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Collation of Operations Between a mono transistor Amplitude and a Balanced Amplitude Modulators

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Abstract

In this article we study simple amplitude and balanced amplitude modulators and compare the result of them. Both of them can produce the standard amplitude modulation signal. The simple amplitude modulator has one bipolar transistor and it has upper THD , lower DC gain and lower generative power. But the balanced amplitude modulator is structured of the differential stage of bipolar transistors and it has lower THD , upper DC gain and upper generative power and these are important advantages for this modulator.

Key words: Gain; Transistor; Differential; Modulator; Balanced Introduction

1. Introduction

However the modulation systems are old but they are used still in communication systems. Modulation and coding are processes that performed in transmitter for accessing to effective and dependable transfer. There are different methods for modulation. One of them is Amplitude modulation or AM. In this modulation method a signal that we want to transmit it, changes the Amplitude of the other signal.

One common kind of amplitude modulation is the standard sinusoidal amplitude modulation. There are different circuits for this kind of modulation, for example: mono transistor AM modulator circuit and balanced AM modulator circuit with differential stage.[2],[3],[4]

In this paper we study the resuls of a research about designing and comparison of results of the simulation of two circuits: a mono transistor AM modulator circuit and a balanced AM modulator circuit with differential stage that both of them are made of bipolar transistors, to represent the operation of the balanced AM modulator circuit with differential stage.

2. Circuit selection and simulation

1-2. Circuit selection

At first we select a circuit from each sample to simulate it . For monotransistor modulator we select the circuit of figure 1 and for balanced modulator with differential stage we select the circuit of figure 2 .

The output of both circuits if they designed correctly will be standard amplitude modulation.

2-2. Monotransistor modulator

Take into consideration the curcuit of figure 1 . We design and simulate it by the help of Hspice software . After designing the ultimate amounts of the curcuit parameters are as the amounts of table 1. For designing we use the BC548 witch is an NPN silicon epitaxial transistor.[7]

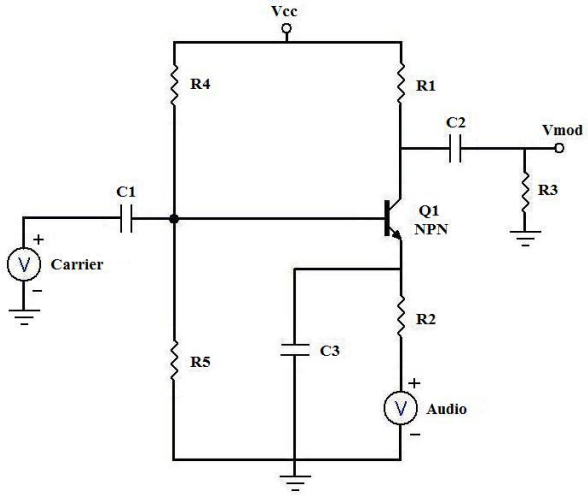

Fig1 : The circuit of the mono transistor amplitute modulator [5]

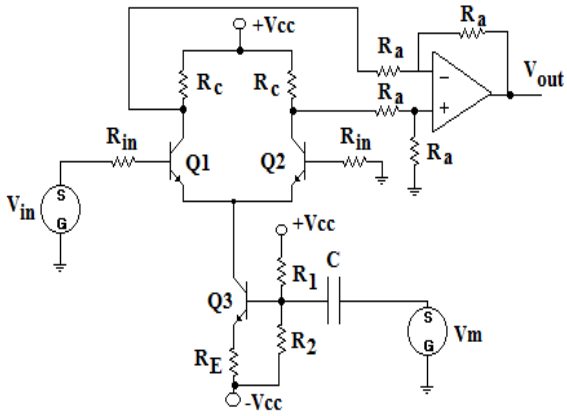

Fig 2 : The circuit of balanced amplitude modulator with differential stage [6]

Element	R1 (KΩ)	R2 (KΩ)	R3 (KΩ)	R4 (KΩ)	R5 (KΩ)	C1 (pf)	C2 (nf)	C3 (nf)
Amount	4.7	1	56	15	100	470	100	100

TABLE 1 : amounts related to the elements of the curcuit of shape 1 .

For simulation , we apply one signal with the amplitude of 5v and frequency of 1 KHZ to V(G2)as a voice signal and one high frequency signal with the amplitude of 10mv and frequency of 200 KHZ as a carrier signal to V(G1) .
The input signals and AM output signal which is resulting from transient analysis of circuit are as the figure 3 .

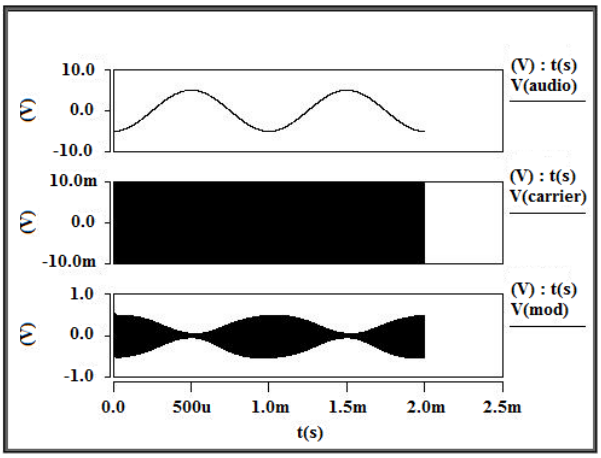

Fig 3 : The input signals and output AM signal of the circuit of figure 1 .

We see that the AM output signal of the circuit is standard. Figure 4 showes the AC analysis related to output node of circuit of figure 1 .

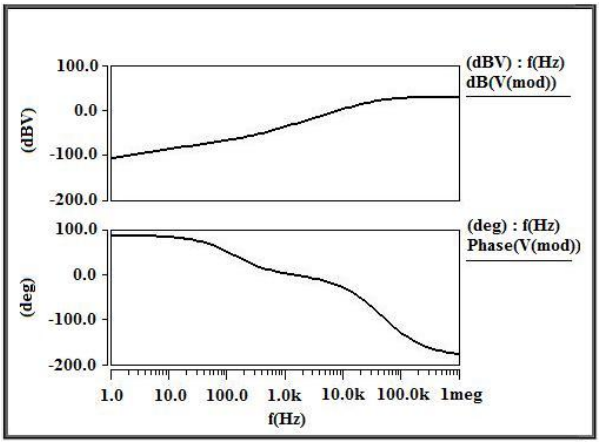

Fig 4 : AC analysis of circuit of figure 1 .

By the use of fourier Analysis , hspice software calculate Fourier series of the output signal of transient analysis and by the use of it calculates the THD[1] of circuit .
Total harmonic distortion =5.1204 percent .
By use of noise Analysis hspice software calculate noise parameters of circuit of figure 1. For this case at first as the figure 5 an external noise source with the amplitude of 1mv is affixed to the circuit of the figure 1.

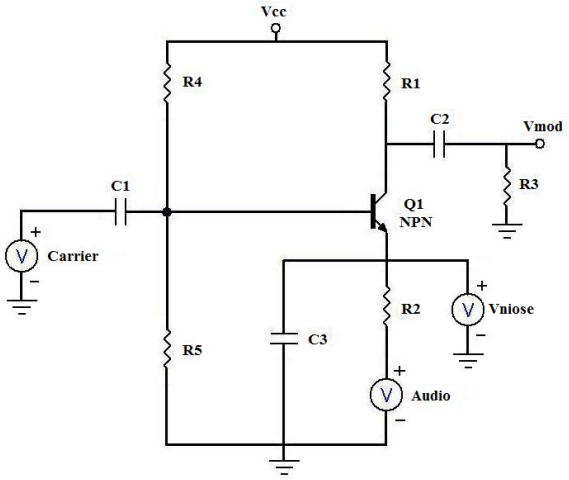

Fig 5 : The circuit of the mono transistor amplitute modulator with external noise source

Now we use noise analysis to achieve the noise parameter of circuit of figure 1 due to external noise source. The result is:

total output noise voltage = 16.1292a sq v/hz
= 4.0161n v/rt hz
transfer function value: v(3)/vn = 207.6952m
equivalent input noise at vn = 19.3366n /rt hz
the results of the sqrt of integral (v**2 / freq)
from fstart upto 48.6968k hz. using more freq points
results in more accurate total noise values.
total output noise voltage = 892.3435n volts
total equivalent input noise = 1.3789m
and the waveform of output signal of circuit of figure 5 is as figure 6. We see that the output signal of the circuit is not an AM signal. Then we use noise analysis to achieve the noise parameter of circuit of figure 1 due to internal sources . At first the carrier source, The result is:

total output noise voltage = 138.1109a sq v/hz
= 11.7521n v/rt hz
transfer function value: v(3)/vg2 = 18.1345
equivalent input noise at vg2 = 648.0505p /rt hz

[1] - Total harmonic distortion

the results of the sqrt of integral (v**2 / freq)
from fstart upto 48.6968k hz. using more freq points
results in more accurate total noise values.
total output noise voltage = 1.6210u volts

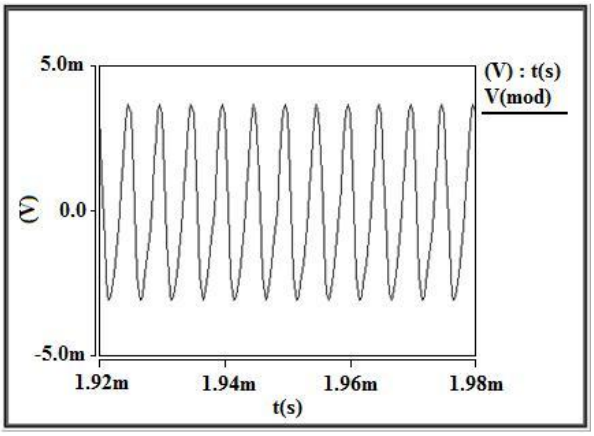

Fig 6 : waveform of output signal of circuit of figure 5.

total equivalent input noise = 51.8221m
Then the Audio source, the result is:

total output noise voltage = 138.1109a sq v/hz
= 11.7521n v/rt hz
transfer function value: v(3)/vg1 = 126.1552m
equivalent input noise at vg1 = 93.1556n /rt hz
the results of the sqrt of integral (v**2 / freq)
from fstart upto 48.6968k hz. using more freq points
results in more accurate total noise values.
total output noise voltage = 1.6210u volts
total equivalent input noise = 658.7494u

In both states, the noise of internal elements of circuit has not any effect on the output signal and the output signal is standard AM signal as figure 7.

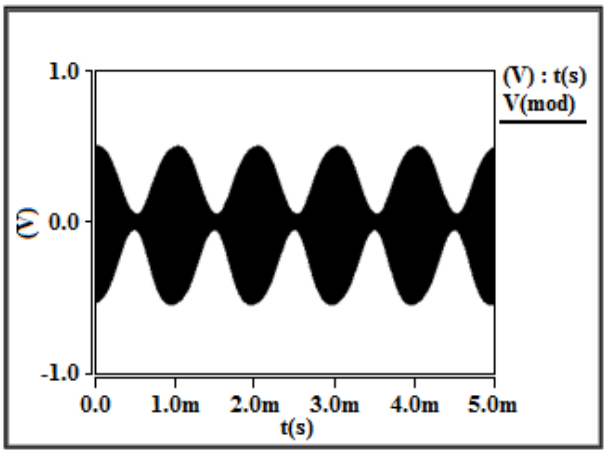

Fig 7: output AM signal of the circuit of figure 5.

3-2. Balanced modulator with differential stage

Now take figure 2 into consideration [6] . We design this circuit by the help of Hspice software too . For designing ,we should take into consideration that , because we want to compare the results of this circuit with the curcuit of figure 1 , so we take the used OP-AMP in the curcuit as ideal and equal to gain of 1 . Like the former case , for the designing we have used a BC548 transistor which is an NPN silicon epitaxial transistor . [7]
The ultimate amounts of the circuit parameters of figure 2 after designing is as table 2 .

Element	Amount	Element	Amount
R1 (kΩ)	3	Ra (K Ω)	15
R2 (kΩ)	1	C (µF)	10
Rin (Ω)	97	Vcc (V)	20
Rc (kΩ)	1	Q1-Q3	BC548
Re (Ω)	680		

TABLE 2: The ultimate outcome of the elements of circuit of figure 2 after designing

Like the former case . For studying and comparing the circuits under the same conditions , for simulation , we apply one signal with the amplitude of 5v and frequency of 1 KHz as a voice signal to V(m) and one high frequency signal with the amplitude of 10mv and frequency of 200KHz as a carrier signal of RF to V(in) . The input signals and output AM signal resulting of analytic transient of curcuit is as the figure 8.

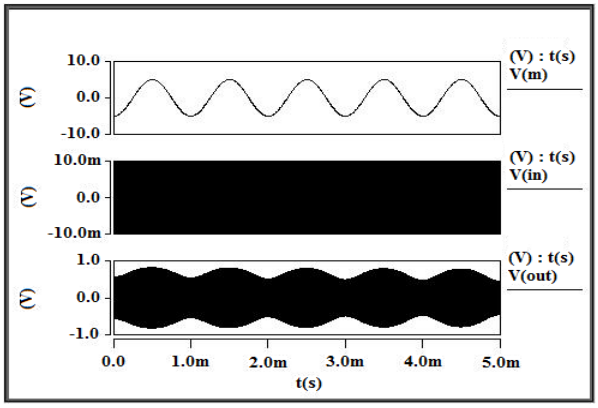

Fig 8 : Input signals and AM output signal of the circuit of figure 2 .

Figure 9 showes the AC analysis related to output node of circuit of figure 2 . By the use of fourier Analysis , hspice software calculates Fourier series of output signal of transient analysis and by the use of it calculates THD of curcuit .

Total harmonic distortion = 543.3247m percent .

Similar to former case by use of noise Analysis hspice software calculate noise parameters of circuit of figure 2. For this case at first as the figure 10 an external noise source with the amplitude of 1mv is affixed to the circuit of the figure 2.

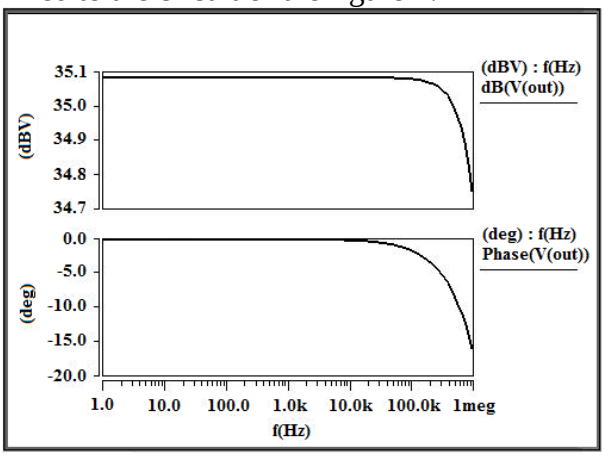

Fig 9 : AC anlysis of the curcuit of figure 2 .

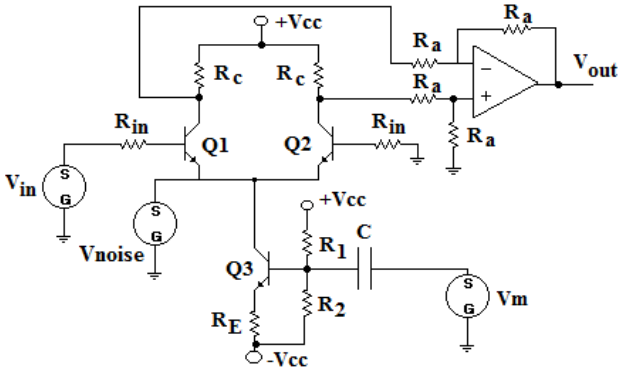

Fig 10 : The The circuit of balanced amplitude modulator with differential stage with external noise source

Now we use noise analysis to achieve the noise parameter of circuit of figure 2 due to external noise source. The result is:

total output noise voltage = 110.9116a sq v/hz
= 10.5315n v/rt hz
transfer function value: v(13)/vn = 1.108e-21
equivalent input noise at vn = 9.501e+12 /rt hz
the results of the sqrt of integral (v**2 / freq)
from fstart upto 48.6968k hz. using more freq points
results in more accurate total noise values.
total output noise voltage = 2.3240u volts
total equivalent input noise = 1.649e+17

and the waveform of output signal of circuit of figure 10 is as figure 11. We see that the output signal of the circuit is not an AM signal. Then we use noise analysis to achieve the noise parameter of circuit of figure 2 due to internal sources.

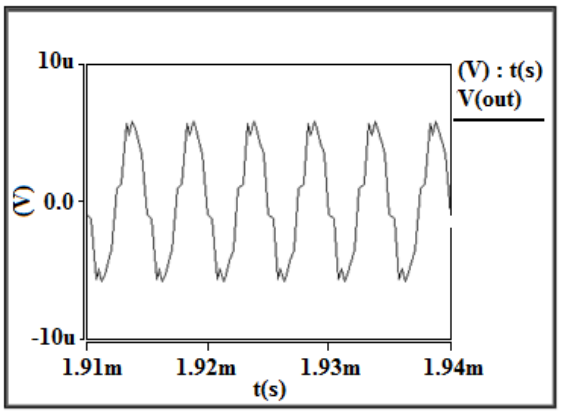

Fig 11 : waveform of output signal of circuit of figure 10.

At first the carrier source, The result is:

total output noise voltage = 12.1658f sq v/hz
= 110.2988n v/rt hz
transfer function value: v(13)/vin = 56.7783
equivalent input noise at vin = 1.9426n /rt hz
the results of the sqrt of integral (v**2 / freq)
from fstart upto 48.6968k hz. using more freq points
results in more accurate total noise values.
total output noise voltage = 24.3414u volts
total equivalent input noise = 428.6804n

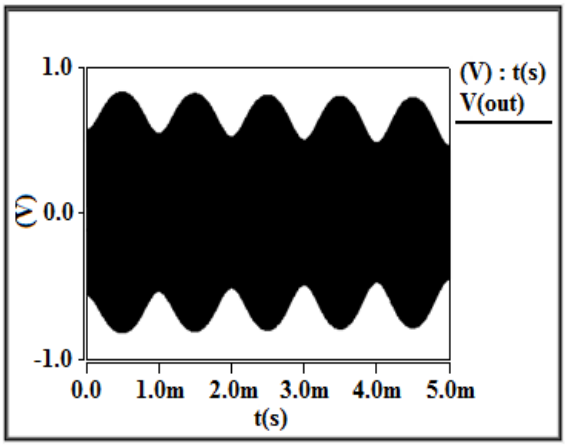

Fig12: output AM signal of the circuit of figure 10.

Then the Audio source, the result is:

total output noise voltage = 12.1658f sq v/hz
= 110.2988n v/rt hz
transfer function value: v(13)/vmod = 16.5040f
equivalent input noise at vmod = 6.6832x /rt hz
the results of the sqrt of integral (v**2 / freq)
from fstart upto 48.6968k hz. using more freq points
results in more accurate total noise values.
total output noise voltage = 24.3414u volts
total equivalent input noise = 1.4792g
In both states, the noise of internal elements of circuit has not any effect on the output signal and the output signal is standard AM signal as figure 11.

3. Comparison between two curcuits

Figures 13 and 14 are in order to show the output resulted of transient analysis of circuits of figures 1 and 2 . Peak to peak amplitude of the output voltage of the circuit of figure 1 according to figure 13 is :
0.49447-(-0.54712) = 1.04159v .
Peak to peak amplitude of the output voltage of the circuit of figure 2 according to figure 14 is:
0.80593-(-0.8058) = 1.61173v .

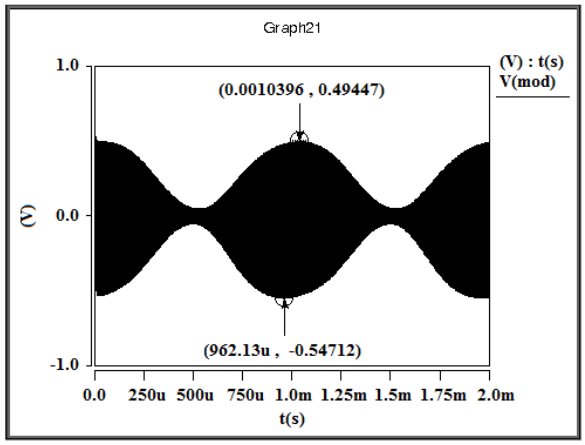

Fig 13 : AM output signal of the curcuite of figure 1 .

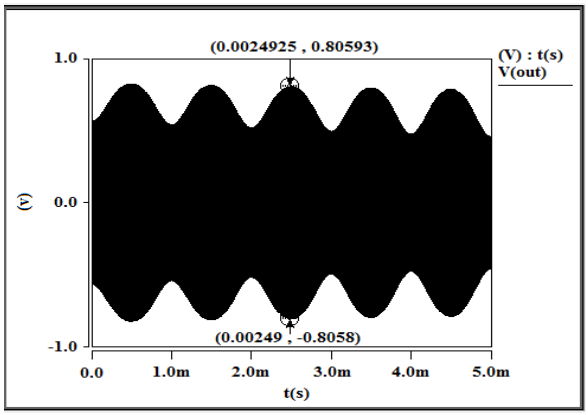

Fig 14 : AM output signal of the curcuite of figure 2.

The amount of output DC offset voltage of the circuiti of figure 1 is :

0. 49447-(0.520792) = -0.026323v

And the amout of DC offset of output voltage of the circuiti of figure 2 is :
0.80593-(-0.8058) = 6.5e-5v

Therefor , the peak to peak amplitude voltage of balanced modulator with differential stage is much and the amount of DC offset of output voltage of it is less than the amplitude of peak to peak voltage and the amount of DC offset of output voltage of monotransistor modulator .
THD of the balanced amplitude modulator is less than the mono transistor modulator, this means that the balance is a linear modulator than the mono transistor modulator.
The noise analysis of both of circuits has same result. In both of circuit the noise of internal elements of circuit has not any effect on the output signal and the output signal is standard AM signal, but the noise of external noise source has effect on the output signal and the output signal is not AM signal.

4. Conclusion

According to what said , although both circuit of figure 1 and 2 are able to produce AM signals , but balanced modulator has higher DC gain and lesser THD because of the use of differential stage and therefore AM produced by it , will have high peak to peak voltage and more importantly it will have more power and better quality . The important result is that except in balanced modulator , modulation is done at a low power level and then it's amplified to acheive the optimal level. But the modulator with balanced circuit directly amplified the carrier amplitude (high frequency) which has acheived to optimal level by the use of amplifier [1],[8] .

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