BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Department of Electrical and Electronic Engineering

Course No: EEE 208(s)
Course Title: Electrical Circuits Laboratory
Project Title: Frequency Division Multiplexing

Submitted to:

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Project Title: Frequency Division Multiplexing (FDM)

Introduction:

In real life, signal transmission is a very important factor to control the overall data flow of every system. FDM enables single transmission mediums, such as copper cable or fiber optic cable, to be shared by multiple independent signals that are generated by multiple users. In frequency-division multiplexing (FDM), multiple signals are combined for transmission on a single communications line or channel, with each signal assigned to a different frequency (subchannel) within the main channel.

What is Frequency division multiplexing:

In telecommunications, frequency-division multiplexing (FDM) is a technique by which the total bandwidth available in a communication medium is divided into a series of non-overlapping frequency bands, each of which is used to carry a separate signal. To accommodate the successful transmission of multiple signals over a single line, FDM separates the assigned frequency bands signal with the help of carrier signals. The proper selection of carrier signals prevents overlapping between signal frequencies over a shared medium.

Theory:

The multiple separate information that are sent over an FDM system, such as video signals, audio signals that are sent over a transmission system are called baseband signals. At the source end for each baseband frequency an electronic oscillator generates a carrier signal, that serves to carry information. The carrier signal frequency is much higher than the baseband signal frequency. Here in this project, we used sinusoidal waves as the baseband signals. The carrier signal and baseband signal are combined (multiplied in time domain) in a modulator circuit. This modulator alters some aspect of the carrier signal, such as amplitude, frequency, or phase, with the baseband signal.

The result of modulating (mixing) the carrier with the baseband signal is to generate sub-frequencies near the carrier frequency, at the sum ($f_C + f_B$) and difference ($f_C - f_B$) of the frequencies.

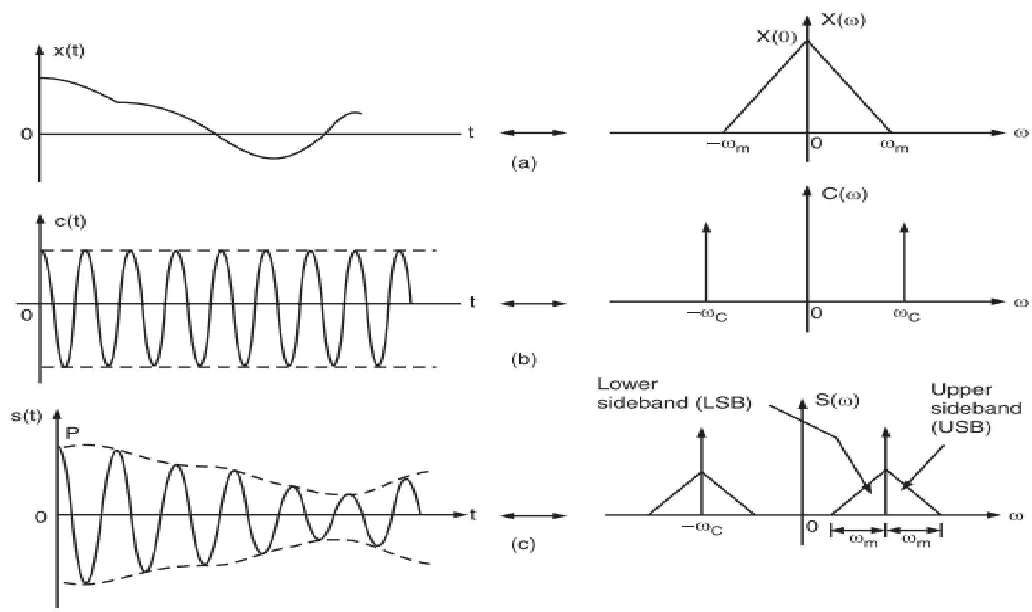
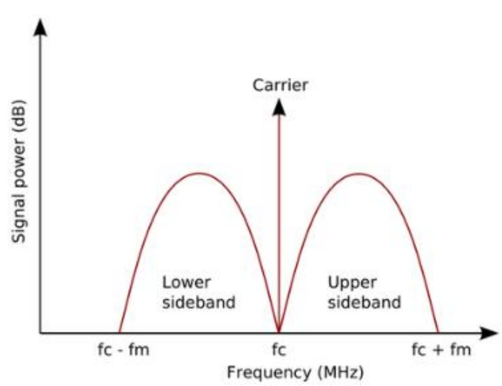


Fig: Modulation process - a) baseband signal b) carrier signal c) modulated signal

The information from the modulated signal is carried in sidebands on each side of the carrier frequency.



Therefore, all the information carried by the channel is in a narrow band of frequencies clustered around the carrier frequency, this is called the passband of the channel.

Similarly, additional baseband signals are used to modulate carriers at other frequencies, creating other channels of information. The carriers are spaced far enough apart in frequency that the band of frequencies occupied by each channel, the passbands of the separate channels, do not overlap. All the channels are sent through the transmission medium, such as a coaxial cable, optical fiber, or through the air using a radio transmitter. As long as the channel frequencies are spaced far enough apart that none of the passbands overlap, the separate channels will not interfere with each other. Thus, the available bandwidth is divided into "slots" or channels, each of which can carry a separate modulated signal.

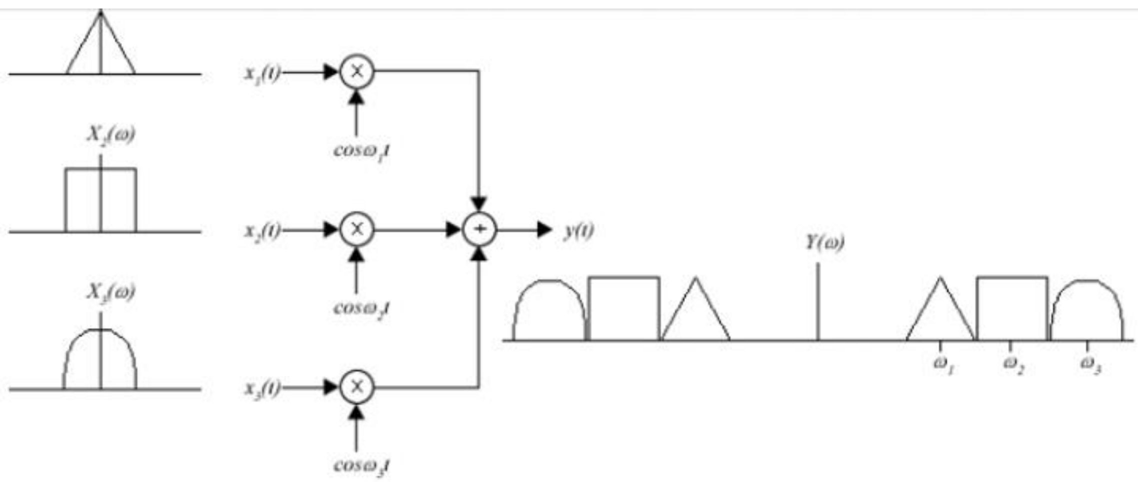


Fig: FDM-Modulation

Now the modulated transmission signal is passed through the band pass filter. And then at the destination end of the cable or fiber, or the radio receiver, for each channel a local oscillator produces a signal at the carrier frequency of that channel, that is mixed with the incoming modulated signal. The frequencies subtract, producing the baseband signal for that channel again. This is called demodulation. The resulting baseband signal is filtered out of the other frequencies and output to the user.

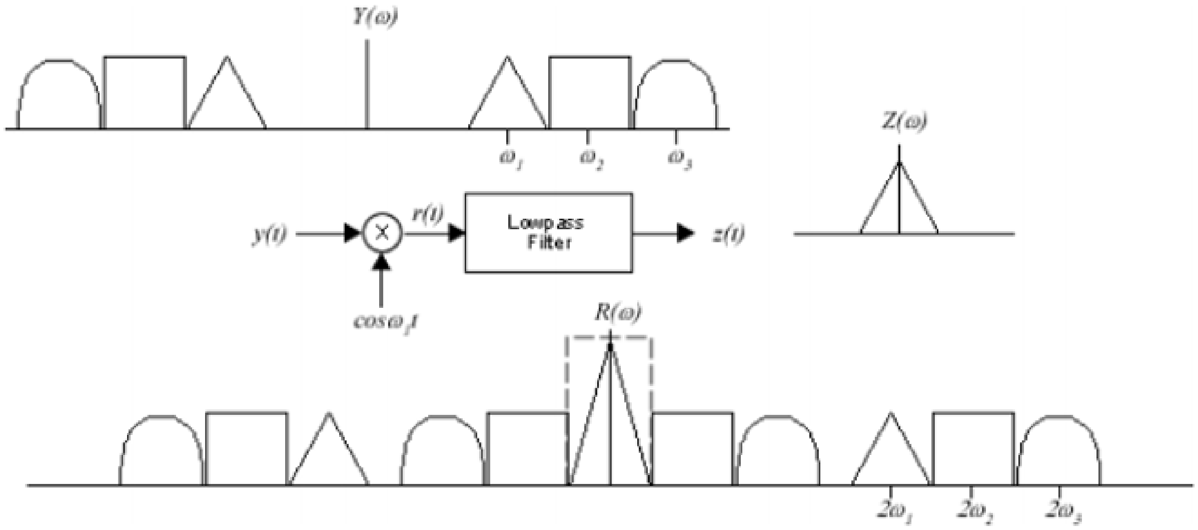


Fig: FDM-Demodulation

Project simulation Process through pspice

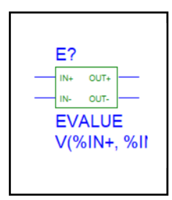
In this project we transmitted sinusoidal signals as baseband frequencies through a single transmission channel.

Here is list of design components needed to implement a sample fdm model circuit:

- DC source (+15v)
- Function generator(sinusoidal)
- General Purpose Op-Amp(uA741)
- Evalue

  AD633

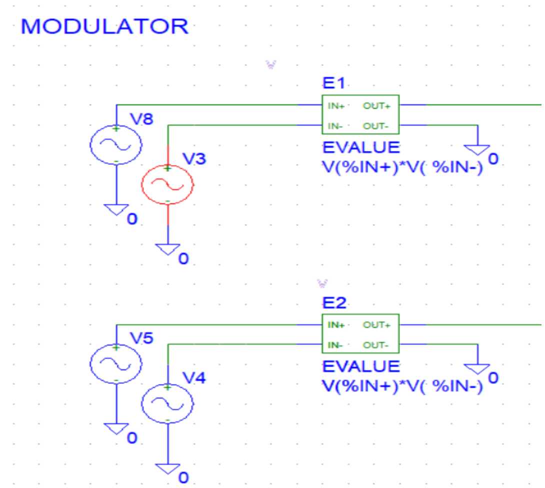
  IRfp460
- Resistor
- Capacitor
- Bubble
- Analog ground



At first, we should go through the modulation process to preprocess the baseband signals.

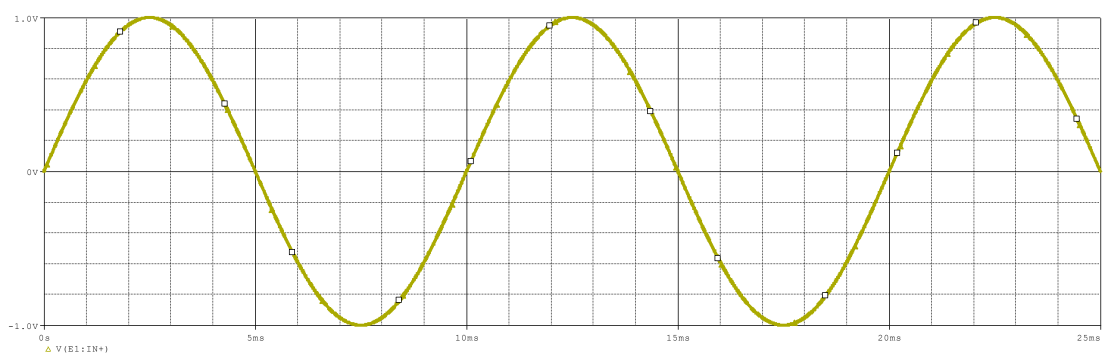
Modulator circuit:

In case of building a modulator circuit we need to multiply our signal with the carrier signal.



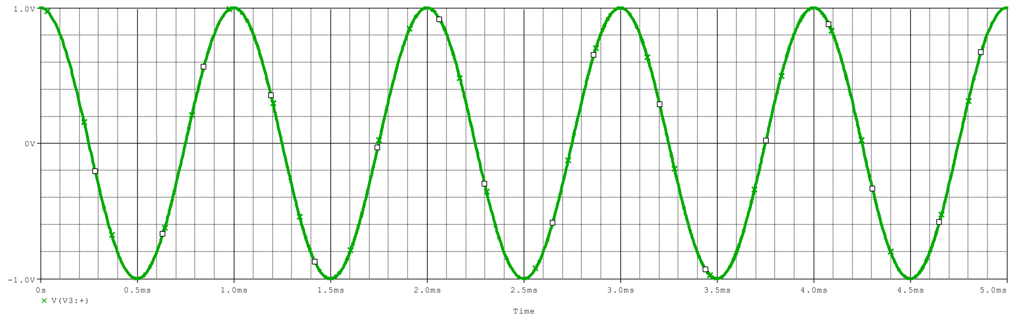
In this modulator circuit V8 and V5 is baseband signal of 100Hz and 200Hz respectively.

Baseband signal 1 (V8) f=100Hz:

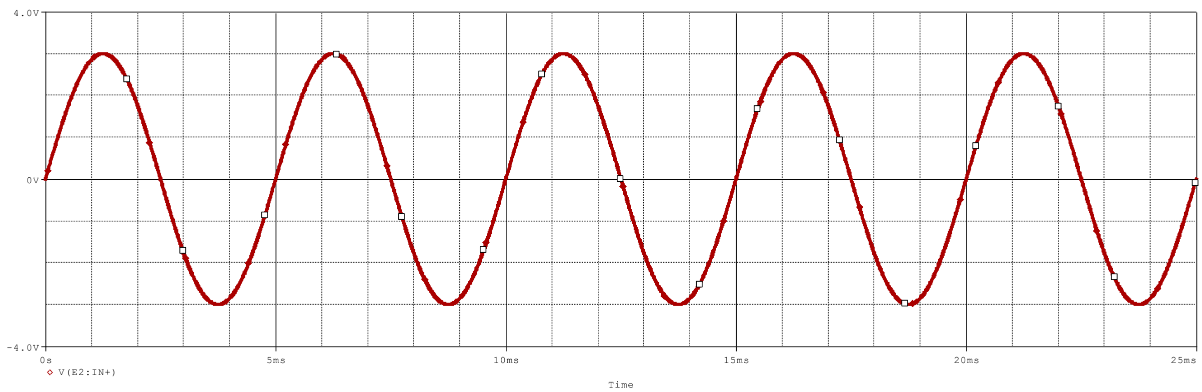


Carrier signal corresponding to baseband signal 1(V8):

V3= $\cos(2\pi 1000t)$

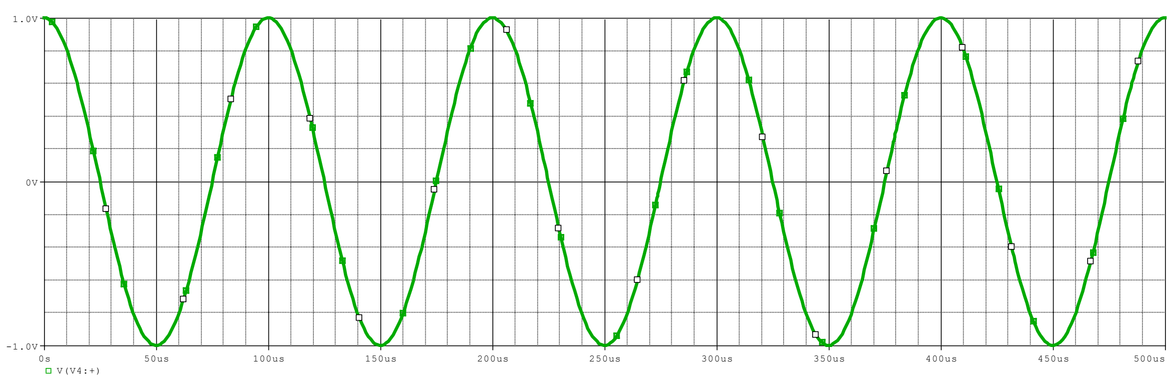


<u>Baseband Signal 2 (V5) f=200Hz:</u>

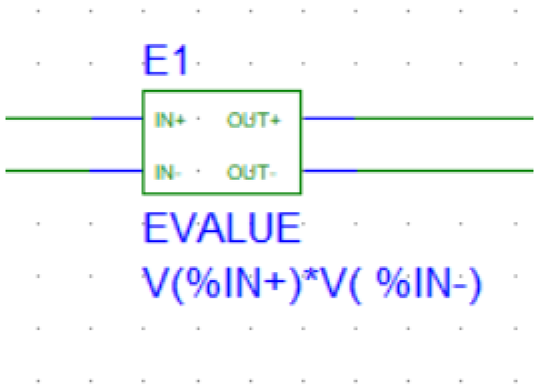


<u>Carrier signal corresponding to baseband signal 2(V5):</u>

V4=cos $(2\pi 10000t)$



Multiplier Circuit (to shift the baseband frequencies around the carrier frequency):



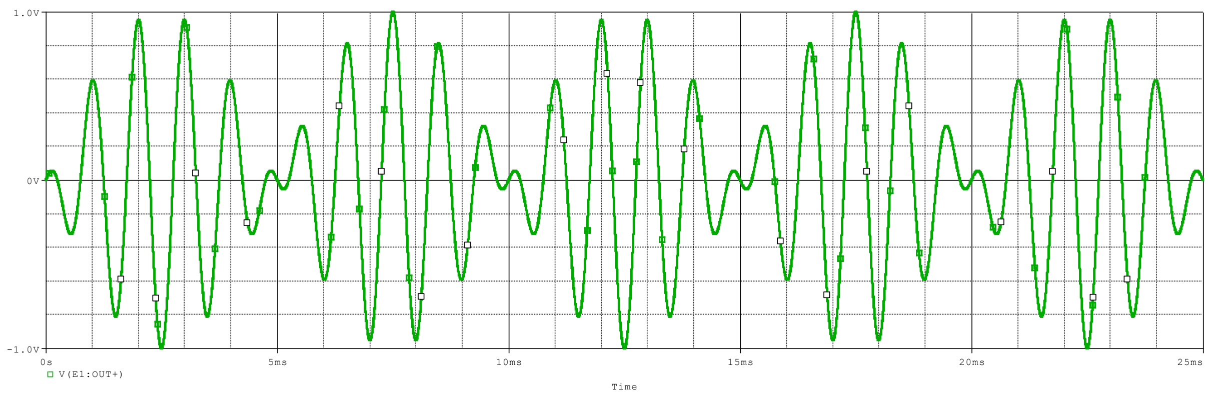
The multiplier circuit uses a tool of Analog behavior modeling of PSpice library. This block takes two inputs at its input pin, does the required operation of the two signals at every instance and gives the result at the output pin.

Here EVALUE is determined by V(%IN+) * V(%IN-) which multiplies the given signals. And the multiplied signal appears in Out+ node. So, output is taken from that node

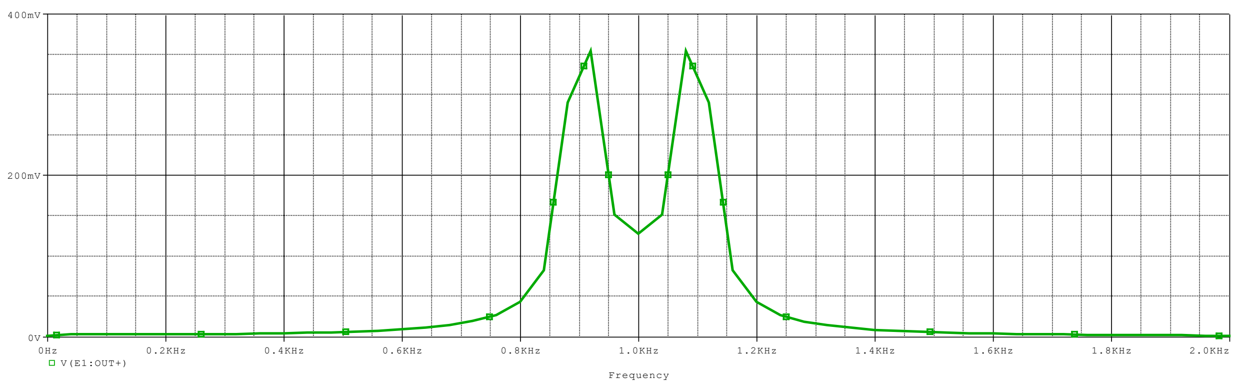
We tried using analog modulator circuits using BJT and Mosfet. But they introduced noise to the circuit. Hence, we used a PSpice library block.

Now we will see the modulated signals

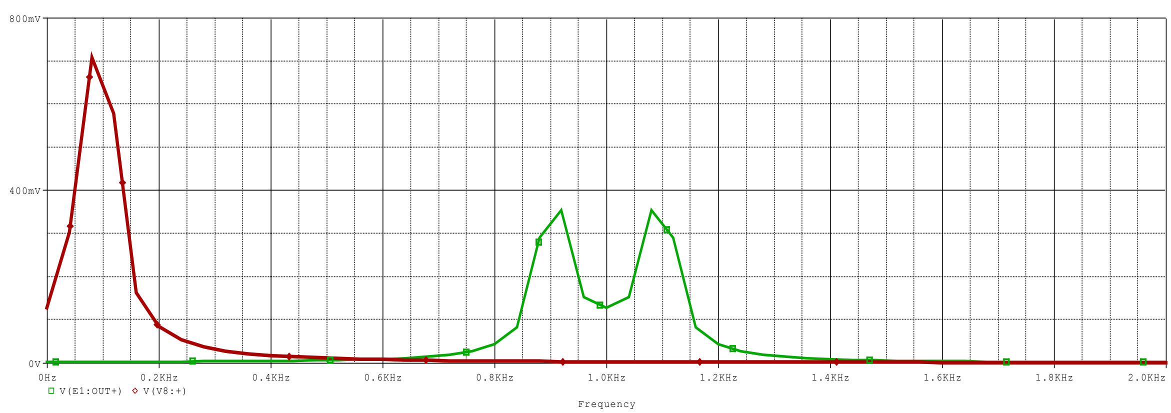
Signal 1(V8) modulated at 1kHz frequency:



In frequency domain the modulated signal looks like this:

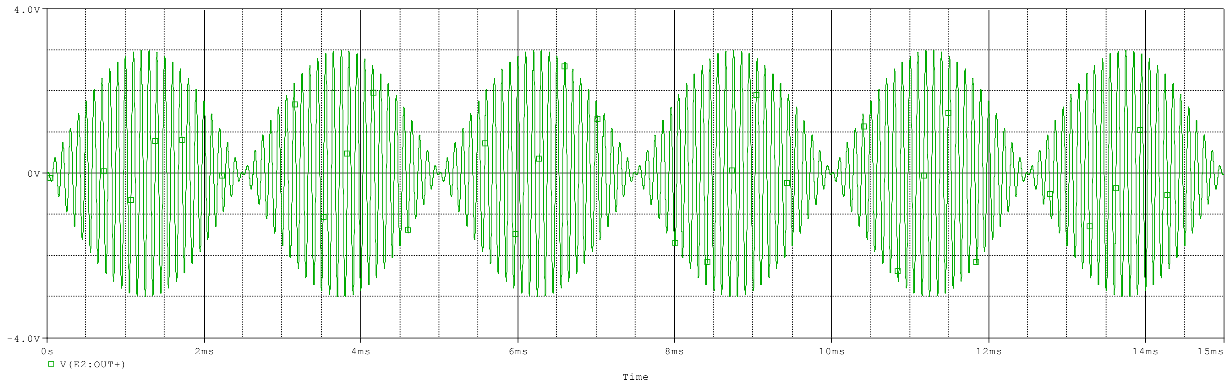


Baseband signal and modulated signal is a single frame:

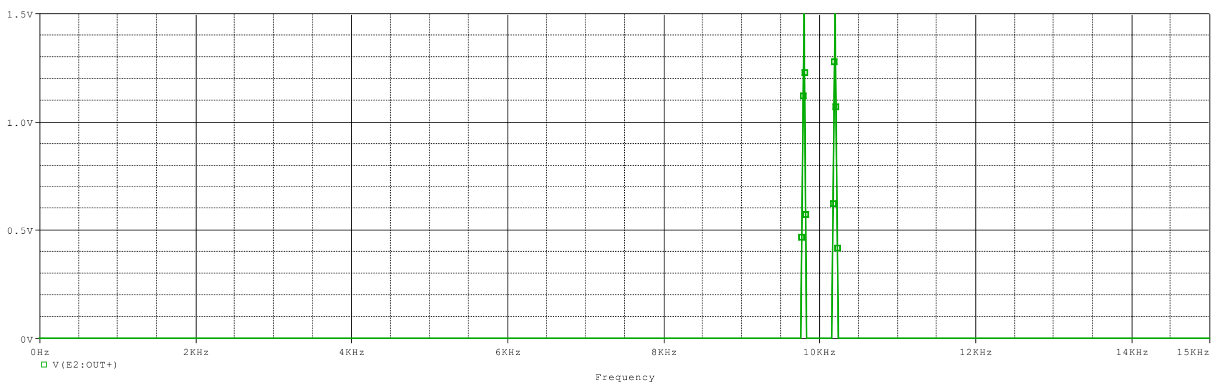


Here the baseband signal 1 ets shifted to around the carrier frequency which is here is 1KHz.

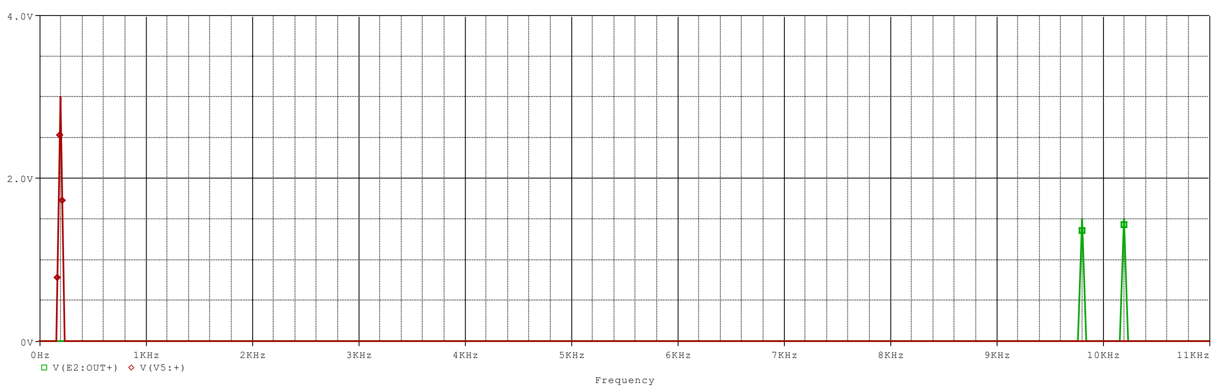
Signal 2(V5) modulated at 10kHz frequency:



In frequency domain the modulated signal looks like this:

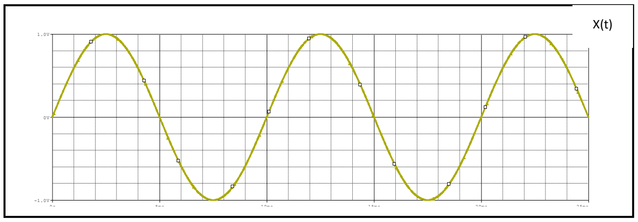


Baseband signal and modulated signal is a single frame:



Here the baseband signal 2 gets shifted to around the carrier frequency which is here is 1KHz.

Modulation process of 1st Baseband Signal:



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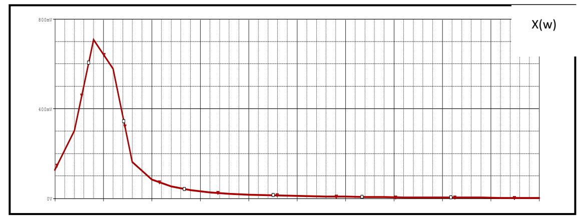

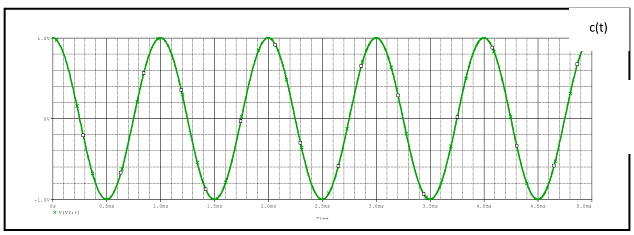

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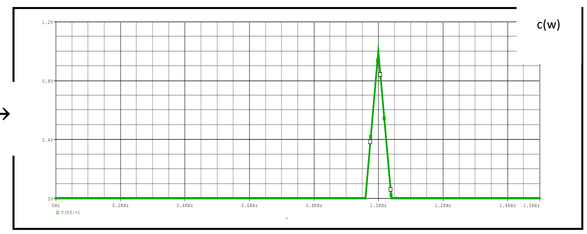

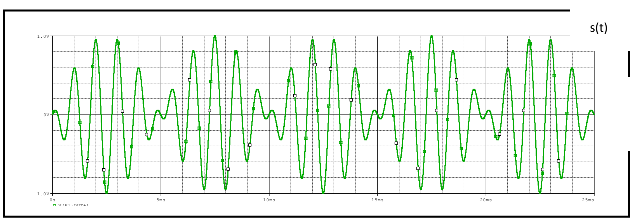

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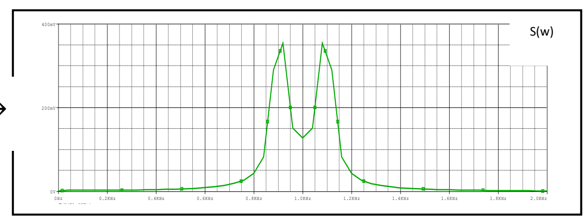
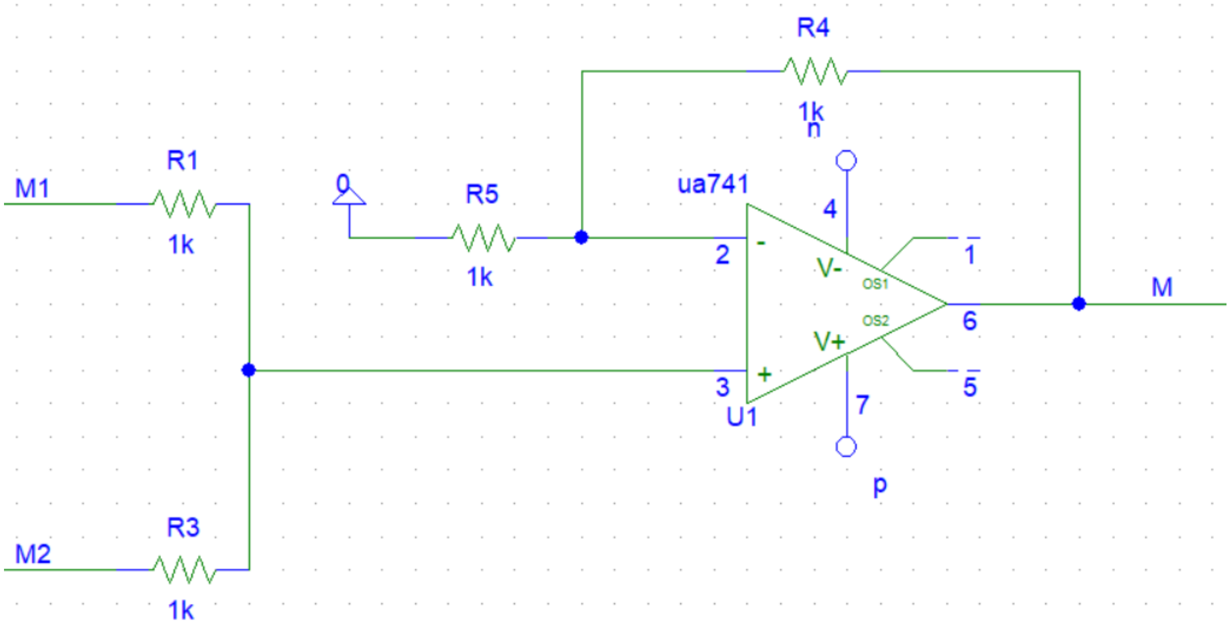
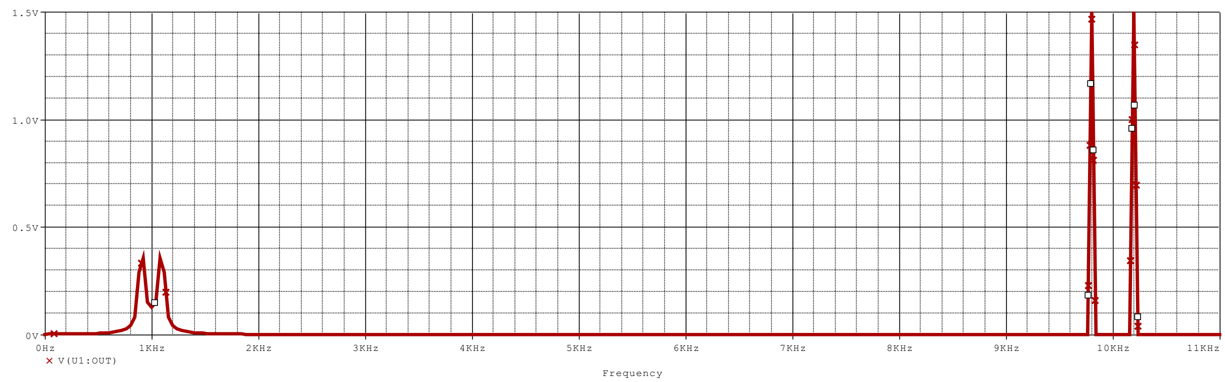


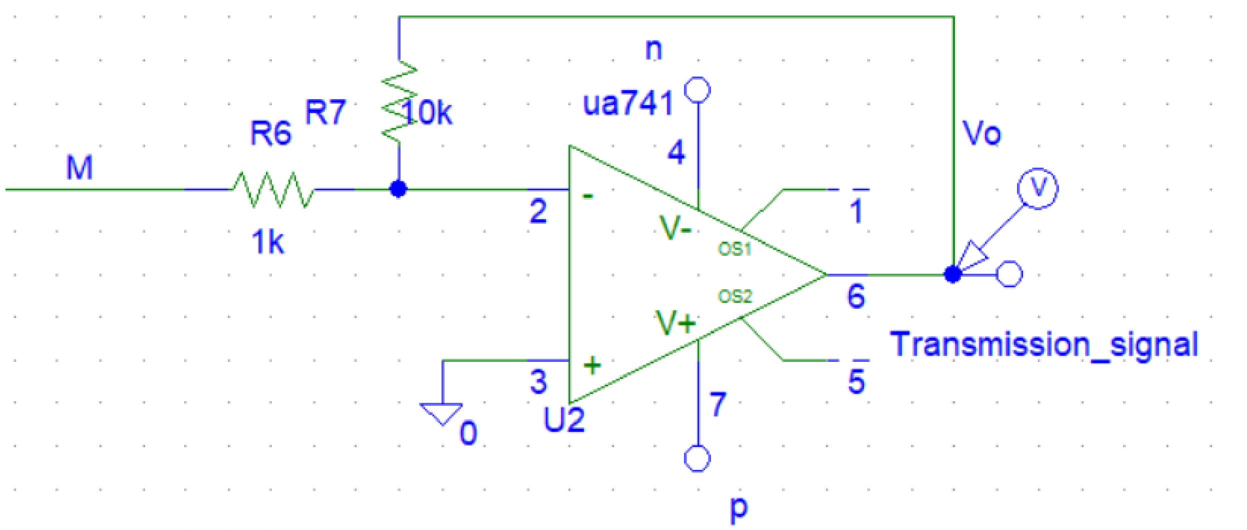
Now the two Modulated signal is added through the adder circuit. This circuit takes the two modulated signal M1 and M2 and adds them



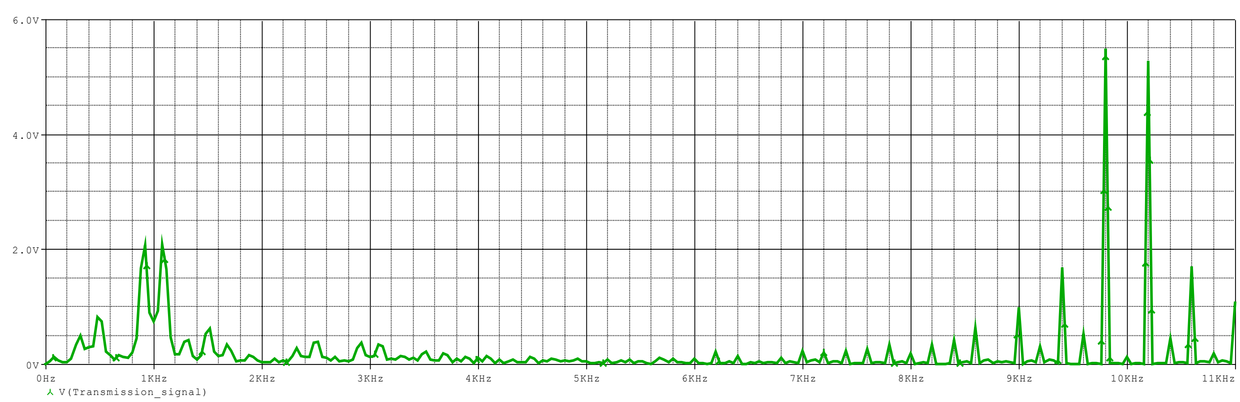
After adding M1 and M2 the output looks like:



Now to transmit the information carried by the baseband signal we amplified the modulated signals so that the signal doesn't decays in magnitude after modulation.

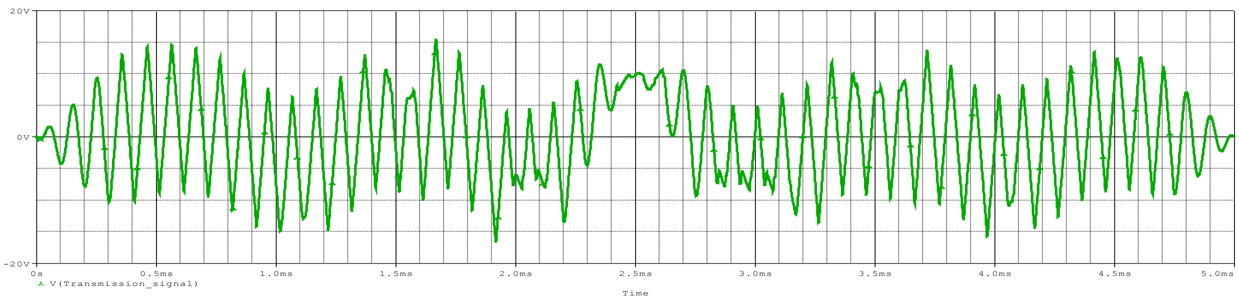


Transmission signal in Frequency domain:

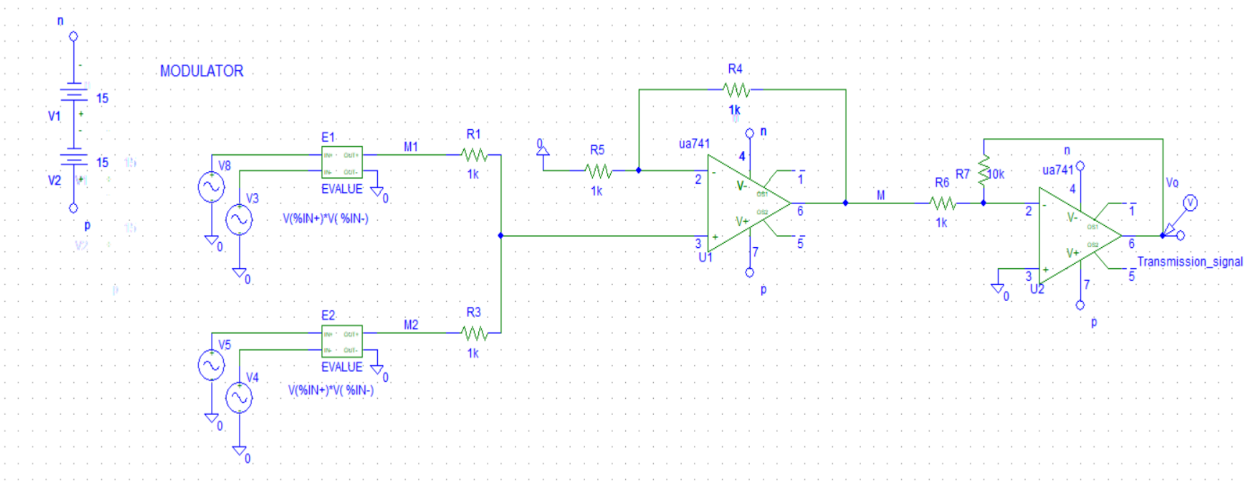


Here we notice that the noise attached with the transmission signal is also increased.

Transmission signal in Time domain:

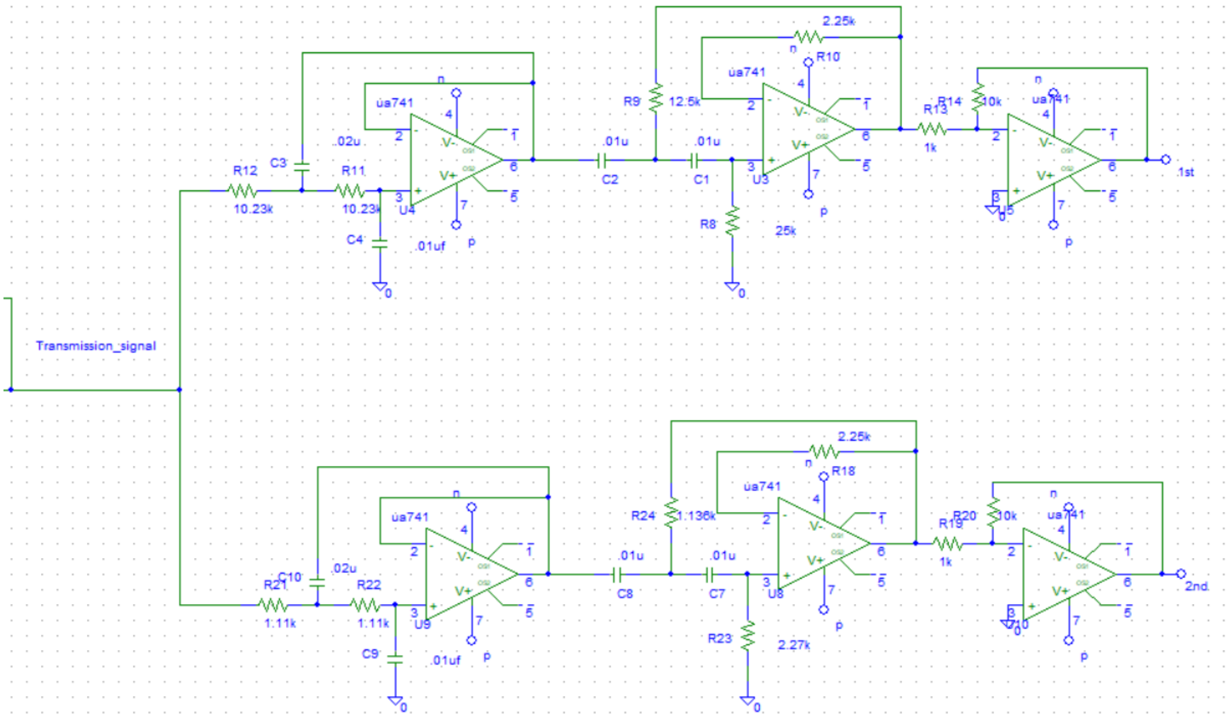


Circuit that preprocesses the baseband signal before transmission:



Here we have selected the carrier signal frequencies in such a way that they are spaced far enough that none of the passbands overlap. In this way the available bandwidth is divided into "slots" or channels, each of which can carry a separate modulated signal.

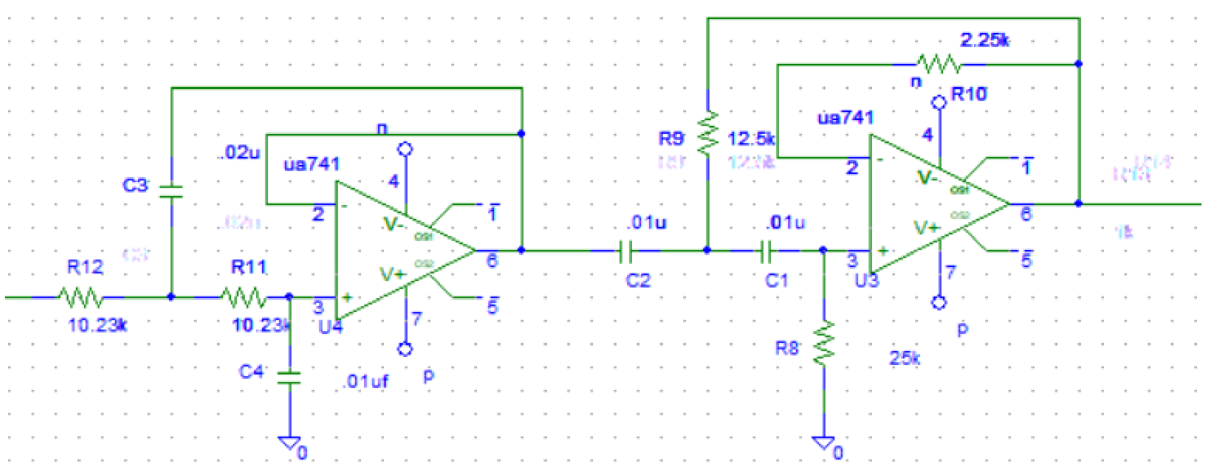
Now we use two bandpass filters to get our desired frequency of bandpass filter from the transmission signal



Here we have designed two 40dB/decade bandpass filter at near the modulated frequency to extract our desired signal of frequency. We couldn't use the narrow band pass filter because the quality factor is greater than 0.5.

<u>Designing the 40dB/decade bandpass filters</u>

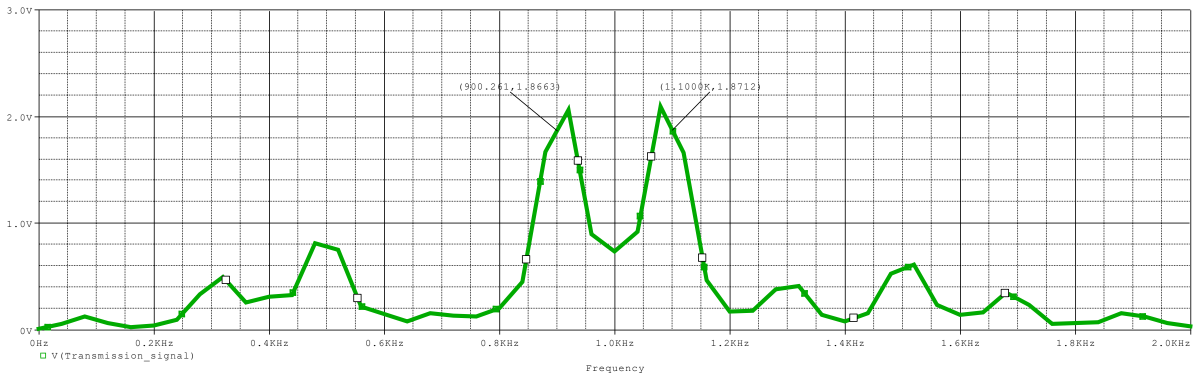
<u>Filter to extract the modulated signal at 1kHz frequency</u>



Determining the parameters of the filter:

We cascaded a 40dB/decade high pass and -40db/decade low pass filter to make a wide band filter.

Modulated signal 1:



As we have selected the roll of is 40dB/decade. So, we have chosen a narrow bandwidth and it gives us a good result.

Design procedure for 40dB/decade high pass

1.cutoff frequency f=900Hz

2.Let C1=C2=0.01uF

3.R8=$\frac{\sqrt{2}}{2\pi \times f \times C}$=25k

4.R9=$\frac{R1}{2}$=12.5k

5.To minimize dc offset, let Rf=R10=R8

Design procedure for -40dB/decade low pass

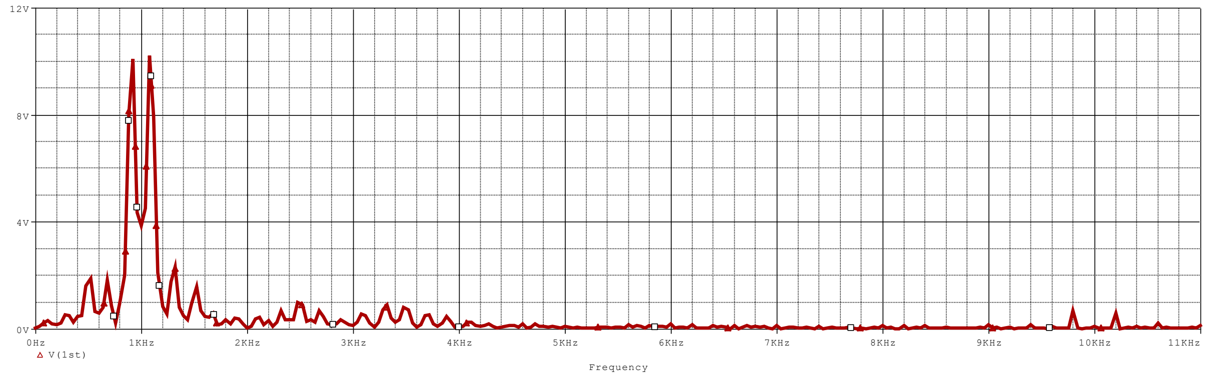
1.cutoff frequency f=1100Hz

2.Let R11=R12=10.23k ohms

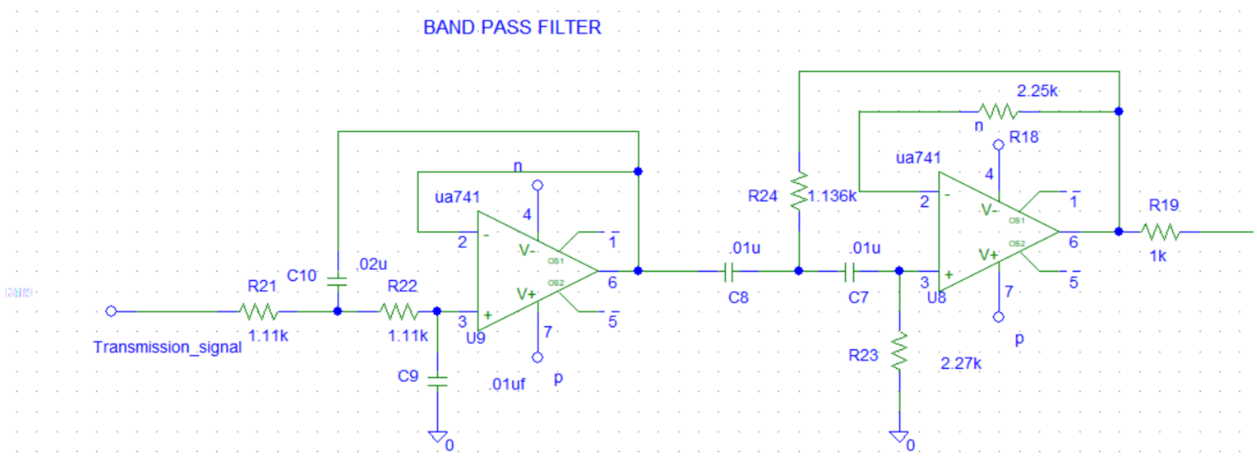
3.C4=$\frac{1}{\sqrt{2} \times 2\pi \times f \times R}$=0.01uF

4.C3=2C4=0.02uF

Filtered signal output:

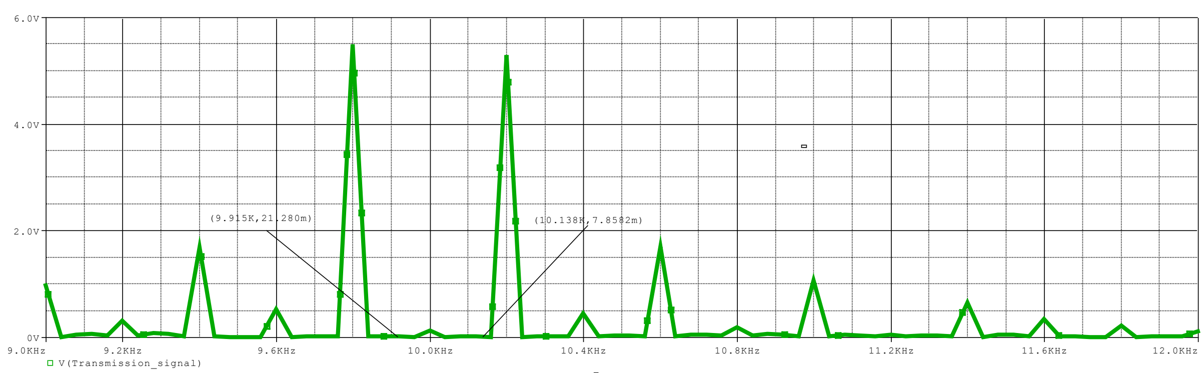


Filter to extract the modulated signal at 10kHz frequency



Determining the parameters of the filter:

We cascaded a 40dB/decade high pass and -40db/decade low pass filter to make a wide band filter.



Design procedure for 40dB/decade high pass

1.cutoff frequency f=9915Hz

2.Let C8=C7=0.01uF

3.R23=$\frac{\sqrt{2}}{2\pi \times f \times C}$=2.27k ohms

4.R24=$\frac{R1}{2}$=1.136k ohms

5.To minimize dc offset, let Rf=R18=R23

Design procedure for -40dB/decade low pass

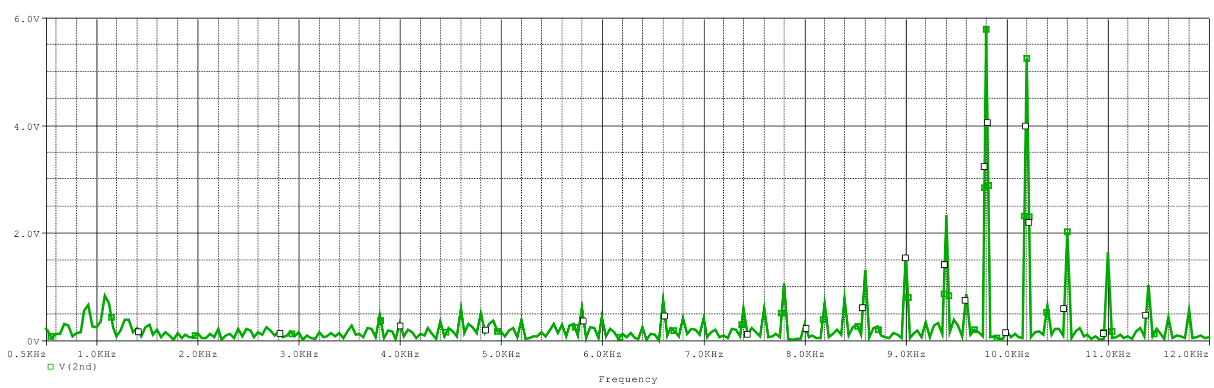
1.cutoff frequency f=10.138kHz

2.Let R21=R22=1.1k ohms

3.C9=$\frac{1}{\sqrt{2} \times 2\pi \times f \times R}$=0.01uF

4.C10=2C9=0.02uF

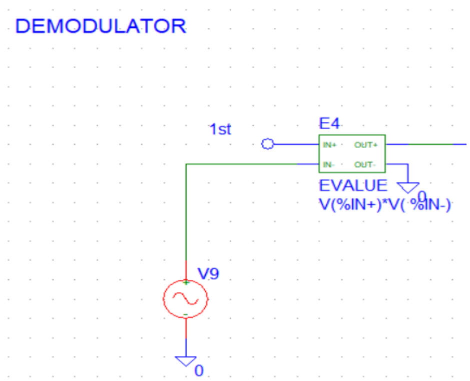
Filtered signal output:



Demodulator circuit:

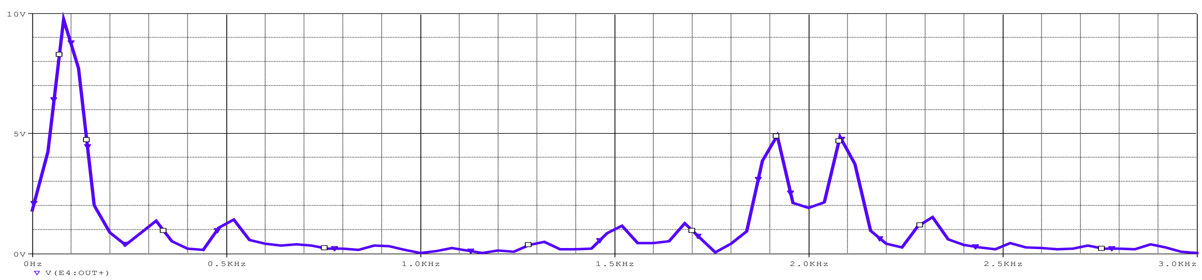
Now in this circuit we need to demodulate the modulated signals to get back the baseband signals at the receiver end. We again used this multiplier circuit block to mix the carrier frequency (corresponding to the baseband signal) with the incoming modulated frequency. After mixing the passband shifts near to the original frequency.

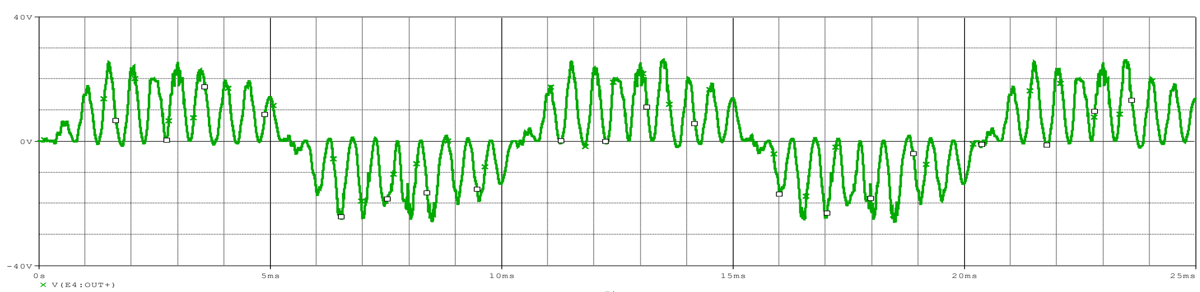
Demodulation of the 1st Modulated signal:



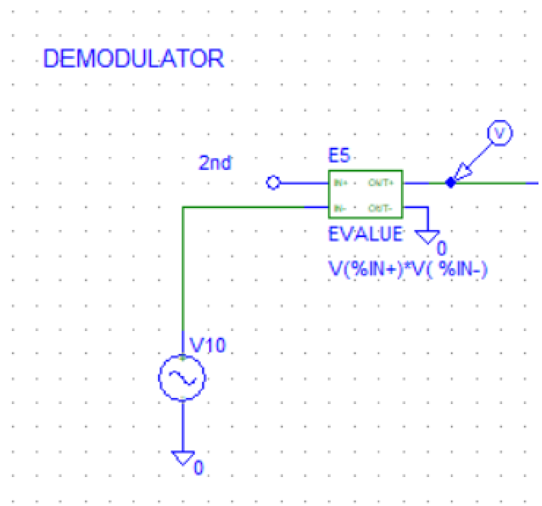
V9=cos $(2\pi \times 1000t)$, Carrier signal frequency 1000Hz

After demodulation the 1st modulated signal looks like this :

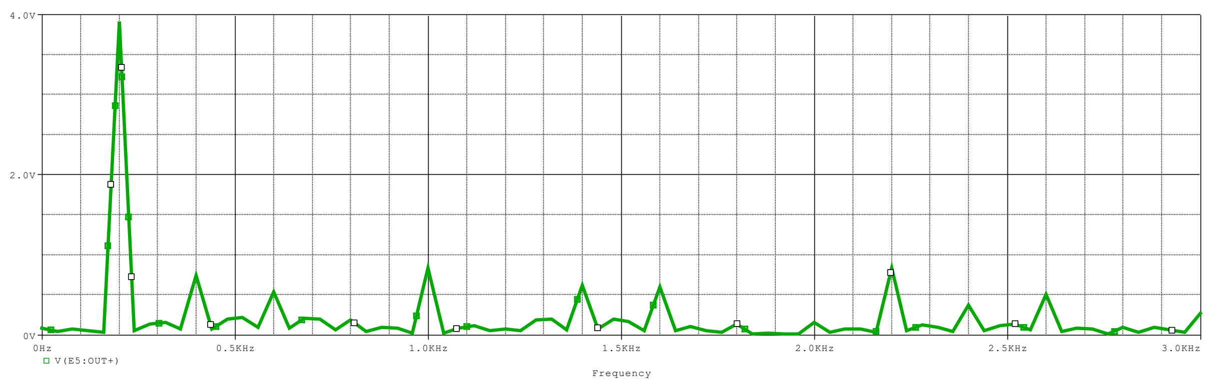


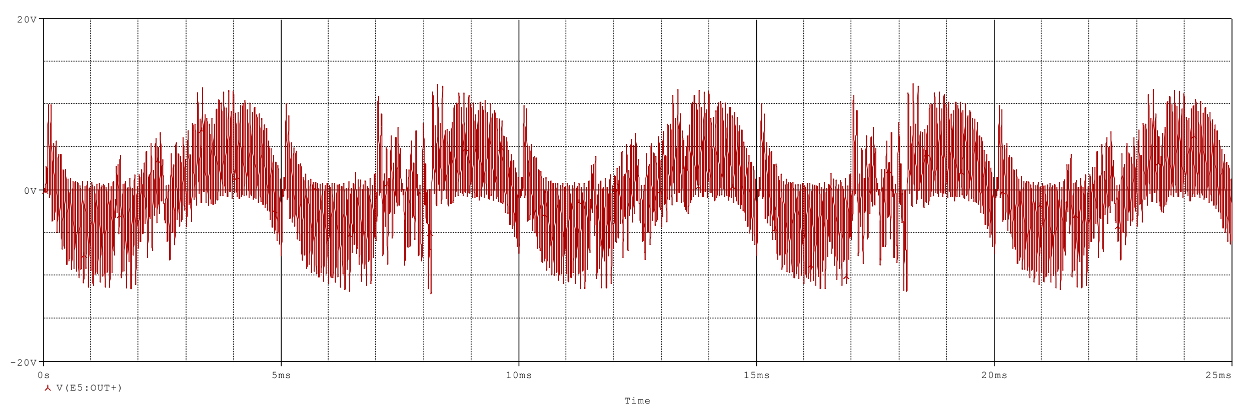


Demodulation of the 2nd Modulated signal:



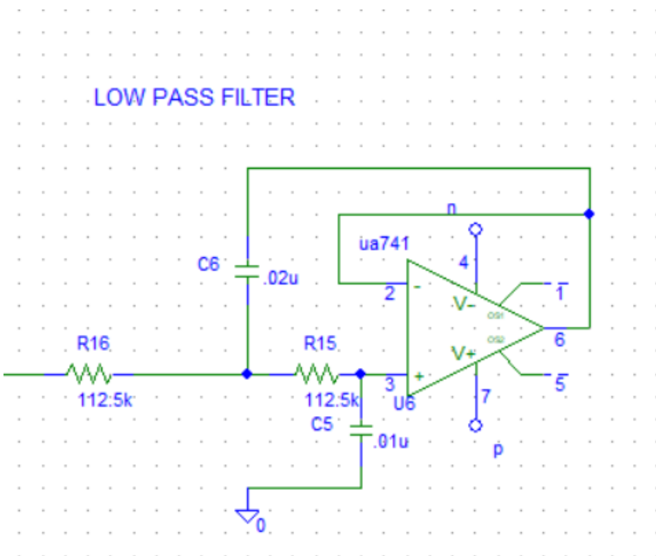
After demodulation the 1st modulated signal looks like this:





Designing a Low Pass filter to get the final result:

For 1st signal:



Here we have used resonant frequency of 100Hz, and it gives a good result because of 40 dB roll off.

Design procedure for -40dB/decade low pass

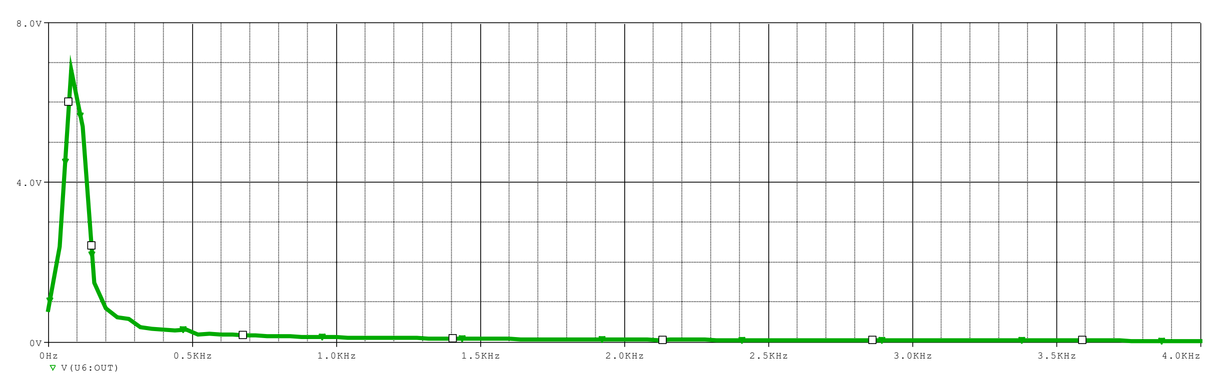
1.cutoff frequency f=100Hz

2.Let R15=R16=112.5k oms

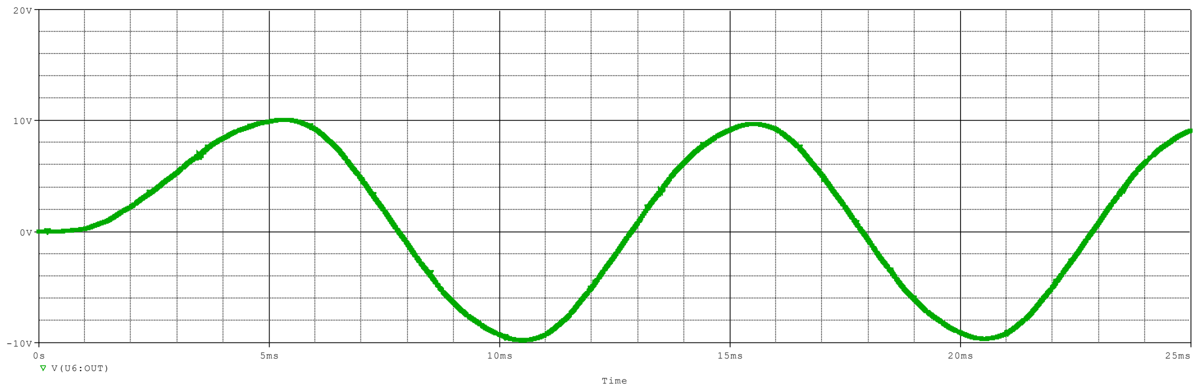
3.C9=$\frac{1}{\sqrt{2}\times 2\pi\times f\times R}$=0.01uF

4.C6=2C5=0.02uF

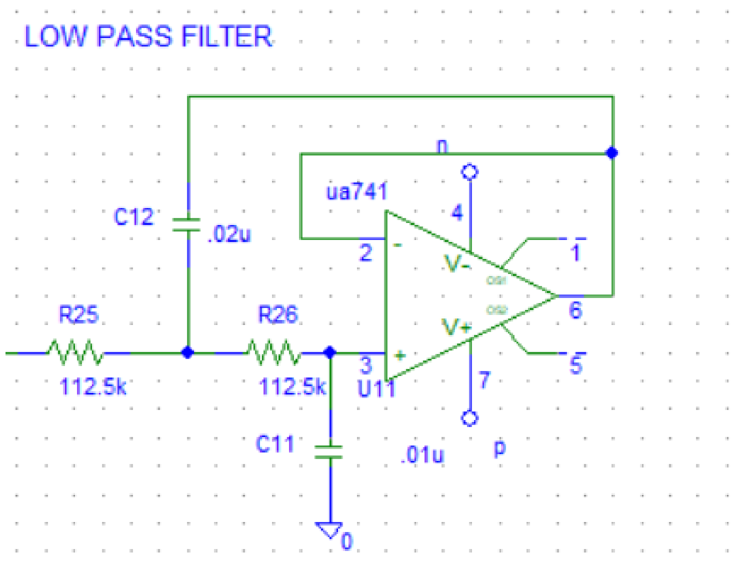
Output of the low pass filter:



Now if we see the signal in time domain we get our desired output signal that matches with source signal.



For 2^{nd} signal



Design procedure for -40dB/decade low pass

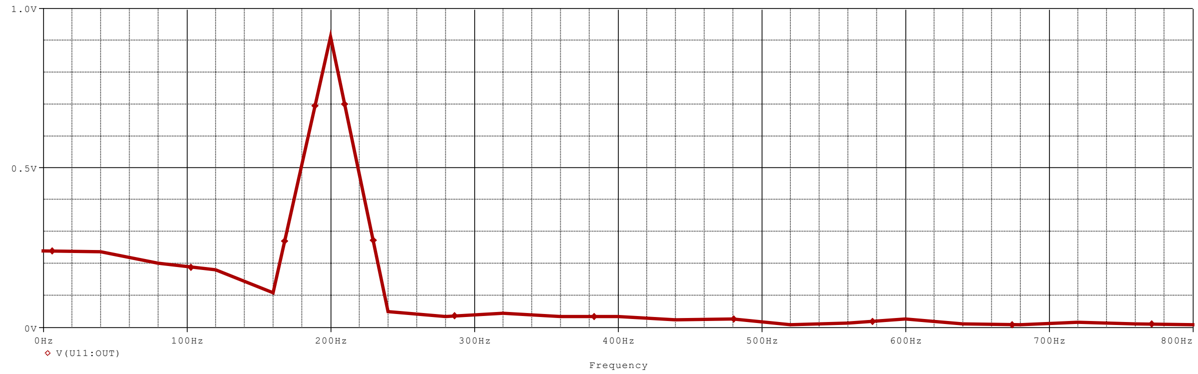
1.cutoff frequency f=100Hz

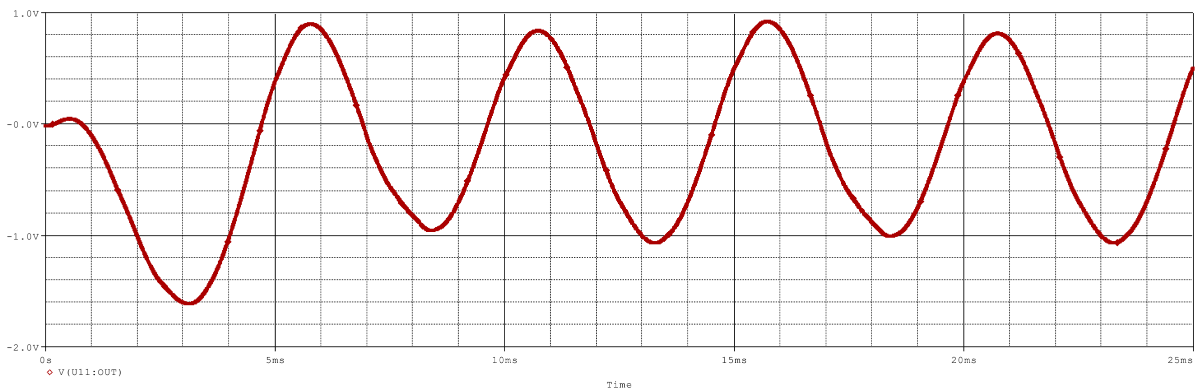
2.Let R25=R26=112.5k oms

3.C9=$\frac{1}{\sqrt{2}\times 2\pi\times f\times R}$=0.01uF

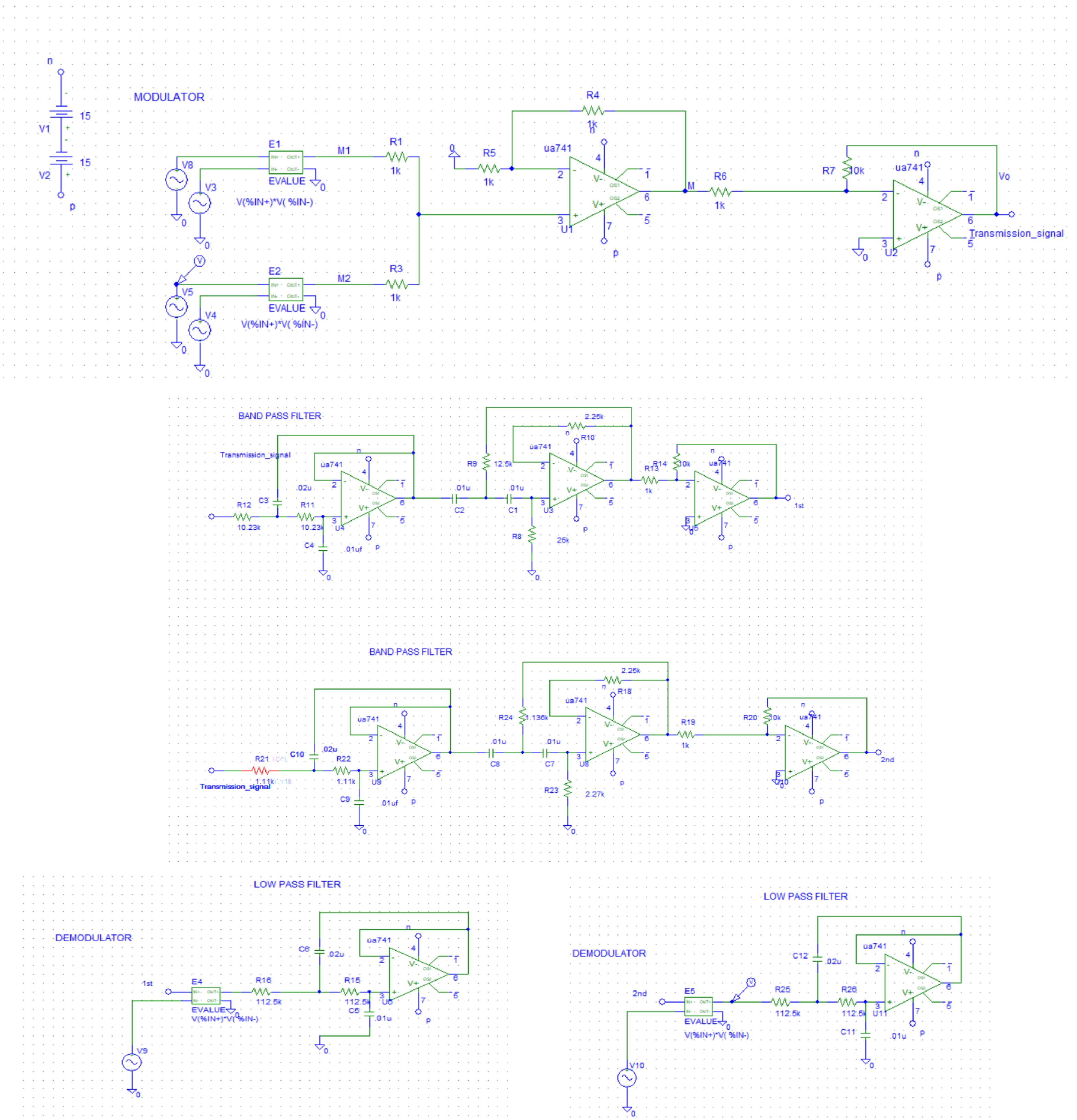
4.C12=2C11=0.02uF

<u>Output of the low pass Filter:</u>



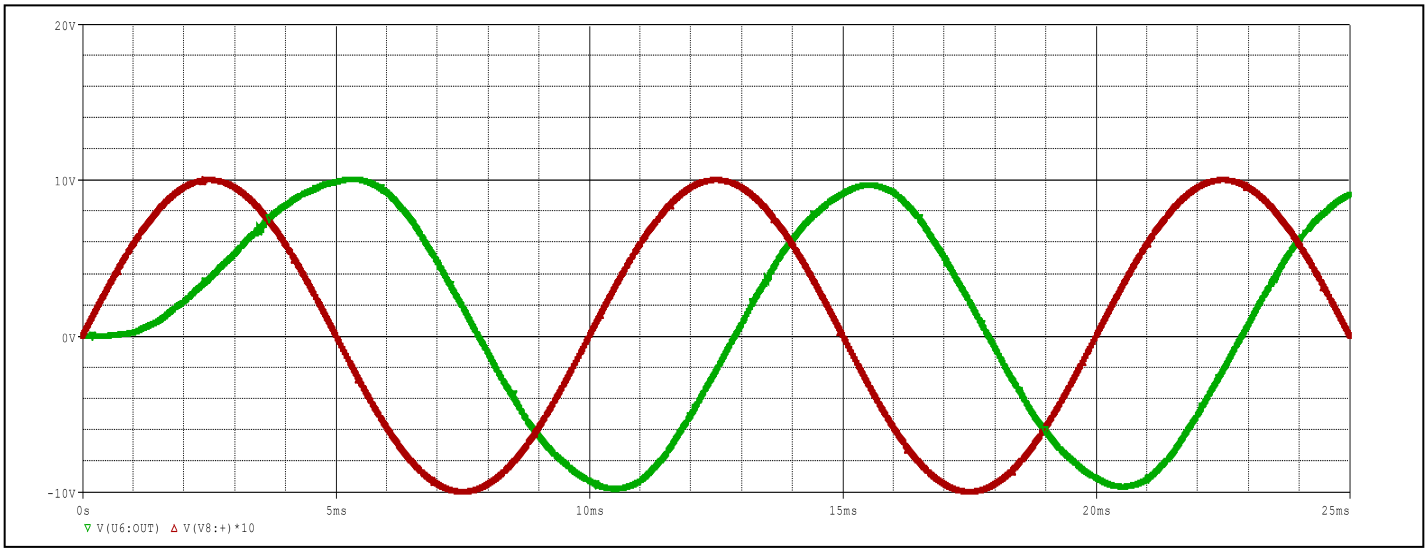


The whole circuit modeled to implement FDM

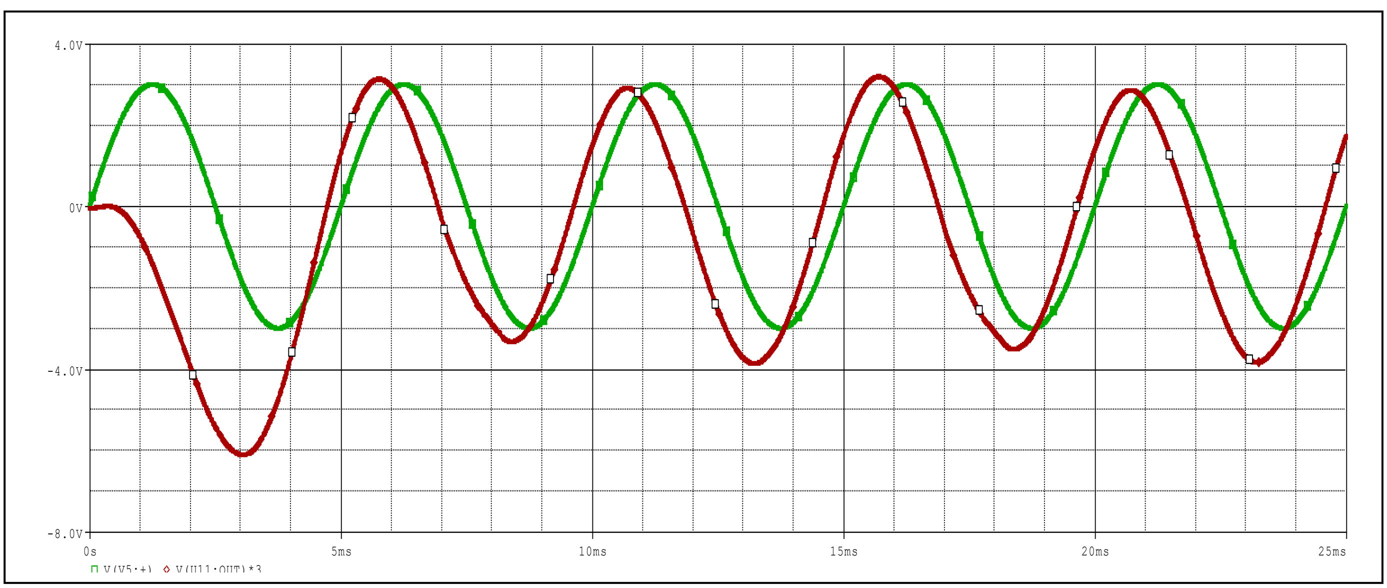


The final output (signal in source end vs signal in receiver end)

Signal 1:

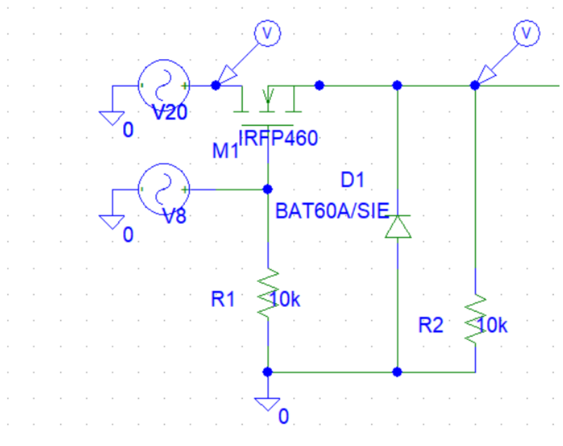


Signal 2:

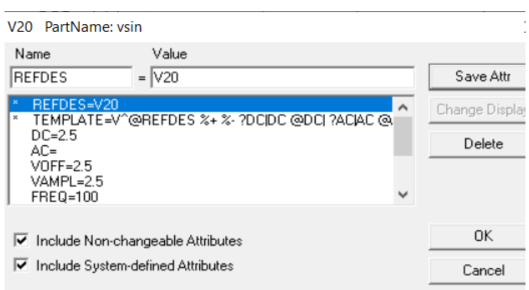


We also tried to build an analog multiplier circuit with Mosfet

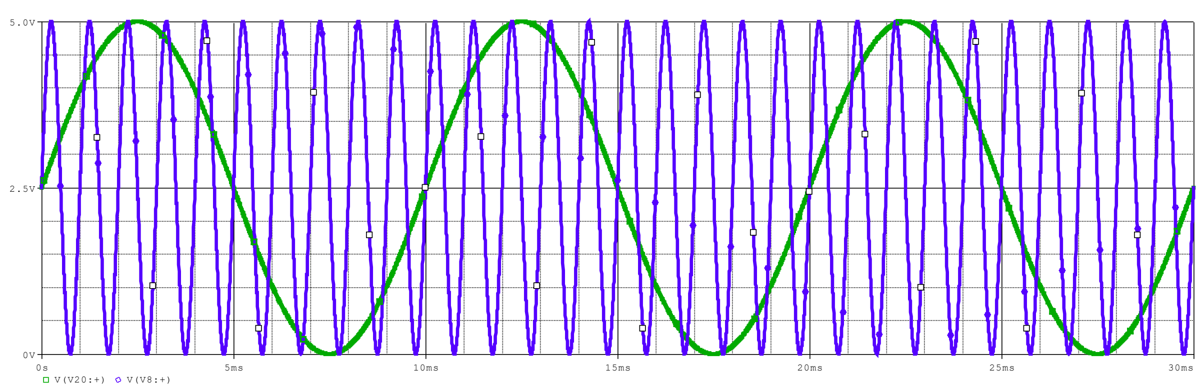
Modulator circuit using Mosfet:



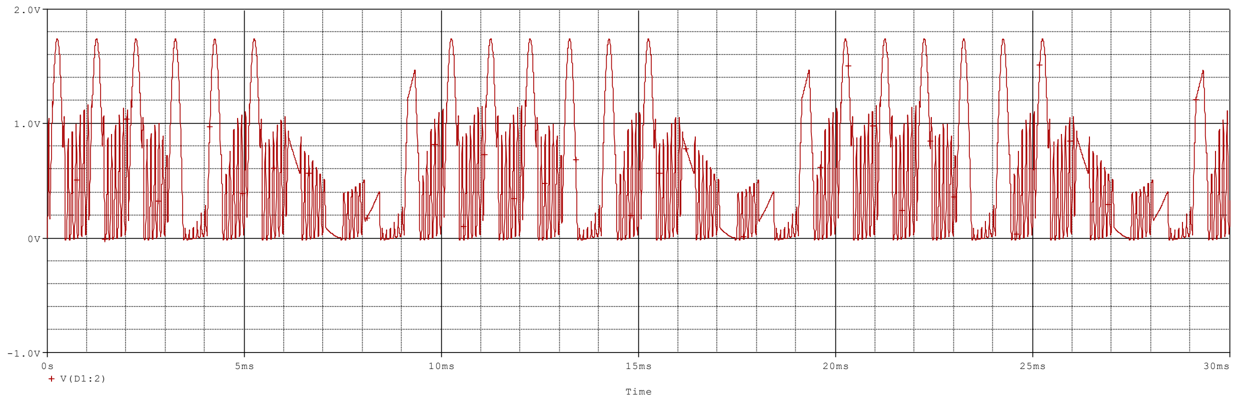
Mosfet doesn't work in negative region. So, we added a 2.5-volt dc offset with our baseband signal

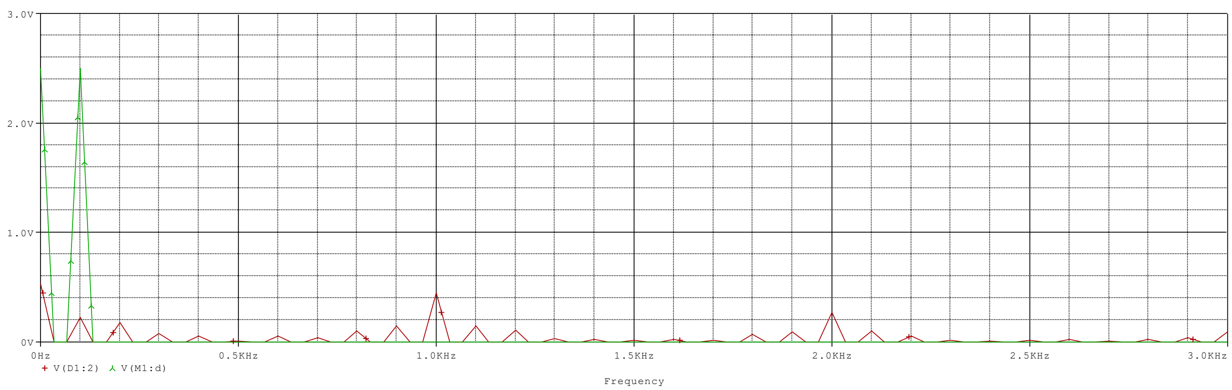


Baseband signal and carrier signal

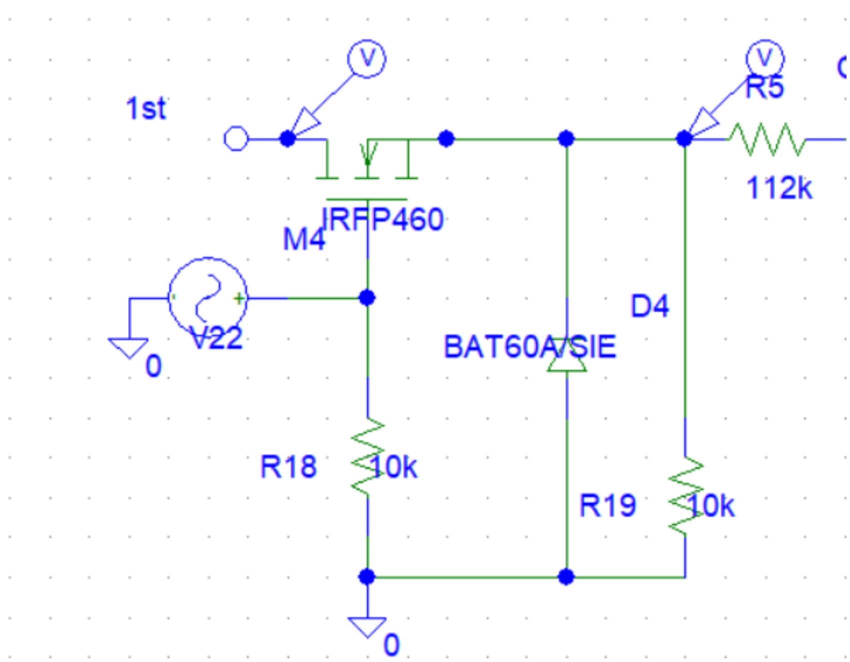


After mixing with the help of Mosfet output:

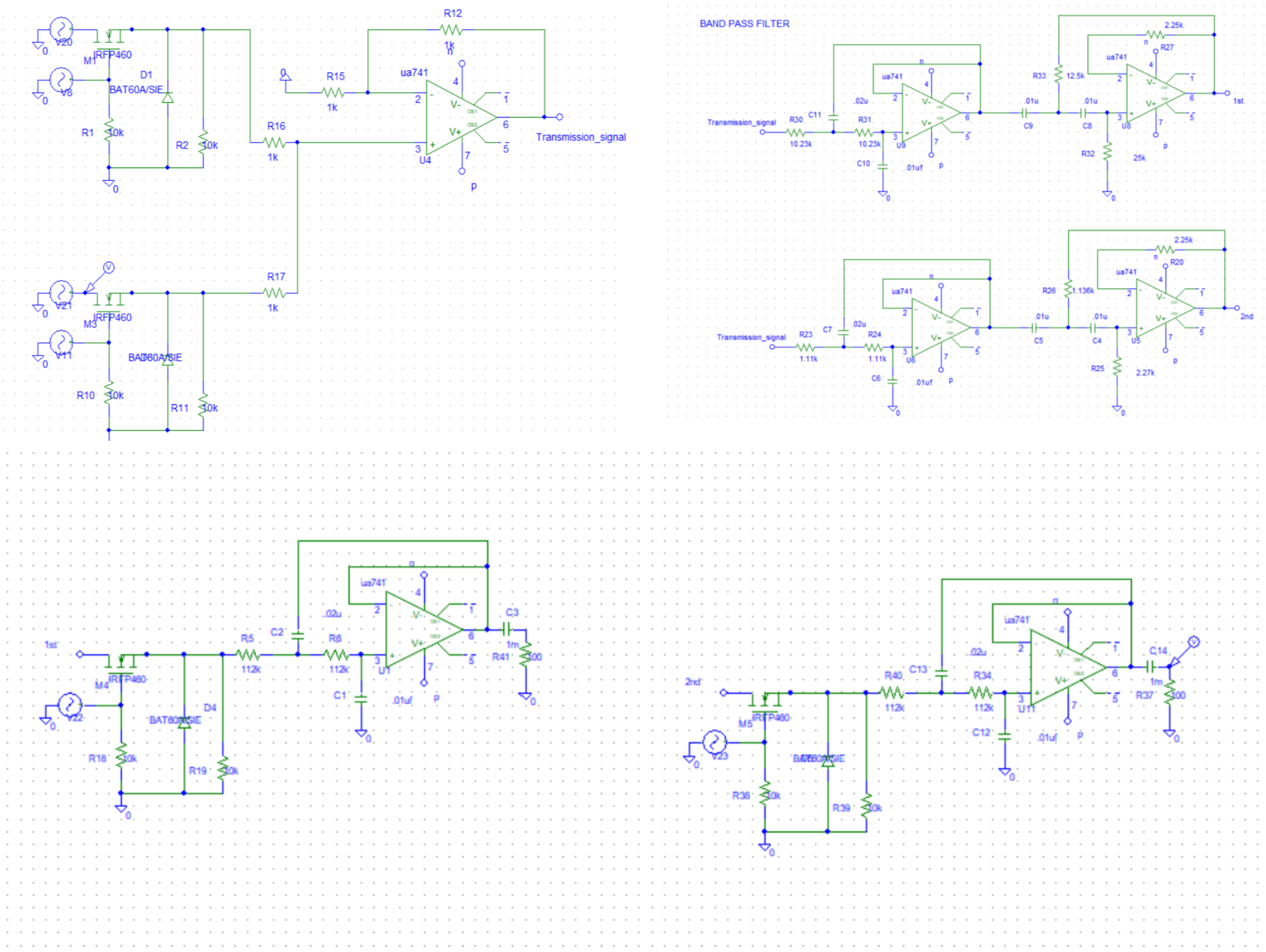




Demodulator circuit using Mosfet:

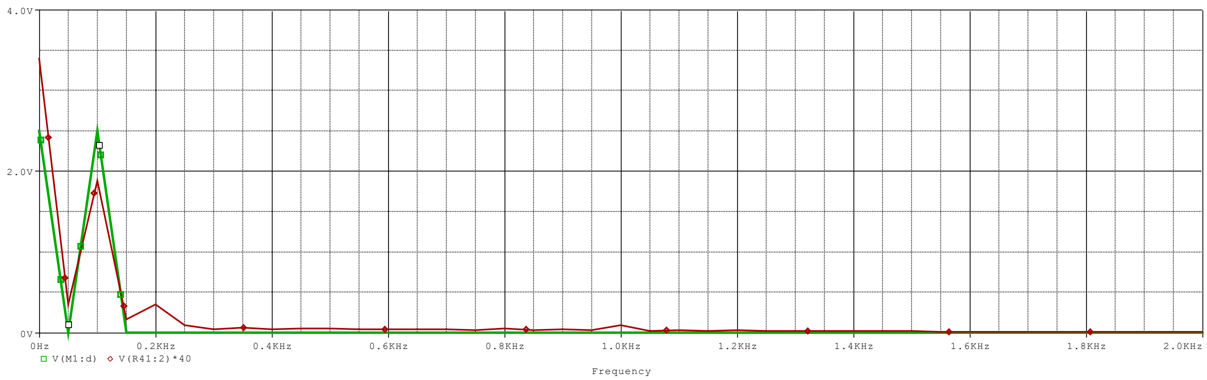


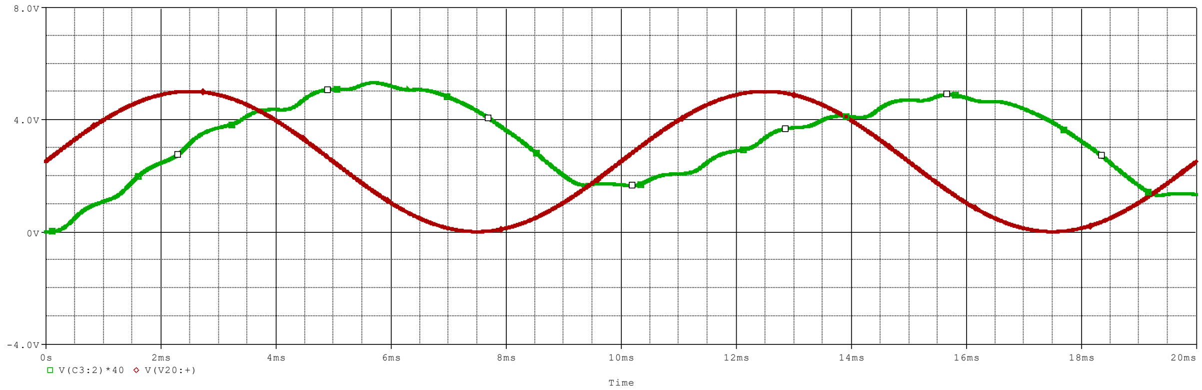
The whole circuit modeled to implement FDM(using Mosfet)



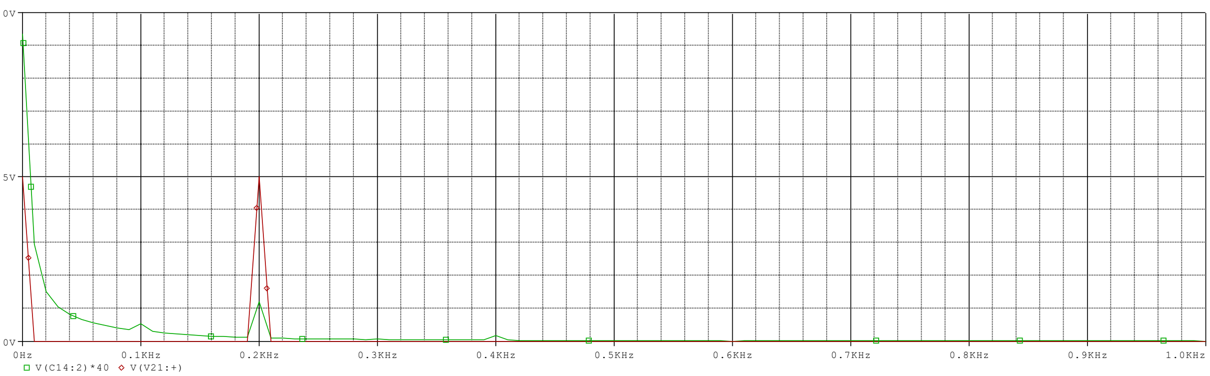
Final Output of FDM (using Mosfet)

1st signal (Source end & Receiver end):

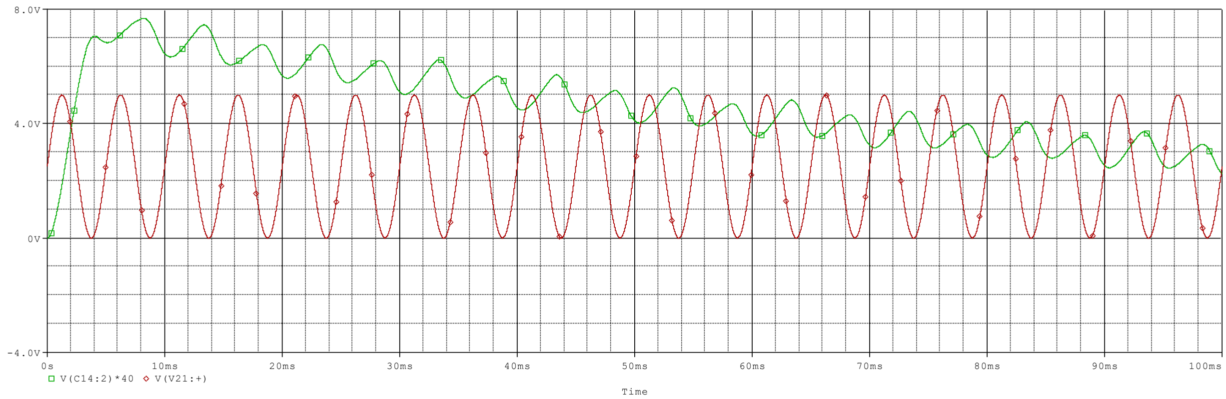




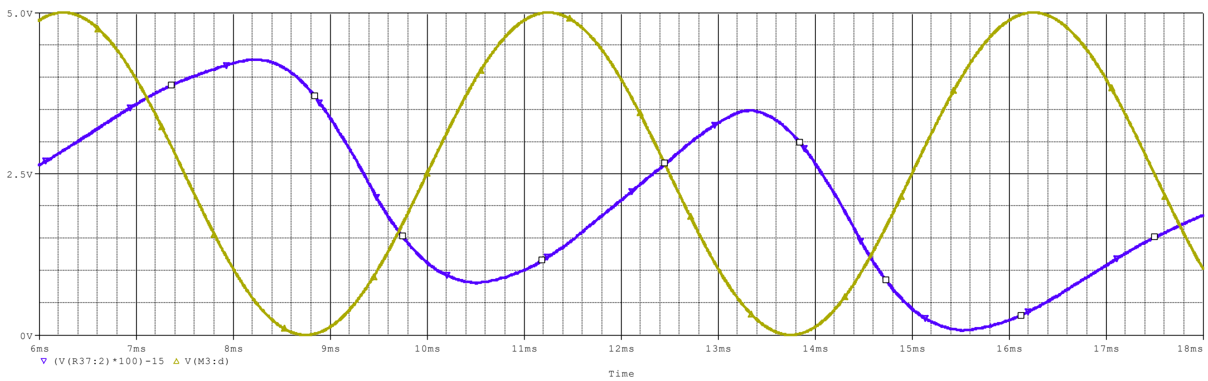
2nd (source end vs Receiver end)



Transient:



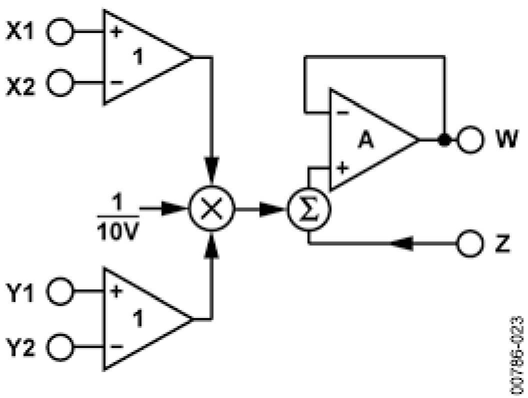
Steady state:

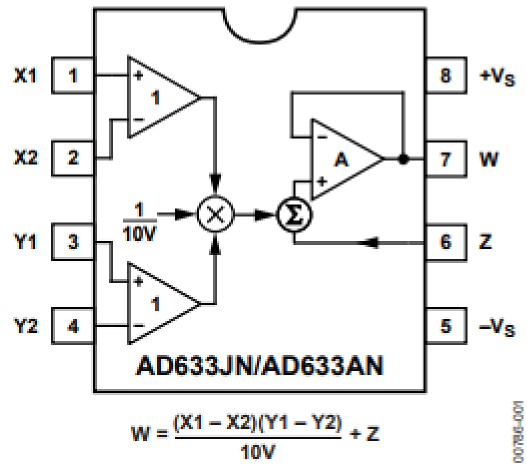


Using Mosfet noise couldn't be eliminated. So, the output comes somewhat distorted. The noise was added due to the DC bias of the system. We wanted the low frequency signal to come to the output, so we used a low pass filter. However, the dc component due to Mosfet biasing requires a high pass filter. The bandwidth required for the filter is so small (100Hz) that after implementing it the signal got highly attenuated.

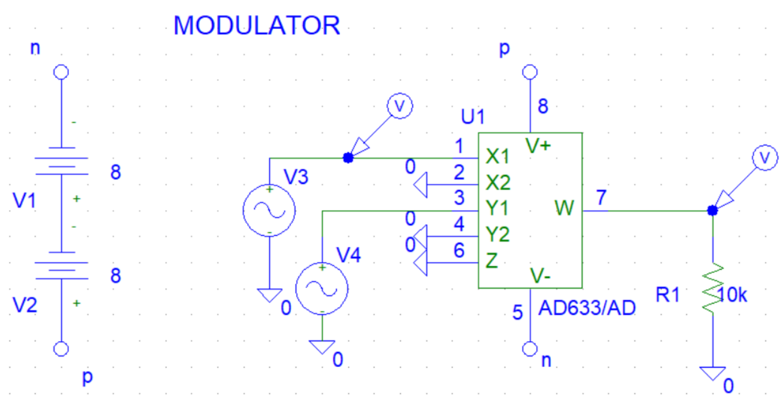
We can also build a modulator using an integrated analog circuit

AD633

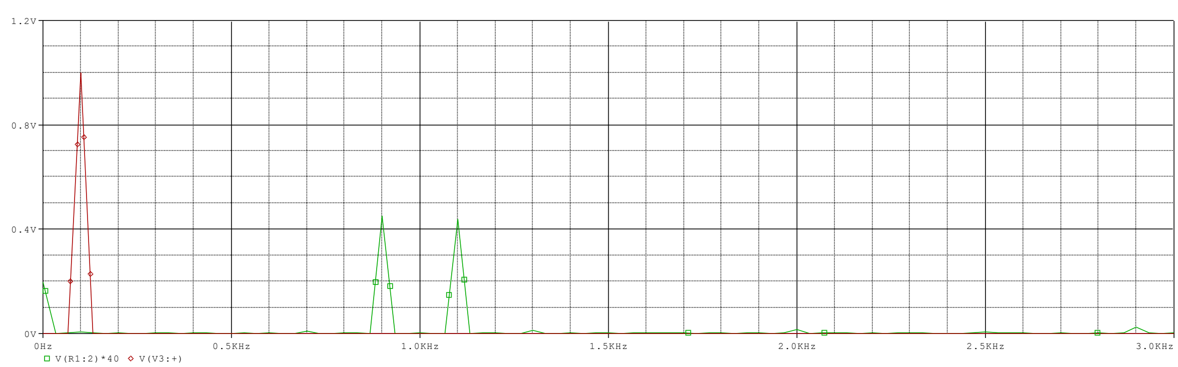


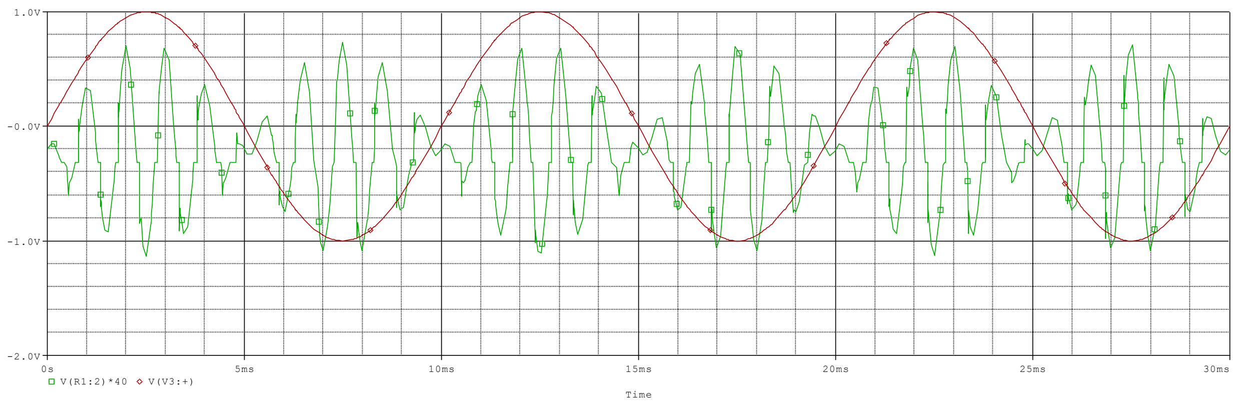


Modulator Circuit using AD633:



Modulated signal (1st baseband signal):





Limitation:

- This simulation using pspice can't deal with high frequency carrier signal. Whereas in Real life FDM the frequency of the carrier signal is in the Mega hertz range. If we work with high frequency carrier signal it introduces noises at various frequency.
- In this FDM system we had to manually set the values of filters according to the baseband signal frequency.

Conclusion:

In this circuit we developed a model of FDM to transmit multiple signals within a range of bandwidth through a single transmission line. We have modeled this FDM project with two different frequency baseband signals to transmit through a transmission line. We also demodulated the signal in the destination end to retrieve the baseband signal. In the modulation part we needed to multiply two analog signals (baseband signal and carrier signal). We have done this using AD633 and Mosfet. Before this we have modeled this using a pspice component that simply multiplies two analog signals which gives an ideal result. We have carefully designed the filters according to the bandwidth of the frequency that is needed to be extracted. As we have used 40dB/decade band pass filters we have selected the the bandwidth to be very small according to signal. At the final output we have compared the signals of source end and receiver end. Because the shape and frequency of the signal determines the information quality that is transmitted to receiver end.