifier

The circuits of Fig.3.(a) are transformed into the SC circuits such as Fig.3(b) by the forward Z transform method.

The transfer function G(Z) of SC circuit is

$$G(Z) = \frac{AZ^2+BZ+C}{DZ^3+EZ^2+FZ+G} \tag{11}$$

where,

$A = N^2\tau^2$
$B = N\tau[T(N-1) - 2N\tau]$
$C = N^2\tau(\tau - T) + T[T(N-1)^2 + N\tau]$
$D = 3N^2\tau^3$
$E = 3N\tau^2(-3N\tau + T)$
$F = 3\tau[3N^2\tau^2 - 2NT\tau + T^2(N-1)]$
$G = 3\tau[(-N^2\tau^2 + 3NT\tau - T^2(N-1)] +$
$T^3(N-1())^2$

N : Capacitance ratio
$\tau = 10^{-6} / 2\pi$
$T = 1/100KHz$

Also, the capacitance ratio N can required from Table 1. Note that it is to be the optimal value at N=3.

For $r = 1/2\pi \times 10^{-6}$, the upper half plane pole resulting from Eq.(8) and (11) is plotted as a function of fo in Fig.5. Even at 60KHz, the desired pole deviation from the imaginary axis is less than that of Reddy (2 OA N=3). Budak and Nay's (2 OA N= $\sqrt{3}$) at the much lower frequency of 14KHz and 50KHz. Furthermore, the locus

Table 1 Magnitude and phase of G(Z) for N.

N \ ωτ		0.000	0.004	0.008	0.012	0.016	0.020
2.9	G(Z)	3	3.0000007	3.0000030	3.0000069	3.0000126	3.0000204
	θ(Z)	0	- 0.0120370	- 0.0239230	- 0.0355065	- 0.0466364	- 0.0571610
3	G(Z)	3	3.0000000	3.0000000	3.0000002	3.0000007	3.0000017
	θ(Z)	0	0.0000247	0.001980	0.0006684	0.0015845	0.0030957
3.1	G(Z)	3	2.9999992	2.9999969	2.9999931	2.9999881	2.9999819
	θ(Z)	0	0.0109378	0.0220216	0.0333977	0.0452121	0.0576113
4	G(Z)	3	2.9999922	2.9999689	2.9999301	2.9998759	2.9998061
	θ(Z)	0	0.0764158	0.0764158	0.1529605	0.2297629	0.3069521

And, the magnitude and phase of G(Z) for N=3 are plotted in Fig.4. From the result of Fig.4, we can know that the magnitude and phase of G(Z) are satisfied perfectly the condition of Eq.(9).

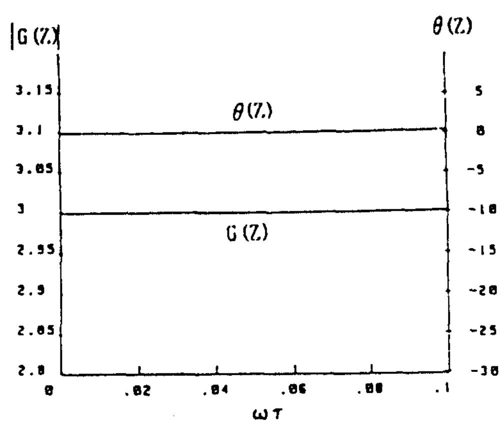


Fig. 4 Magnitude and phase of Fig.3(b) for N=3 (3 OA).

follows the imaginary axis almost perpectly for frequencies up to 20KHz. In interpreting these results, it should be realized that the horizontal axis is greatly expanded. Thus, the new circuits have shown that the frequency range can be improved considerably.

IV. Computer Simulation

The performance of the improved SC oscillator was tested using the open-loop measurements of in Fig.6.

In Fig.7, the theoretical loop-gain by Eq.(5) and (11) for N=3 as a function of ω/ω_0 using $\omega_0\tau$ as a parameter. For τ fixed, say $1/2\pi \times 10^{-6}$ these curves can be interpreted as being a function of the oscilltor frequency fo. Note that at $\omega = \omega_0$ as $\omega_0\tau$ is increased from), loop gain LG(Z) increases and the phase θ(Z) introduces more lag. Also, for each constant $\omega_0\tau$ curve,

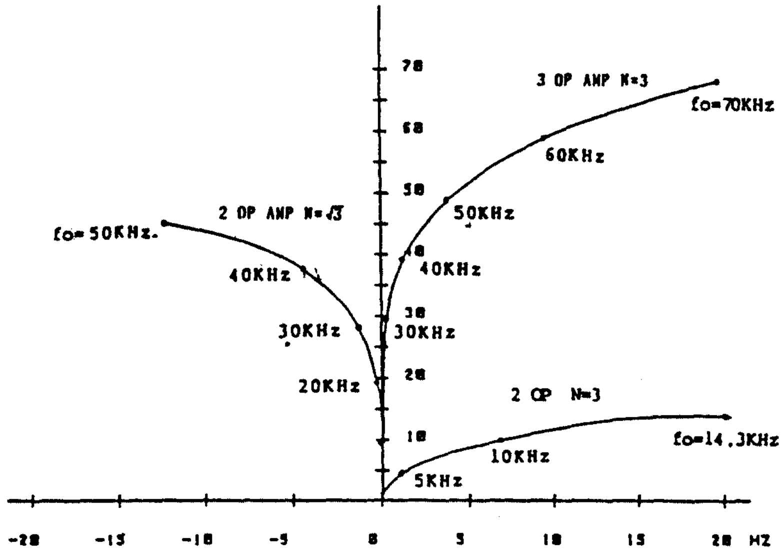


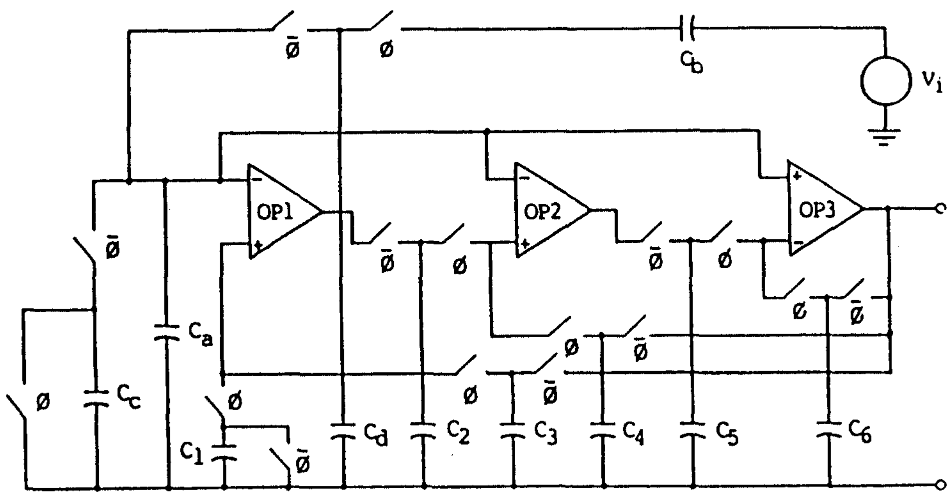
Fig. 5 Upper half plane pole loci as a function of fo.

a vertical line drawn, at the frequency that results in θ=O, would intersect the corresponding magnitude curve of loop gain at unity, or very nearly so, as shown by the dots. Only at the highest value of $\omega_0\tau$ is there a noticeable depature from unity.

Also, a new oscillator is satisfied that the loop gain has substantially the magnitude of 1 and phase of 0 in the Table 2.

Table 2, Loop gain frequency response for N=3 (3 OA)

$\omega_0\tau$	ω/ω_0	0.96	0.96	1.00	1.02	1.04
0.00	LG(Z)	0.9996328	0.9999125	1.0000033	0.9999162	0.9996616
	θLG	1.5593606	0.7717050	- 0.0000315	- 0.7564097	- 1.4981817
0.02	LG(Z)	0.9996334	0.9999131	1.0000039	0.9999168	0.9996622
20KHz	θLG	1.5624583	0.7748007	0.0030641	- 0.7533140	- 1.4950860
0.04	LG(Z)	9.9996422	0.9999215	1.0000127	0.9999256	0.9996710
40KHz	θLG	1.5841682	0.7965126	0.0247760	- 0.7316021	- 1.4733740
0.06	LG(Z)	0.9996801	0.9999598	1.0000506	0.9999635	0.9997089
60KHz	θLG	1.6433247	0.8556691	0.0839325	- 0.6724456	- 1.414276
0.07	LG(Z)	0.9997814	1.0000612	1.0001520	1.0000649	9.9998102
80KHz	θLG	0.7591895	0.9715339	0.1997973	- 0.5565807	- 1.2983527
0.10	LG(Z)	0.9999928	1.0002726	1.0003034	1.0002163	1.0000216
100KHz	θLG	1.9517082	1.1640426	0.3923160	- 0.3640621	- 1.1058341



OP AMP : CA3140, C_1, C_2, C_6 = 20pF

C_3, C_4, C_5 = 10pF

T = 1/100KHz (variable)

Fig. 6 The oscillator for analysis of loop gain.

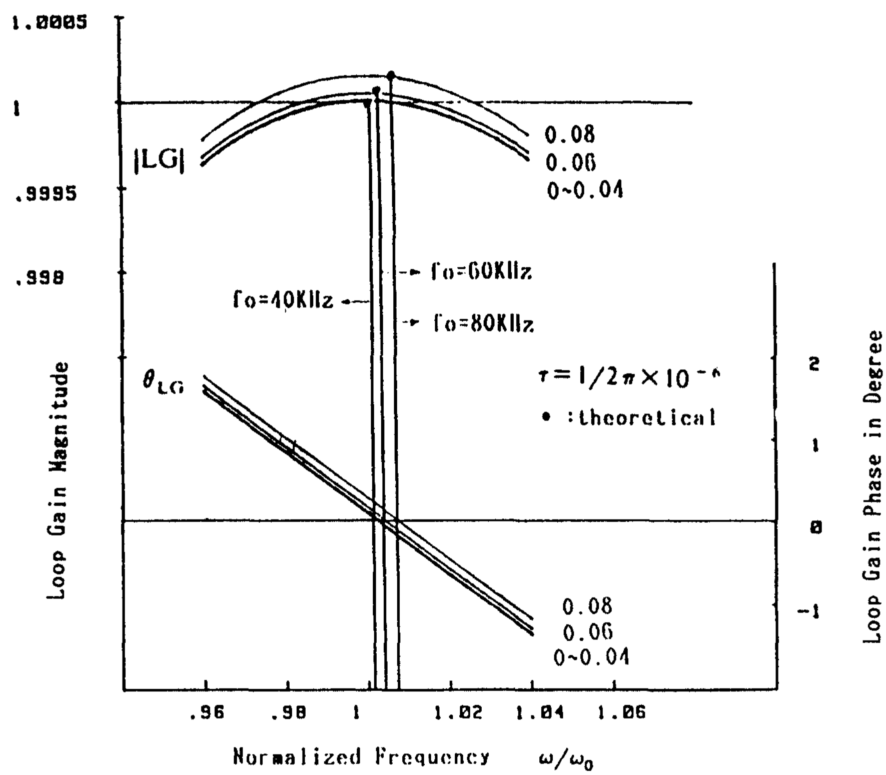


Fig. 7 Theoretical loop gain frequency response for N=3.

V. Conclusion

We have proposed the gain amplifier consisting of a new switched-capacitor circuits. And the performance of the improved oscillator has been tested using the open-loop measurement.

By properly shaping the magnitude and phase response of the advanced amplifier, it has been possible to keep the poles on the imaginary axis at much higher frequencies than Budak and Nay's, thus extending the range of operation of the oscillator.

However, this technique suffers from inherent problems due to sampling, such as: band-limited signal processing, clock feed trough, operational amplifier high frequency noise aliased into the base band etc.

Thus, we will develop further research using the MOSFET-capacitor circuits of analog continuous-time approach to avoid the problems.

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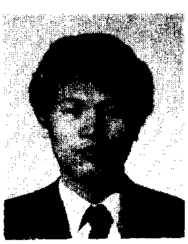

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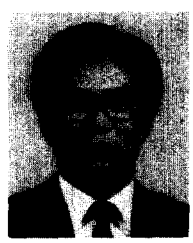

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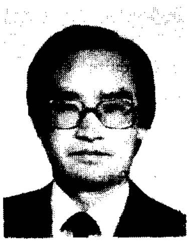

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