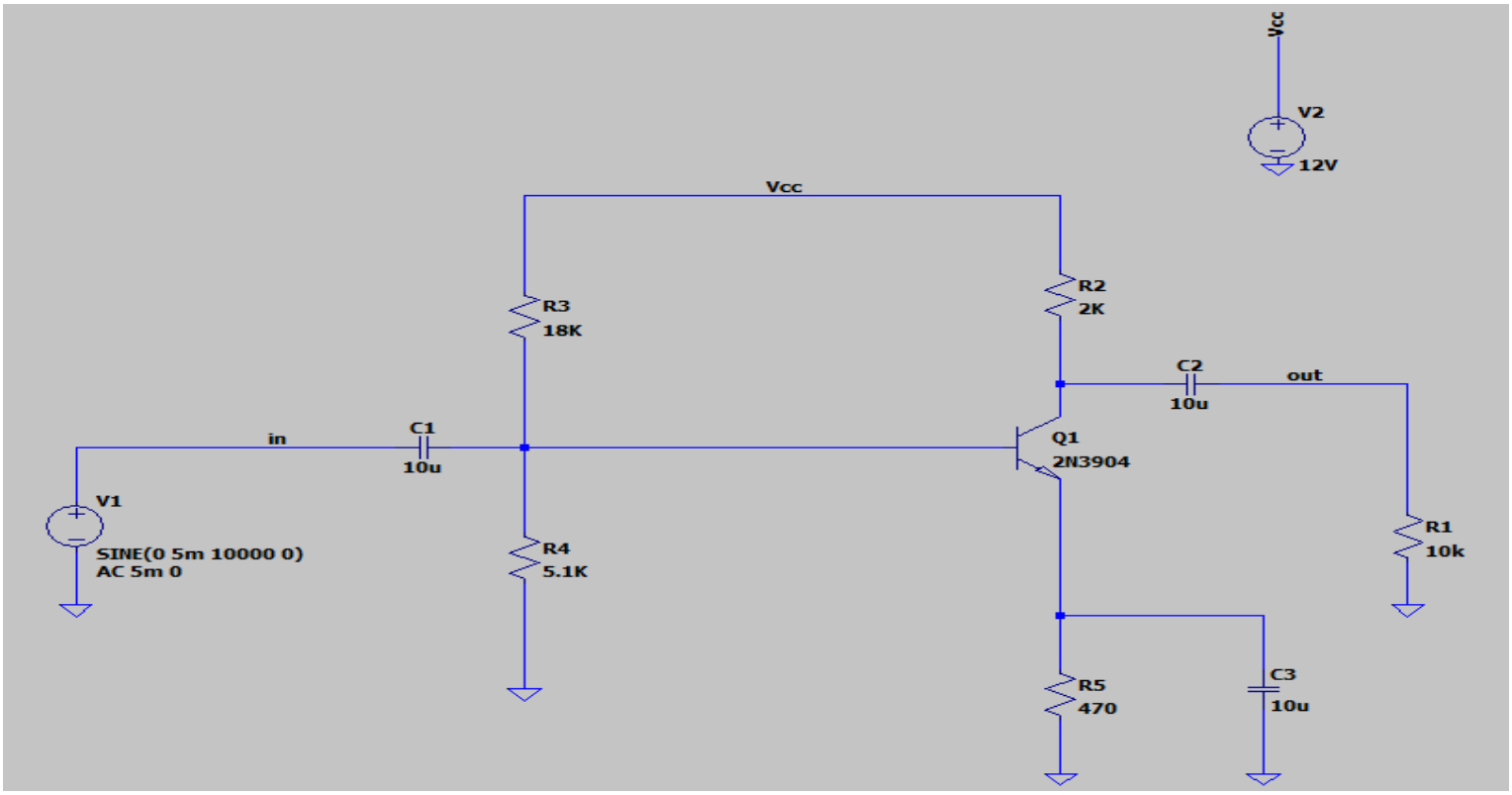
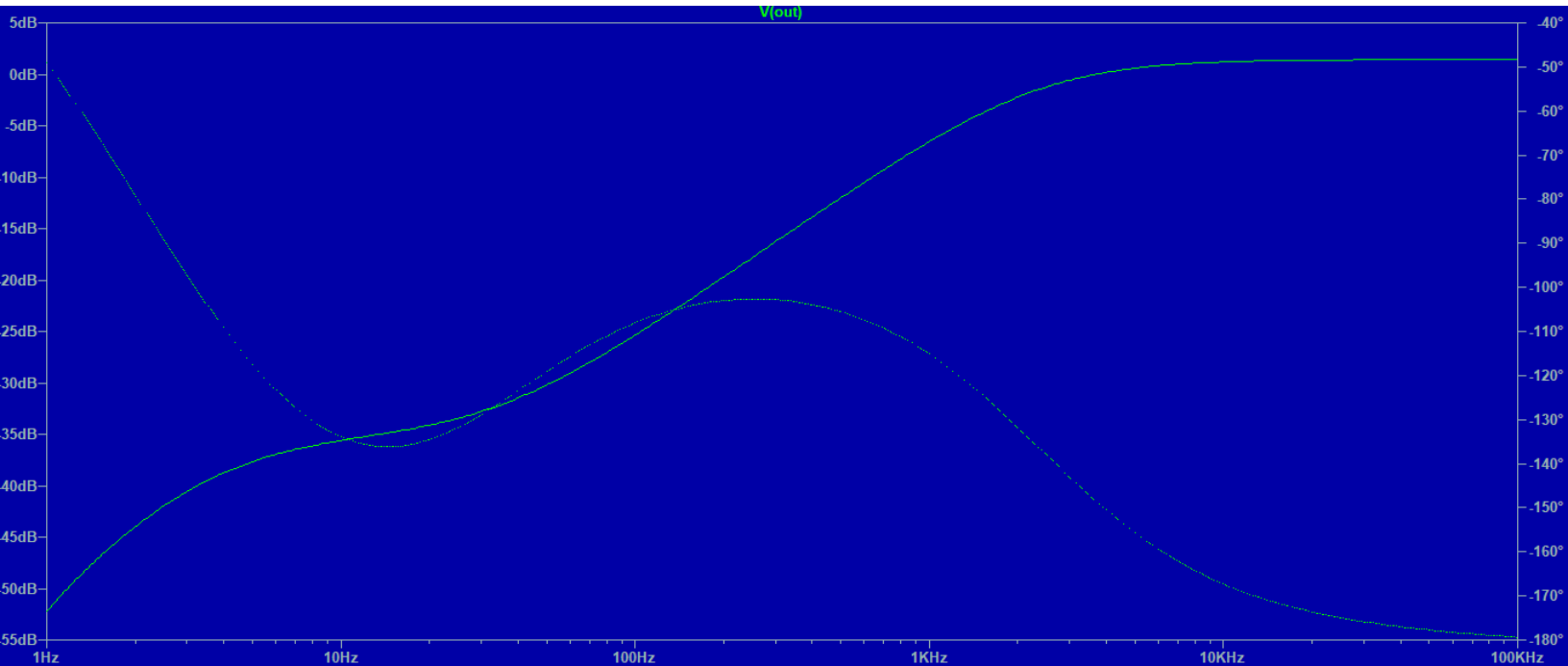
2 laboratory work
Negative feedback in amplifier (modelling with LTspice)

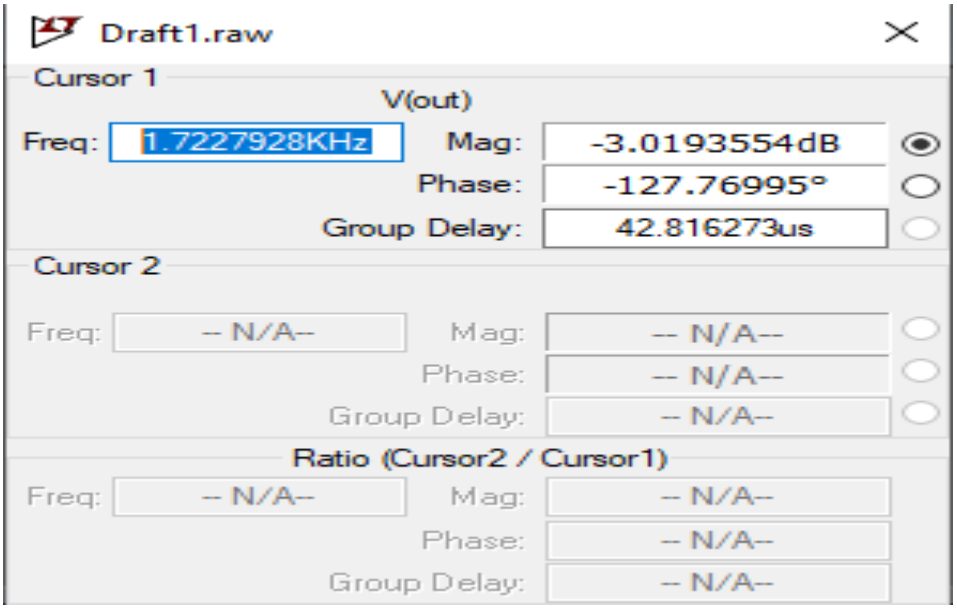
Work aim: During laboratory work you will investigate negative feedback (NF) in amplifier and learn how it influences parameters of amplifier.

Fig. 1. Amplifier without NF

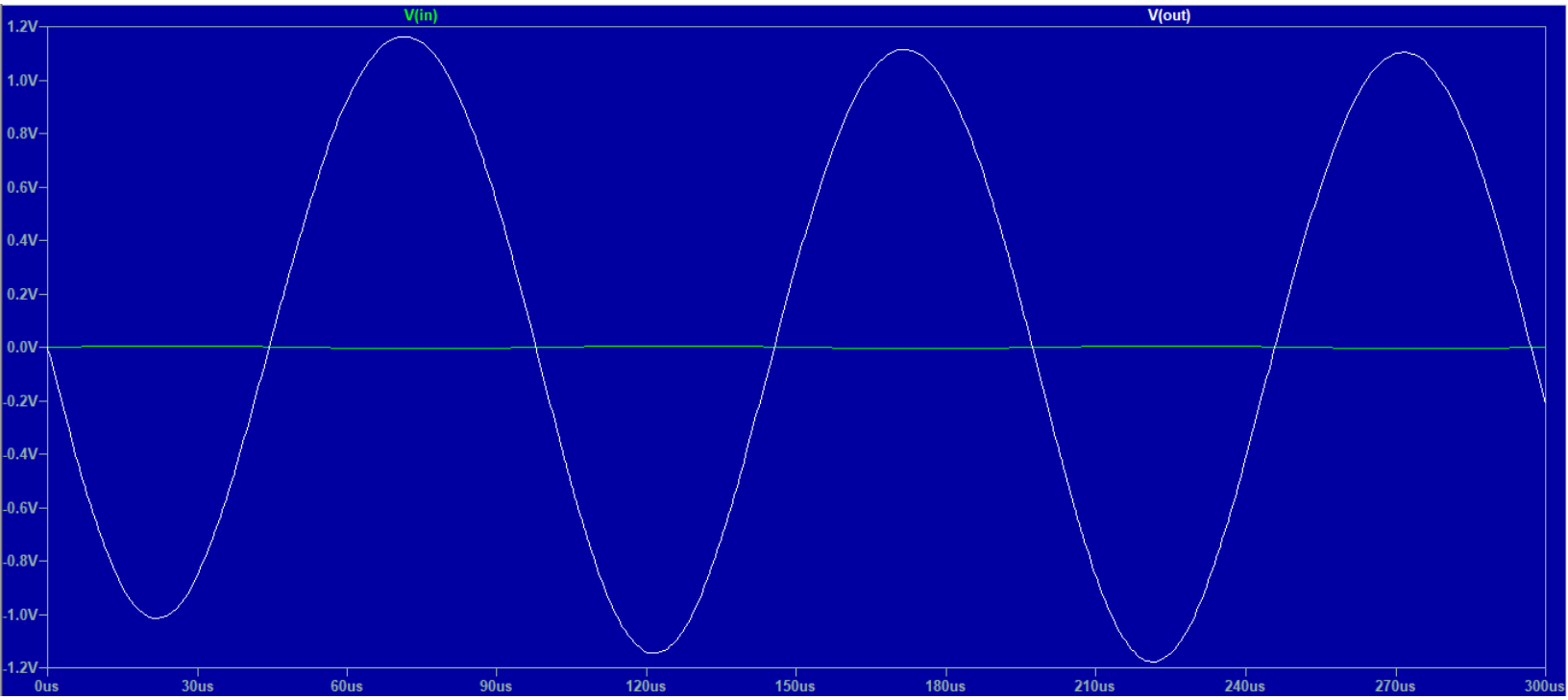


AC RESPONSE






```
Direct Newton iteration for .op point succeeded.
N-Period=1
Fourier components of V(out)
DC component:0.00575388

Harmonic            Frequency           Fourier             Normalized
 Number               [Hz]              Component            Component
    1                1.000e+4           1.141e+0             1.000e+0
    2                2.000e+4           4.279e-2             3.751e-2
    3                3.000e+4           1.088e-3             9.543e-4
    4                4.000e+4           3.785e-4             3.319e-4
    5                5.000e+4           8.776e-4             7.694e-4
    6                6.000e+4           9.783e-4             8.577e-4
    7                7.000e+4           6.661e-4             5.840e-4
    8                8.000e+4           3.178e-4             2.786e-4
    9                9.000e+4           9.770e-5             8.566e-5
Total Harmonic Distortion: 3.754777%(3.756457%)


Date: Wed May 13 16:08:55 2020
Total elapsed time: 0.089 seconds.

tnom = 27
temp = 27
method = modified trap
totiter = 2107
```



71.264368us-25.306748us = **45.95762**

Φ= (45.95762 / 100.07669us) . 360° = 165.3206476

Amplifier Input Resistance

$U_1 = 5 \text{ x}10^{-3}$ V $\qquad$ $U_2 = 628.51516 \text{ x}10^{-6}$ V

$$I_{in} = \frac{U_1 - U_2}{R} \qquad U_1 - U_2 = R \cdot I_{in} \qquad Z_{in} = R_{in} = \frac{U_2}{I_{in}} = \frac{R \cdot U_2}{U_1 - U_2} = \frac{R}{U_1 / U_2 - 1}$$

$$\frac{10 \text{ x}10^{3}\ \Omega}{\frac{5 \text{ x}10^{-3}}{628.51516 \text{ x}10^{-6}} - 1} = \mathbf{1{,}437.7612710651}\ R_{in}$$

Amplifier Output Impedance

U is voltage which is measured when S is OFF and load is not connected

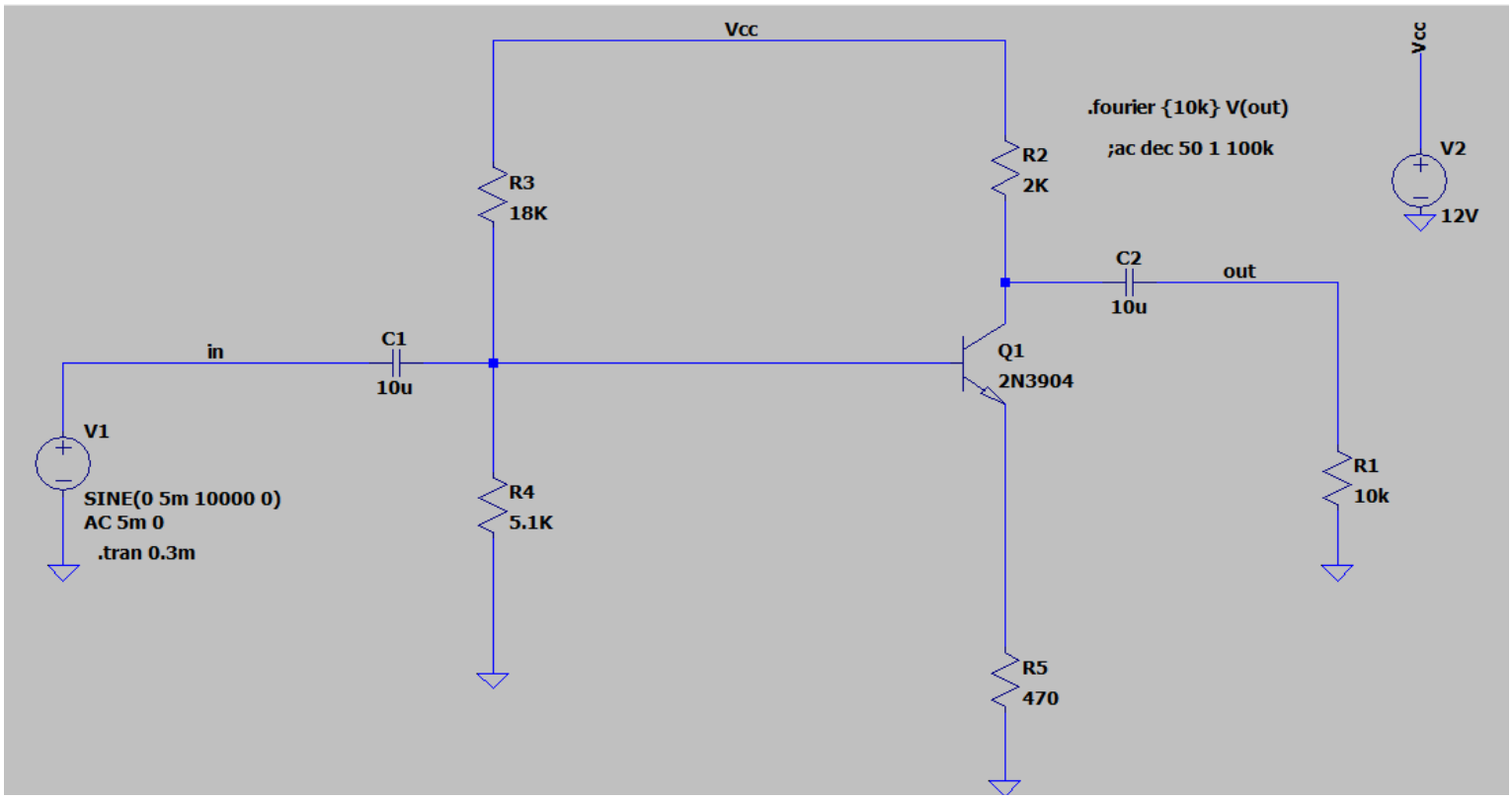
$$\Delta U = U - U_R \qquad Z_{out} = \frac{\Delta U}{I} = \frac{U - U_R}{I} = \frac{R(U - U_R)}{U}$$

U = 1.3251121V $\qquad$ R = 10K $\qquad$ U_R = 1.1151184V

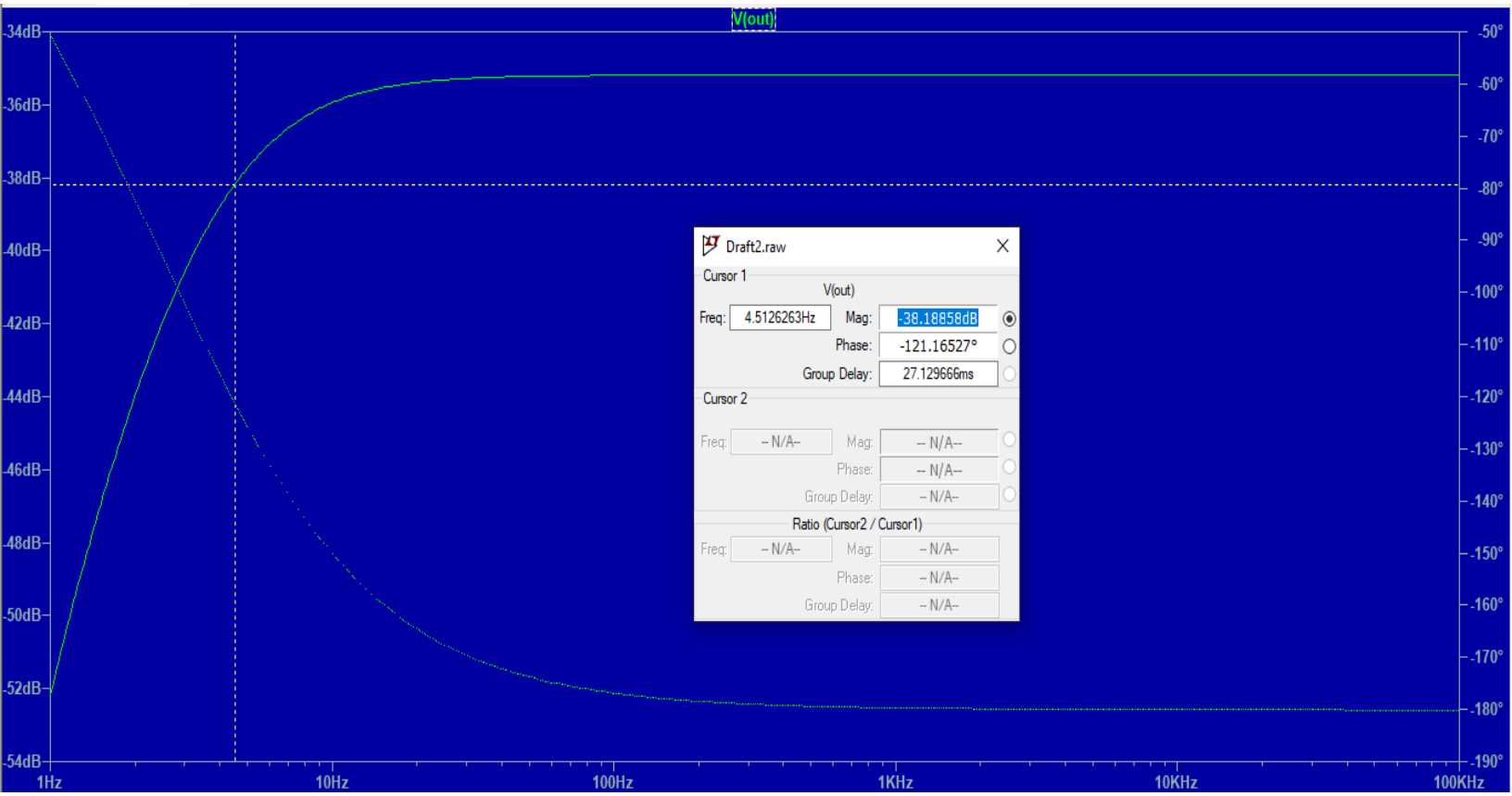
$$R(U-U_R) / U = Z_{out}$$

$$\frac{10\text{x}10^{3}\ (1.3251121 - 1.1151184)}{1.3251121} = \mathbf{1{,}584.7240395737}$$

Fig. 2. Amplifier with current-series NF



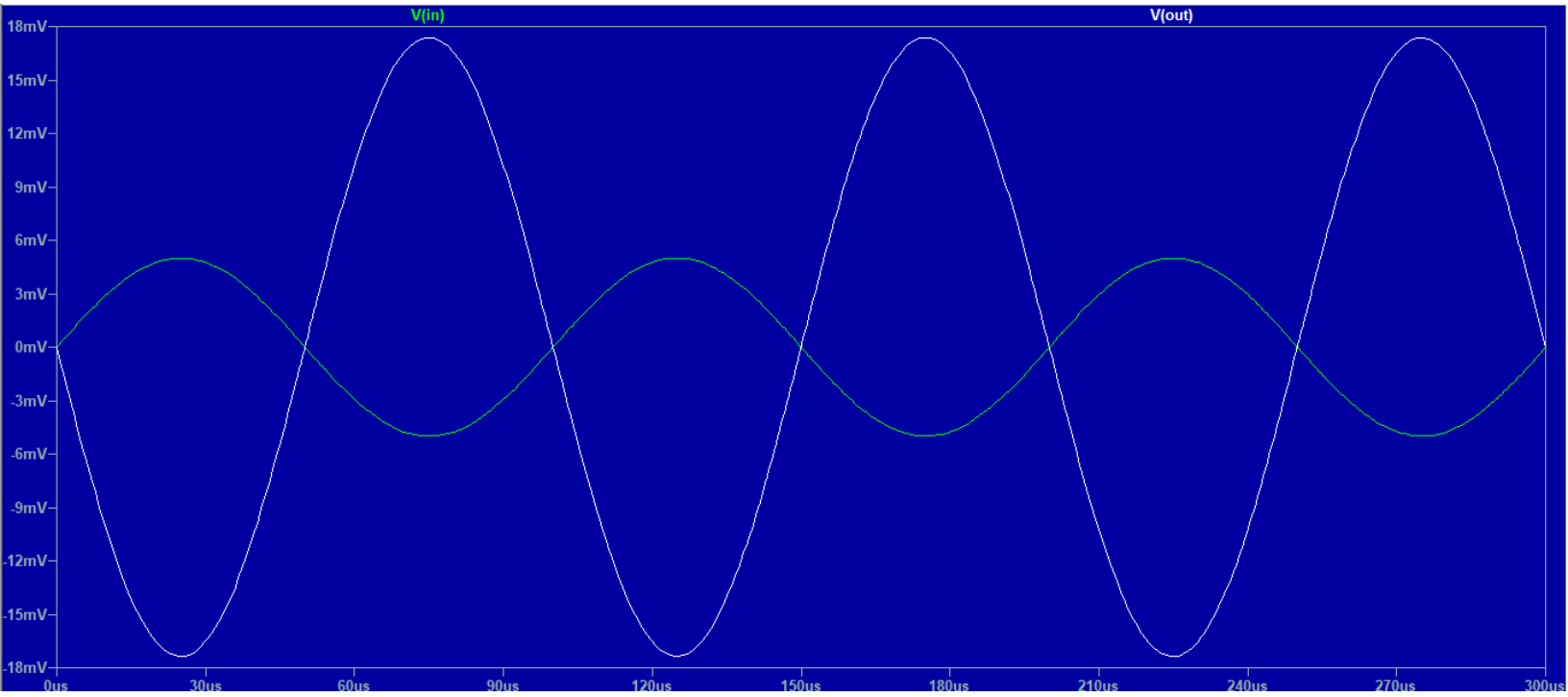
AC Response and Bandwitdh



SPICE Error Log: C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\2\Draft2.log

```
Circuit: * C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\2\Draft2.asc

Direct Newton iteration for .op point succeeded.
N-Period=1
Fourier components of V(out)
DC component:-1.35685e-06

Harmonic              Frequency              Fourier              Normalized
 Number                 [Hz]                Component              Component
     1                1.000e+4              1.740e-2              1.000e+0
     2                2.000e+4              7.577e-6              4.355e-4
     3                3.000e+4              8.813e-6              5.065e-4
     4                4.000e+4              1.185e-5              6.808e-4
     5                5.000e+4              7.785e-6              4.474e-4
     6                6.000e+4              4.515e-6              2.595e-4
     7                7.000e+4              8.387e-6              4.821e-4
     8                8.000e+4              9.804e-6              5.635e-4
     9                9.000e+4              7.787e-6              4.476e-4
Total Harmonic Distortion: 0.138833%(0.161176%)


Date: Sat May 16 22:16:00 2020
Total elapsed time: 0.126 seconds.

tnom = 27
temp = 27
method = modified trap
totiter = 2089
```

Phase difference between input and output



175.55898us – 124.90362us = 50.655336 us

Φ= (50.655336 us / 100.1542us) . 360° = 182.079

Amplifier Input Resistance

$U_1 = 5 \text{ x}10^{-3}$ V $\qquad$ $U_2 = 1.3901944 \text{ x}10^{-3}$ V

$$I_{in} = \frac{U_1 - U_2}{R} \qquad U_1 - U_2 = R \cdot I_{in} \qquad Z_{in} = R_{in} = \frac{U_2}{I_{in}} = \frac{R \cdot U_2}{U_1 - U_2} = \frac{R}{U_1 / U_2 - 1}$$

$$\frac{10 \text{ x}10^{3}\ \Omega}{\frac{5 \text{ x}10^{-3}}{1.3901944 \text{ x}10\text{-}3} - 1} = \mathbf{3{,}851.1614032623}\ R_{in}$$

Amplifier Output Impedance

U is voltage which is measured when S is OFF and load is not connected

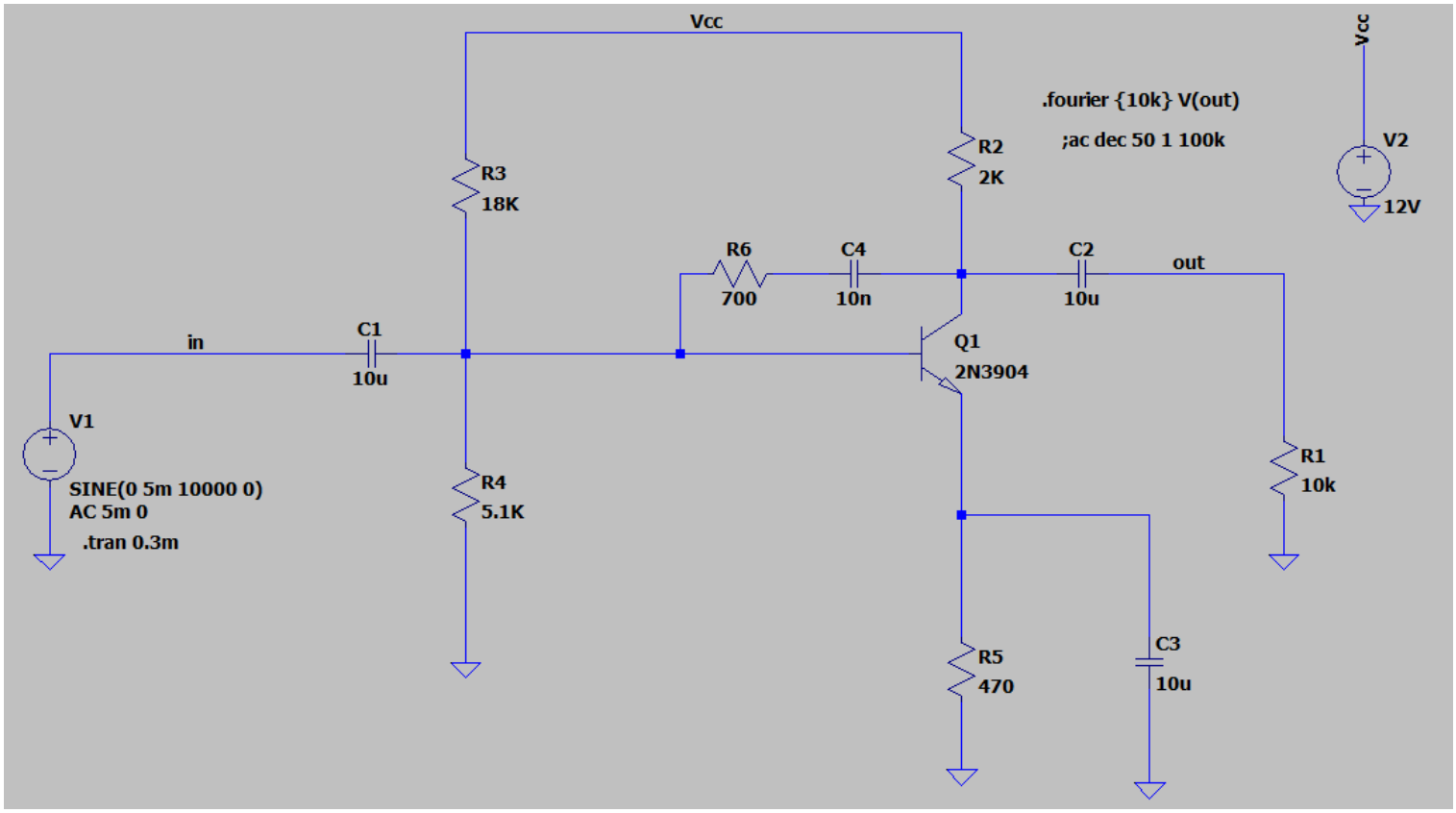
$$\Delta U = U - U_R \qquad Z_{out} = \frac{\Delta U}{I} = \frac{U - U_R}{I} = \frac{R(U - U_R)}{U}$$

U = 20.875709mV $\qquad$ R = 10K $\qquad$ U_R = 17.36763mV

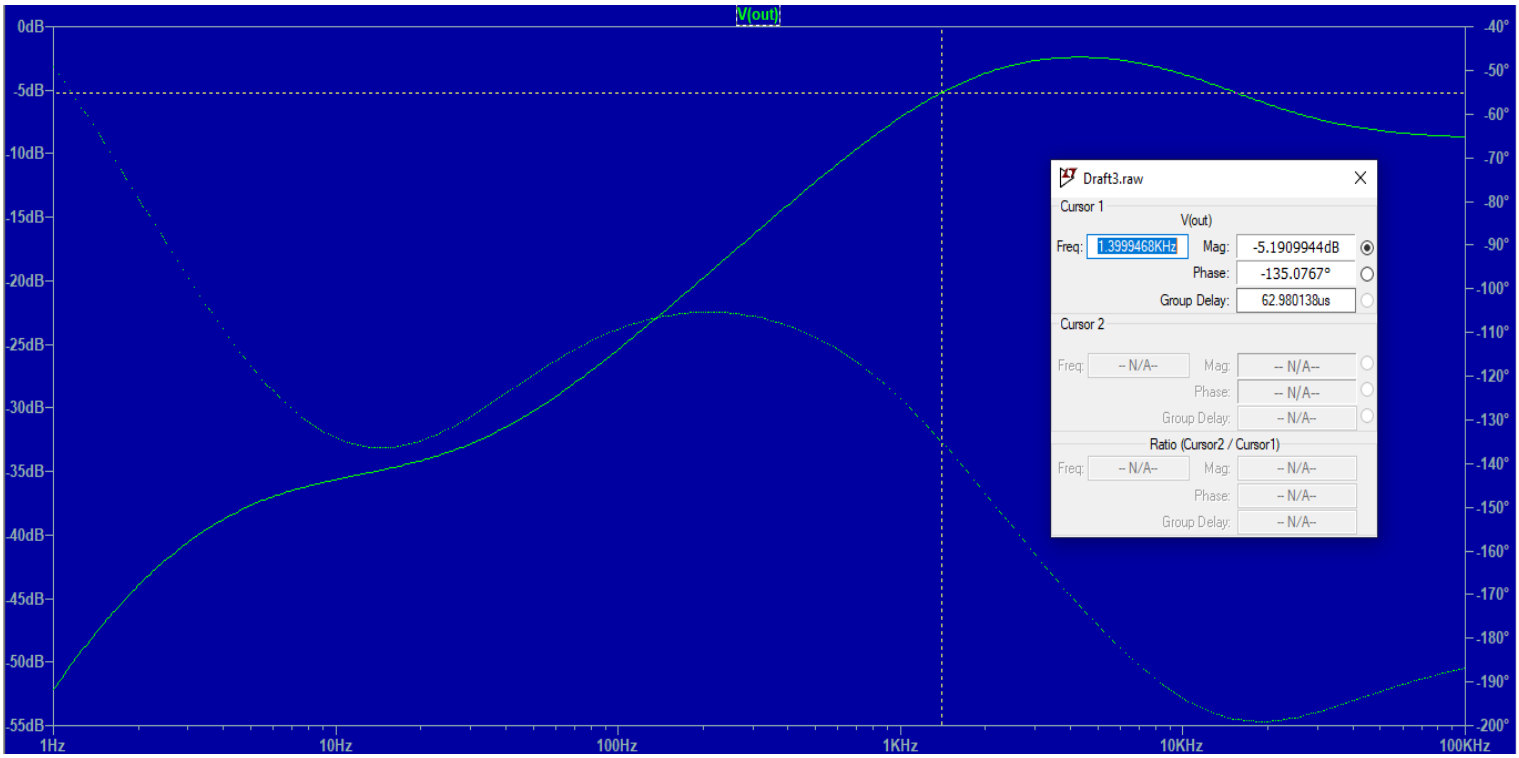
$$R(U\text{-}U_R) / U = Z_{out}$$

$$\frac{10\text{x}10^{3}\ (1.3251121 - 1.1151184)}{1.3251121} = \mathbf{0.0016804598\ R}$$

Fig. 3. Amplifier with voltage-shunt NF

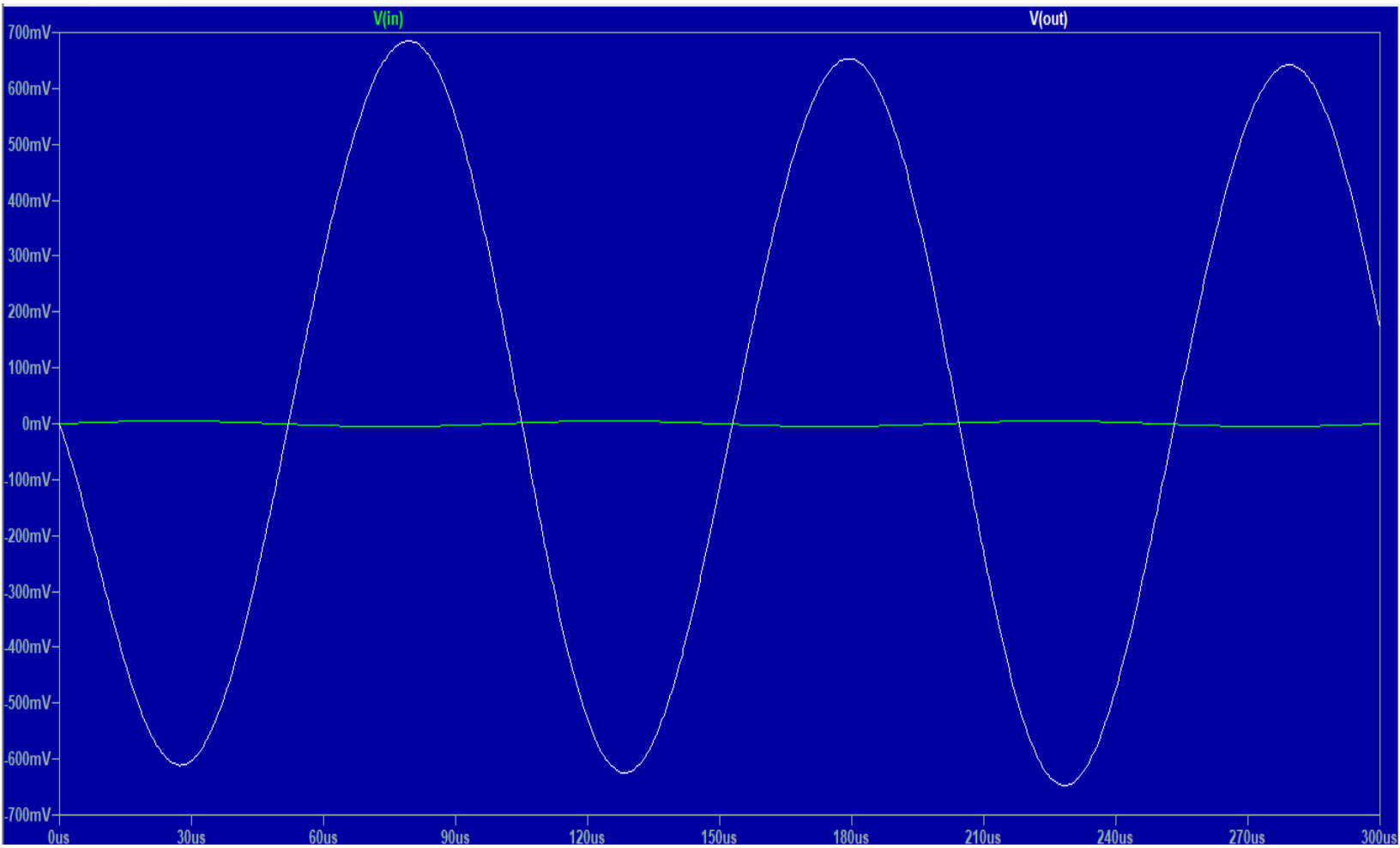


AC Response and Bandwitdh



SPICE Error Log: C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\3\Draft3.log

```
Circuit: * C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\3\Draft3.asc

Direct Newton iteration for .op point succeeded.
N-Period=1
Fourier components of V(out)
DC component:0.00861999

Harmonic            Frequency            Fourier            Normalized
 Number               [Hz]              Component            Component
    1                1.000e+4            6.439e-1            1.000e+0
    2                2.000e+4            1.571e-2            2.440e-2
    3                3.000e+4            1.093e-3            1.698e-3
    4                4.000e+4            7.541e-4            1.171e-3
    5                5.000e+4            6.729e-4            1.045e-3
    6                6.000e+4            6.205e-4            9.637e-4
    7                7.000e+4            4.551e-4            7.068e-4
    8                8.000e+4            3.329e-4            5.170e-4
    9                9.000e+4            4.068e-4            6.318e-4
Total Harmonic Distortion: 2.455304%(2.460752%)



Date: Sat May 16 22:45:31 2020
Total elapsed time: 0.114 seconds.

tnom = 27
temp = 27
method = modified trap
totiter = 2141
```



Phase difference between input and output

124.46319us – 79.302326us = 45.160864

Φ= (45.160864 / 105.11628) . 360° = 154.666

Amplifier Input Resistance

$U_1 = 5 \times 10^{-3}$ V $\qquad$ $U_2 = 29.173455 \times 10^{-6}$V

$$I_{in} = \frac{U_1 - U_2}{R} \qquad U_1 - U_2 = R \cdot I_{in} \qquad Z_{in} = R_{in} = \frac{U_2}{I_{in}} = \frac{R \cdot U_2}{U_1 - U_2} = \frac{R}{U_1 / U_2 - 1}$$

$$\frac{10 \times 10^{3}\ \Omega}{\frac{5 \times 10^{-3}}{1.3901944 \times 10^{-3}} - 1} = \mathbf{58.6893441883}\ R_{in}$$

Amplifier Output Impedance

U is voltage which is measured when S is OFF and load is not connected

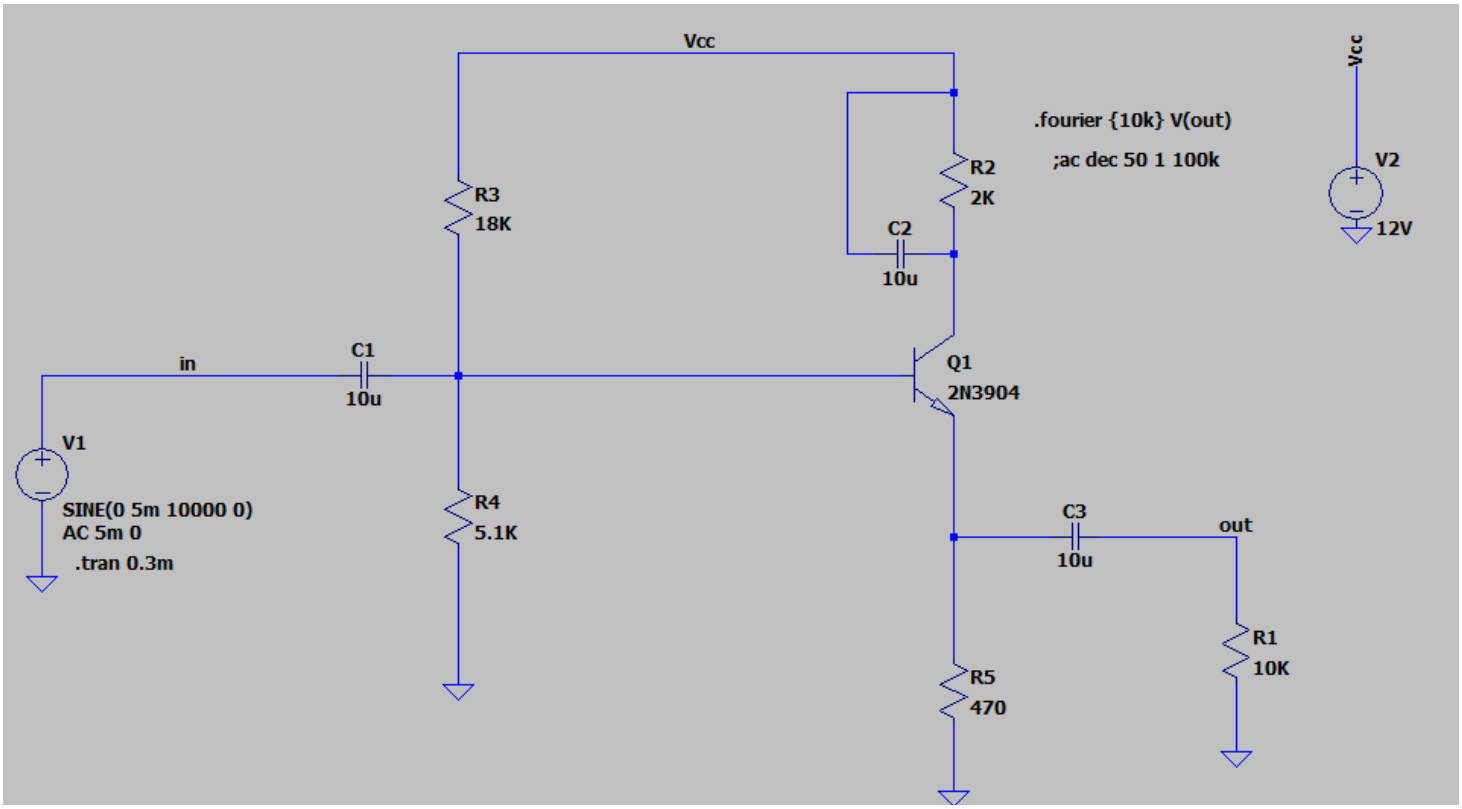
$$\Delta U = U - U_R \qquad Z_{out} = \frac{\Delta U}{I} = \frac{U - U_R}{I} = \frac{R(U - U_R)}{U}$$

U = 711.007mV $\qquad$ R = 10K $\qquad$ U_R = 652.99687mV

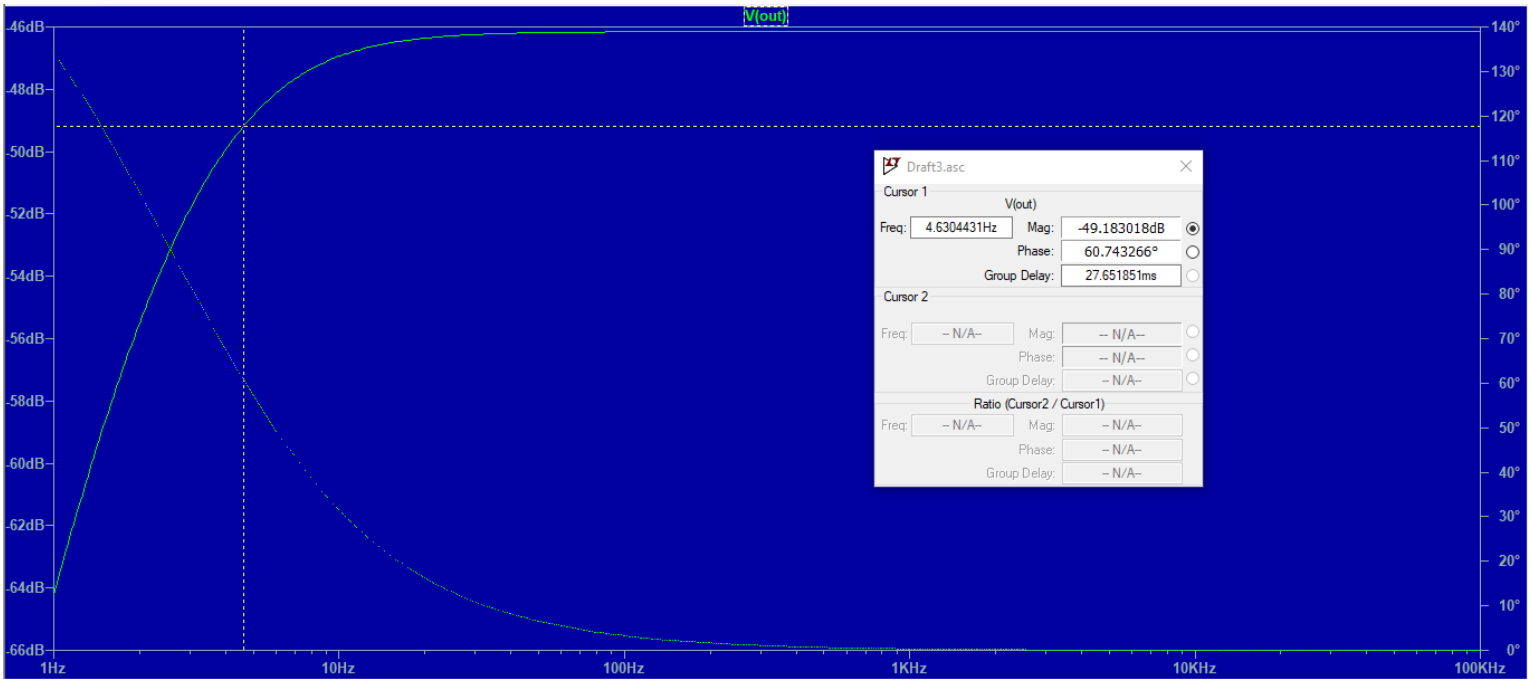
$$R(U-U_R) / U = Z_{out}$$

$$\frac{10 \times 10^{3}\ (1.3251121 - 1.1151184)}{1.3251121} = \mathbf{815.886904067\ R}$$

Fig. 4. Amplifier with voltage-series NF

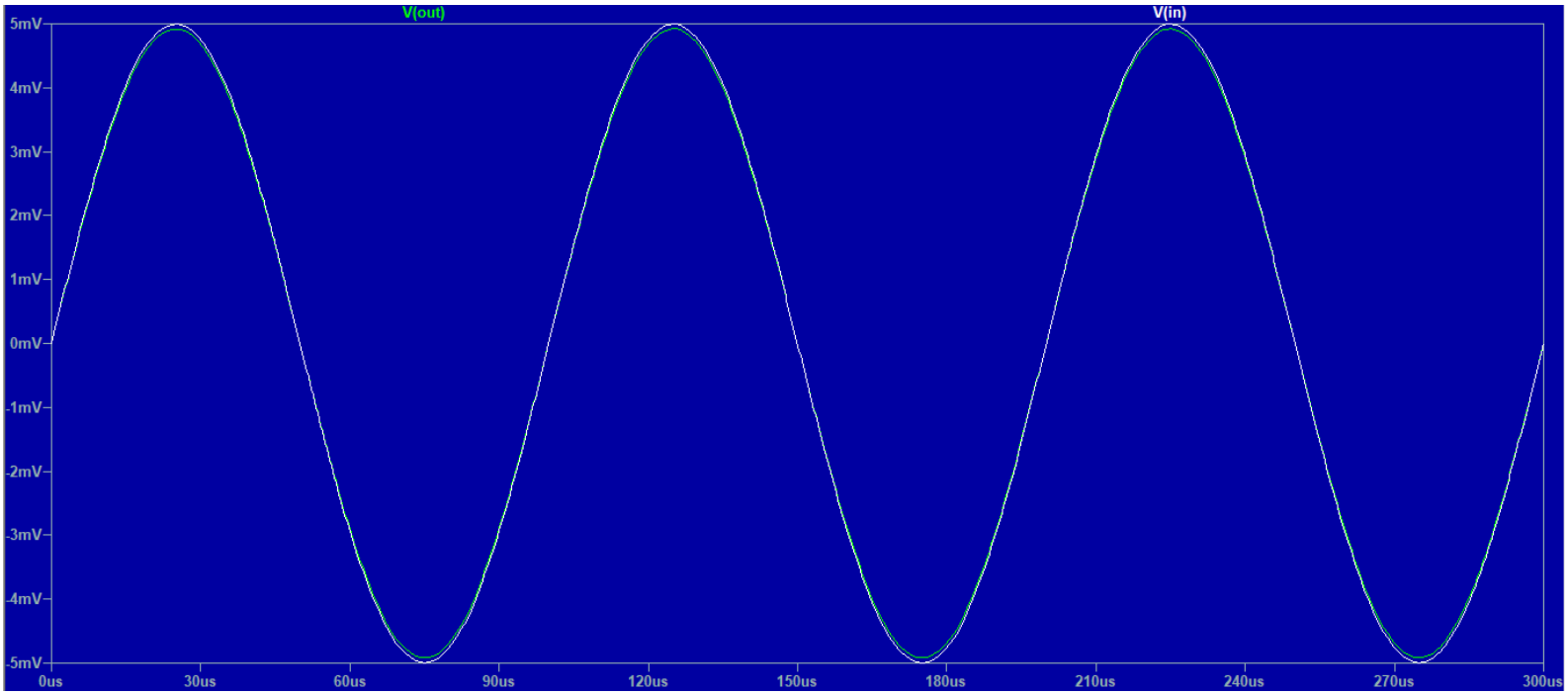


AC Response



SPICE Error Log: C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\3\Draft3.log

```
Circuit: * C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\3\Draft3.asc

Direct Newton iteration for .op point succeeded.
N-Period=1
Fourier components of V(out)
DC component:5.21588e-07

Harmonic            Frequency           Fourier             Normalized
 Number               [Hz]              Component            Component
    1                1.000e+4           4.925e-3             1.000e+0
    2                2.000e+4           7.472e-7             1.517e-4
    3                3.000e+4           3.105e-6             6.303e-4
    4                4.000e+4           1.552e-6             3.152e-4
    5                5.000e+4           3.021e-6             6.134e-4
    6                6.000e+4           1.727e-6             3.506e-4
    7                7.000e+4           1.601e-6             3.251e-4
    8                8.000e+4           1.110e-6             2.254e-4
    9                9.000e+4           1.714e-6             3.480e-4
Total Harmonic Distortion: 0.113862%(0.139162%)



Date: Sun May 17 13:33:26 2020
Total elapsed time: 0.134 seconds.

tnom = 27
temp = 27
method = modified trap
totiter = 2090
```



25.233645us-25 us =0.233645

Φ=(0.233645 / 100us) .360 = 0.841

Amplifier Input Resistance

$U_1 = 5 \times 10^{-3}$ V $\qquad$ $U_2 = 1.389993$mV

$$I_{in} = \frac{U_1 - U_2}{R} \qquad U_1 - U_2 = R \cdot I_{in} \qquad Z_{in} = R_{in} = \frac{U_2}{I_{in}} = \frac{R \cdot U_2}{U_1 - U_2} = \frac{R}{U_1 / U_2 - 1}$$

$$\frac{10 \times 10^3\ \Omega}{\frac{5 \times 10^{-3}}{1.389993 \times 10^{-3}\ \text{V}} - 1} = \mathbf{3{,}850.3886557561}\ R_{in}$$

Amplifier Output Impedance

U is voltage which is measured when S is OFF and load is not connected

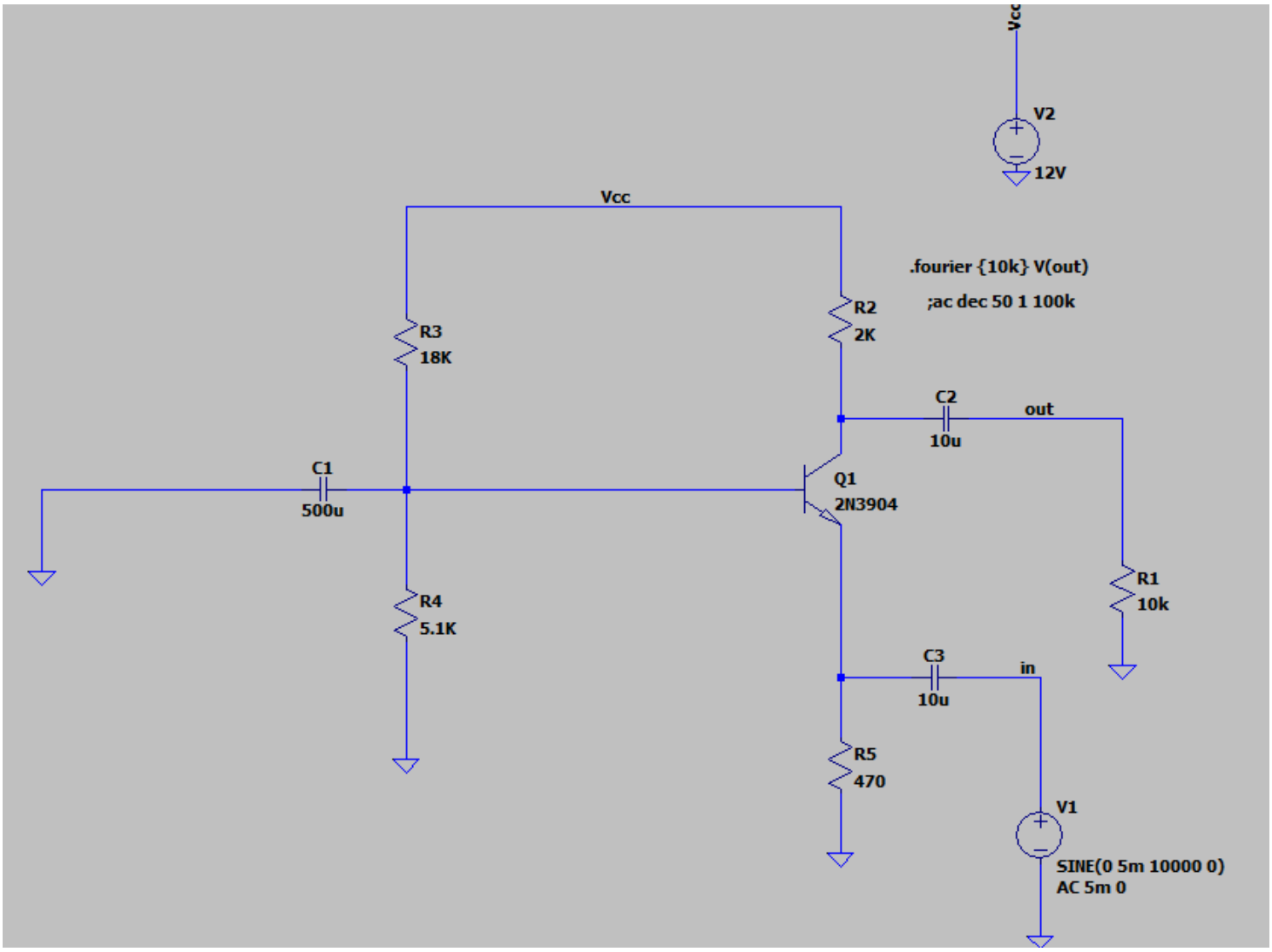
$$\Delta U = U - U_R \qquad Z_{out} = \frac{\Delta U}{I} = \frac{U - U_R}{I} = \frac{R(U - U_R)}{U}$$

$U = 4.9453263$mV $\qquad$ $R = 10$K $\qquad$ $U_R = 4.9257289$mV

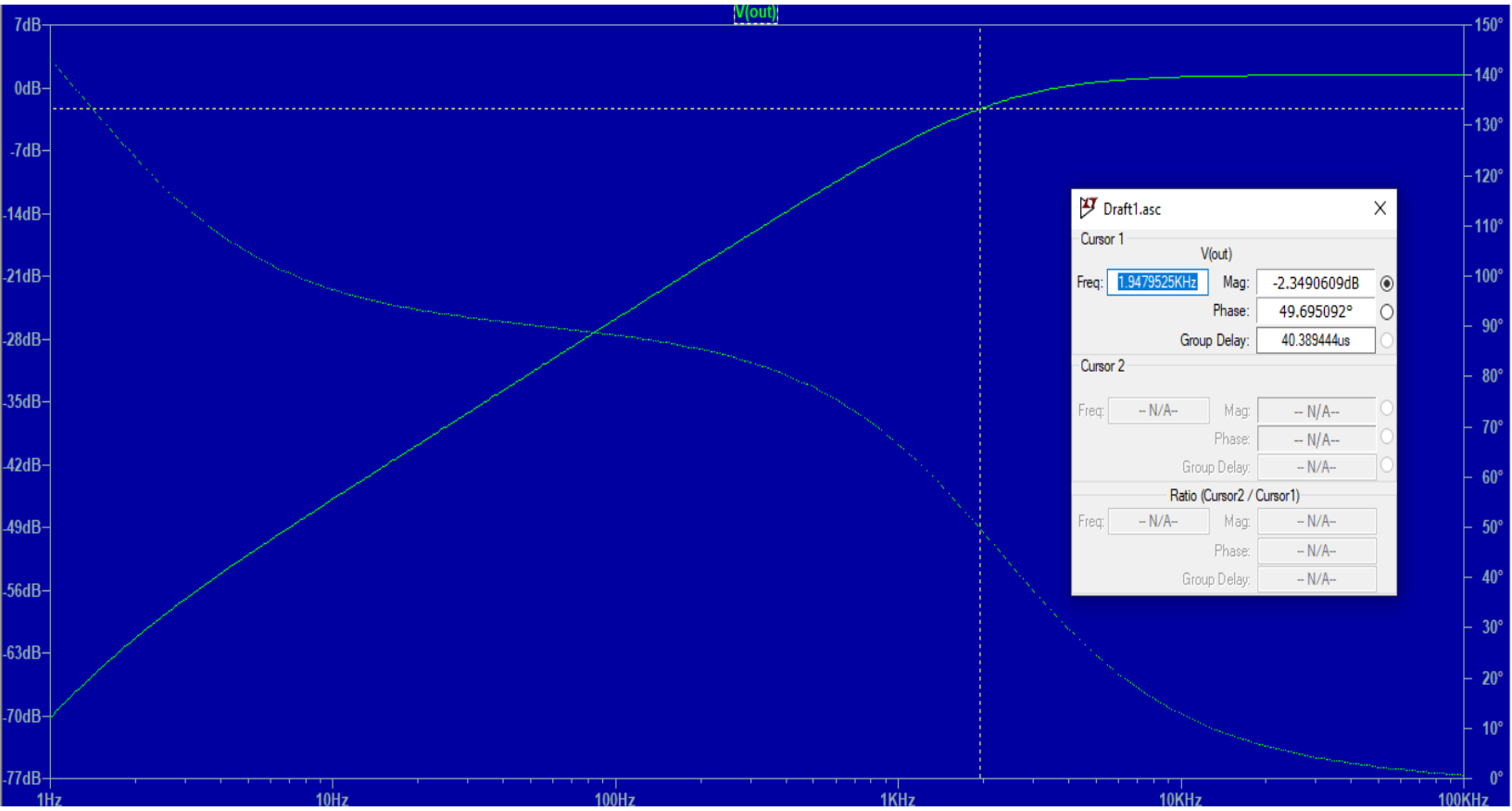
$$R(U - U_R) / U = Z_{out}$$

$$\frac{10 \times 10^3\ (4.9453263\text{mV} - 4.9257289\text{mV})}{4.9453263\text{mV}} = 39.628123\ R$$

Fig. 5. Amplifier with current-shunt NF

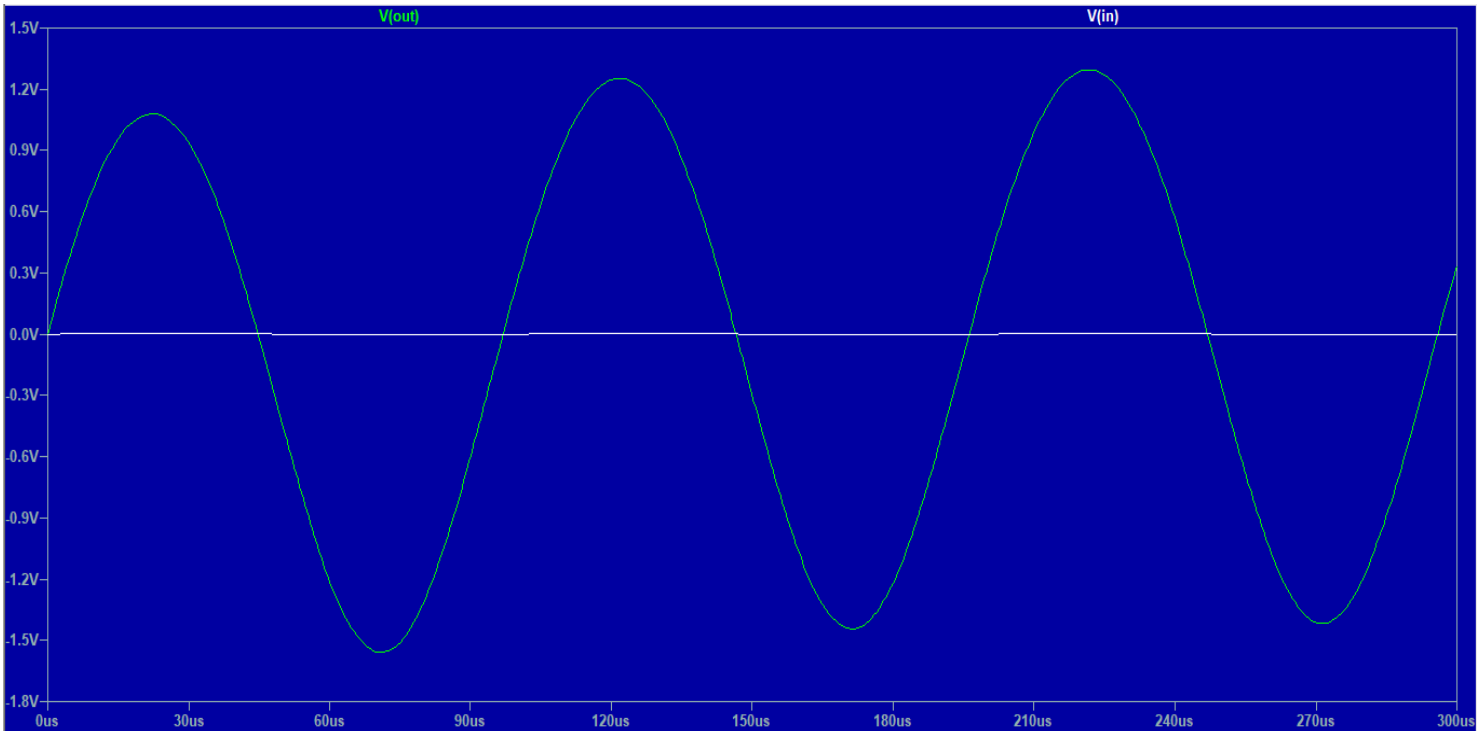


AC Response and bandwitdh



SPICE Error Log: C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\5\Draft1.log

```
Circuit: * C:\Users\templ\OneDrive\Masaüstü\lab work 2 anal\5\Draft1.asc

Direct Newton iteration for .op point succeeded.
N-Period=1
Fourier components of V(out)
DC component:-0.00929792

Harmonic            Frequency            Fourier            Normalized
 Number               [Hz]              Component            Component
    1               1.000e+4             1.142e+0             1.000e+0
    2               2.000e+4             4.421e-2             3.870e-2
    3               3.000e+4             1.498e-3             1.311e-3
    4               4.000e+4             1.299e-3             1.137e-3
    5               5.000e+4             9.073e-4             7.943e-4
    6               6.000e+4             2.229e-4             1.951e-4
    7               7.000e+4             7.642e-4             6.690e-4
    8               8.000e+4             4.032e-4             3.529e-4
    9               9.000e+4             3.459e-4             3.028e-4
Total Harmonic Distortion: 3.875656%(3.878008%)



Date: Sun May 17 13:52:54 2020
Total elapsed time: 0.131 seconds.

tnom = 27
temp = 27
method = modified trap
totiter = 2087
```



25.076687us – 22.758621us =2.318066

Φ= (2.318066 / 96.781609us) . 360° = 8.622544824

Amplifier Input Resistance

$U_1 = 5 \times 10^{-3}$ V $\qquad$ $U_2 = 7.640542$uV

$$I_{in} = \frac{U_1 - U_2}{R} \qquad U_1 - U_2 = R \cdot I_{in} \qquad Z_{in} = R_{in} = \frac{U_2}{I_{in}} = \frac{R \cdot U_2}{U_1 - U_2} = \frac{R}{U_1 / U_2 - 1}$$

$$\frac{10 \times 10^{3}\ \Omega}{\frac{5 \times 10^{-3}}{7.640542\text{uV}} - 1} = \mathbf{15.3044708905}\ R_{in}$$

Amplifier Output Impedance

U is voltage which is measured when S is OFF and load is not connected

$$\Delta U = U - U_R \qquad Z_{out} = \frac{\Delta U}{I} = \frac{U - U_R}{I} = \frac{R(U - U_R)}{U}$$

$U = 1.2524552$ V $\qquad$ $R = 10$K $\qquad$ $U_R = 1.0555553$ V

$R(U\text{-}U_R) / U = Z_{out}$

$$\frac{10 \times 10^{3} \left(1.2524552\text{V} - 1.0555553 \right)}{1.2524552\text{V}} = 1{,}572.111322\ R$$