About Oscillators with Current Conveyors and De-Phasing Circuit with Current Divisor

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Abstract: - In this paper it was made a RC oscillator and its transfer function, and it was made a study of errors which affects frequency of oscillation. The paper point out the experimental results obtain through RC oscillator implementation with PA 630A current-conveyors showing that the current mode oscillators appears to be an interesting approach from the perspective of the simplicity/performance compromise.

Key-Words: - frequency, oscillator, de-phasing circuit

1 Introduction

This paper proposes a systematic approach on the generation of second order current mode RC oscillators (CMO-RC). Theoretically such current amplifiers can be easily obtained, and the use of the complementary bipolar process can be now used for the practical implementation of such high performance amplifiers. The generation is done by starting from a classification of the reactive oscillators designed by linear frequency selective network, a current repeater and an ideal current amplifier. This classification is made by the current transfer ratio of the opened loop obtainable while the loop is broken on either the input or the output of the current amplifier. For a given oscillator, should the amplifier and selective network be correctly identified, the transfer function is unique.

The block schema of a reactive RC oscillator is presented in figure 1, where by A we mean an ideal current amplifier (amplifier trans-resistance or trans-conductance), whose gain is

\[ A = \frac{i_i}{i_A} \] (1)

For a linear second order RC network, the current transfer function can be described as

\[ \beta(s) = \frac{a_2s^2 + a_1s + a_0}{b_4s^2 + b_2s + b_0} \] (2)

where \( s = j\omega \) is the complex frequency value and \( a_n \) (n=0,1,2) are real numbers. In practice only stable networks are of interest so the \( b_n \) (n=0,1,2) coefficients must be positive real numbers. Current buffer is an ideal current amplifier with unit gain and having an impedance adapter role between amplifier and the selective network. Because the selective network output current has to be a short circuit current and because the input amplifier has high impedance than the buffer presence is a must. To calculate the oscillating frequency and the gain of the amplifier from Figure 1, this has to self-start and to keep the sinusoidal oscillations, so it has to be applied Barkhausen formula, valid for any feed-forward oscillator, \( \beta \cdot A = 1 \). The values of coefficients from (2) for which formulas (3) and (4) have physics meaning will give us all transfer functions shapes acceptable for harmonic oscillator’s construction.

Fig. 1. The ideal current oscillator
For the circuit in figure 1 with the closed reaction loop, the \( \omega_0 \) angular oscillation frequency and the oscillation maintaining necessary gain \( (G_0) \) have the below expressions

\[
\omega_0 = \sqrt{b_0 b_2} \frac{1 - a_2 b_1}{a_1 b_0 b_2} \quad (3)
\]

\[
G_0 = \frac{b_1}{a_1} \quad (4)
\]

The above scopes will be further called “the oscillation frequency” and “maintaining gain”. Since the gain in (4) must be finite, the \( a_1 \) can’t be zero while expression (4) allows for \( a_0 \) and \( a_2 \) to be zero both simultaneously and each at a time.

## 2 Practical implementations

Our proposed oscillator scheme is an oscillator with de-phasing circuit with current divisor and grounded capacitor, with a CR net with a single section, separated through a current amplifier. The oscillator is the second type one and its net transfer function coefficients respect the following conditions: 

\[ a_2 = 0, a_0 \neq 0, a_1 \neq 0. \]

The oscillator transfer function result by multiply those two nets transfer functions followed by multiplication with amplifiers gain and has the following form (5):

\[
\frac{i_0}{i_i} = A \cdot A_1 \cdot \frac{k - 1 + skR_2C_2}{s^2R_1R_2C_1C_2 + s(R_1C_1 + R_2C_2) + 1} \quad (5)
\]

Using relation (5) and also the Barkhausen relation it can be measured the gain and pulsation necessary to keep sinusoidal oscillation.

\[
s^2R_1R_2C_1C_2 + s(R_1C_1 + R_2C_2 - kA_1AR_2C_2) + 1 - A_1A(k - 1) = 0 \quad (6)
\]

\[
R_1C_1 + R_2C_2 - kA_1AR_2C_2 = 0 \quad (7)
\]

\[
G_0 = A = \frac{1}{k} \left( 1 + \frac{R_1C_1}{R_2C_2} \right) \quad (8)
\]

\( G_0 \) is the maintaining gain. Available limits for \( k \) variation are given by restriction:

\[
0 < k < 1 + \frac{R_2}{R_1} \cdot \frac{C_2}{C_1} \quad (9)
\]

For particular case \( R_1 = R_2, C_1 = C_2 \), the maintaining gain becomes:

\[
G_0 = \frac{2}{k} \quad (10)
\]

Coming back to (6) and knowing that \( A_1 = 1 \) and \( s = j\omega \) it can be calculated oscillation frequency \( \omega_{osc} \):

\[
j^2\omega^2R_1R_2C_1C_2 + 1 - \frac{1}{k} \left( 1 + \frac{R_1C_1}{R_2C_2} \right)(k - 1) = 0 \quad (11)
\]

\[
\omega_{osc}^2 = \frac{1 - k - 1}{k} \left( 1 + \frac{R_1C_1}{R_2C_2} \right) \quad (12)
\]

\[
\omega_{osc} = \frac{1}{\sqrt{R_1R_2C_1C_2}} \sqrt{1 - \frac{k - 1}{k} \left( 1 + \frac{R_1C_1}{R_2C_2} \right)} \quad (13)
\]

Noting with \( S_2 = \sqrt{1 - \frac{k - 1}{k} \left( 1 + \frac{R_1C_1}{R_2C_2} \right)} \) scale factor for which \( R_1 = R_2, C_1 = C_2 \), has the value \( S_2 = \sqrt{\frac{2 - k}{k}} \).

Into this situation, “k” variation limits become:

\[
0 < k < 2 \quad (14)
\]
The top edges given by relations (9) and (14) for “k” are meaningless because “k” high value equals unit. Practically speaking, this means that there are no restrictions for “k” value. Amplifier A₁ can not missing because it has also the role to separate the used nets. The scale factor can be modified between zero and infinite. This can get for very restricted variations of G. For particular situation of resistances and capacities respectively equals, the scale factor for the circuit from Figure 2 can be modified between unit and infinite, while “k” varies between zero and unit.

For the created oscillator, the required gain for the sustaining of a unary transfer ration in the loop, was ensured by the first differential stage, all the other active stages, having a unary gain. One can’t discard the use of the current repeating stage because we require the RC de-phasing networks to be evaluated against their current behavior.

For the implementation of a SIDO stage we require two PA630 current conveyors, while for the implementation of a current repeater there was only one PA630 current conveyor required.

To avoid the latch-up phenomenon specific to the PA630 current conveyor, we will use (if required) on the Z outputs of the conveyor, some 3.6V Zenner diodes (DZ3V6), in series with 1N4148 fast diodes, as shown in the PA630 catalogue. Obviously the use of such diodes will lead to a change in the loop transfer ratio and also of the oscillation amplitude.

The conveyors polarization was done according to the catalogue schemas, by ensuring a polarization current of 1.26mA. In order to implement the RC de-phasing circuits, we used 1% tolerance metal foil resistors, high precision capacitors (1-2% precision) and high tolerance electrolytical capacitors (20-50) % tolerance.

The correctness of the circuit running has been verified using specialized OrCAD PSpice 10.5 soft. The current conveyors we're designed by NS 3905 and NS3904 transistors (see figure 3), and the obtained shapes of waves are in Figure 4.

Fig. 3 RC oscillator with PA630
In following label could be noticed the evolution of measured frequency values opposite the calculated ones, when the $C_1$ and $C_2$ value 47nF. It is noticed that for $R_1$ and $R_2$ values growing the frequencies values are decreasing (both measured and calculated values) until its equals and so the relative value decreases, too.

Table 1

<table>
<thead>
<tr>
<th>No.</th>
<th>$R_1$-$R_2$ [Ω]</th>
<th>Measured frequency [Hz]</th>
<th>Calculated frequency [Hz]</th>
<th>Relative error [%]</th>
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3 Conclusions

This paper showed that using of current mode circuits has some practical advantages confronted by conventional devices with voltage operating mode, such as higher working speed and a better working linearity. Speaking about this aspect, one of this paper goal is, first of all, to show that the current mode circuits can be used to produce high frequency oscillations and to show in what conditions this could be happened.

It is usual that the electronic device performances used in oscillators to be expressed by some feature of output signal, such as: maximum frequency, frequency stability, distortion level.

Speaking about the highest limitation of working frequency, this depends of many intrinsic parameters of the semiconductor or of the electronic device design. High operating speeds, meaning high frequency of oscillations, offer many other devices with semiconductors such as semiconductors of bipolar types or with field effect, diodes with negative resistance which are already used in very high frequencies technique.

Frequency stability depends, first of all, by stability of passive elements values with environment factors, of which the most important is the temperature the others such as humidity and pressure have low influences. The electronic device temperature produced by the environment or by dissipate energy on device can affect the frequency stability frequency less than passive elements. The temperature influence can be reduced through a judicious semiconductor microchip design so that dissipative high power junctions to carry out an intensive heat transfer towards external surface.

One observes the stability of the amplitude and the oscillation frequency obtained with the current mode oscillator is superior the ones obtainable by means of voltage mode circuits.
References: