# New Chopper Modulators Using Differential Voltage Current Conveyor

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**Abstract.** *This paper presents new chopper modulators which can enable to assign three modulators in one circuit. Full amplitude modulators as Cowan and Ring modulators are kinds of the amplitude modulators as well. The proposed circuit is implemented from the differential voltage current conveyor, four-MOS transistors switch and two-MOS transistors inverter. The advantage of this proposed circuit is high-input and low-output impedance and is able to be connected with any load without buffer and the number of transistors is quite less which is suitable for integrated circuits. The technique is to control the switch by using the square pulse which is obtained from a direct signal generator. All simulation results are based on the PSPICE program simulator which confirms the performance of the proposed circuit and technique.*

## Keywords

Chopper modulator, differential voltage current conveyor, Cowan modulator, ring modulator, AM modulator.

## 1. Introduction

Second generation current conveyors (CCIIs) have been found very useful in many applications. This is attributed to their high signal bandwidths, greater linearity, and larger dynamic range than operational amplifiers (op-amps) based ones [1]–[3]. Recently, a new current conveyor circuit called the differential voltage current conveyor (DVCC) was presented [4]. This circuit has been developed and realized next by Elwan and Soliman [5]. The DVCC has the advantages of both the CCII and the differential amplifier (DA) (such as high input impedance and arithmetic operation capability).

An amplitude modulation (AM) is a technique that modulates between a baseband signal with the frequency $f_m$ and a carrier signal with the frequency $f_c$, where $f_c$ is much higher than $f_m$, the amplitude of an AM output signal is controlled by the baseband amplitude and its frequency is equal to $f_c$. The full amplitude modulation (Full-AM), the double side band suppress carrier (DSBSC) and the single side band (SSB) are three common types of AM. Either sine wave or square wave can be used as the carrier signal. If the carrier signal is the square wave, it is called 'chopper modulator' [6]. The chopper modulator uses the square wave carrier to chop the baseband signal. Typically, a chopper modulator using the square wave carrier is better than using the sine wave carrier in the case of a conventional AM modulator because the square wave oscillator consists of lesser devices than the sine wave oscillator [7]. The chopper modulators can be divided into Cowan and Ring modulators that use diodes and transformers as their components. The Cowan circuit balances out the carrier only to produce the DSBSC form of the output but with the baseband also present. Thus it is a single balanced modulator. It requires more filtering at the detector than the Ring circuit which balances out both carrier and baseband and so acts as a double balanced modulator.

Recently, a new technique for realizing Cowan and Ring chopper modulators using a current conveyor analogue switch is proposed as shown in Fig. 1 [7]. In this circuit, the carrier signal is applied through the bias current of the current conveyor which makes chop signal possible through the bias current. The advantages of this circuit identified by the author are the following:

- The chopper modulators based on current conveyors are suitable for integrated circuit implementation.
- The proposed chopper modulators offer low power consumption.
- The modulation index of the proposed AM chopper modulator can be easily applied to an automatic over-modulation protection system.

When referencing three items mentioned, the circuit of [7] is a good chopper modulator circuits for IC fabrication. However, it suffers from three disadvantages. First, it uses an excessive active component. Second, the carrier signal is of the current form which applies through the bias current of the current conveyor but a relaxation square wave oscillator is of the voltage form. Therefore, an additional voltage-to-current converter is maybe required. Third, it is suitable for a high impedance load. If the low impedance load is applied, the circuits need a voltage buffer at an output.

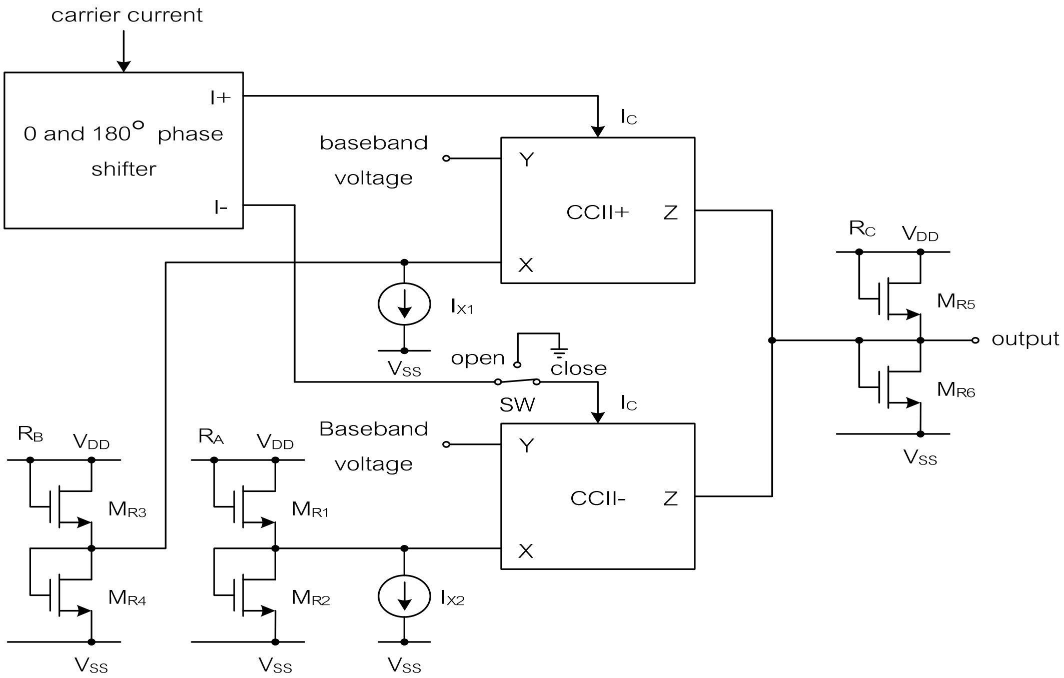



**Fig. 1.** Chopper modulators proposed by Monpapassorn [7].

In this paper, we pursue the objective of developing chopper modulators that are suitable for IC fabrication. We propose a new circuit that improves on the advantages of the circuit of [7] while overcoming the disadvantages. The proposed circuit employs one DVCC, four MOS switches, and one inverter circuit. In particular, the circuit has the following features:

- The proposed chopper modulators use 18 MOS transistors whereas the proposed rectifier in [7] uses 43 MOS transistors; hence when the rectifier circuits are fabricated, the proposed rectifier will use smaller area of chip than the previous rectifier.
- The voltage square wave signal of the relaxation oscillator can be directly controlled by the MOS switch without additional voltage-to-current converter.
- It possesses low output impedance voltage signal.

## 2. Circuit Description

Fig. 2 shows the symbol of the DVCC. The CMOS implementation for DVCC can be shown in Fig. 3 [5]. The port relations can be characterized by the following matrix equation:

$$\begin{pmatrix} V_X \\ I_{Y1} \\ I_{Y2} \\ I_Z \end{pmatrix} = \begin{pmatrix} 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} I_X \\ V_{Y1} \\ V_{Y2} \\ V_Z \end{pmatrix} \quad (1)$$

The proposed Cowan, Ring, and Full-AM chopper modulators are shown in Fig. 4 as a circuit consisting of one DVCC, four-MOS transistors switch ($M_{S1}$ to $M_{S4}$), one MOS inverter ($M_{C1}$ and $M_{C2}$) to provide inverting phase and one switch (SW). Each type of modulations can be achieved by selecting the switch (SW) and the constant voltage source ($V_{DC}$). An inverter circuit in Fig. 4(b) is used to control transistors $M_{S1}$ to $M_{S4}$. The input and output of this inverter is out of phase. Compared to chopper modulators in [7], the circuit in this paper employs lesser MOS transistors and has low-output impedance.

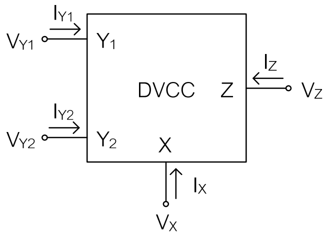



**Fig. 2.** Electrical symbol of DVCC.

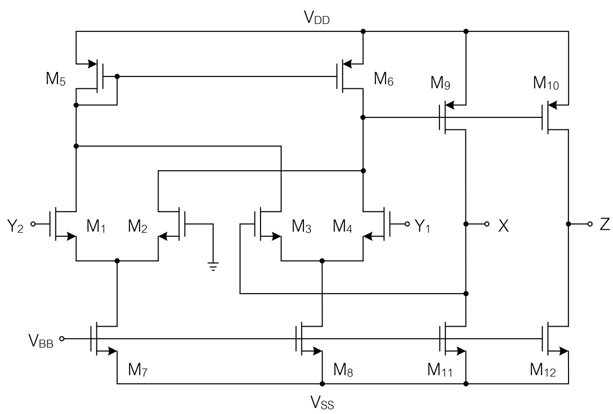
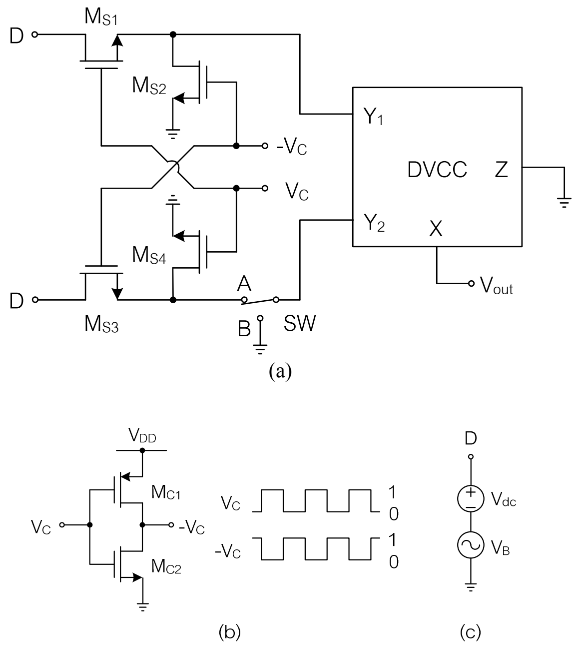



**Fig. 3.** CMOS implementation for DVCC.




(b)

**Fig. 4.** (a) Proposed chopper modulators, (b) MOS inverter and (c) adder voltages between $V_{dc}$ and $V_B$.

| Chopper type | SW | $V_{DC}$ |
|---|---|---|
| Cowan | B | not used |
| Ring | A | not used |
| Full-AM | A | used |

**Tab. 1.** Using proposed chopper modulators.

The proposed circuit will operate as a Cowan chopper modulator when SW is opened (B) and $V_{DC}$= 0 V. For these conditions, the square wave carrier voltage $V_C$ and the square wave carrier voltage $-V_C$ are supplied to control the MOS switches $M_{S1}$–$M_{S4}$ and $M_{S2}$–$M_{S3}$, respectively. Using (1), it finds that the output is a baseband signal chopped at the carrier rate, which is the Cowan output. Again, if setting SW to close (A) and $V_{DC}$=0V, a Ring output can be obtained. The square wave carrier voltages $V_C$ and the square wave carrier voltage $-V_C$ are applied to control a two-MOS switch $M_{S1}$–$M_{S4}$ and a two-MOS switch $M_{S2}$–$M_{S3}$, respectively. Using (1), it achieves an output that swings from the negative to positive of the baseband signal at the carrier rate. It is the operation of the Ring chopper modulator.

A new AM chopper modulator products the output to be similar to the output of the conventional AM using a sine wave carrier. This means that its output frequency is equal to the carrier frequency and its output amplitude depends on the baseband amplitude. In order to obtain these, SW has to be closed (A) and $V_{DC}$ is used. In this case, if we want to shift these signals as the upper and lower envelopes of the complete AM signal, two signals have to be shifted up with an offset higher than $V_B$ peak. These shifting are carried out by the use of the fixed voltage ($V_{DC}$), namely the modulation index is controlled by $V_{DC}$. Hence, to avoid the over-modulation, the condition of $V_B$ peak must be used. Therefore, AM chopper modulator products can be obtained by using $V_{DC} > V_{B(peak)}$ and the closed SW when $V_C$ and $-V_C$ make that $V_{Y1}$ and $V_{Y2}$ alternately operate at the carrier rate, the output ($V_X$) of the proposed circuit is the envelopes of the AM signal chopped at the carrier rate. That is the AM chopper output. The conditions of SW and $V_{DC}$ for each chopper modulator are concluded in Tab. 1.

Note from the proposed chopper modulators that it requires an adder circuit for adding DC voltage ($V_{DC}$) and baseband signal ($V_B$) (Fig. 4(c)). In this case, $V_{DC}$ and $V_B$ maybe directly cascaded. For integrated circuits, the adder circuit can be obtained by using an additional DVCC. It can achieve by modifying the DVCC in Fig. 3 by floating the gate $M_2$ to obtain additional plus type input ($Y_3$). The voltages $V_{DC}$ and $V_B$ are applied to $Y_1$ and $Y_3$, respectively, and the minus type input ($Y_2$) is attached to ground.

## 3. Simulation Results

To verify the theoretical prediction of the proposed circuit, the proposed chopper modulator in Fig. 4 has been simulated using PSPICE simulation program. The CMOS DVCC in Fig. 3 was simulated using the 0.5μm MIETEC [8]. The transistor aspect ratios are listed in Tab. 3 [8] and the supply voltages were $V_{DD}$=$-V_{SS}$= 2.5 V and the biasing voltage was $V_{BB}$=-1.7 V. The aspect ratios of the transistors in Fig. 4 used are W/L = 2μm/1μm for $M_{S1}$ to $M_{S4}$, W/L = 8μm/1μm for $M_{C1}$ and W/L = 20μm/1μm for $M_{C2}$.

Applying the 200 mVpeak of 10 kHz sine wave at $V_B$, the 1.5 V of 100 kHz square wave at $V_C$ of the proposed circuit and selecting SW = B and $V_{DC}$= 0 V, the output waveform of Cowan chopper modulator can be shown in Fig. 5. Under the same condition, if SW is changed to A position, the output waveform of Ring chopper modulator can be shown in Fig. 6.

Again, if $V_{DC}$= 0.25 V is applied and SW is still A position, the output waveform of AM chopper modulator can be shown in Fig. 7. These show the relations of square wave carriers, sine wave basebands and chopper modulator outputs that correspond to the theory. In simulation, the frequencies of the carrier and the baseband are chosen to be simple to understand the operation of the chopper modulators.

| MOS transistor | W/L |
|---|---|
| $M_1$–$M_4$ | 1.6/1 |
| $M_5$–$M_6$ | 8/1 |
| $M_7$–$M_8$ | 20/1 |
| $M_9$–$M_{10}$ | 29/1 |
| $M_{11}$–$M_{12}$ | 90/1 |

**Tab. 2.** Transistor aspect ratios of the used DVCC.

| Parameter | Proposed circuit | Conventional circuit [6] | Circuit of [7] |
|---|---|---|---|
| Components | 1 DVCC (12 MOS's),<br>4 MOS switches,<br>1 inverter (2 MOS's) | 1 transformer,<br>4 diodes | 1 CCII+ (13 MOS's),<br>1 CCII- (17 MOS's),<br>3 MOS resistors (6 MOS's),<br>1 phase shifter circuit (7 MOS's),<br>5 current sources |
| Supply voltage | ±2.5V | - | ±1.5V |
| Input range | ±0.5V | - | ±0.3V |
| Power consumption | 2mW | - | 0.8mW |
| Suitable for IC | Yes | No | Yes |

**Tab. 3.** Comparison of proposed chopper modulators with those of previous circuit.

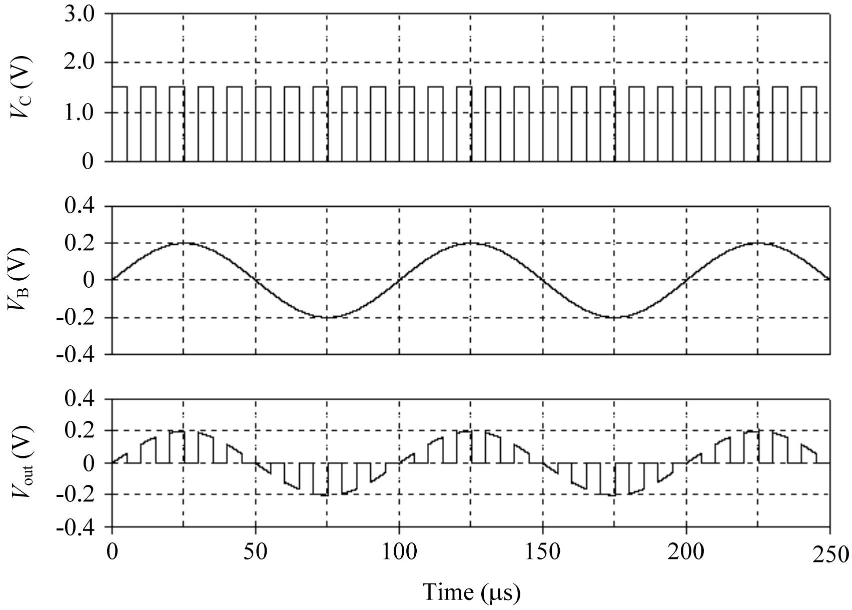



**Fig. 5.** Operation of the proposed Cowan chopper modulator.

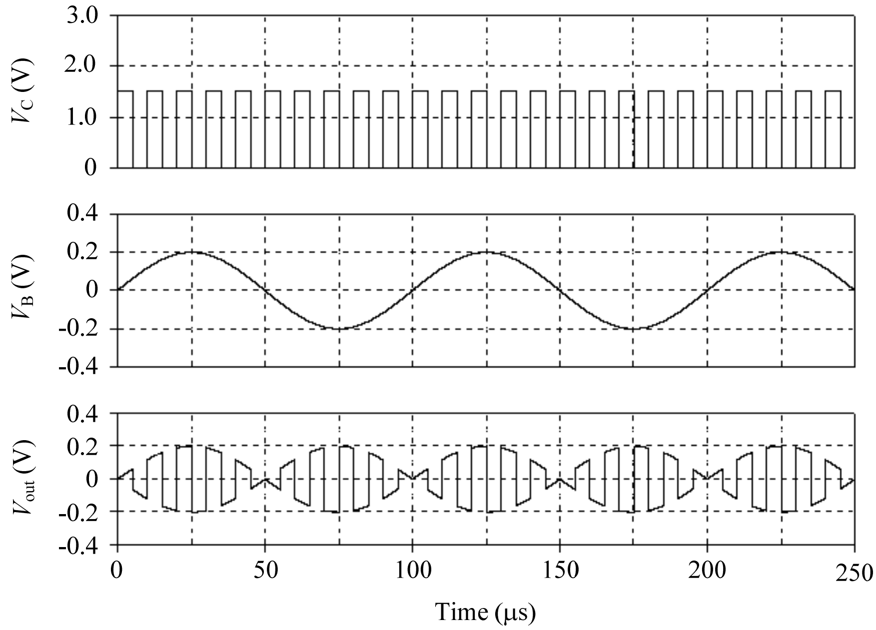



**Fig. 6.** Operation of the proposed Ring chopper modulator.

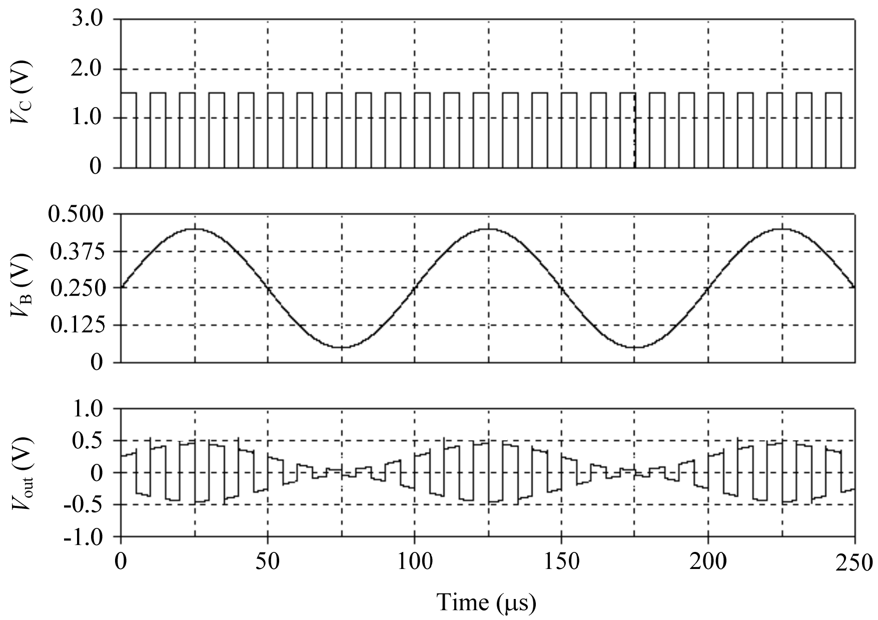



**Fig. 7.** Operation of the proposed AM chopper modulator.

# 4. Conclusions

In this paper, new Cowan, Ring, and AM chopper modulators using DVCC has been presented. The proposed chopper modulators yield the advantages in view of using all MOS structure to be easy for IC fabrication, low component count and adjusting modulation index by a controlling voltage to be easy to protect the over-modulation. The proposed chopper modulators are suitable for electronic communication applications. A comparison of this paper and previous works is summarized in Tab. 1. It is evident from Tab. 1 that the proposed circuit employs lesser circuit components. Then, it exhibits more suitable for IC implementation than these previous works.

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