Comparative Analysis of Proportional Integral Derivative Controller Using CCII and DVCC

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Abstract- *In this paper realization of PID controller using CCII (Current Conveyor II) and DVCC (differential voltage current conveyor) is done using PSpice. PID controller has very much importance in current industry scenario. Normally operational amplifier is used for analog controlling but we can use the CCII and DVCC in place of OPAMP due to having more stability, wider frequency range and lower power consumption as compared to OPAMP.*

In this paper , In the first section we will discuss about proportional (P), integral (I) and derivative (D) and proportional integral derivative (PID) controller. Then in next sections, we realized the PID controllers by CCII and differential voltage current conveyor and in both current and voltage mode.

Keywords- DVCC, PID controller, OPAMP, CCII

I. INTRODUCTION

It is observed that approximate 90% of all control loops involve PID controllers [1] due to their simplicity in design, easiness in parameter tuning, and cheap in cost [3]. A PID controller consist (1) proportional, (2) integral, and (3) derivative. The proportional term control the speed of response of the system, the integral term control the steady-state error of the system and the derivative term control the degree of stability of the system.

It is well known that a PID controller can be realized using op-amp circuits (integral, derivative and proportional circuits together with a summer circuit) as shown in Figure 1. It can be seen from the Figure that the circuit contains four op-amps and ten floating passive elements.

Contrary to PID controllers realized with OP-AMPs, PID controllers designed by the current conveyors provide good results, such as greater linearity, wider bandwidth, better dynamic range, less chip area, less power dissipation and easy realization, etc. [3,4]. The second-generation current conveyor (CCII) has proved to be a versatile analog building block that can be used to implement numerous high frequency analog signal applications.

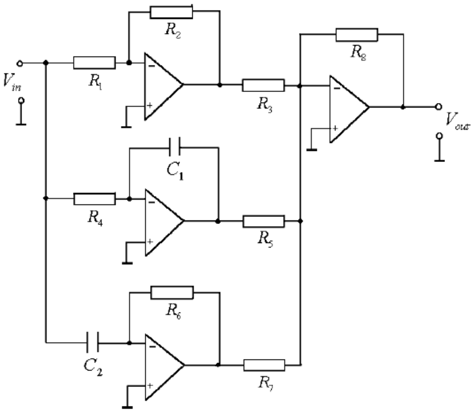

Figure 1. PID controller using op-amp

However, when it comes to applications demanding differential or floating inputs like impedance converter circuits and current mode instrumentation amplifiers, which also require two high input impedance terminals, a single CCII block is no more sufficient. In addition, most of these applications employ floating elements in order to minimize the number of used CCII blocks. For this reason and in order to provide two high input impedance terminals, two active building blocks, namely, the differential voltage current conveyor (DVCC) have been proposed in the late 90s. Although this building blocks has been used in a variety of applications, their CMOS circuit realizations exhibited mainly low input and output dynamic ranges. CDBA is a universal element for filter design, primarily for voltage-mode operation. Some of the applications from the basic CDBA feature, i.e. the non-problematic implementation of both non inverting and inverting integrator as a building block of filters of arbitrary order.

A. Proportional Controller

Proportional control is a simple and widely used method of control for many kinds of systems. With this type of controller, the controller output (control action) is proportional to the error in the measured variable. The error is defined as the difference between the current value (measured) and the desired value (setpoint). If the error is large, then the control action is large. Mathematically:

$$C(t) = K_c * e(t) + C_s \text{.................................(i)}$$

where e(t) represents the error, Kc represents the controller's gain, and Cs represents the steady state control action necessary to maintain the variable at the steady state when there is no error.

B. Integral Controller

Integral control is what we have when the signal driving the controlled system is derived by integrating the error in the system. The transfer function of the controller is K_i/s, if you think in terms of transfer functions and Laplace transforms. With integral action, the controller output is proportional to the amount of time the error is present. Integral action eliminates offset that remains when proportional control is used.

The integral term is given by

$$\text{controller output} = \frac{1}{T_i} * \text{int(error)}$$

or

$$I_{out} = K_i \int_0^t e(\tau)\, d\tau \text{ ....(ii)}$$

Where I_{out} is Integral term of output, K_i is Integral gain, a tuning parameter and e is error = SP − PV , t is Time or instantaneous time (the present), τ: a dummy integration variable, the parameter T_i is called the integral time. Integral action is also known as reset and the parameter T_i as reset time.

C. Derivative Controller

The derivative function looks at the rate at which the proportional offset changes over time (thus the term derivative) and adjusts the output of the controller as required to minimize the rate of change. When properly applied, the derivative function will help to minimize the deviation from set point that a system will experience when it sees a sudden change in the requirements of the process.

The rate of change of the process error is calculated by determining the slope of the error over time (i.e., its first derivative with respect to time) and multiplying this rate of change by the derivative gain K_d. The magnitude of the contribution of the derivative term (sometimes called rate) to the overall control action is termed the derivative gain, K_d.
The derivative term is given by:

$$\text{controller output} = T_d * \frac{d(\text{error})}{dt} = T_d * \frac{d(SP - PV)}{dt}$$

$$D_{out} = K_d \frac{d\,e(t)}{dt} \text{ ....(iii)}$$

Where D_{out} is Derivative term of output, K_d is Derivative gain, a tuning parameter and e is error = SP − PV , t is Time or instantaneous time (the present), the parameter Td is called derivative time.

II. PID CONTROLLER USING CCII

The current mode and voltage mode controllers are shown in figure 2.

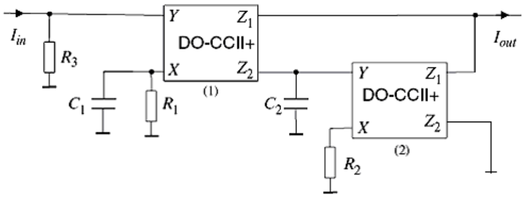

Figure 2. PID Controller using CCII (a) current mode

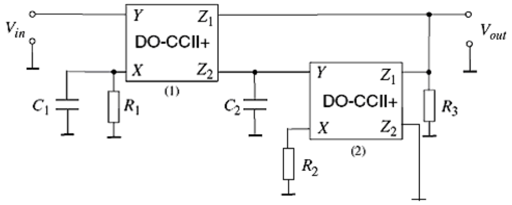

Figure 2. PID Controller using CCII (b) voltage mode

Transfer function of the circuit are

$$H_v(s) = \frac{V_{out}(s)}{V_{in}(s)} = K_{pv} + \frac{1}{sT_{iv}} + sT_{dv}$$
$$\text{...........................(iv)}$$

$$H_i(s) = \frac{I_{out}(s)}{I_{in}(s)} = K_{pi} + \frac{1}{sT_{ii}} + sT_{di}$$
$$\text{...........................(v)}$$

the proportional gain (K_p=K_{pi}=K_{pv}), the integral time constant (T_i =T_{ii} =T_{iv}) and the derivative time constant (T_d =T_{di} =T_{dv}) parameters of both PID controllers are as:

$$K_p = \alpha_1 \beta_1 \frac{R_3}{R_7} + \alpha_2\, \beta_1 \beta_2\, \gamma_1\, \frac{C_1 R_3}{C_2\, R_2}$$
$$\text{...........................(vi)}$$

$$T_i = \frac{C_2 R_1 R_2}{\alpha_2 \beta_1 \beta_2 \gamma_1 R_3} \quad \text{(vii)}$$

$$T_d = \alpha_1 \beta_1 C_1 R_3 \quad \text{(viii)}$$

where, α_1, α_2, β_1, β_2 and γ_1 are in form of multiplier constants for the parameters.

III. PID CONTROLLER USING DVCC

It should be noted that using a single DVCC and two grounded admittances Y1 and Y2, it is easy to construct the basic current processing block as shown in Figure 3[8-10] which has the following transfer function

$$I_{out\,1} = \frac{Y_2}{Y_1} I_{in} = -I_{out\,2} \quad \text{(ix)}$$

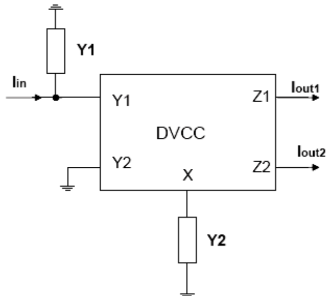

Figure 3. DVCC based basic current processing block

By choosing Y_1 and Y_2 appropriately, various basic blocks operating in CM can be obtained:

(A) Amplifier: If the admittances are $Y_1 = 1/R_1$ and $Y_2 = 1/R_2$, the current-mode amplifier can be found as

$$\frac{I_{out\,1}}{I_{in}} = -\frac{I_{out\,2}}{I_{in}} = \frac{R_1}{R_2} \quad \text{(x)}$$

The gain of the amplifier can be adjusted by changing R_1 and R_2.

(B) Integrator: If the admittances are $Y_1 = sC_1$ and $Y_2 = 1/R_2$ the current-mode integrator can be achieved as

$$\frac{I_{out\,1}}{I_{in}} = -\frac{I_{out\,2}}{I_{in}} = \frac{1}{sC_1 R_2} \quad \text{(xi)}$$

(C) Differentiator: If the admittances are $Y_1 = 1/R_1$ and $Y_2 = sC_2$ the current-mode differentiator can be obtained as

$$\frac{I_{out\,1}}{I_{in}} = -\frac{I_{out\,2}}{I_{in}} = sC_2 R_1 \quad \text{(xii)}$$

The current mode and voltage mode controllers are shown in figure 4. The circuit consist two DVCC and grounded passive element which is important in IC implementation.

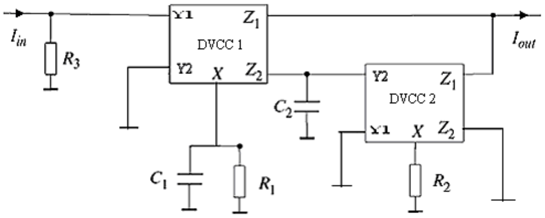

Figure 4. PID Controller using DVCC (a) current mode

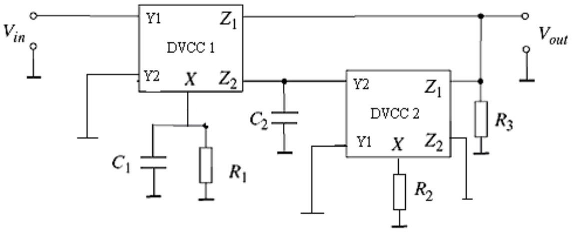

Figure 4. PID Controller using DVCC (b) voltage mode

Transfer function of the circuit are same as equation (iv)-(viii).

IV. SIMULATION RESULT

A. PID Controller using CCII

(i) Current Mode PID:

For this mode we have taken R1= 0.5k, R2=R3=1k and C1=C2=100pF and calculated the Kpi=3,Tii=50ns and Tdi=10-7 s.

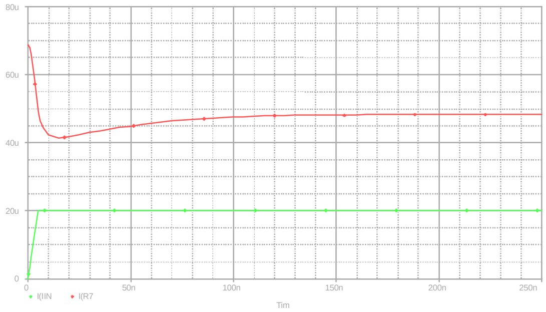

Figure 5. Simulation of PID Controller in current mode

(ii) Voltage Mode PID:

For this mode we have taken R1=.5k, R2=R3=1k and C1=C2=100pF and calculated the Kpi=1.001, Tii =50ns, and Tdi=10-7 s.

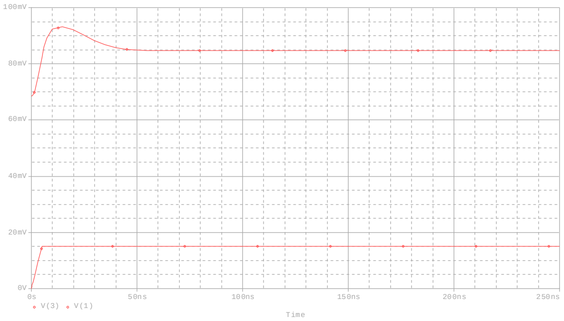

Figure 6. Simulation of PID Controller in voltage mode

B. PID Controller using DVCC

(i) Current Mode PID:

For this mode we have taken R1=R3=10k, R2=1M and C1=C2=10nF and calculated the Kpi=1.0001,Tii =10-2 s, and Tdi=10-4 s.

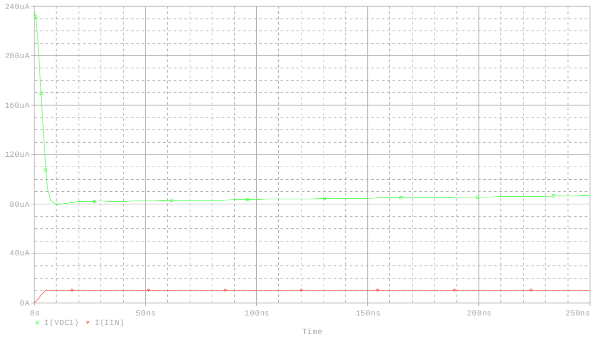

Figure 7. Simulation of PID Controller in current mode

(iii) Voltage Mode PID:

For this mode we have taken R1=R3=1k, R2=1M and C1=C2=10pF and calculated the Kpi=1.0001, Tii =10-5 s, and Tdi =10-8 s.

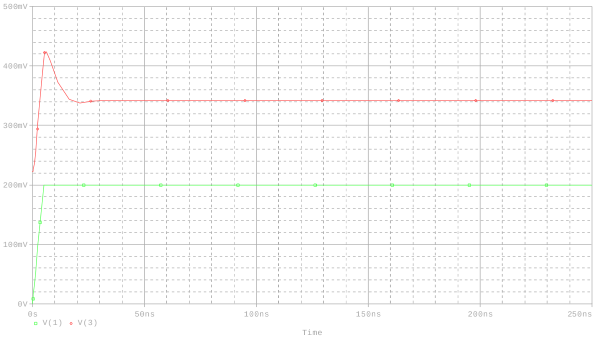

Figure 8. Simulation of PID Controller in voltage mode

V. CONCLUSION

PID controller using CCII and DVCC in current mode and voltage mode is realized and performance analysis of each mode is done using Pspice (CMOS version of active element).

We observe that realization of PID using op-amp required four op-amps and ten floating passive elements.

PID controller using CCII employs two CCII and five passive elements (two capacitors and three resistor), which are all grounded.

However PID controller realization using DVCC required two DVCC and only three passive elements (two capacitors and five resistor), which are all grounded.

So, it requires less chip area and having less power consumption and also employ grounded passive element in the circuits which is advantageous from the integrated circuit implementation point of view.

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