Low-cost and flexible Electronic Study KIT through Project-Based Learning and Design-Build hands-on activities.

Students:

Nguyễn Huỳnh Đăng Khoa
Phan Duy Linh
Nguyễn Đình Vinh
Nguyễn Thị Minh Hiền
Trần Trọng Đức
Nguyễn Đức Khải

Advisor:

Lê Quốc Huy, PhD

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FAST — FACULTY OF ADVANCED SCIENCE AND TECHNOLOGY

Introduction

Abstract

Fundamental and most popular Analog electronic circuit Amplifier and Filter Designing are hard to calculate and test in real circuit.

Team 16ES bring you multi-solution with various low-cost and flexible Filter and Amplifiers circuits based on a 3-step process: Design-Build-Test.

Objectives

This project contains 4 KITs:

1) High-Q Amplifier with UA741 .
2) Notch Filter with UA741 .
3) BJT CE Amplifier - frequency response with 2n2222.
4) High frequency band-pass Amplifier with 2n2222 .

- On-going work: Multi-stage Amplifier with 2n7000 and 2n22222.

In this articles, we decide to demonstrate 2 KITs: Band-pass Amplifier and High-Q Amplifier.

Method

3-step method: Design-Build-Test

Step 1: Design the circuit based on hand calculation and MATLAB simulation.

- Step 2: Build and simulate the circuit in LTSpice, then build real circuit.
- Step 3: Testing the real circuit in laboratory.

MATLAB

LTspice®

Conclusions

Achievements

- Exclusive hands-on KITs for students
- Very low-cost and highly flexible, can be implemented on general analog purposes.

References

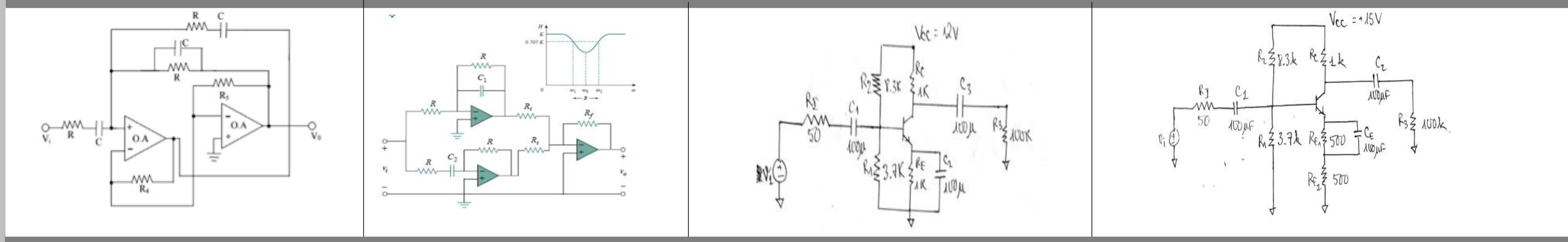
[1] Green, A. K. (2014-2015). Analog Engineer's Pocket Reference. Texas Instrument Incorporated.

[2] Le Quoc Huy, P. (2018-2019). Electronic 1 & 2 Slide (Adapted from Microelectronic Circuit Design-Jaeger, Blalock. Danang.

[3] N.Blalock, R. C. (2006). Microelectronic Circuit Design. New York: McGraw-Hill

Results

HAND CALCULATION



FORMULAR

$Z_1 = Z_2 = \frac{1+sCR}{sC}, \quad Z_3 = \frac{R}{(1+sCR)},$

$Z_4 = R_4, \quad Z_5 = R_5, \quad K = \frac{R_4}{R_5}$

$For\ A_0, f_0 = 20\ kHz,$

$A_0 = \frac{1}{2-k} = 4 \to k = 1.75 = \frac{R_4}{R_5}$

$Choose\ R_4 = 8.2\ k\Omega,$

$R_5 = 4.7\ k\Omega,$

$f_0 = 20\ kHz \to \frac{1}{2\pi CR} \to CR \approx 7.96 \times 10^{-6}$

$Choose\ R = 8.2\ k\Omega, C = 1\ nF$

$u_l = \frac{-(2-K)+\sqrt{(2-K)^2+4}}{2} = 0.88 \to f_l = u_l f_0 = 17.66\ kHz$

$u_h = \frac{(2-K)+\sqrt{(2-K)^2+4}}{2} \to f_h = u_h f_0$

With $Av = 5$, design Rf & Ri:

$Av = 5 => \frac{Rf}{Ri} = 5$

Choose $Rf = 50kOhm$ & $Ri = 10kOhm$

With $\omega_0 = 35k\ rad/s, B = 87.5k\ rad/s$, design R_1, R_2, C:

$\omega_0 = \sqrt{\omega_1\omega_2} = 35k\ rad/s, B = \omega_1 - \omega_2 = 87.5k\ rad/s$

$=> \begin{cases} \omega_1 = 12.277k\frac{rad}{s} = \frac{1}{R_1C} \\ \omega_2 = 100k\frac{rad}{s} = \frac{1}{R_2C} \end{cases}$

Choose C = 2nF, we have $\begin{cases} R_1 = 40kOhm \\ R_2 = 3kOhm \end{cases}$

Choose $\begin{cases} R_1 = 43kOhm\ (standard\ value) \\ R_2 = 5kOhm\ (standard\ value) \end{cases}$

Giver information

$R_I = 50\ \Omega, R_3 = 100\ k\Omega, R_2 = 8.3\ k\Omega, R_1 = 3.7\ k\Omega, C_1 = C_2 = CE = 100\ \mu F, RC = RE = 1\ k\Omega, R_L = 100\ k\Omega$

DC Analysis

$V_{EQ} = V_{CC} \times \frac{R_1}{R_1 + R_2} = 3.7\ V, R_{EQ} = R_1//R_2 = 2.56k\Omega$

$I_C = \beta \times I_B = 2.95\ mA \approx I_E, V_{CE} = V_{CC} - I_CR_C - I_ER_E = 6.09V,$

$V_{CB} = V_{CE} - V_{BE} = 5.39\ V$

AC Analysis

$g_m = 40I_C = 118\ ms, r_\pi = \frac{\beta}{g_m} = 1.7k\Omega, C_{JC0} = 8\ pF, C_{JE0} = 25pF,$

$\emptyset_{JC} = 0.75, \tau_F = 400\ ps, m = 0.33, r_\pi = 10\Omega, V_A = 100V$

$C_\mu = \frac{C_{JC0}}{(1+\frac{5.39}{0.75})^{0.33}} = 4\ pF, C_{de} = \tau_F g_m = 47.2\ pF, C_{je} = 2C_{JE0} = 50\ pF$

$C_\pi = C_{de} + C_{je} = 97.2\ pF, C_{in} = C_\pi + C_\mu(1 + g_mR_L') = 0.55\ nF$

$A_M = \frac{R_B}{R_B + R_{Sig}} \times \frac{r_\pi}{r_x + r_\pi + (R_{Sig}//R_B)} \times g_mR_L' = 107.6$

$f_H = \frac{\omega_H}{2\pi} = \frac{1}{2\pi C_{in}R_{Sig}'} = 5.03\ MHz$

Giver information

$R_I = 50\ \Omega, R_3 = 100\ k\Omega, R_2 = 8.3\ k\Omega, R_1 = 3.7\ k\Omega,$

$C_1 = C_2 = CE = 100\ \mu F, RC = RE = 1\ k\Omega, R_L = 100\ k\Omega$

DC Analysis

$V_{EQ} = V_{CC} \times \frac{R_1}{R_1 + R_2} = 3.7\ V, R_{EQ} = R_1//R_2 = 2.56k\Omega$

$I_C = \beta \times I_B = 2.95\ mA \approx I_E, V_{CE} = V_{CC} - I_CR_C - I_ER_E = 6.09V,$

$V_{CB} = V_{CE} - V_{BE} = 5.39\ V$

AC Analysis

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$\emptyset_{JC} = 0.75, \tau_F = 400\ ps, m = 0.33, r_\pi = 10\Omega, V_A = 100V$

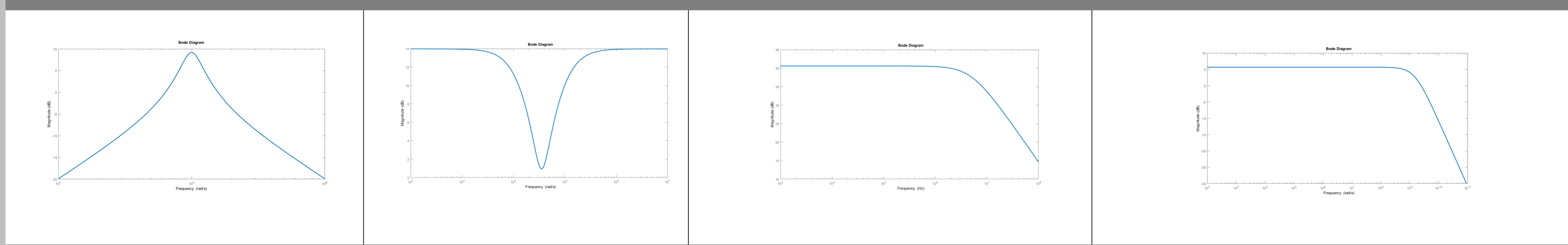
$C_\mu = \frac{C_{JC0}}{(1+\frac{5.39}{0.75})^{0.33}} = 4\ pF, C_{de} = \tau_F g_m = 47.2\ pF, C_{je} = 2C_{JE0} = 50\ pF$

$C_{in} = \frac{C_\pi}{1+g_mR_E} + C_\mu[\frac{(1+g_mR_L') + g_mR_E}{1+g_mR_E} = 11.72\ pF$

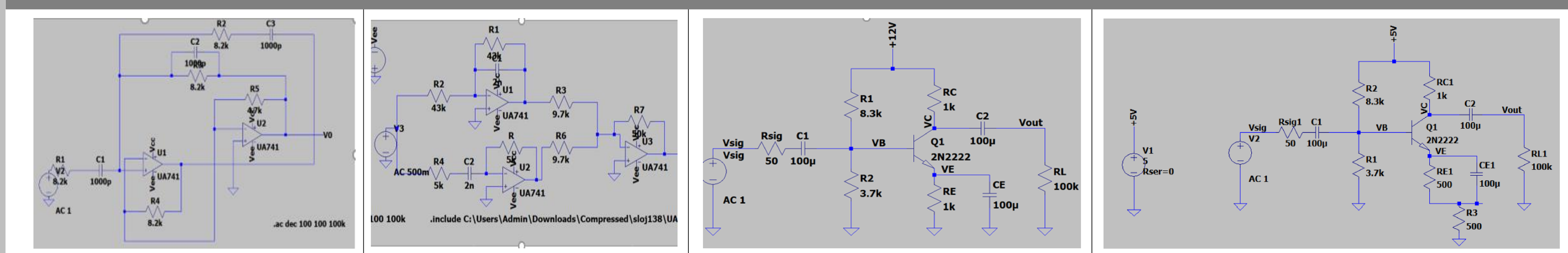
$A_M = \frac{-g_mR_L'}{1+g_mR_E} = -1.92, C_\pi = C_{de} + C_{je} = 97.2\ pF$

$f_H = \frac{\omega_H}{2\pi} = \frac{1}{2\pi C_{in}R_{Sig}'} = 238\ MHz$

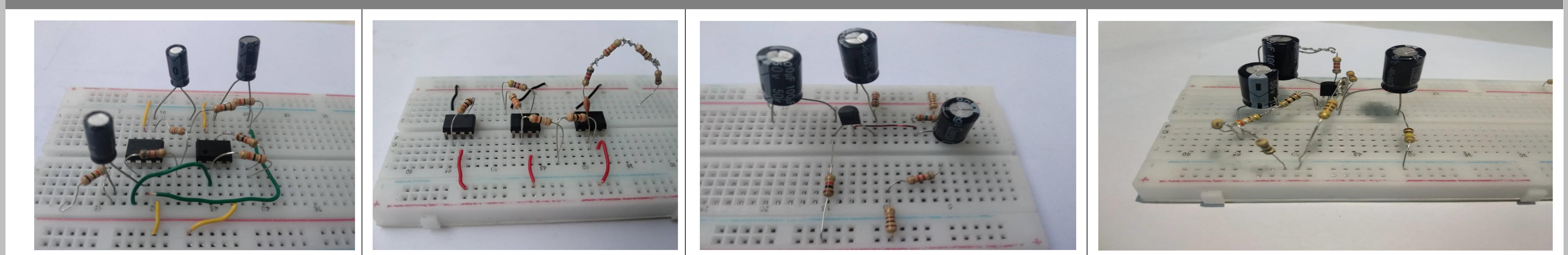
MATLAB SIMULATION



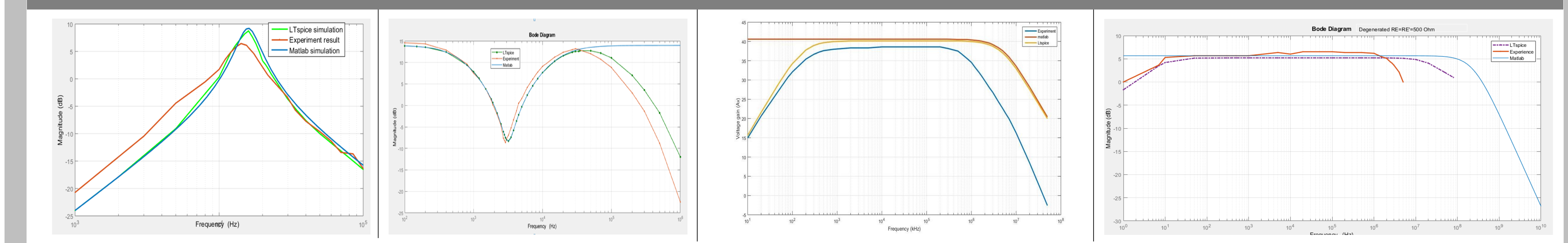
LTSPICE SIMULATION



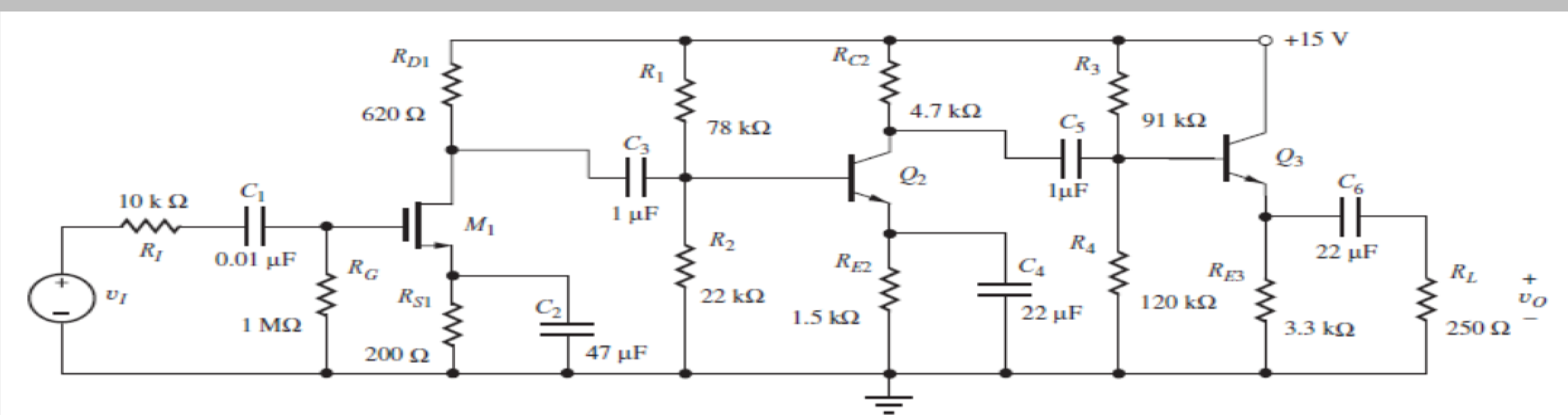
REAL CIRCUIT

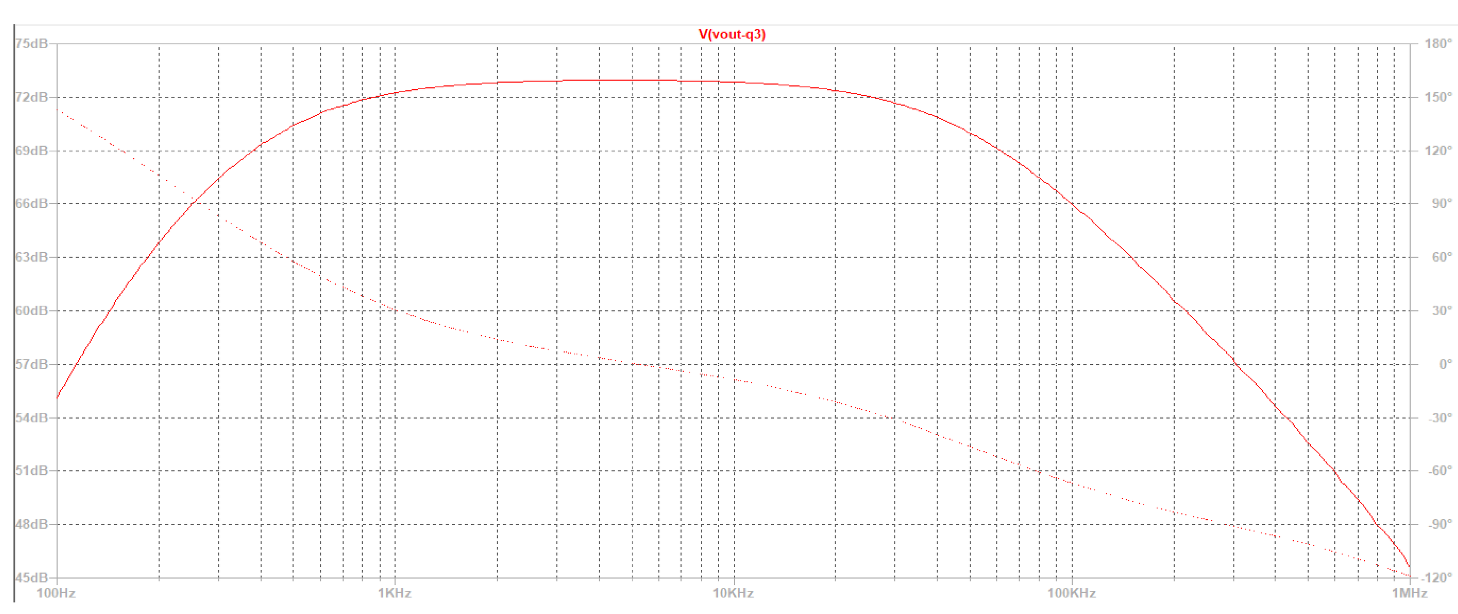


EXPERIMENT



On-going Work





- Recommend working carefully .
- Update the circuits on PCB layout .
- Choose resistor with low tolerance (5%).
- Choose better transistor from Texas instrument,

or Onsemi for higher performance.