FAST FOURIER TRANSFORM, AC AND TRANSIENT ANALYSIS OF AN INVERTING AMPLIFIER

Aim: To determine the non ideal characteristics of an op-amp using various types of analysis. (Transient, AC and FFT)

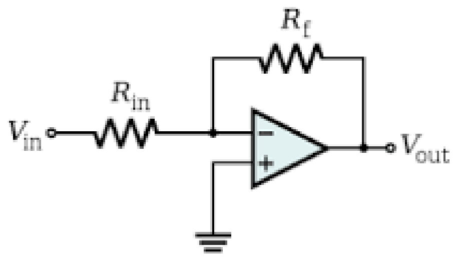
Op-amp parameters: Out of several existing parameters of the op-amp, the ones that are responsible for behaviour of non ideal characteristics of the integrated circuit are slew rate, slew rate limiting frequency, attenuation of bandwidth, linear and non linear distortion.

Slew rate: Slew rate is defined as the maximum rate of change of output per unit of time and is expressed in terms of volts per micro second. Slew rate indicates how rapidly the output of an op-amp can change in response to changes in the input frequency. The slew rate changes with change in voltage gain and is normally specified at unity gain. The slew rate of the op-amp is fixed, therefore, if the slope requirements of the output signal is greater than the slew rate then distortion occurs.

Non linear distortion: Non linear distortion is used to describe the phenomenon of non-linear relationship between the input and the output. Whenever this distortion occurs, the output will no longer be following the input linearly or proportionally. For a practical non-ideal amplifier, the amplification may not produce a linear signal over a wide range of frequencies.

Introduction:

An inverting amplifier is mainly composed of an op-amp and some passive components, mainly resistors along with a signal source to feed an input signal. In this amplifier only one input is applied to the inverting input terminal and the non inverting terminal is grounded, hence the name of the amplifier.



To find the gain of the above inverting amplifier:
(Let gain be ‘A’)
$V_{out}/R_f = -V_{in}/R_{in}$
$V_{out}/V_{in}=A$
Therefore $A= -R_f/R_{in}$
The negative sign indicates that output voltage is out of phase w.r.t input by 180 degrees or is of opposite polarity. Thus in an inverting amplifier the input signal is amplified by gain A and is also inverted at output.

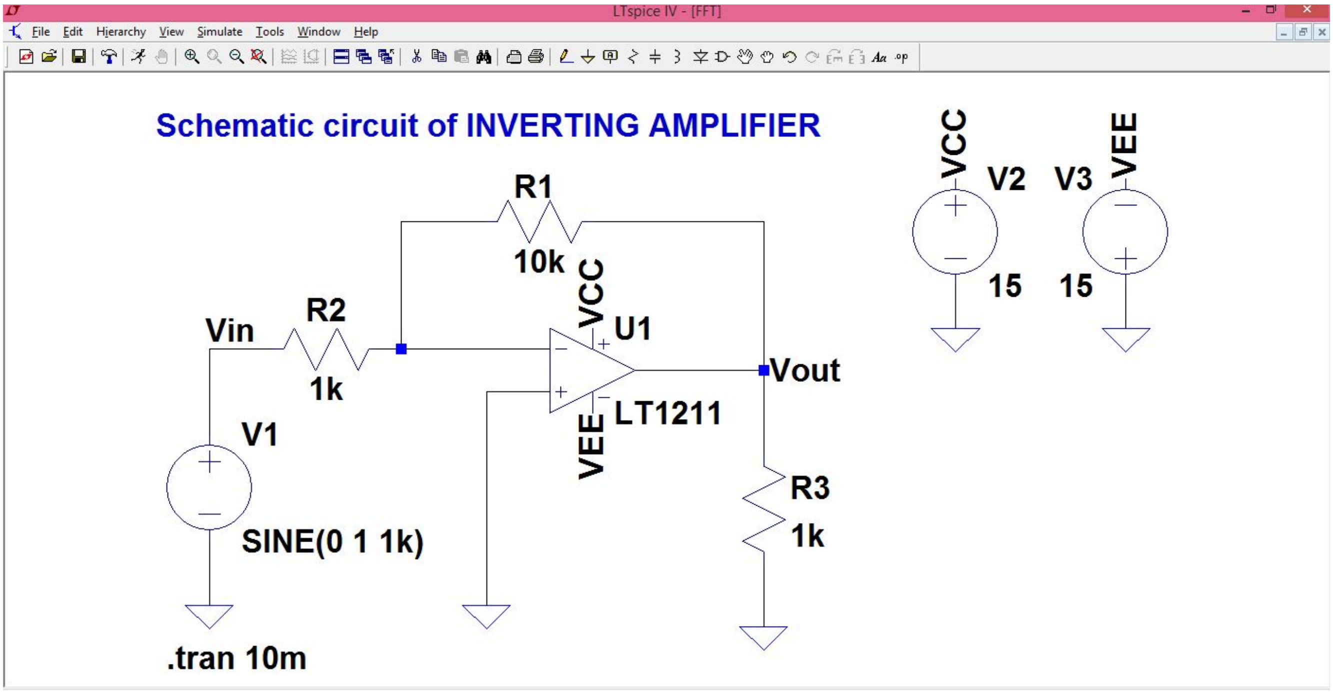

LTspice IV - [FFT]
File Edit Hierarchy View Simulate Tools Window Help
Schematic circuit of INVERTING AMPLIFIER
R1
10k
R2
1k
Vin
V1
SINE(0 1 1k)
VCC
VEE
U1
LT1211
Vout
R3
1k
V2
V3
15
15
.tran 10m

Fig.1

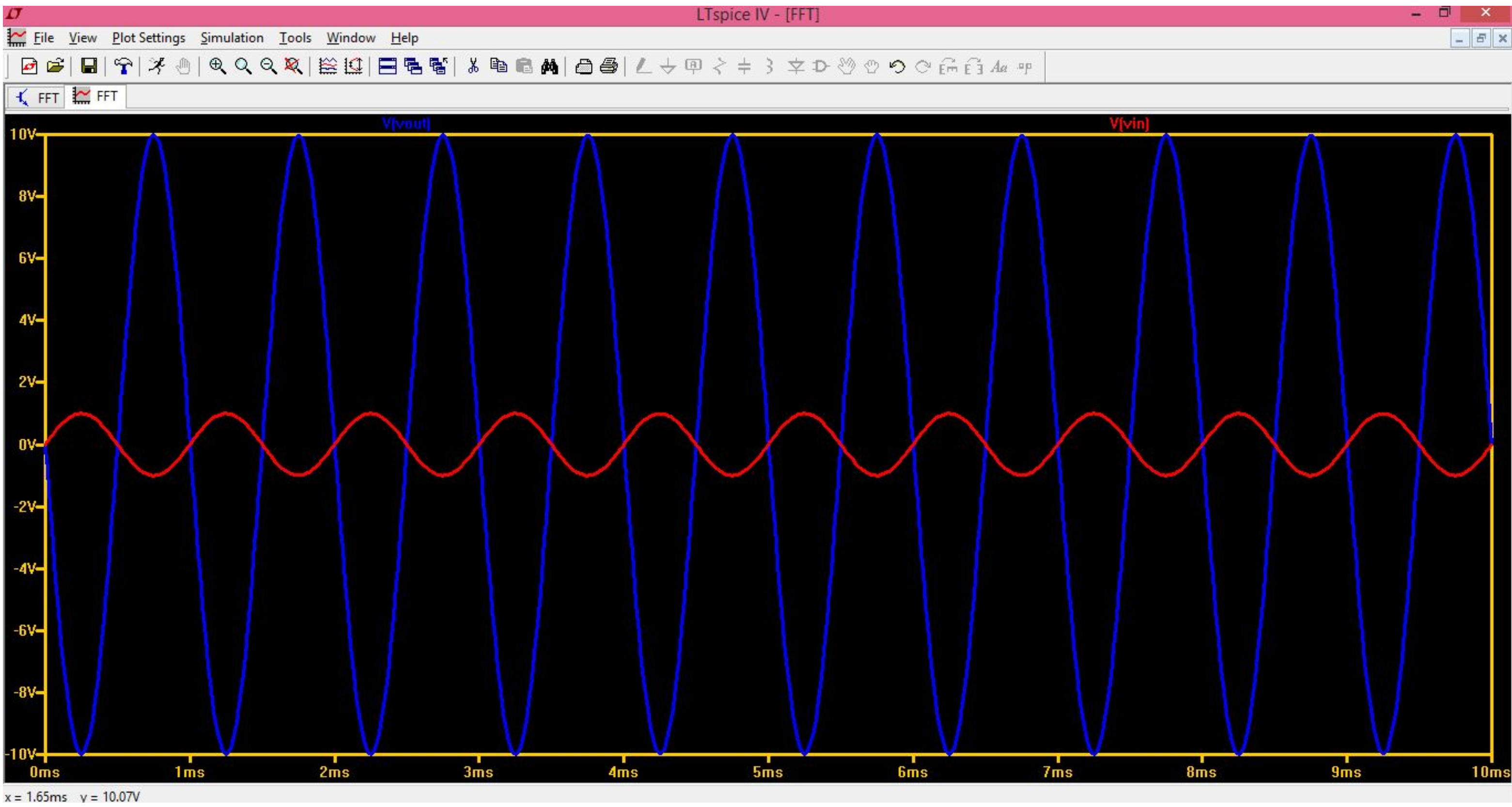

LTspice IV - [FFT]
File View Plot Settings Simulation Tools Window Help
FFT
FFT
V[vout]
V[vin]
10V
8V
6V
4V
2V
0V
-2V
-4V
-6V
-8V
-10V
0ms
1ms
2ms
3ms
4ms
5ms
6ms
7ms
8ms
9ms
10ms
x = 1.65ms y = 10.07V

Fig2.

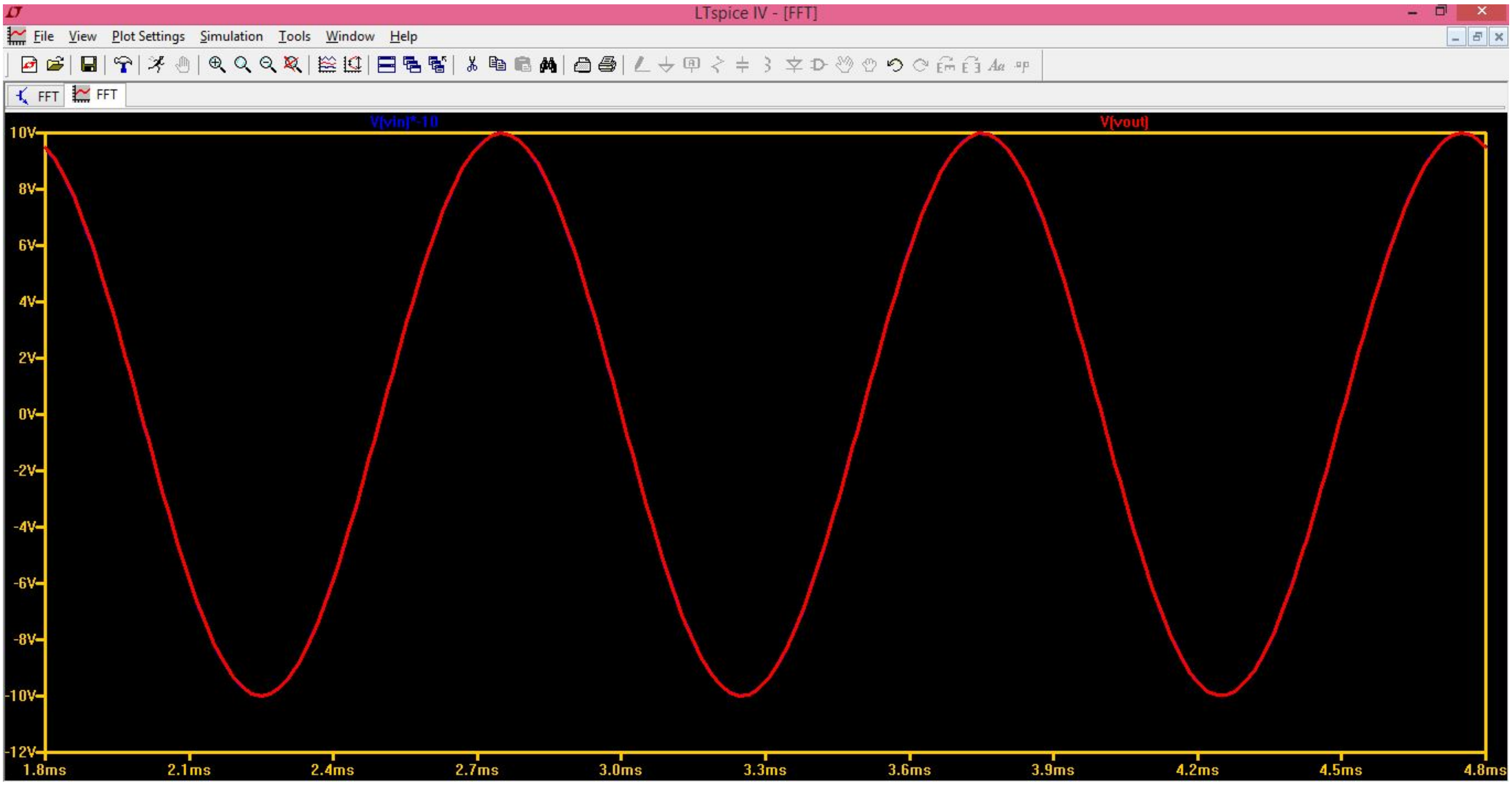


Fig3.

In the transient analysis Fig1. Is a schematic having a sine wave of 1kHz, since the gain of the amplifier is -10, the output of an inverted phase waveform with a smaller magnitude is observed in Fig.2. In order to observe the superimposition of waveforms, the input voltage can be multiplied by -10 for compensating towards the output voltage and the waveforms of the same can be seen in Fig.3

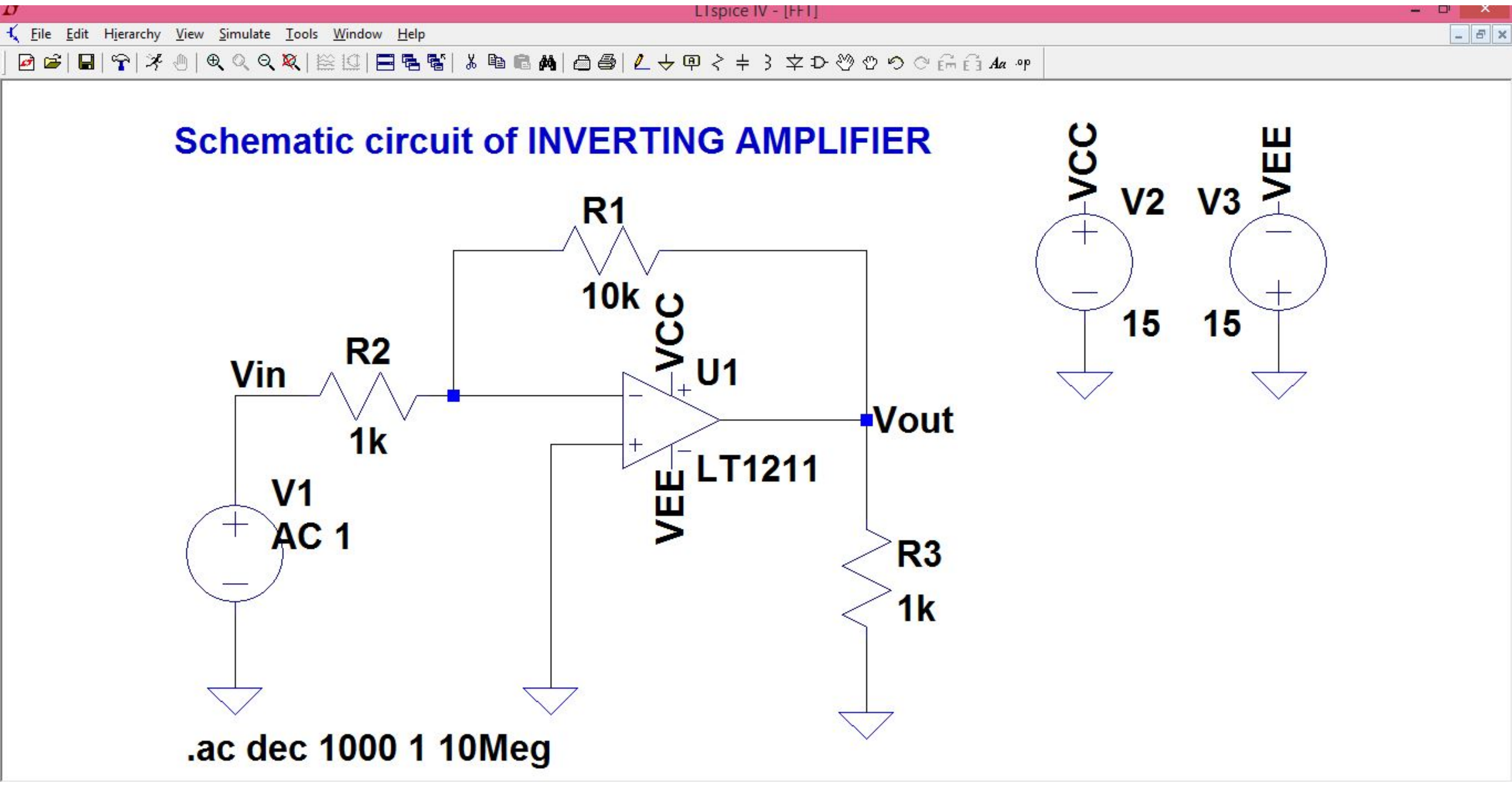
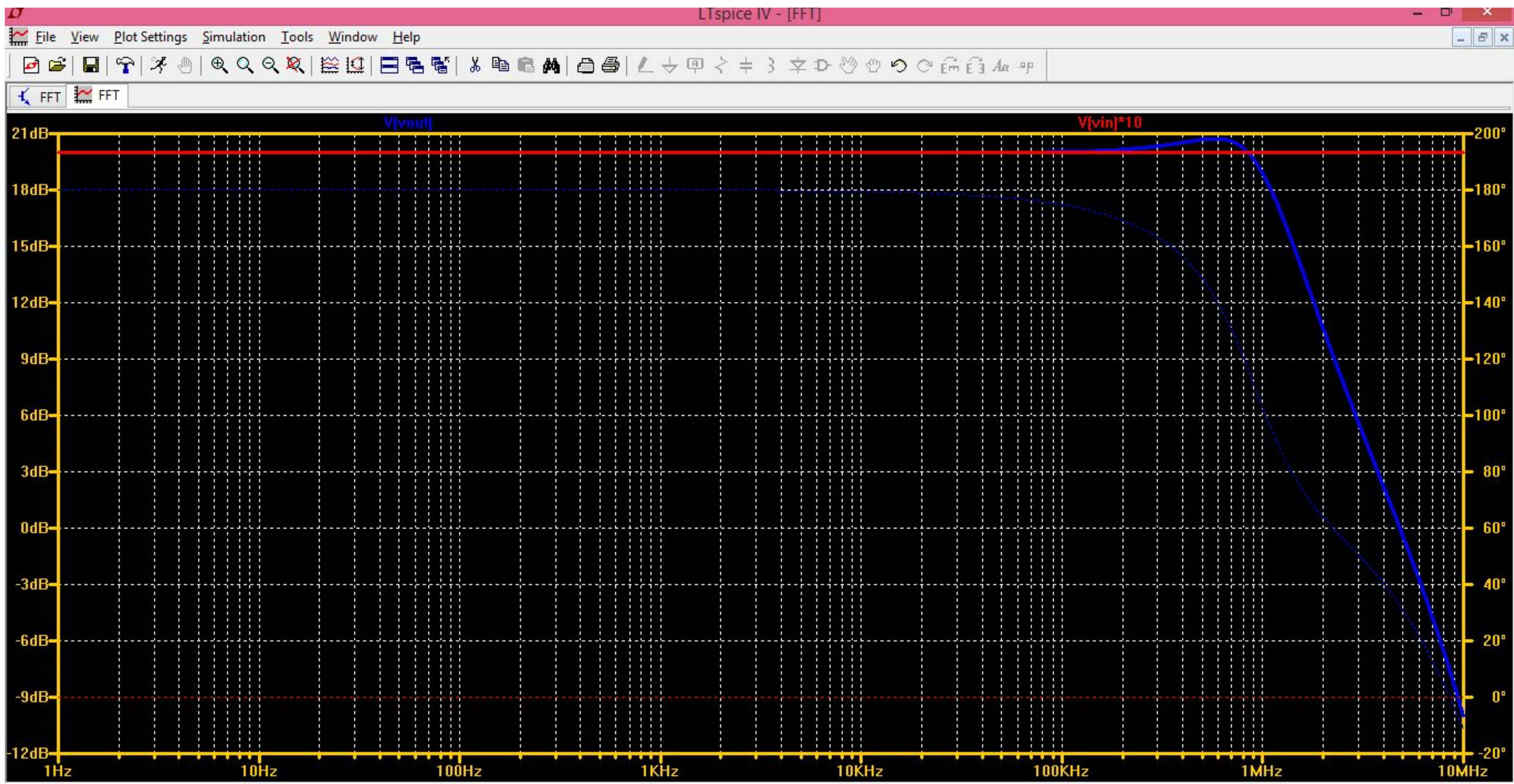


Fig.4

From the AC analysis it is observed that there is an attenuation in the output wave starting from about 150Khz. Which means that after that frequency, the output will no longer be following the input sinosoidally and increasing frequency will give rise to a non-linear distortion due to the limitation of slew rate. The schematic and simuation is in Fig4. And 5 respectively.

Fig.5



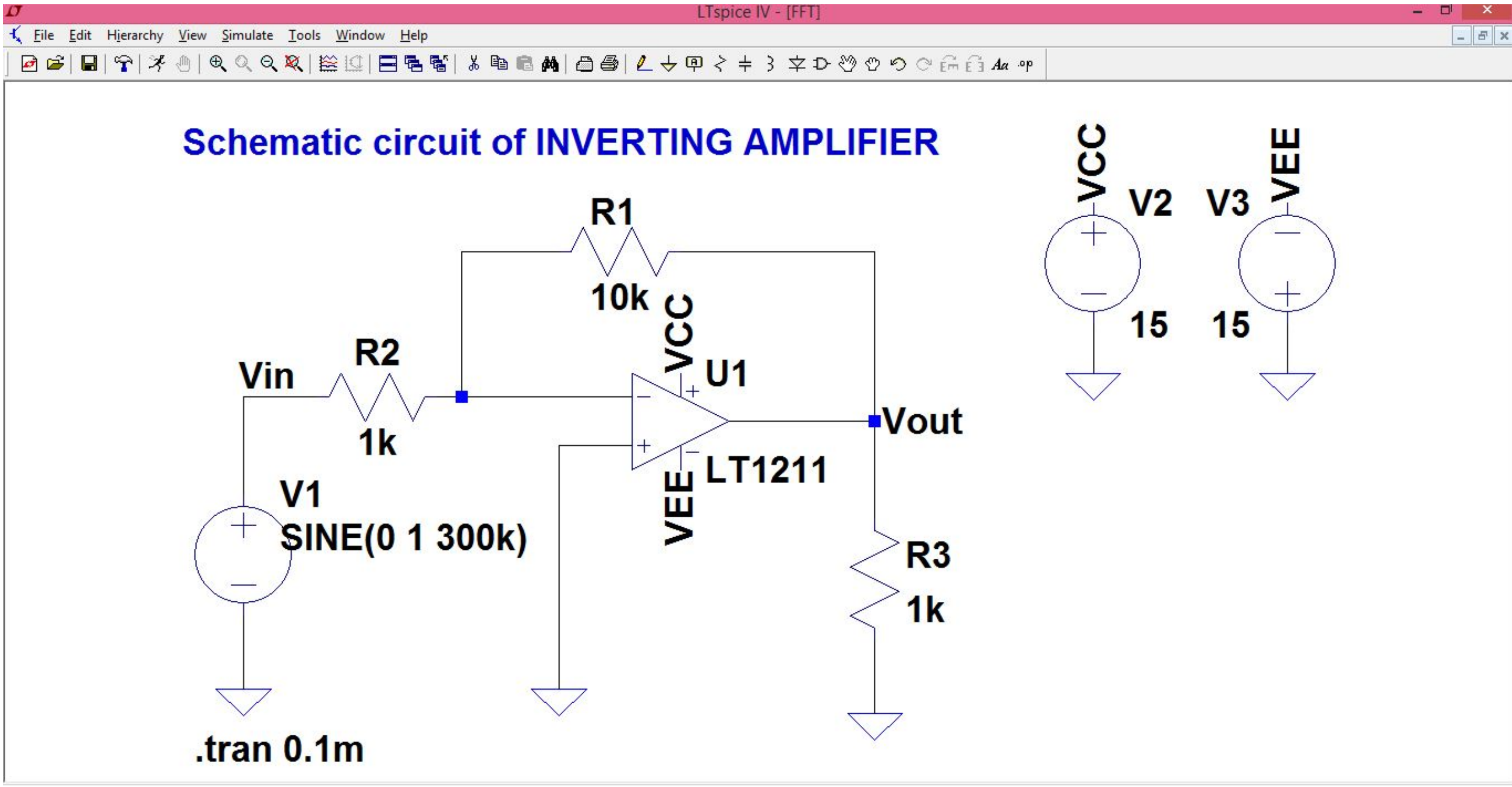

LTspice IV - [FFT]
File Edit Hierarchy View Simulate Tools Window Help
Schematic circuit of INVERTING AMPLIFIER
R1
10k
R2
1k
Vin
VCC
U1
LT1211
VEE
Vout
R3
1k
V1
SINE(0 1 300k)
.tran 0.1m
VCC
V2
15
V3
VEE
15

Fig.6

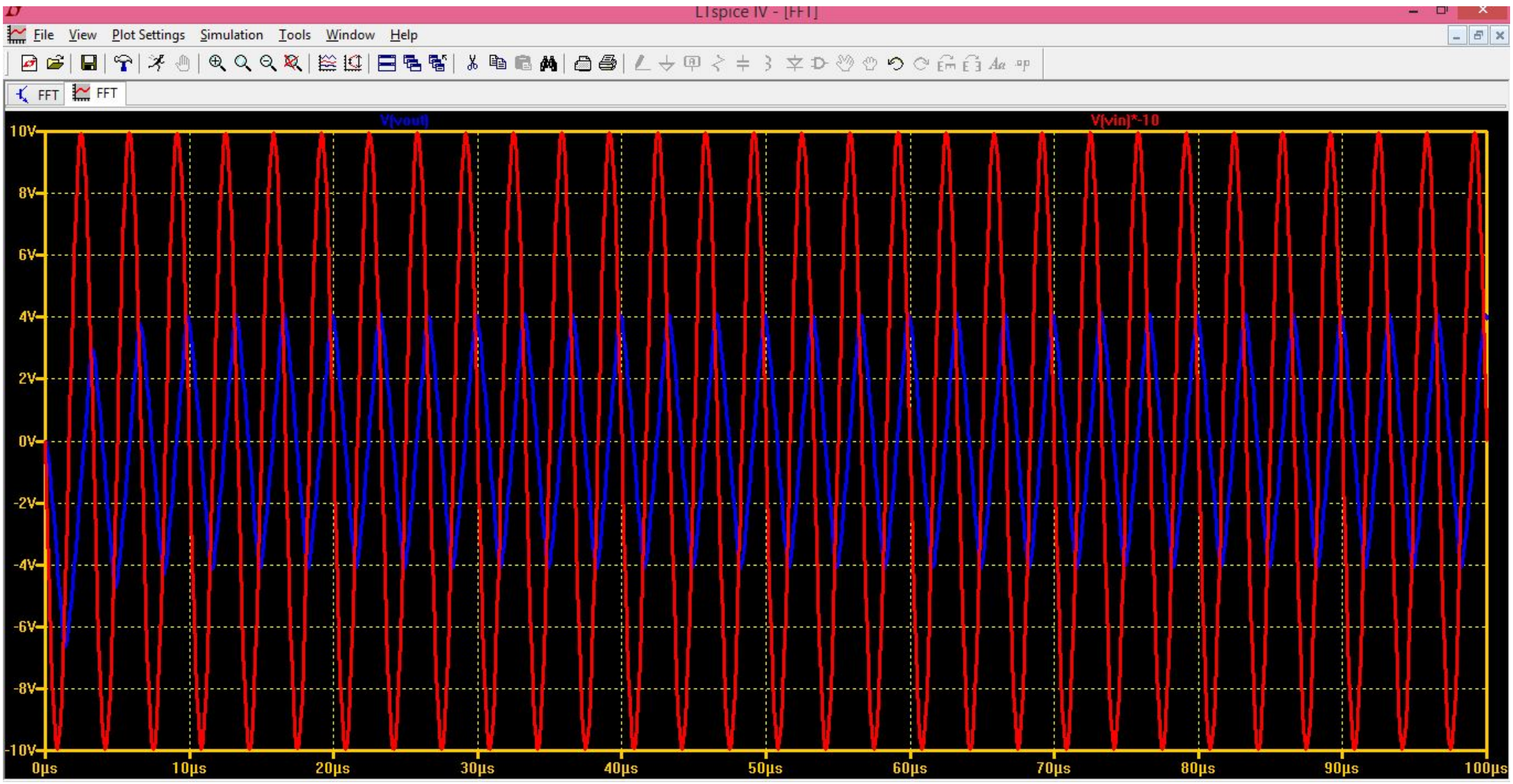

LTspice IV - [FFT]
File View Plot Settings Simulation Tools Window Help
FFT
FFT
V[vout]
V[vin]*-10
10V
8V
6V
4V
2V
0V
-2V
-4V
-6V
-8V
-10V
0µs
10µs
20µs
30µs
40µs
50µs
60µs
70µs
80µs
90µs
100µs

Fig.7

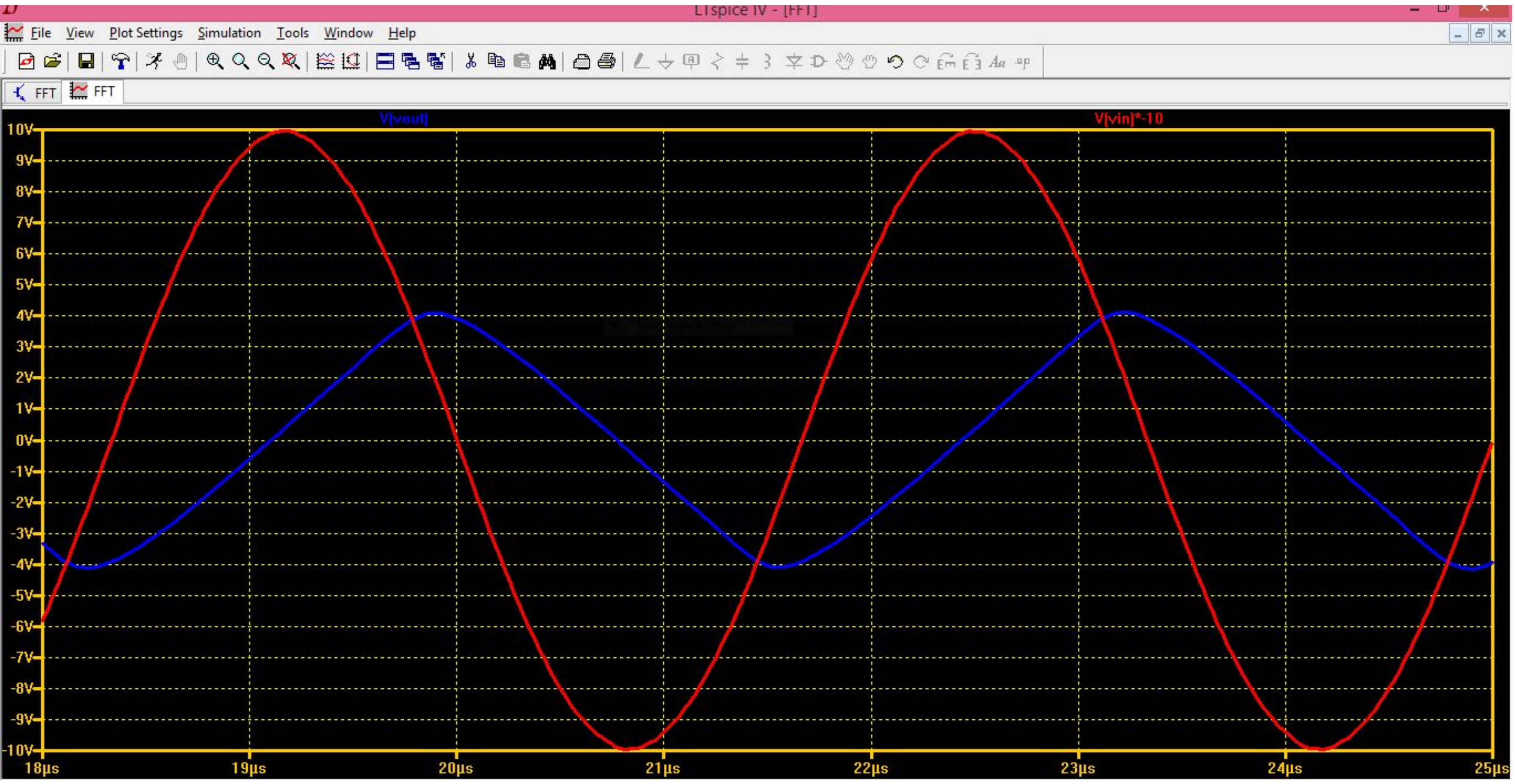


Fig.8

W.r.t. Fig.6,7 and 8, the for a sine wave of 300KHz, it is proven that the output is no longer following the input. The output is changing at about 7V per microsecond which is infact the slew rate of the op-amp LT1211. Fig.8 is the zoomed version of Fig.7 where the input voltage is compensated to be equal to the output voltage so that the op-amp properties can be compared.

Fig. 9,10,11 and 12 are the fast fourier transform(FFT) waveforms of schematic Fig.1 and 6. for sine wave of frequencies 1KHz and 300KHz respectively. To calculate FFT, right click on the simulation window ->view-> FFT-> select the Blackman window option and the desired parameter and observe the waveform in linear representation of the vertical Y axis. Fig.9 and 11 are the normal input waveforms for sine value 1KHz and 300KHz frequency respectively. And Fig. 10 and 12 are the respective output waveforms. In Fig.10 the waveform shows no undesired harmonics while the 300KHz output waveform shows a few harmonics of non-linear distortion, proving the above AC and transient analysis.

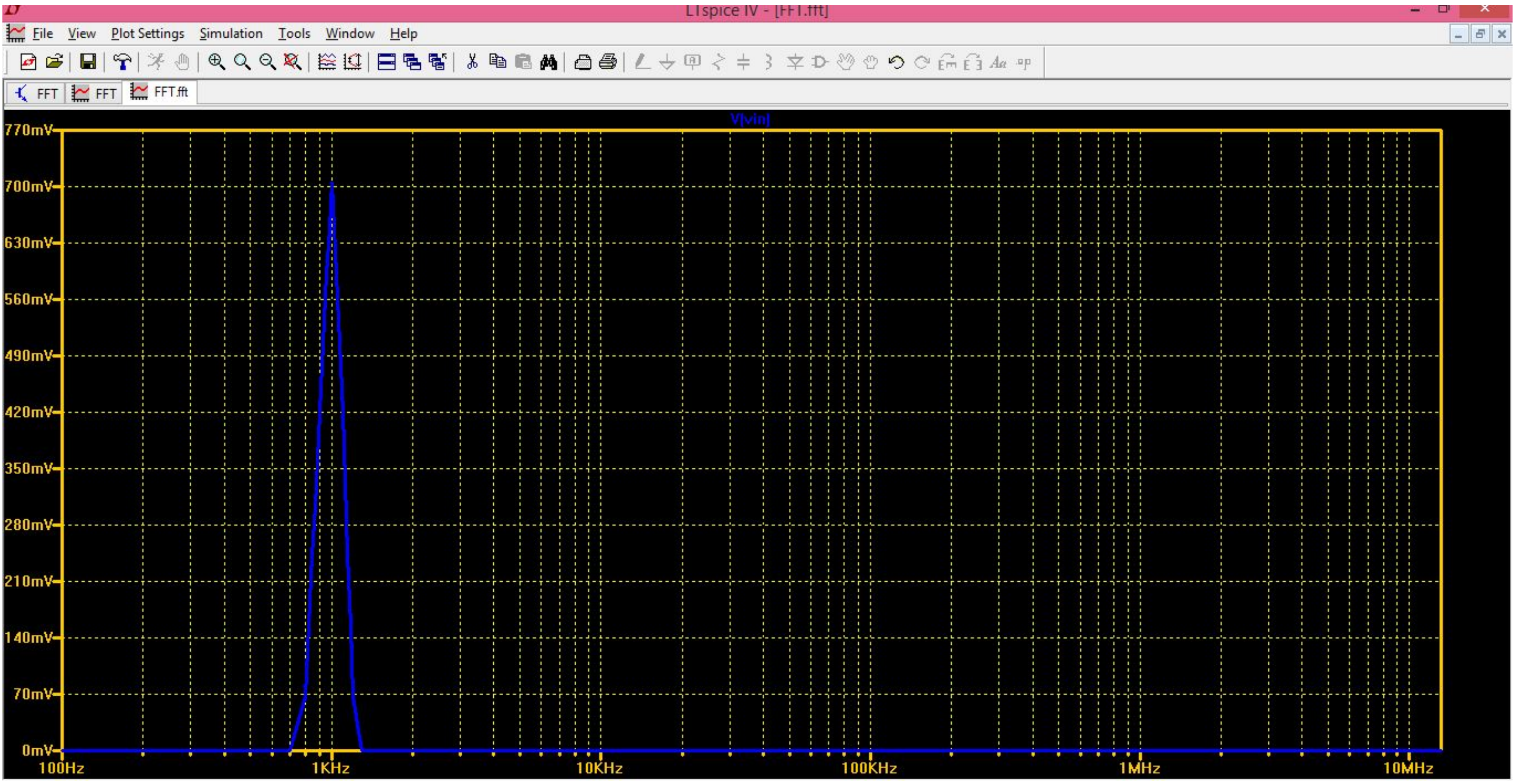

LTspice IV - [FFT.fft]
File View Plot Settings Simulation Tools Window Help
FFT FFT FFT.fft
V(vin)
770mV
700mV
630mV
560mV
490mV
420mV
350mV
280mV
210mV
140mV
70mV
0mV
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz

Fig.9

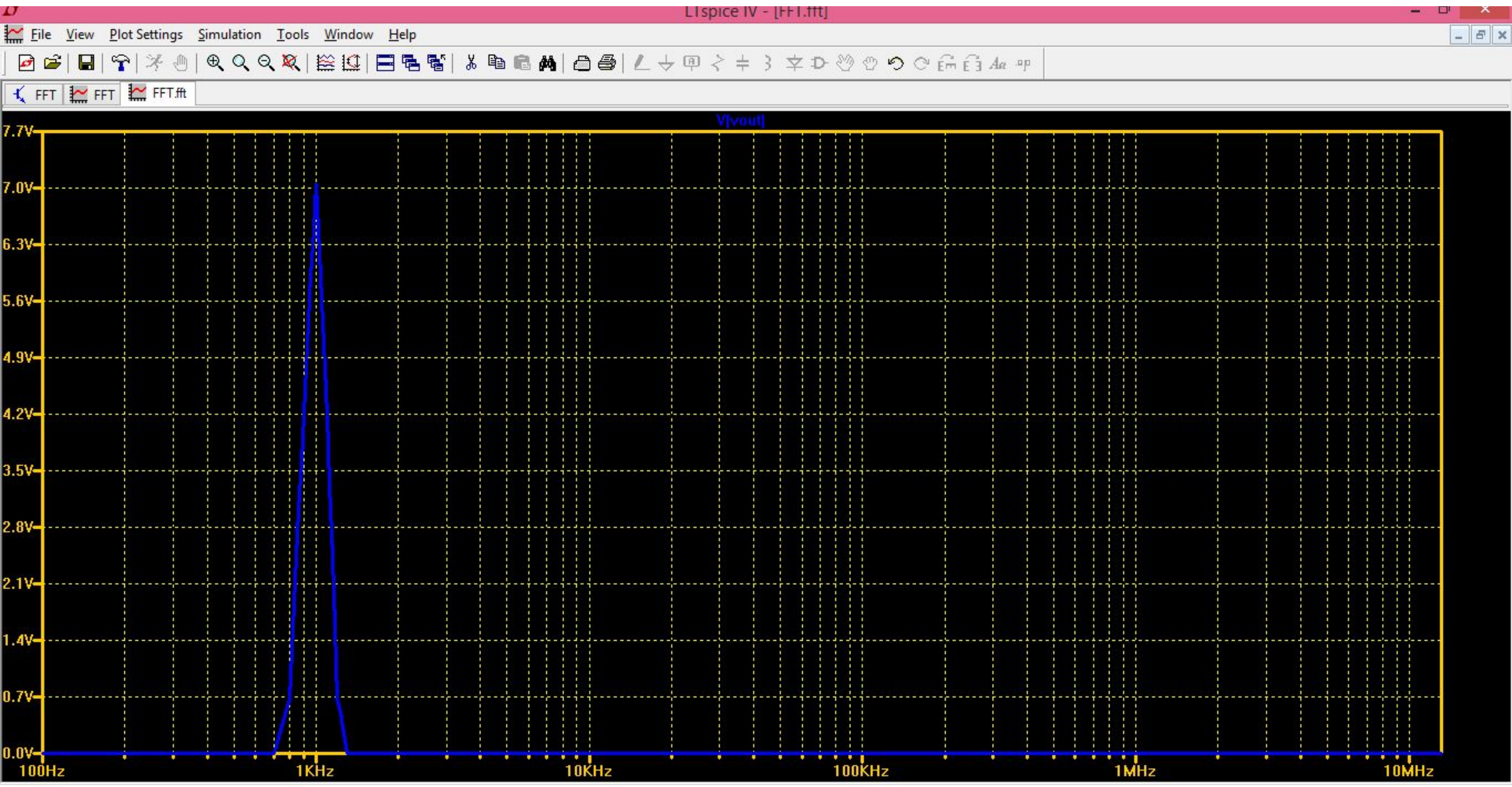

LTspice IV - [FFT.fft]
File View Plot Settings Simulation Tools Window Help
FFT FFT FFT.fft
V(vout)
7.7V
7.0V
6.3V
5.6V
4.9V
4.2V
3.5V
2.8V
2.1V
1.4V
0.7V
0.0V
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz

Fig.10

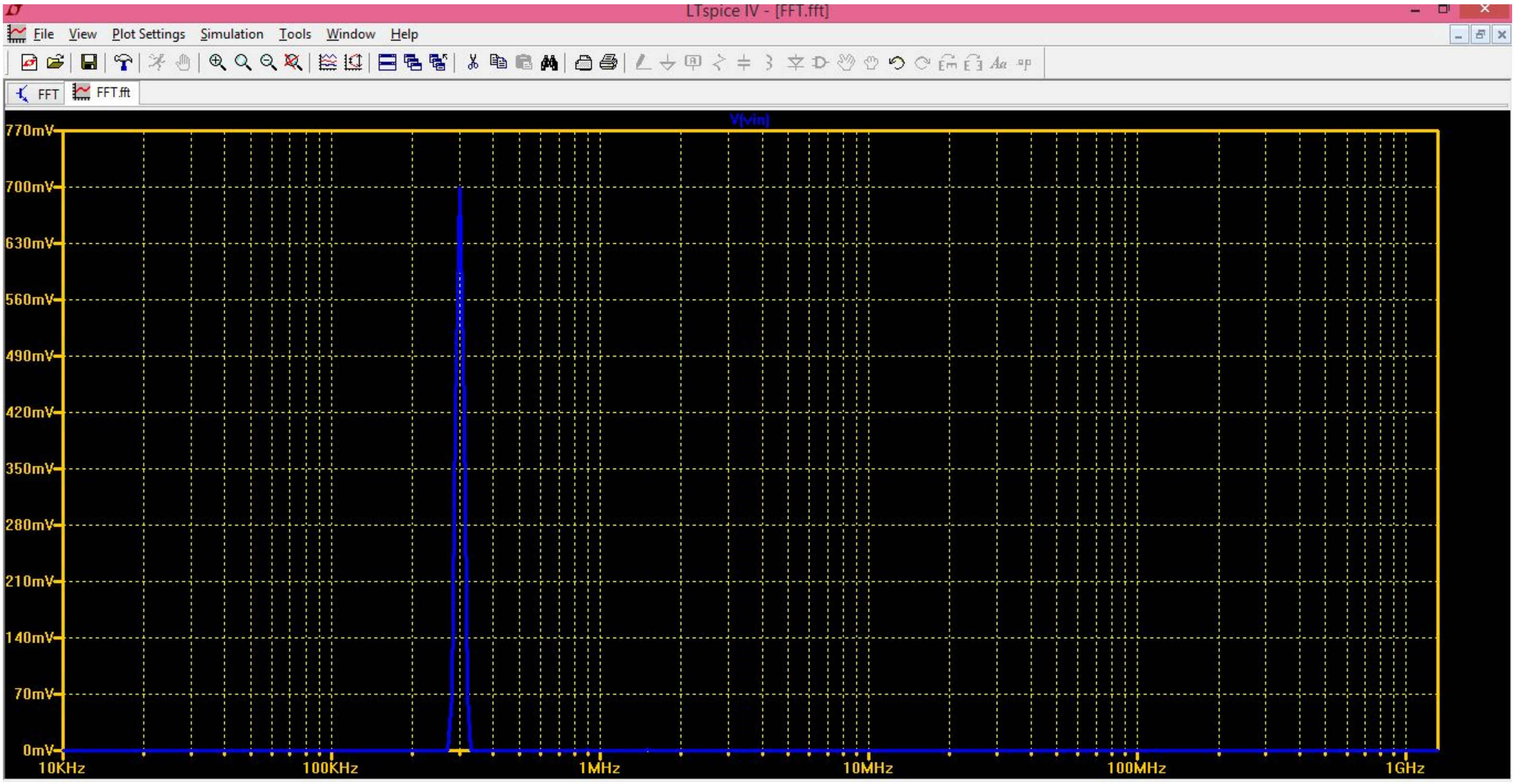
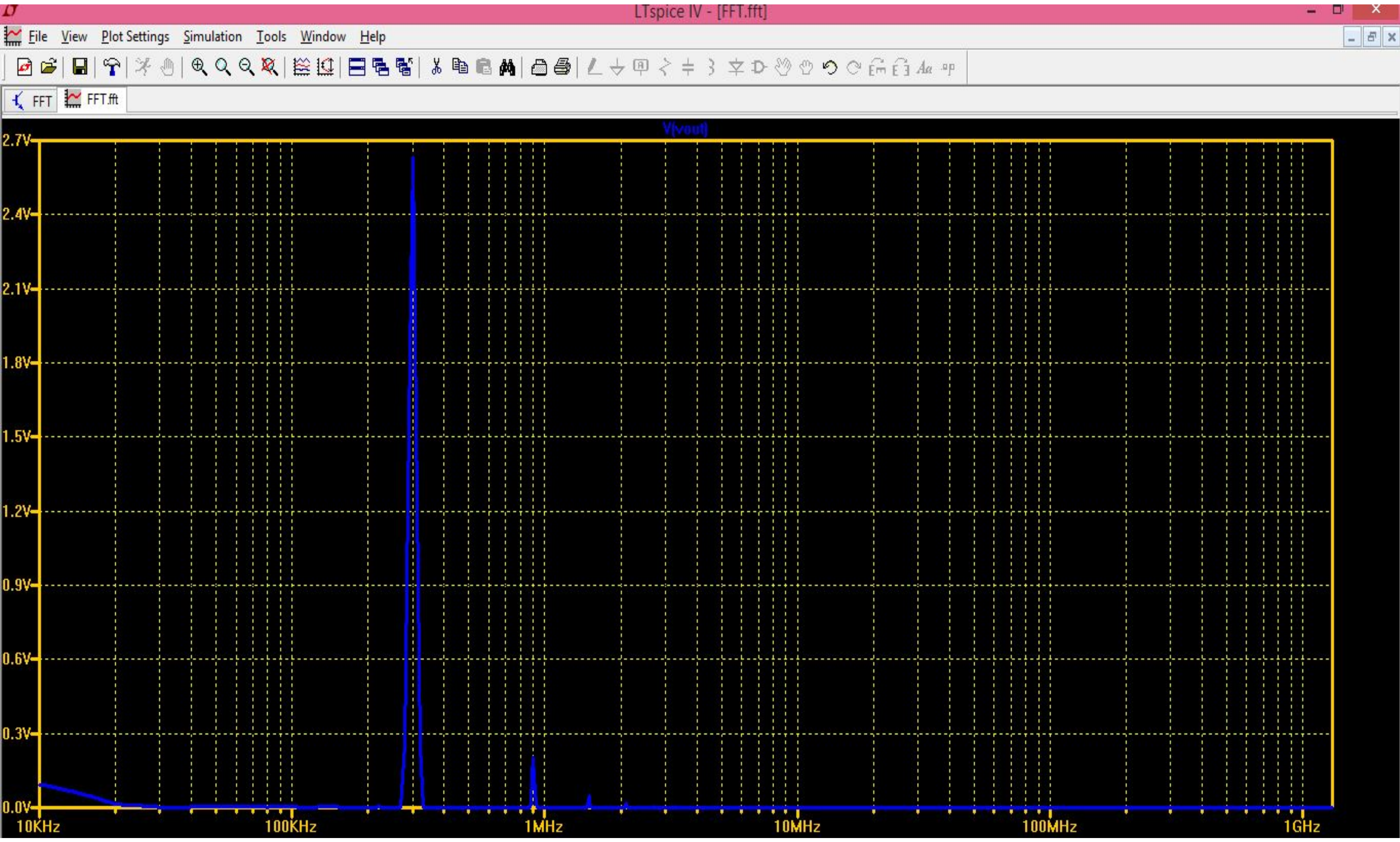

LTspice IV - [FFT.fft]
File View Plot Settings Simulation Tools Window Help
FFT FFT.fft
V(vin)
770mV
700mV
630mV
560mV
490mV
420mV
350mV
280mV
210mV
140mV
70mV
0mV
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz

Fig.11

Fig.12


LTspice IV - [FFT.fft]
File View Plot Settings Simulation Tools Window Help
FFT FFT.fft
V(vout)
2.7V
2.4V
2.1V
1.8V
1.5V
1.2V
0.9V
0.6V
0.3V
0.0V
10KHz
100KHz
1MHz
10MHz
100MHz
1GHz