EE254

Project 1

09/17/13

Frequency response of a Single Stage Common Emitter (CE) BJT Amplifier

A Common Emitter (CE) BJT amplifier was designed using 2N5088BU transistor obtained from Newark.com website. The transistor's spice model was also obtained from fairchildsemi.com which was used in the analysis of the experiment. The amplifier was designed as shown in figure 1 in the Design section and the data used was obtained from the transistor datasheet. Random capacitors were used at first which was able to assist in biasing the amplifier and obtaining the Ic and Vce readings.

Small signal analysis (figure 2 in the design section) was then performed to obtain $r\pi$ and gm which were used to calculate the actual capacitors needed for the experiment (Ce, Cc1 and Cc2). Low cut frequency requirements was to make the bypass capacitor the dominant component and its frequency was chosen to be 100Hz. Calculation of the capacitors was performed as shown in page 2, 3 and 4 of the Design and calculations section.

The observed measurements (using the calculated capacitors) were obtained and noted in page 4 of the Design and calculation section. It was observed that the midband gain, the upper cutoff frequency and the lower cutoff frequency to be 58.2, 645 KHz and 65 Hz respectively (figures 4, 5 and 6 in the Oscilloscope screenshot section). Gm and $r\pi$ were recalculated using the obtained measured values of Ic, Ie, and β then using the spice model, upper cutoff frequency was calculated and found to be 6.67361MHz which was extremely higher than the observed value. After a small consultation regarding the high calculated upper cutoff frequency, it was suggested that increasing the source resistance (Rs) can bring the frequency down but the measured values of the amplifier might change. The Rs value was increased to 604Ω then midband gain, Vrc, Vre, Ib, Vce and Vb measurements were taken and noted down as shown in page 6 (Design and calculation section). The upper and lower cutoff frequency were observed to be lower than the previous values (250 KHz and 78 Hz respectively). Gm and $r\pi$ were calculated using the second measurements, then using the spice model values, lower and upper cutoff frequency were recalculated as shown in page 7 of the design and calculation section. The lower cutoff frequency of 96.02Hz and upper cutoff frequency of 586.06 KHz were obtained.

The upper cutoff frequency value dropped significantly as expected with the introduction of higher value source resistance. The measured upper cutoff frequency was lower than the calculated value. The reason for the discrepancy might be due to the fact that the load capacitor (Cc2) used was a combination of four different capacitors in parallel, namely; 47uF, 22uF, 10uF and 4.7uF. The use of many components introduces more errors in the system and that explains the difference in the observed and calculated upper cutoff frequencies. The calculated lower cutoff frequency (96.02 Hz) was compared to the chosen dominant component (bypass capacitor) frequency of 100Hz and a small error of 4% was noted. When Rs was changed, the capacitor values (Ce, Cc1 and Cc2), were not recalculated and that can be the reason why there was a discrepancy in the observed lower cutoff (78Hz) and the calculated value (96.02Hz).

DESIGN & CALCULATIONS

TRANSISTON 2N5088

Low cut freq Requirements
Make Bypass cap as dominant compor
100Hz

From Data sheet

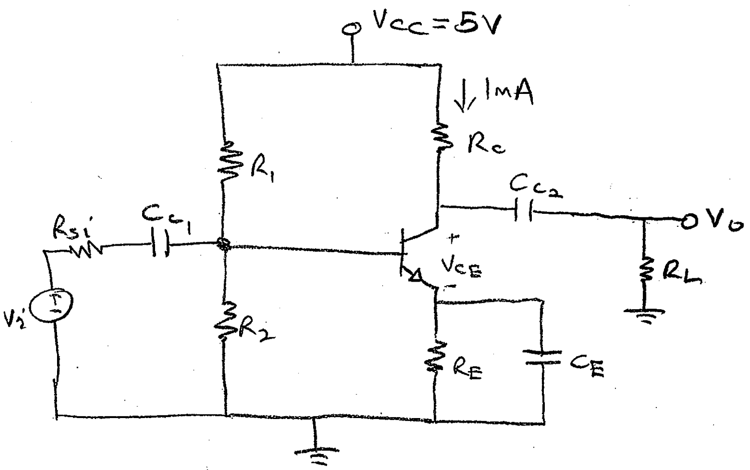
$\beta = 350$

$I_C = 1mA$

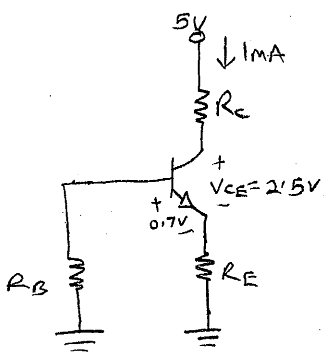
$V_{BE(ON)} = 0.7$

$V_E = 0.7V$

$V_T = 26mV$



$R_B = R_1 // R_2$



$R_{TH} = \frac{R_1 R}{R_1 +}$

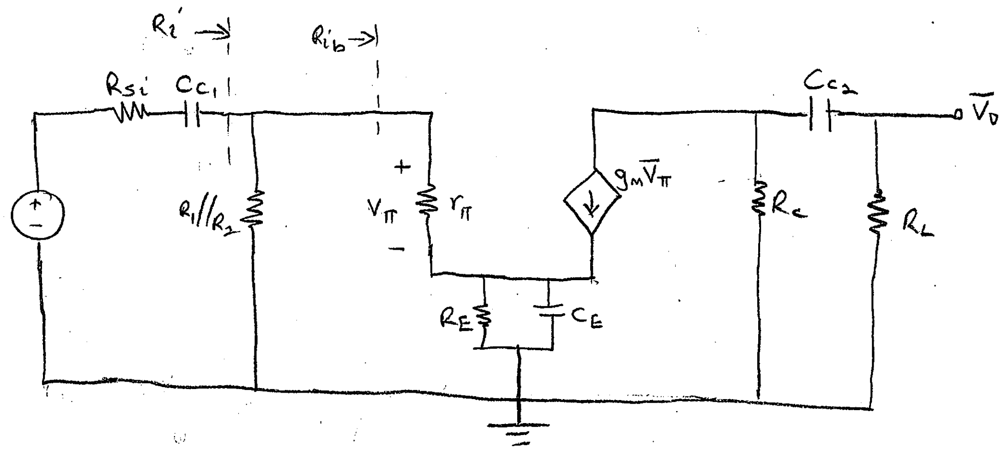
Observed $V_{CEQ} = 2.33V$

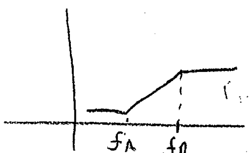
$I_{CQ} = 1mA$

Observed

Input Pk-Pk = 120mV

Output Pk-Pk = 3.16V





Measured

$V_E = 0.726V$

$V_C = 1.94V$

$I_B = 0.0023mA$

$I_C = \frac{V_C}{R_C} = \frac{1.94V}{1.87K\Omega} = 1.037 mA$

$\beta = \frac{I_C}{I_\beta} = \frac{1.037mA}{0.0023mA}$

$= 450.87$

$I_E = \frac{V_E}{R_E} = \frac{0.726}{698.04}$

$= 1.04mA$

$\alpha = \frac{I_c}{I_E} = \frac{1.037mA}{1.04mA}$

$\alpha = 0.9971$

$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9971}{1-0.9971}$

$\beta = 343.8$

$f_L = 100Hz = \frac{1}{2\pi \tau_L}$

$\tau_L = 1.592 ms$

6.275 M

$$C_E = 63.34\ \mu F$$

$$f_L = \frac{1}{2\pi \tau_s} = \frac{1}{2\pi (R_{si} + R_i) C_c}$$

$$C_{c_1} = 71.4\ \mu F$$

$$\tau_s = (R_C \| R_L) C_{c_1}$$

$$f_L = \frac{1}{2\pi \tau_s}$$

$$1Hz = \frac{1}{2\pi \tau_s} \qquad \tau_s = 159.15ms$$

$$159.15ms = (966k\Omega \| 1.87k\Omega) C_{c_1}$$

$$C_{c_2} = \frac{159.15ms}{1.866k\Omega}$$

$$\boxed{C_{c_2} = 85.29\mu F}$$

Mid Band Gain Before change of capacitors $= \frac{730mV}{13.1mV} = 5$

Observed Measurements with

MidBand gain $= \frac{780mV}{13.4mV} =$

$V_{RC} = 1.9333V$

$V_{RE} = 0.723V$

$V_{CE} = 2.300V$

$I_B = 0.0023mA \qquad V_B = 1.338V$

$I_C = 1.03mA$

$I_E = 1.02mA$

Max V = 780mV

$780mV * 0.707 = 551.46mV$

Upper Cutoff freq (oscilloscope value) = 630KHz — Function generator value = 645 KHz

lower Cutoff freq (oscilloscope value) = 66 Hz → Function generator value = 65Hz

$13.3mV$

$= 57.9$

$C_{c_2} = 47\mu F \| 22\mu F \| 10\mu F$

$$\boxed{C_{c_2} = 83.7\mu}$$

MB Gain $= \frac{770mV}{12.7mV}$

$= 60.63$

Measured values after change of capacitors

(5)

$$I_C = \frac{V_{RC}}{R_C} = \frac{1.9333V}{1.87 K\Omega} = 1.034 \, mA$$

$$I_E = \frac{V_{RE}}{R_E} = \frac{0.725V}{698.04\,\Omega} = 1.0386 mA$$

$$V_{BE} = V_E - V_B = 0.725 - 1.338$$

$$V_{EB} = -0.613 V$$

$$\alpha = \frac{I_C}{I_E} = \frac{1.034mA}{1.0386mA} = 0.996$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.996}{1-0.996} = 249$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{1.034mA}{26mV} = 39.77 \, mA/V$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{249(26mV)}{1.034mA} = 6.26K\Omega$$

After increasing the R_S from 50Ω to 604Ω

Observed Measurement

$$\text{Mid band gain} = \frac{980mV}{20.6mV} = 47.57$$

Upper cut off freq = 250 kHz
Lower cut off freq = 78 Hz.

$V_{RC} = 1.845V$ $\quad$ $V_{RE} = 0.687V$

$I_B = 0.002mA$ $\quad$ $V_{CE} = 2.323V$

$V_B = 1.302V$

$$I_C = \frac{V_{RC}}{R_C} = \frac{1.845V}{1.8k\Omega} = 1.025mA$$

$$I_E = \frac{V_{RE}}{R_E} = \frac{0.687V}{698.04\Omega} = 0.984mA$$

$$\beta = \frac{I_C}{I_B} = \frac{1.025mA}{0.002mA} = 512.5$$

Calculated Values with R_S and Capacitors Changed

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{512.5(26mV)}{1.025mA} = 13k\Omega.$$

$$g_m = \frac{I_C}{V_T} = \frac{1.025mA}{26mV} = 39.42\frac{mA}{V}$$

$R_{ib} = r_\pi$

$R_{ib} = 13k\Omega$

$R_i = R_B \| R_{ib} = 24.41k\Omega \| 13k\Omega$

$R_i = 8.482k\Omega$

$$\left|\frac{V_o}{V_i}\right| = \left(\frac{-g_m R_C r_\pi}{R_{si} + R_i}\right)\left(\frac{R_B}{R_B + R_{ib}}\right) = \left(\frac{39.42\,mA/V\,(1.8k\Omega)(13k\Omega)}{604 + 8.482k\Omega}\right)\left(\frac{24.41k\Omega}{24.41k\Omega + 8.482}\right)$$

$$\left|\frac{V_o}{V_i}\right| = 75.3$$

Design

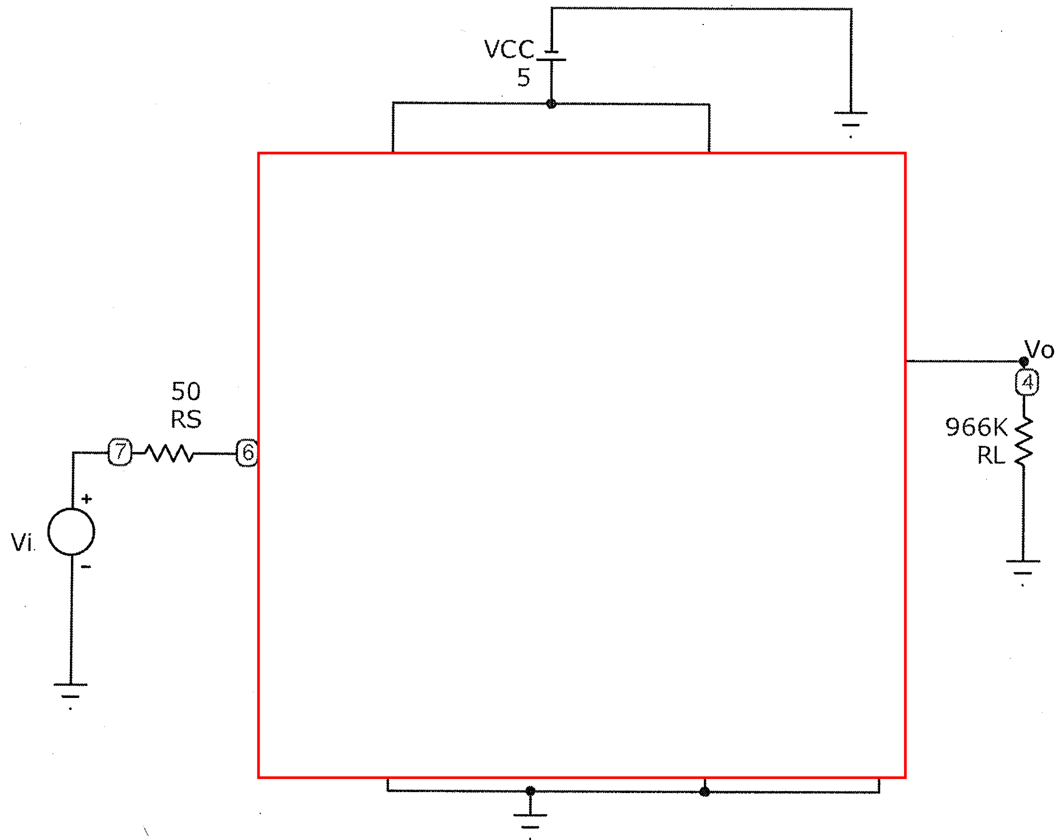


Figure 1: Designed circuit

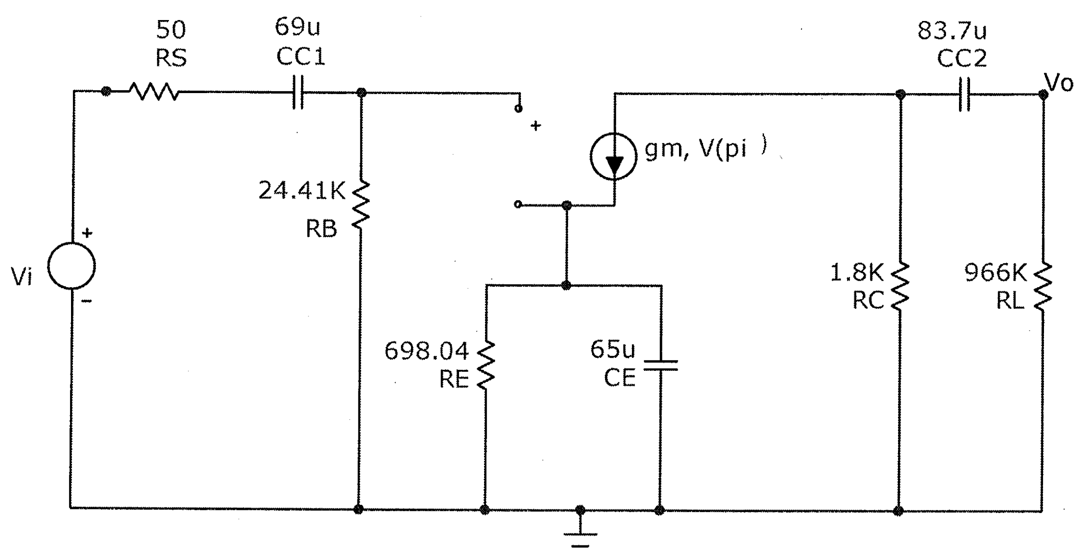


Figure 2: Small signal circuit from the design

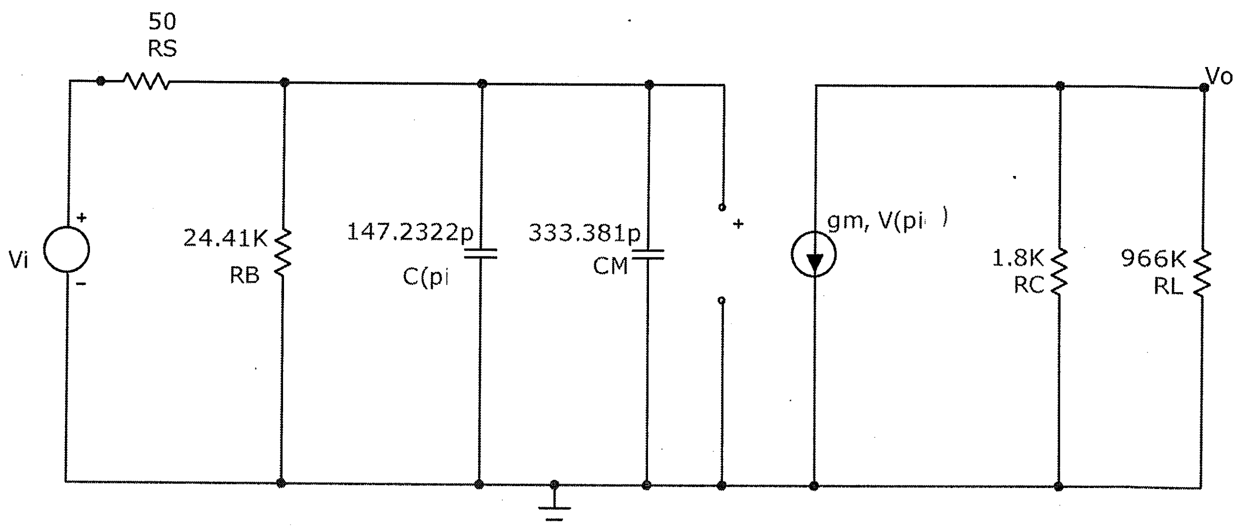


Figure 3: High-frequency equivalent circuit

Oscilloscope screenshots

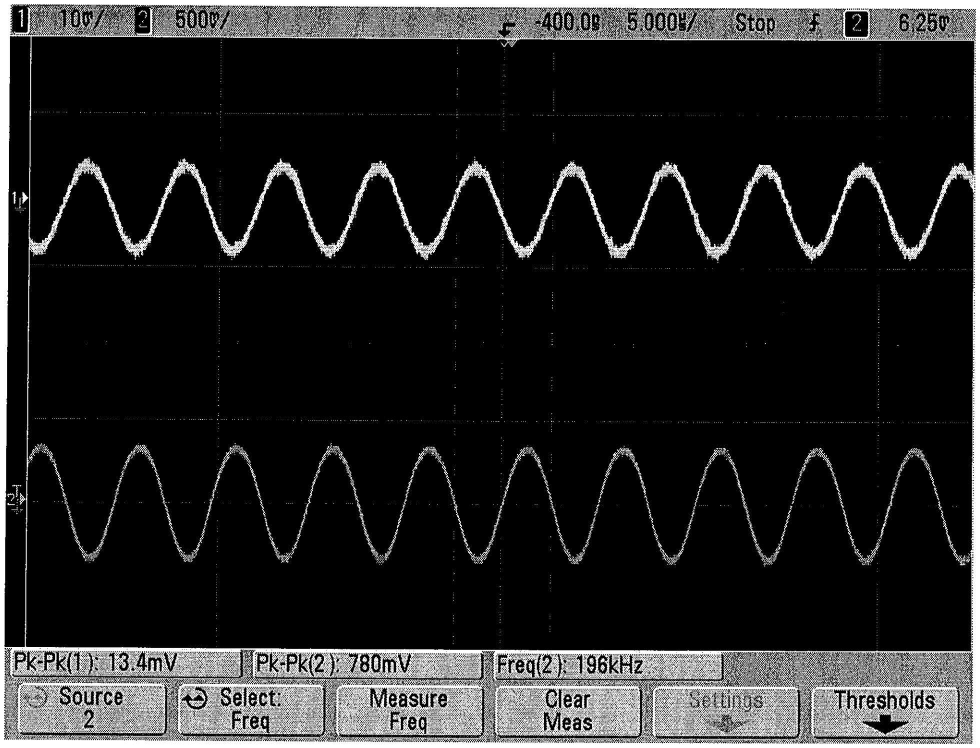


Figure 4: Midband gain obtained using the calculated capacitors

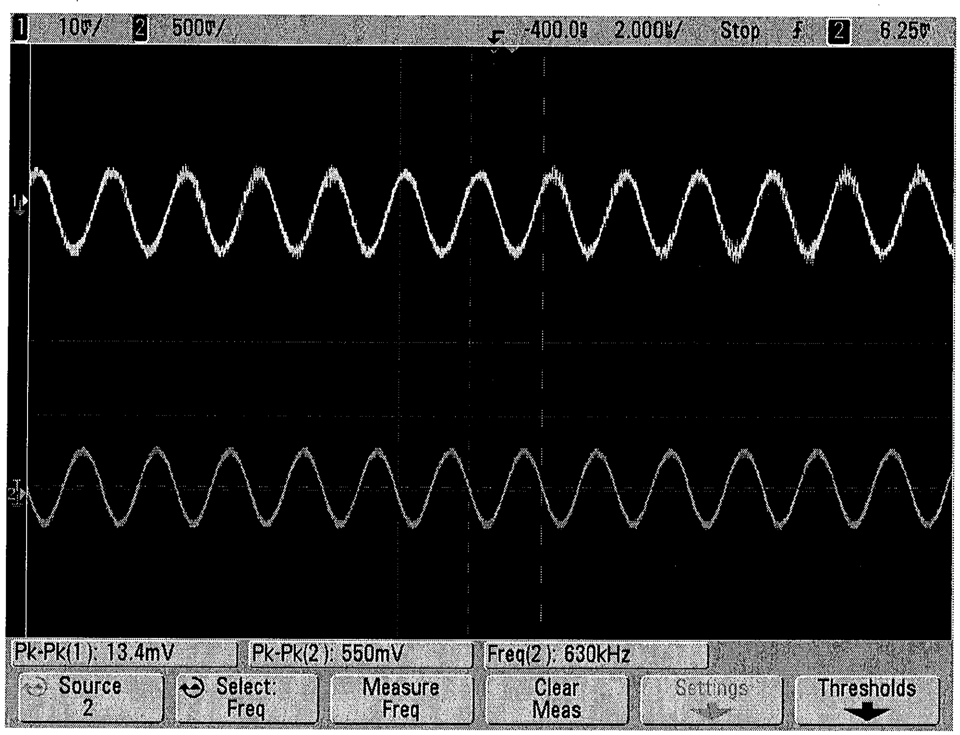


Figure 5: Upper cutoff frequency observed on the oscilloscope

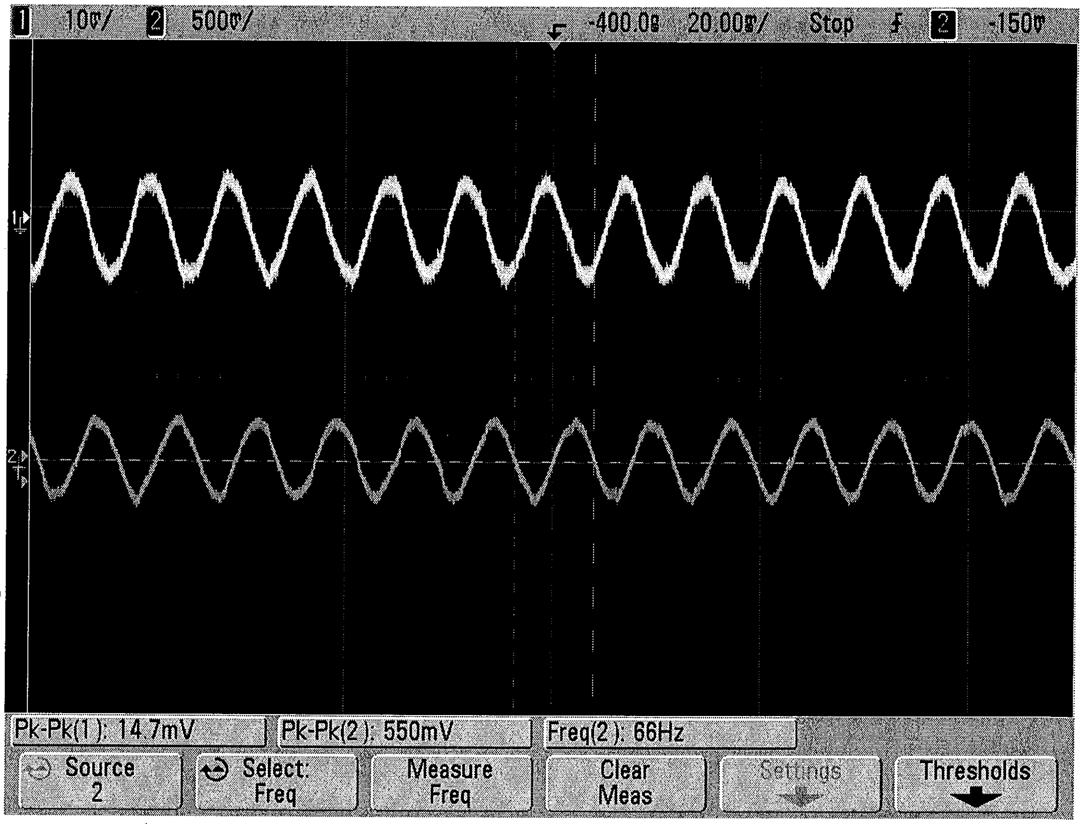


Figure 6: Lower cutoff frequency observed on the oscilloscope