ANALOG CIRCUITS LAB DESIGN PROJECTS

Group 7

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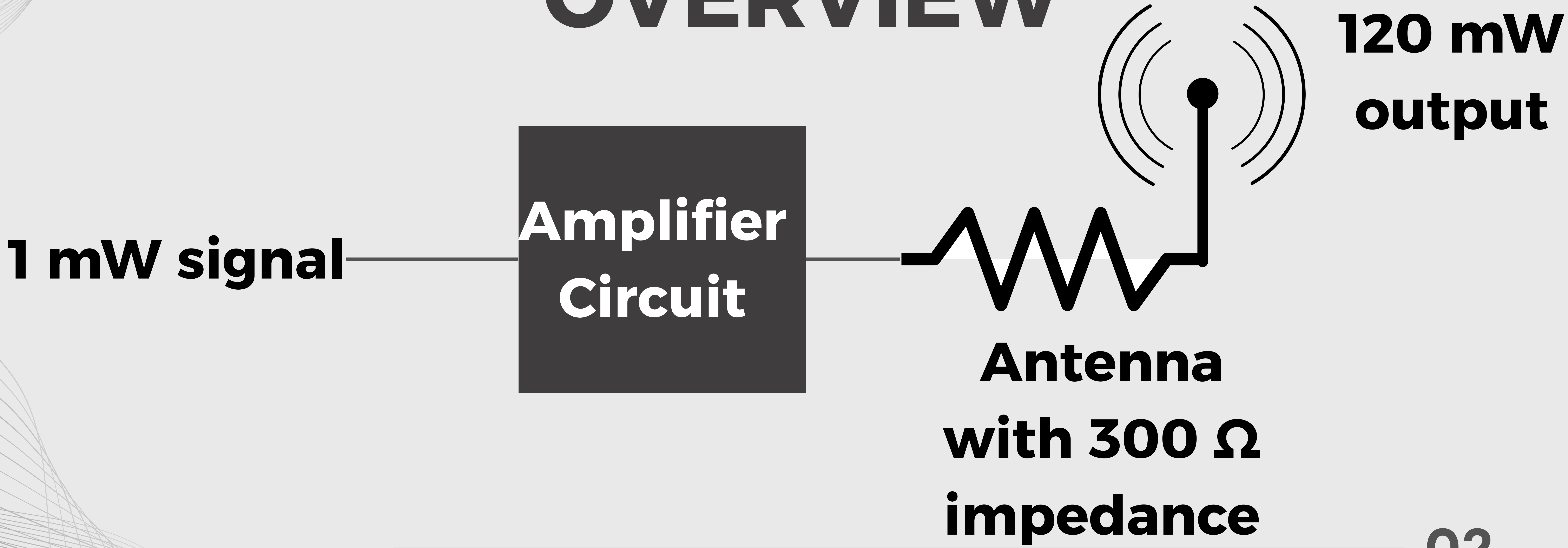
PROBLEM STATEMENT

A 120 milliwatt signal needs to be transmitted from an antenna with 300 Ω impedance using a transmitter which can generate 1 mW signal at 200 kHz .Design a suitable amplifier circuit to connect transmitter and antenna. Find out its input and output impedances. Draw gain vs frequency response and find out its bandwidth.

PROJECT OVERVIEW



PROJECT GOALS

1. Generation of a 1mW signal through function generator by carefully fixing input voltage and current, similarly fixing the output voltage and current from power relations to find constant gains.
2. Designing an amplifier topology which can provide the necessary voltage gain through the fixed input signal.
3. Designing a current booster circuit that can increase the current to match output power without distorting the signal.

METHODOLOGY

Input Signal Amplitude fixed: 1 V r.m.s

Given,

Input power= 1mW

Power= $V_{in(rms)} \times I_{in(rms)}$

hence, $I_{in(rms)}$ =1 mA

Similarly for output: Voltage fixed at 8.41 V

Given output power=120mW

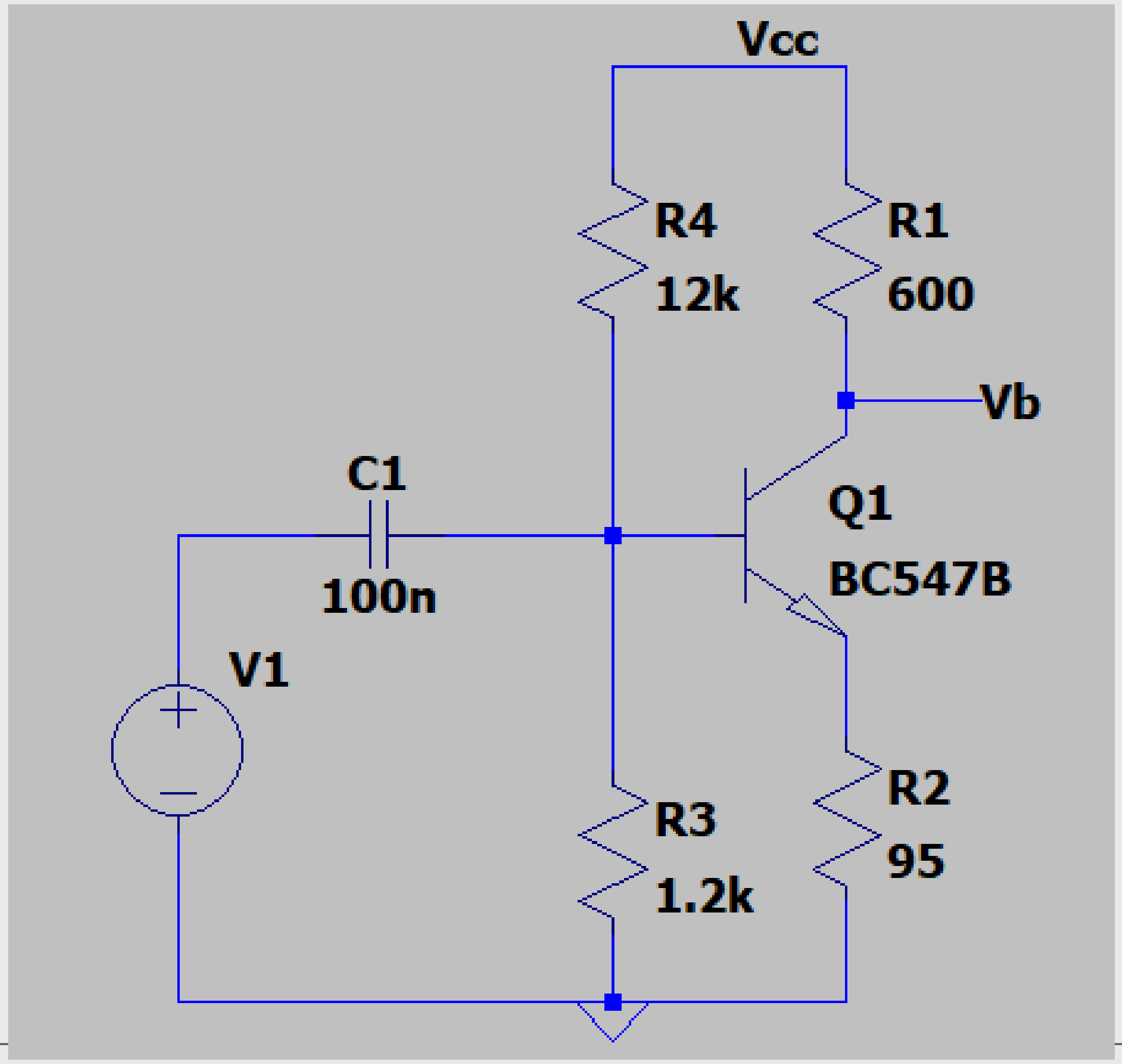
Power= $V_{out(rms)} \times I_{out(rms)}$

hence, $I_{out(rms)}$ = 20 mA

Thus gain = $\frac{V_{out(rms)}}{V_{in(rms)}}$ = 6

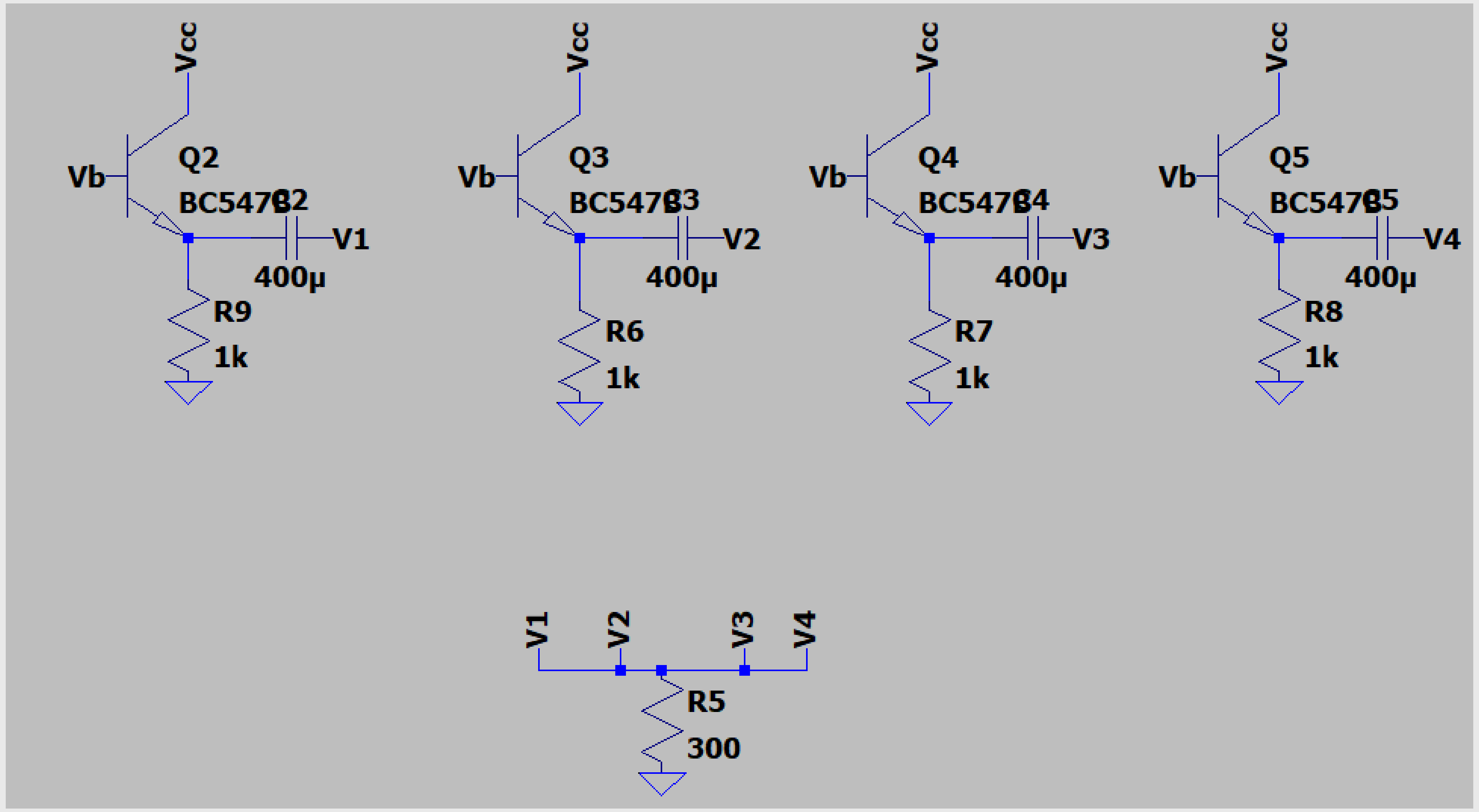
METHODOLOGY

To make an amplifier with BJT of gain 6:
We used the the C-E



METHODOLOGY

To obtain the required output current, we have used the following circuit combination. This divides the output current between four stages so that each of them works in the linear region without distorting the signal shape.

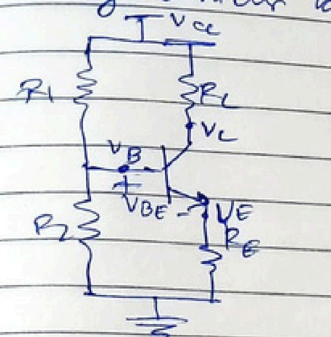


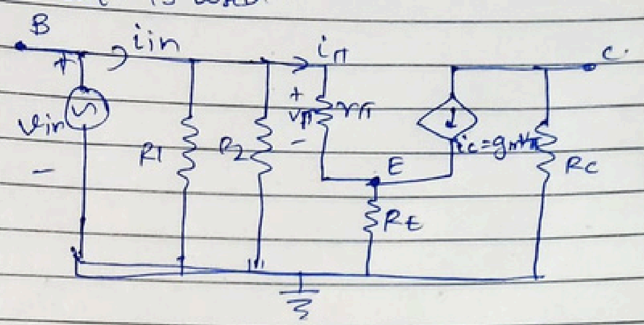
CALCULATIONS

Date :
P. No. :

• 1st stage:

- voltage divider bias ckt. is used.





from 2nd stage calc.:

V_C (dc oper pt) = 18V

ΔV_C (pk-pk ripple) = $12\sqrt{2}$V.

• Also $\beta = 266$ (from datasheet)

let $I_C = 20mA$

neglecting $I_B (= 75\mu A)$

$\therefore I_C \simeq I_E$

→ DC analysis

• from datasheet,

for $I_C = 2mA$, $V_{CE} = 5V$,

we have $V_{BE} = 0.660V$

$$\therefore \boxed{I_S = \frac{I_C}{\exp(V_{BE}/V_T)} = 1.681 \times 10^{-14} A}$$

• ~~New~~ VBE: ($I_C = 20mA$)

$$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right)$$

$$\therefore \boxed{V_{BE} = 0.7196V}$$

V_C (dc) = 18V.

KVL at output side:

$V_{CC} - I_C R_C = V_C$.

$\therefore R_C = (V_{CC} - V_C)/I_C$

$\therefore R_C = (30 - 18)/20m$

$$\boxed{R_C = 600\Omega}$$

→ Using small signal model:

• $g_m = I_C/V_T = 0.77279$ A/V

• $r_\pi = 344.204\Omega$ ($= \beta/g_m$)

• $A_V = \frac{v_{o,rms}}{v_{in,rms}} = \frac{6V}{1V} = 6$

Now, $A_V = \frac{-g_m R_C}{1 + g_m R_E}$

$\therefore R_E = \frac{g_m R_C - A_V}{A_V g_m}$

$$\therefore \boxed{R_E = 98.70\Omega}$$

→ Back to DC model.

* KVL at input side:

$V_B - V_{BE} - I_E R_E = 0$.

$\therefore V_B = V_{BE} + I_C R_E$

($\because I_E \simeq I_C$).

$$\therefore \boxed{V_B = 2.6936 V}$$

• Finding R_1 & R_2:

from voltage divider ckt:

$\frac{V_{CC}}{V_B} = \frac{R_1 + R_2}{R_2} = 11.1375$

$\therefore R_1/R_2 = 10.1375 \simeq 10$

(from small signal model),

$\because I_B = 0$, $I_\pi \simeq 0$.

$\therefore i_{in}$ completely flows through ($R_1 \| R_2$)

Now, $P_{in} = 1mW$

$v_{in,rms} = 1V$

$\therefore i_{in,rms} = 1mA$.

$\therefore \frac{v_{in}}{i_{in}} = \frac{R_1 R_2}{R_1 + R_2} = 10^3$.

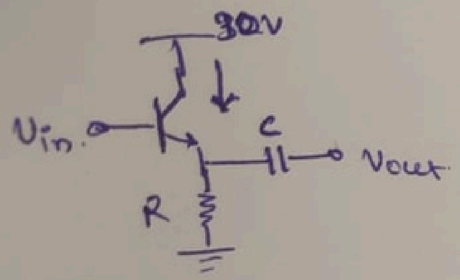
Using (R_1/R_2) relation:

~~10.1375 R2~~

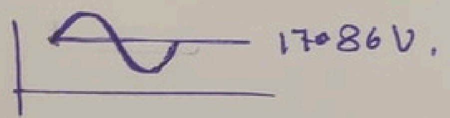
$\frac{10 R_2^2}{11 R_2} = 10^3$

$$\therefore \boxed{R_2 = 1.1k\Omega}$$

$$\therefore \boxed{R_1 = 11k\Omega}$$



V_{in}



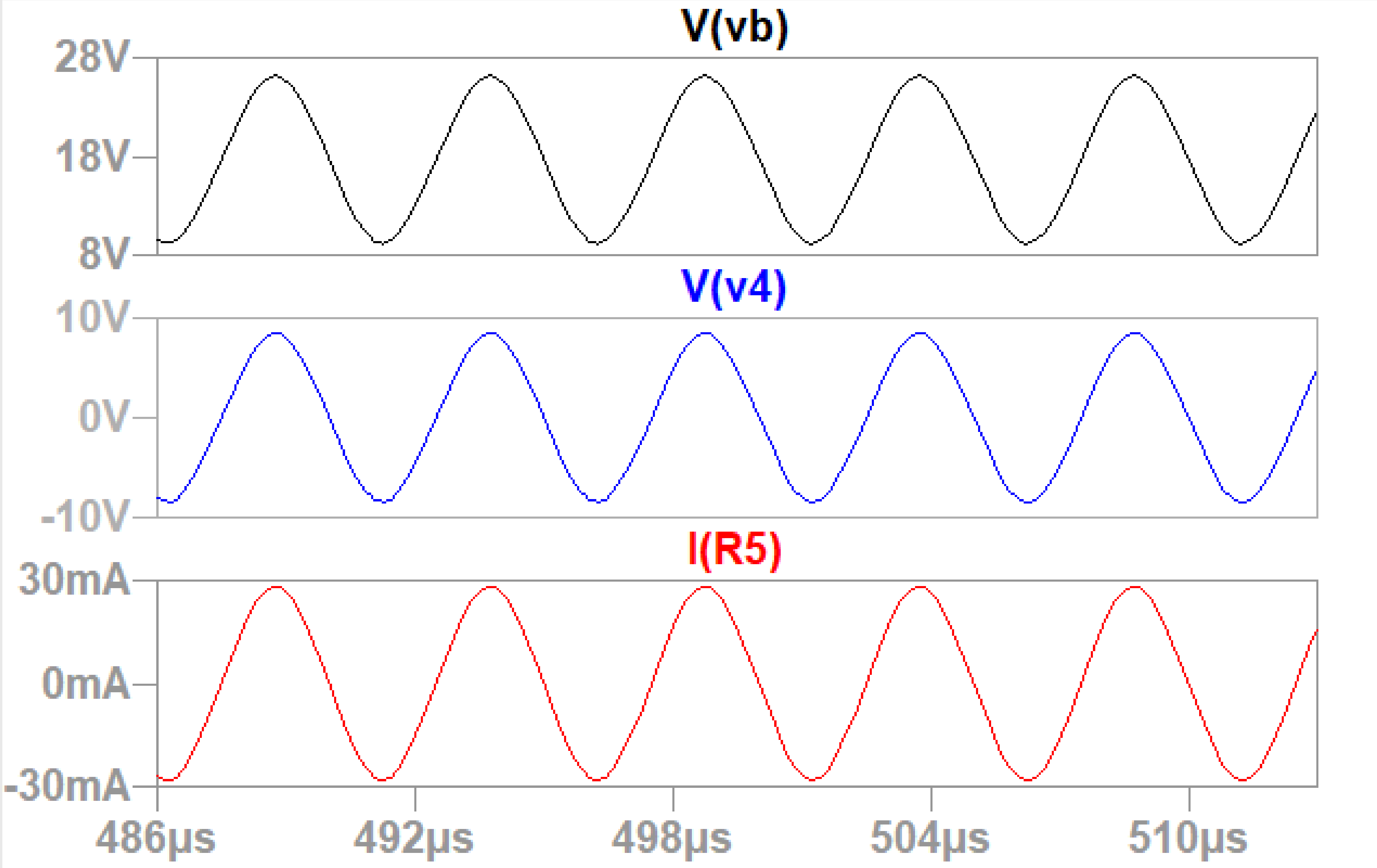
To set the collector current in the linear range

Let $R = 1k$ (standard value)

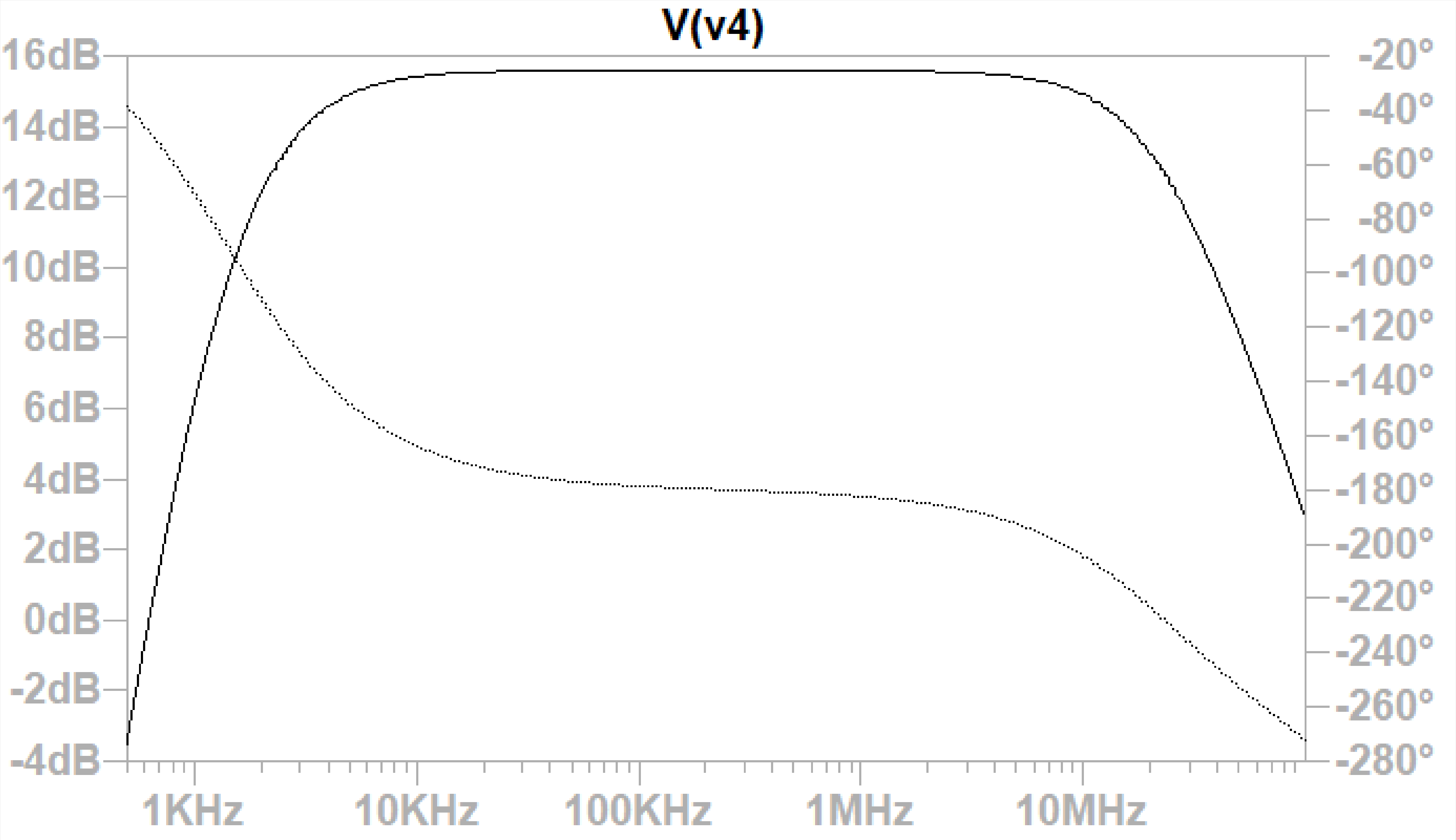
Therefore $I_C = \frac{V_{out}}{R} = \frac{17.89}{1k} = 17.89mA$

(Obtained I_C is in good working range)

OUTPUT WAVEFORMS

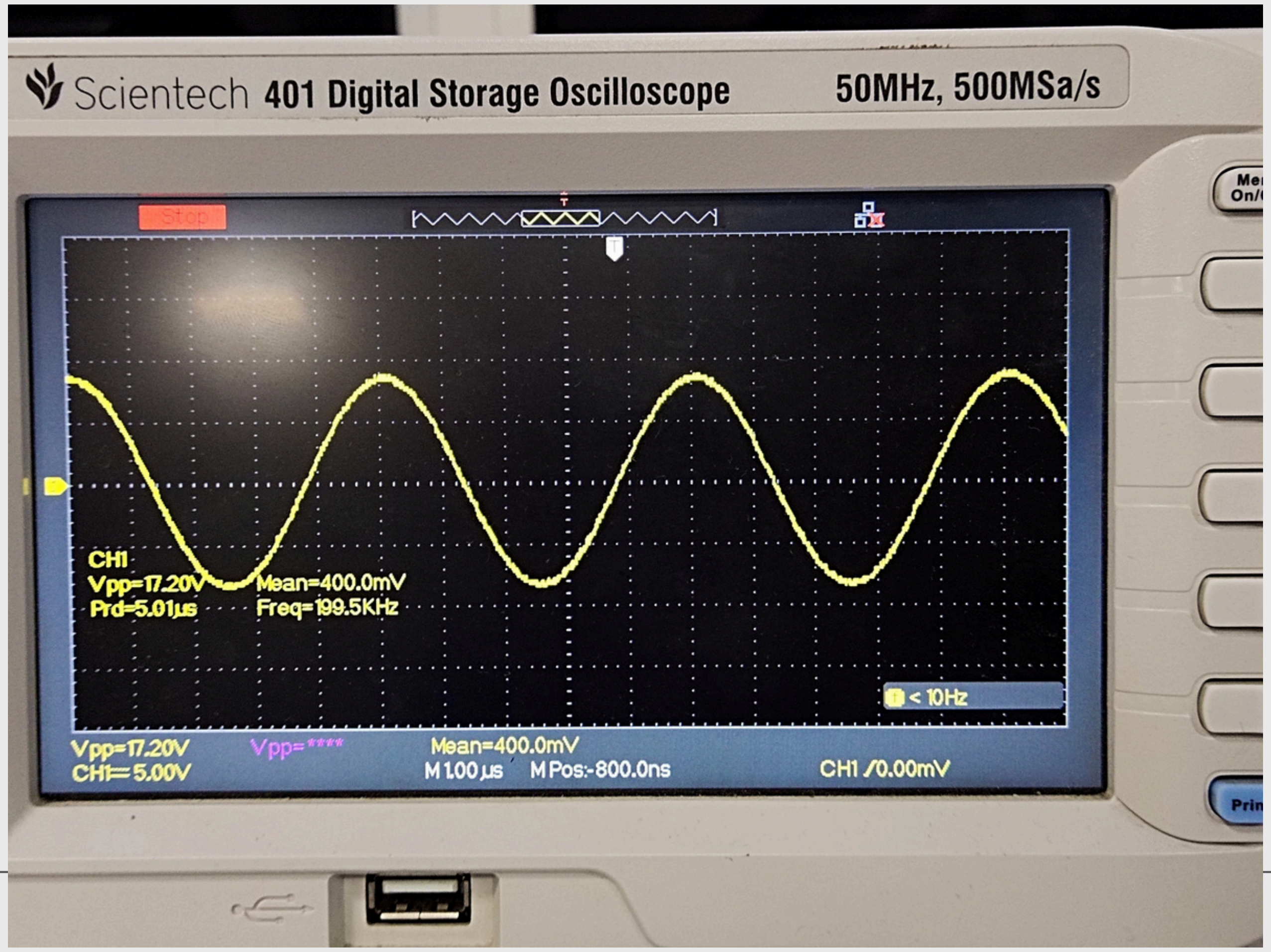


FREQUENCY RESPONSE



RESULTS

- Obtained output voltage at stage 1: 17.86V + 8.45 sin (wt) V
- Obtained output voltage at stage 2: 8.41 sin (wt) V
- Obtained output current at stage 2: 14 sin (wt) A
- Obtained output power at stage 2: 117.6 mW



ROUT/ RIN

$$R_{in} = \left(r_\pi + (\beta+1) R_G \right) \parallel \left(R_1 \parallel R_2 \right)$$

$$\approx r_\pi = \frac{\beta}{g_m} = \frac{\beta}{I_c} \times V_t = 155$$

$R_G = 95$ $\quad R_1 = 12.K$ $\quad R_2 = 1.2K$

Now, $r_\pi + (\beta+1) R_G = 11.65\ K$

$\therefore R_{in} \approx 1K$

→ for R_{out}

$$R_{out} = R_L \parallel R_E \parallel \left(\frac{R_{out_1} \parallel r_\pi}{\beta+1} \right)$$

$R_{out_1} = 600\Omega$ $\quad r_\pi = \frac{\beta}{g_m} = \cancel{120}\ \frac{\beta}{I_c} \times V_t \approx \cancel{180}\ 405.25\Omega$

$\beta = \cancel{180}\ 266$

$R_L = 300\Omega$ $\quad R_E = 1K$

$R_{out} = 0.902\ \Omega$

DISCUSSION

- Amplifying the 1 mW signal to 120 mW output required combining voltage gain with current boosting stages.
- The common emitter topology helped achieve low output impedance, enabling better power transfer to the 300 Ω antenna.
- Voltage divider biasing stabilized the operating point, reducing dependence on transistor variations and ensuring consistent performance.
- Unity gain stages boosted current without disturbing voltage gain, maintaining output signal quality.
- Impedance matching was critical for maximum power transfer and minimal reflection.
- Minor trade-offs between gain flatness and bandwidth were observed, as expected in practical designs.

CONCLUSION

- The amplifier circuit was successfully designed to bridge a low-power transmitter and a medium-impedance antenna, delivering 120 mW output efficiently.
- By using a mix of voltage and current control techniques, stable and reliable performance was achieved without compromising signal integrity.
- Impedance matching and bias stabilization were critical factors in achieving the desired amplification and transmission.

THANK YOU