Faculty of Engineering
ASU

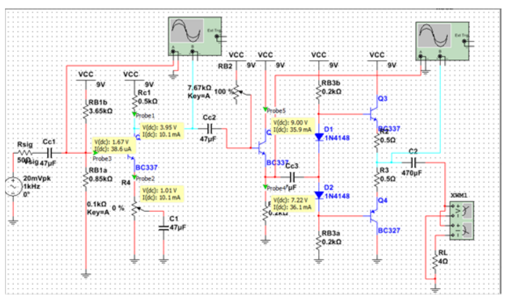
Term Project

MultiStage BJT Audio Amplifier With Volume Control

ECE 131 : Electronic Engineering

1st year Electrical Engineering

Spring 2017



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Submitted To:

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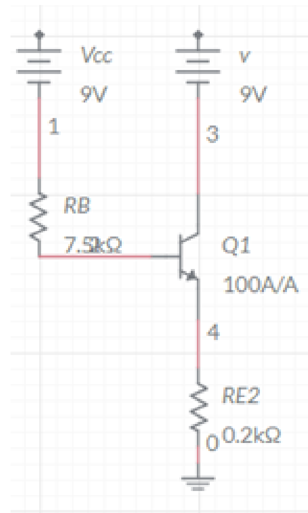
1.Dc and Ac load lines

DC Analysis:



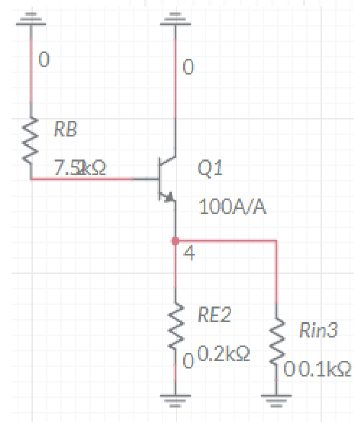
Applying output KVL:

$-Vcc + VcE + IE\ RE2 = 0$

IE = $\frac{Vcc - VcE}{RE2}$; IE ≈ Ic ,

Ic = $\frac{Vcc - VcE}{RE2}$ $\Longrightarrow$ DC load line

AC Analysis:

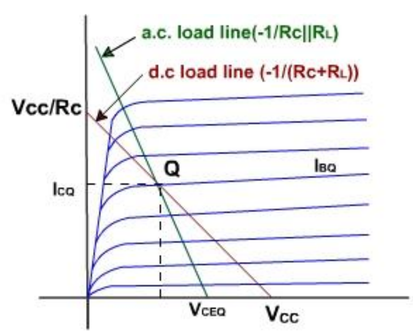


Applying output KVL:

VcE+IE (RE2//Rin3)=0

IE = $\frac{-VcE}{\mathrm{RE2//Rin3}}$; IE ≈ Ic ,

Ic = $\frac{-VcE}{\mathrm{RE2//Rin3}}$ $\Longrightarrow$ AC load line.



Get Vpk:

Slope= $\frac{1}{\mathrm{RE2//Rin3}} = \frac{IcQ}{\mathrm{Vpk}}$

Vpk = IcQ.(RE2//Rin3) ; IcQ = $\frac{VE2}{\mathrm{RE2}}$,

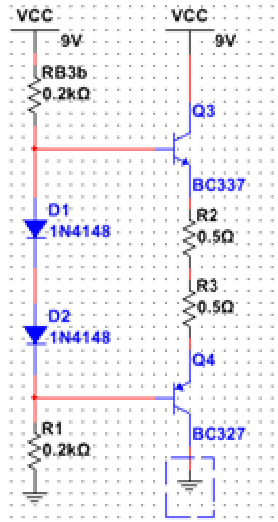
Vpk = $\frac{VE2}{\mathrm{RE2}}$.(RE2//Rin3)

Vpk =VE2. = $\frac{Rin3}{\mathrm{Rin3+RE2}}$

2 . Determination of components values

Power Amplifier AB Class

DC Analysis:



Assume Rin3=0.1kΩ

Since Rin3=RB3a//RB3b//$\boldsymbol{\beta}$RL

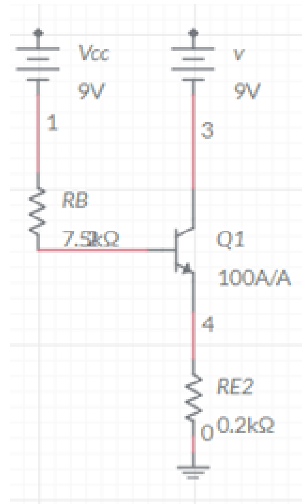
≈ RB3a//RB3b

Since this stage is symmetric :

RB3a=RB3b=0.2kΩ

Av3=1

Common Collector Analysis



DC Analysis:

Vpk =VE2. = $\frac{Rin3}{\text{Rin3+RE2}}$

2 = 6 $\frac{0.1k}{\text{RE2+0.1k}}$ $\Rightarrow$ RE2=0.2Ω

IE2 = $\frac{VE2}{\text{RE2}}$ =30mA , IB2= $\frac{VE2}{\text{RE2}}$ =0.297mA

Applying input KVL:

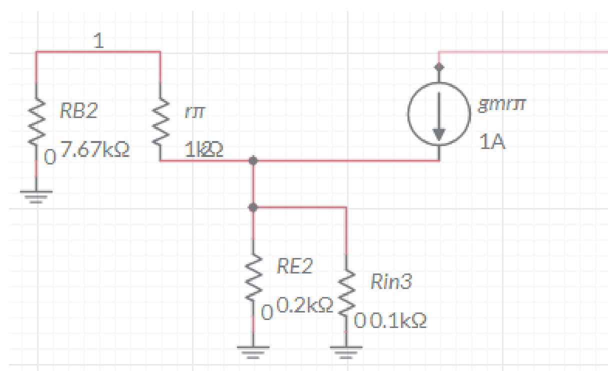
-9+IB RB2 + 0.7+6=0

RB2= 7.67kΩ

GET Small Signal Parameters:

gm= $\frac{IC}{\text{VT}}$ = $\frac{IC}{\text{26m}}$ =1.15 S

rπ= $\frac{\beta}{\text{gm}}$ =86.9Ω



AC Analysis:

Rin2 $= \frac{Vin}{\text{Ix}} = \frac{V\pi + \left(\frac{V\pi}{r\pi} + \text{gV}\pi\right)(\text{RE2//Rin3})}{\frac{V\pi}{r\pi}}$

= r π (1+(RE2//Rin3))=6.72k

Rout2=$\frac{Vout}{\text{Ix}} = \frac{V\pi + \left(\frac{V\pi}{r\pi} + \text{gV}\pi\right)(\text{RE2//Rin3})}{\left(\frac{V\pi}{r\pi} + \text{gV}\pi\right)}$

=$\frac{1+gm(\text{RE2//Rin3})}{\text{gm}}$=99.58 Ω

Vin= $V\pi + \left(\frac{V\pi}{r\pi} + \text{gV}\pi\right)(\text{RE2//Rin3})$

Vout =$\left(\frac{V\pi}{r\pi} + \text{gV}\pi\right)(\text{RE2//Rin3})$

Av2 = $\frac{Vout}{\text{Vin}} = \frac{\left(\frac{V\pi}{r\pi} + \text{gV}\pi\right)(\text{RE2//Rin3})}{V\pi + \left(\frac{V\pi}{r\pi} + \text{gV}\pi\right)(\text{RE2//Rin3})} =$

$\frac{gm\ (\text{RE2//Rin3})}{1+gm\ (\text{RE2//Rin3}}$ = 0.987

Common Emmiter Analysis

DC Analysis:

Ibiase=$\frac{Ic}{5}$ $\Rightarrow$ Ibiase=2m/5A

Rc1=$\frac{9-Vc}{\mathrm{Ic}}$ =$\frac{9-4}{2\mathrm{m}}$ =2.5kΩ

RE1=$\frac{VE}{\mathrm{Ic}\approx\mathrm{IE}}$ =0.1kΩ

GET RB1b & RB1a:

VB=VE1+0.7=1.7 V

VB=9 $\frac{RB1a}{\mathrm{RB1b+RB1a}}$ $\Rightarrow$ 1

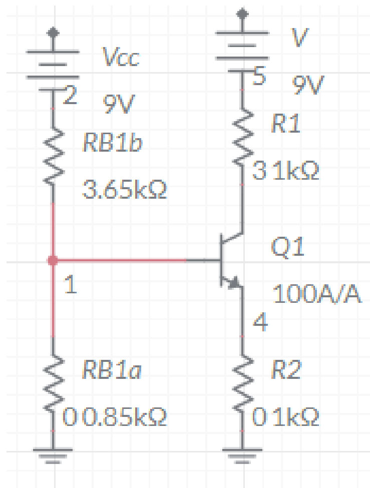
I=$\frac{9}{\mathrm{RB1b+RB1a}}$ =2m/5 $\Rightarrow$ 2

RB1a=4.25kΩ

RB1b=18.2kΩ

gm= $\frac{IC}{\mathrm{VT}}$ = $\frac{IC}{26\mathrm{m}}$ =0.0769 S

rπ= $\frac{\beta}{\mathrm{gm}}$ =1300Ω



AC Analysis:

Rin1= RB1b //RB1a//Rx

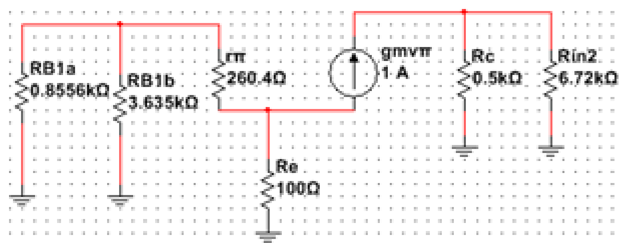
Rx =$\frac{Vin}{\mathrm{Ix}}$=$\frac{V\pi+\left(\frac{V\pi}{r\pi}+\mathrm{gm}V\pi\right)\mathrm{Re}}{\frac{V\pi}{r\pi}}$

=rπ(1+gmRe)

Note that Re is a part of RE,

If Re =0 ; Rin1=943 Ω

If Re=500 Ω ; Rin1=3226.19Ω



Av1=$\frac{Vout}{\mathrm{Vin}}$ =$\frac{-\mathrm{gm}V\pi(\mathrm{Rc}//\mathrm{Rin2})}{V\pi+\left(\frac{V\pi}{r\pi}+\mathrm{gm}V\pi\right)\mathrm{Re}}$

=$\frac{-gm(\mathrm{Rc}//\mathrm{Rin2})}{1+\mathrm{gmRe}}$

If Re =0 ; Av1=-140

If Re=500 Ω ; Av1=-3.55

Rout1=Rc//Rin2=1822 Ω

Over All Gain

$$Av = \frac{Vout}{Vout1} \cdot \frac{Vout1}{Vin} \cdot \frac{Vin}{Vsig} .1 = Av2 \cdot Av1 . \frac{Rin1}{Rin1+Rsig} .1$$

If RE = 0 $\Longrightarrow$ $Av = 0.987 \times 140 \times \frac{943}{943+50} = 131.22$

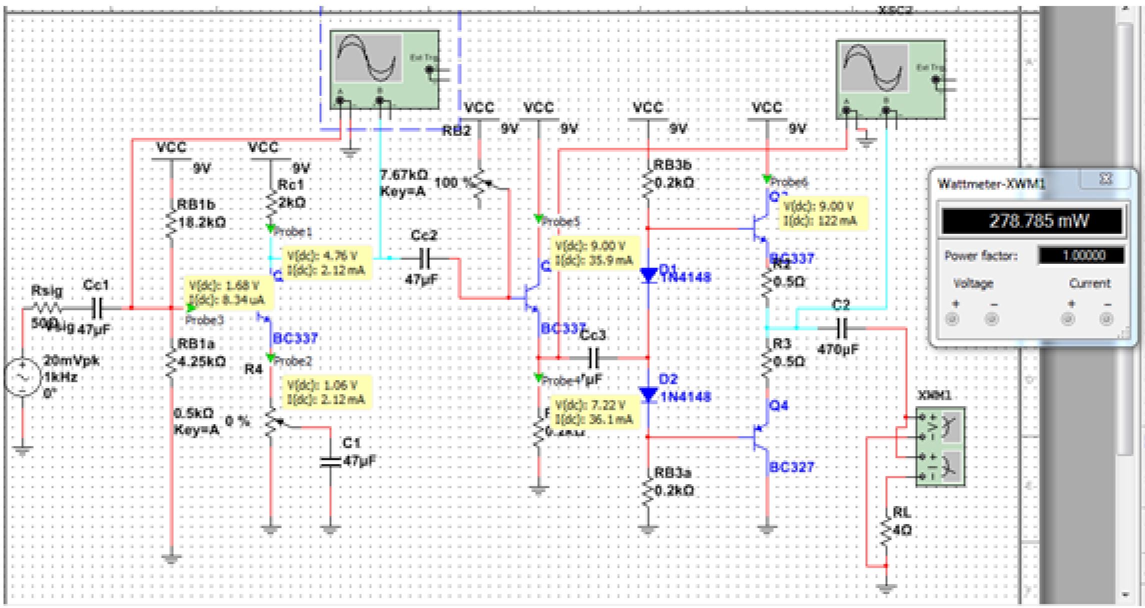
If RE = 0.5kΩ $\Longrightarrow$ $AV = 0.987 \times 3.55 \times \frac{3226.19}{3226.19+50} = 3.45$

3.A table summarizing the component values

First Stage	Common Emmiter
RB1a	0.85kΩ
RB1b	3.65kΩ
Rc1	0.5kΩ
RE1	0.1kΩ
Rin1	943 Ω; If Re =0 ; 3226.19Ω;If Re=500 Ω
Av1	-140; If Re =0 ; -3.55;If Re=500 Ω ;
Second Stage	Common Collector(Emmiter Follower)
RB2	7.67kΩ
RE2	0.2kΩ
Rin2	6.72kΩ
Av2	0.987
Third Stage	Power Amplifier (Class AB)
RB3a	0.2kΩ
RB3b	0.2kΩ
Rin3	0.1kΩ
Av3	1
Over All Gain	
Av	131.22 If RE =0 3.45 If RE =500Ω
Rout1	1822 Ω
Rout2	99.58 Ω

4. Simulation Results

4.a wattmeter reading

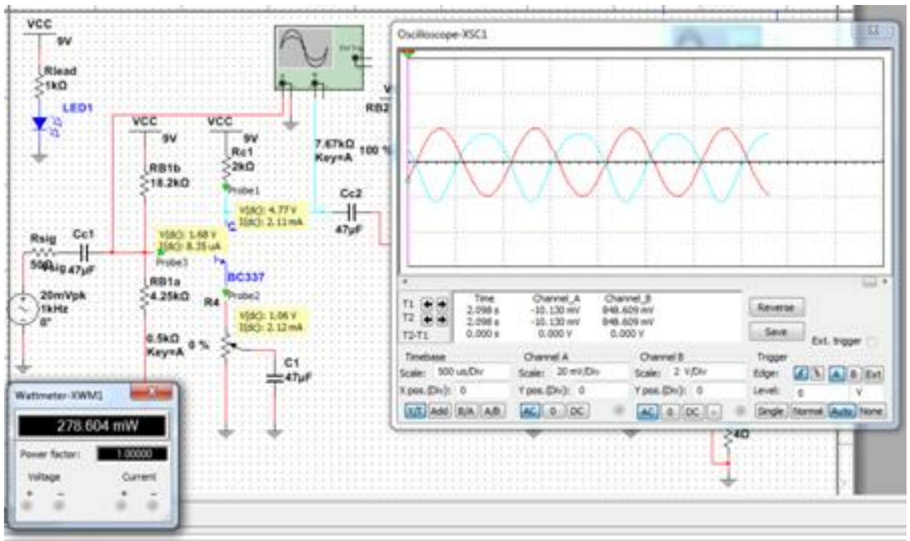


This figure shows the schematic with wattmeter reading.

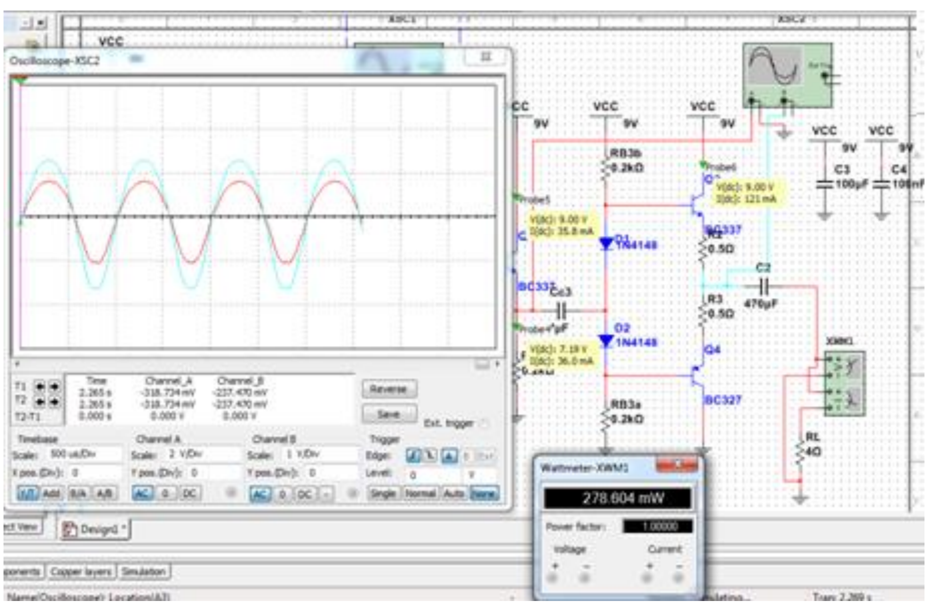
The wattmeter reading is nearly 278mw which is greater than 250mw.

4.b Oscilloscope reading

Output signal of 1st stage



Output signal of 2nd stage



4.c Voltage gain from the simulation

1^{ST} stage :

Av1 $= \frac{channel\ B}{channel\ A} = \frac{-2.287}{19.14}$ = -0.123

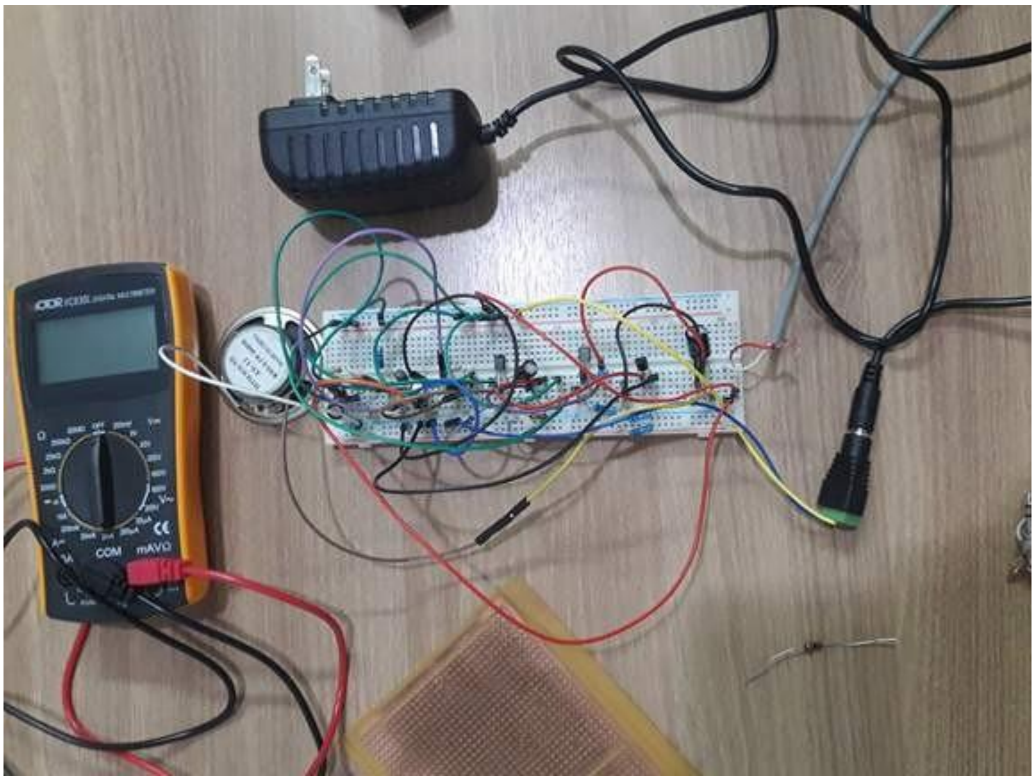
2^{nd} stage :

Av2 $= \frac{channel\ B}{channel\ A} = \frac{1{,}266}{1.587}$ = 0.8

5.Comparison between The Voltage Gain Obtained from the simulation & hand result

Stage	Simulation	Hand result
1^{st}	-0.123	-3.55
2^{nd}	0.8	0.98

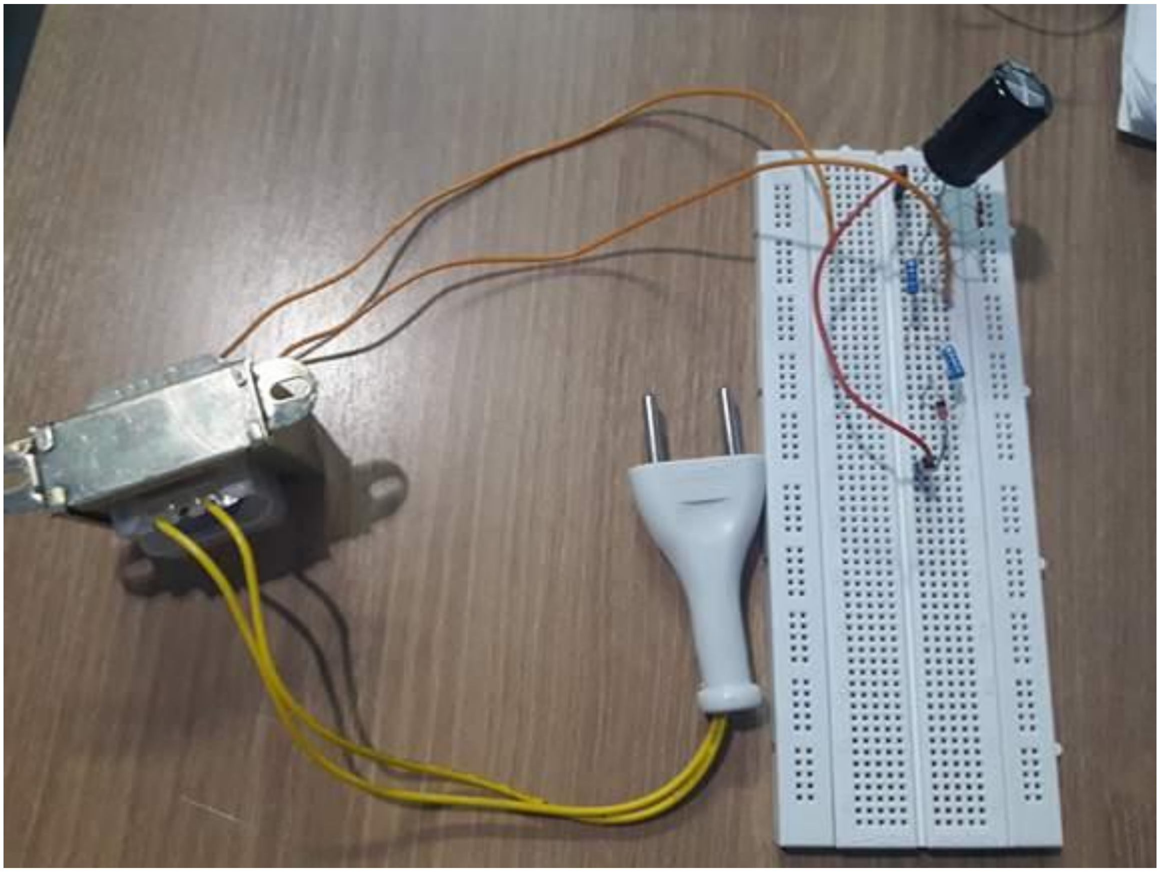
6.Prototype photograph



7.Maximum and Minimum Frequency

Frequency	Simulation	Circuit
Min	245 HZ Power=139.2885mW	
Nominal	1 KHZ Power=278.577mW	
Max	1205 KHZ Power=139.2mW	
Band width	960 HZ	

8. Bonus Project
Regulated Power Supply



Analysis of the power supply

From the simulation of the amplifier project: We get : IL=178mA From the data sheet of zener diode: We get : Iz=150mA I Total=IL+Iz =178m+150m=328m Vc=Vp-2Vdeon =12√2-2x0.8=15.37v I Total= $\frac{Vc-Vz}{\mathrm{R}}$ R=19.42Ω