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by William Utting

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Course: HNC Electrical and Electronic Engineering

Module: SGEE4003 - Electronics I

Assignment Title: Analogue Circuit Design

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University number: 2221112

Date Submitted: 06/02/2023

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- ① EXCELLENT RESEARCH WITH A LARGE RANGE OF SOURCES.
- ② DC + AC INITIAL VALUE CALCULATIONS IN APPENDIX.
- ③ INITIAL TESTING (AS 8)
- ④ DETERMINATION OF Z_{in} + Z_{out} IS MISSING.
- ⑤ EXPLANATION OF RELATIONSHIP B/W f & GAIN IS MIXED UP.
- ⑥ A DEDICATED RESULTS SECTION WOULD HAVE IMPROVED READABILITY.
- ⑦ ANALYSIS + EVALUATION IS EVIDENT.
- ⑧ LARGE AMOUNT OF INFO IN THE APPENDICES WAS HARD TO FIND.

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Executive Summary

Researching amplifiers and oscillators gave a solution to the specification. A class A amplifier with negative feedback was decided on for the amplifier design. The transistor that would be used was the 2N3904 NPN transistor. The oscillator's design was decided to be a Colpitts oscillator. The design would have to include two operational amplifiers as a voltage follower and an inverting amplifier, this shaped the oscillator's waveform to be suitable for the transistor amplifier. After testing various values in both the oscillator and amplifier, the best (on average) values were used. This resulted in a final circuit that covered the specifications, but did not specifically meet them. It is evaluated that the amplifier needs a tuning circuit designed into it to meet the bandwidth requirements.

Assignment Brief**Aim and Objectives**

The aim of this assignment is to design and test an analogue system. The objectives are:

Design and test a small signal Class A voltage amplifier to achieve a given specification

Design and test a suitable oscillator and buffer circuit to provide the amplifier with an input signal

Specification**Amplifier Specification**

- Centre frequency: 1MHz
- Bandwidth: 300KHz
- Gain: 50
- Input signal: 100mV pk-pk

Oscillator Specification

- Output frequency: 1MHz
- Output voltage: >100mV pk-pk

Planning and Reflection

The objective of this assignment is to create a class A amplifier and an oscillator. To complete the objective, research into amplifiers and oscillators must be conducted. After sufficient research, the initial conditions of the amplifier must be chosen. Working around the conditions chosen, the values for the direct current (DC) section of the amplifier need to be calculated. Once calculated a simulation of the circuit can be run. Using data gathered from the simulation, the alternating current (AC) section can be calculated and implemented into the simulation. By simulating the full circuit and taking readings of the values, the circuit can be tuned and manipulated to give the correct gain, bandwidth and centre frequency. Once the circuit is tuned, an oscillator can be constructed and connected to the amplifier. A final set of readings will be taken. A conclusion can then be constructed using the results, any recommendations and observations will be noted.

Research into Amplifiers, Oscillators and Feedback

Configuration of the Amplifier

A transistor amplifier can be configured in a few different ways. Each method has its advantages and disadvantages (as shown in Appendix A, Table 1)(Keylink Microwave, 2022). Appendix A, Figure 1 aids in understanding the data in the table. The assignment requires a full wave amplifier, therefore, the choices are now between class AB and class A amplifiers. Using Appendix A, Figures 2 and 4, it can be seen that the class A circuit is much less complex than the class AB design (Teja, 2021). By choosing to use the class A amplifier it reduces the number of components thus reducing the difficulty in tuning the circuit.

Choice of Transistor

Using the specifications in the brief the range of transistors to choose from can be narrowed down. The centre frequency must be set at 1MHz, the transistor used must be of a high enough frequency. The transistor must have the capability to amplify signals. Moreover, the transistor must be able to amplify an input signal of 100mV. To further narrow down the choices available, the type of transistor can be chosen.

Bipolar Junction Transistor (BJT)

A transistor consisting of two p-n junctions, normally made of silicon or germanium. The junctions can be arranged in two different ways, p-n-p and n-p-n. The current across the base section of a transistor effectively creates a template which the larger current flowing through the transistor copies (Bird 2014, 164 - 170). See Appendix A, Figures 7 and 8 for graphs relating collector current and voltage as well as a diagram on the construction of a BJT transistor.

Junction-Gate Field Effect Transistor (JFET)

"Effectively a reverse biased p-n junction" (Bird 2014, 172). They are made of a channel of p/n type material surrounded by a substrate of the opposite polarity with electrodes connected to the end forming the source and drain (See Appendix A, Figure 9) (Bird 2014, 172; electricaltechnology, 2020). The depletion zones from the gates shape the current flowing from the source to drain by increasing/ decreasing the amount of conductive material available for the current to flow through (See Appendix A, Figure 11) (electricaltechnology, 2020).

Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

MOS stands for metal-oxide-semiconductor. It can operate in depletion and enhancement modes. MOSFETs work like JFETs using the channel between the source and drain to control the flow of current. However, it has a layer of insulation which reduces the leakage current. (electricaltechnology, 2020; Singh, 2020). "It is expensive one" (Singh, 2020), MOSFET is more expensive than JFET due to its added complexity.

The most suitable transistor for this application is the BJT variant. This is due to its ability to produce high gain. The FET transistors are much better suited to switching applications due to their high switching speeds and low gain (electricaltechnology, 2020).

NPN 2N3904 transistor

The 2N3904 transistor will work well for this application. Under the correct conditions it can produce a gain up to 300. Furthermore, the maximum frequency of the amplifier is 300MHz, the maximum frequency for this amplifier design is 1.15MHz. The 2N3904 model has been manufactured with general purpose switching or amplifying operations. The adoption of this transistor will ensure that the objectives of the amplifier can be met (Farnell, 2023).

Bandwidth

Bandwidth is the range of frequencies above -3db from the peak of the amp voltage.

"The quality factor Q of the bandwidth is defined as the ratio of resonant frequency to bandwidth, i.e.,

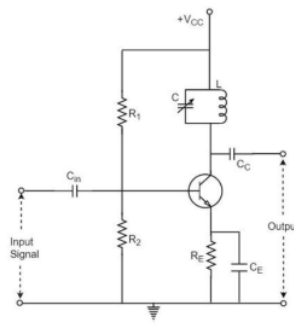
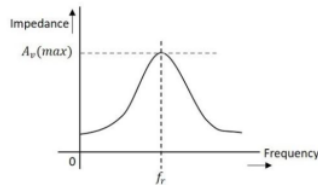
$$Q = \frac{f_r}{BW}$$

In general, a practical circuit has its Q value greater than 10." (Aligarh Muslim University, 2019)

Bandwidth can also be tuned to a select frequency through series or parallel. Series blocks a selected frequency, parallel selects a frequency. There are two basic methods of selecting a frequency:

Single Tuned Amplifier

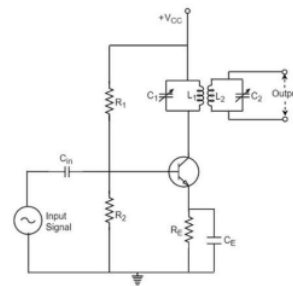
The resonant frequency of the tuning circuit is matched to the frequency of the signal you want to amplify. The tuned circuit has a high impedance towards the selected frequency which rejects the unwanted frequencies.



(Aligarh Muslim University, 2019)

Double Tuned Amplifier

The double tuned circuit consists of 2 coupled single tuned circuits. The extent to which the circuits are coupled determines the bandwidth of the amplifier. The tighter the coupling the higher the bandwidth.



BW = bandwidth of dt circuit

K = coefficient of coupling

F = resonant frequency

$$BW_{dt} = kf_r$$

(Aligarh Muslim University, 2019)

Gain

Voltage gain is the ratio of the voltage inputted into the circuit against the voltage output from the circuit and can be represented as such: (Grgurich, 2020)

Figure
(Grgurich, 2020)

Voltage Gain:

$$A_v = \frac{V_{out}}{V_{in}}$$

Negative Feedback

Negative feedback in an amplifier can be seen as a way to sacrifice gain for less distortion and a higher bandwidth where the gain is constant. The output quantity of the amplifier is fed back into the input. Output voltage (shunt), current (series) or a mixture of both can be used. When the input voltage changes the negative feedback counteracts the effect of that change. If positive feedback is used in the amplifier the effects of the voltage change are increased. "Positive feedback is not normally used in amplifiers" but is used more in oscillators (Bird 2014, 304; Nordholt, 2006; Toshiba, 2022).

Positive feedback: $V_{out} = A_V \times V_{in} / (1 - |A_V \times B|)$

Negative feedback: $V_{out} = A_V \times V_{in} / (1 + |A_V \times B|)$ (Toshiba, 2022)

Operational Amplifier (op amp) Configurations

Operational amplifiers can be used to amplify, follow and complete some basic mathematical/ logical operations (meneu, 2016). The output from the oscillator will need to be transformed into a suitable input for the amplifier, the impedance and voltage of the signal needs to be decreased. An operational amplifier can be configured to conduct both operations (See Appendix A, Figures 12 and 13). The voltage follower lowers the impedance of the inputted signal without distorting or changing the voltage of the original waveform. In addition to the voltage follower, an inverting amplifier will decrease the voltage and invert the waveform. The waveform needs to be inverted before being amplified by the transistor due to the output from the transistor being the inverse of the input.

Types of Oscillator

To decide on an oscillator design there are three main variables to consider: The frequency, type of waveform and whether feedback will be used. The amplifier requires a high frequency, sine wave input; the oscillator must be able to supply these conditions. Positive

feedback will also be used in the oscillator. The most simple oscillator that can be used to achieve these conditions is the Colpitts oscillator. Two capacitors are connected in parallel with an inductor, this creates a tank circuit where oscillations occur when the sum of the capacitive reactance is equal to the inductive reactance. Including a transistor and positive feedback the oscillations can continue as long as power is supplied (See Appendix A, Figure 14). The transistor can be incorporated by centre tapping the capacitors and connecting the centre tap to the base of the transistor. Two resistors are connected to bias the transistor, the resistors values can be changed to manipulate the output voltage. The frequency of the circuit can be changed using the capacitors in the tank circuit (Electronic Tutorials, 2022). There are other oscillators that have similar characteristics to the Colpitts. The Hartley oscillator is the most similar, it has two inductors and one capacitor in a resonance tank. However, the waveform it produces is more distorted than the waveform produced by the Colpitts oscillator. A RC oscillator does not resonate at high enough frequencies for this application, the Colpitts oscillator can resonate at high enough frequencies. A crystal oscillator is very stable, however, it does not have a wide range of frequencies it can operate at. The Colpitts oscillator has all of the properties that are needed.

Summary of the Research

From the research conducted the final design of the amplifier and oscillator can be determined. The amplifier will be of a class A configuration with a BJT npn transistor (2N3904 model). The oscillator will be configured as a Colpitts oscillator. A voltage follower and inverting amplifier will be used between the oscillator and amplifier to change the waveform to become compatible with the transistor amplifier.

Design Method, Calculations and Testing

Amplifier DC Conditions

To begin calculating the values of the resistors in the amplifier a DC supply voltage must be chosen. The higher the voltage, the larger the maximum gain can be. However, this voltage must be below the transistors collector-base breakdown voltage of 60V. The power source must also be considered. Therefore, a voltage of 12V is sufficient. It is enough to have a gain above 50 and it can be provided by a range of power sources. I_q can be determined by taking around 1 percent of I_{cmax} ($0.2A \times 0.01 = 2mA$). V_C is approximately 50% of V_{CC} , this allows the output signal to have the maximum amplitude both positive and negative ($12V \times 0.5 = 6V$). The emitter voltage (V_E) is about 10% of V_{CC} to provide stabilisation to the transistor ($12V \times 0.1 = 1.2V$). Using these values the resistors to bias the transistor can be calculated (See Appendix B: Figure 1). h_{fe} (obtained from the 2N3904 data sheet) is used to calculate the base current (See Appendix B, Figure 2). To ensure the input waveform is being amplified in a linear fashion, V_B should be close to 0.7V above the emitter voltage ($1.2V + 0.7V = 1.9V$). The values of the R_1 and R_2 currents should be around ten times the base current (See Appendix B Figure 3 for resistance calculations of R_1 and R_2). With the DC conditions calculated, a table of values and a circuit can be created (See Appendix B, Figures 4 and 5).

Amplifier AC components

To attach the DC circuit to the AC circuit, capacitors are used to filter out the DC voltage, these coupling capacitors need to be at the least resistance when the circuit is operating at its central frequency of 1MHz (See Appendix B, Figure 6). The input waveform can then be input into the amplifier and the output voltage can be read (See Appendix B, Figure 7).

Refining the Design for Gain, Bandwidth and Centre Frequency

The initial design has a gain of 293, a bandwidth of 28.3MHz and a centre frequency of 63.1KHz (See Appendix B, Figure 8). To reduce the gain and control the bandwidth a potential divider and negative feedback can be fitted to the emitter (See Appendix B, Figure 9). To help with adjusting the bandwidth a variable resistor can be attached next to C_1 , this will filter out the lower frequencies (See Appendix B, Figure 10). A capacitor can connect the output to ground and act as a filter for the higher frequencies (See Appendix B, Figure 11). Upon running the simulation with no changes to the components, the bandwidth and centre frequency has decreased significantly (See Appendix B, Figure 12) and the gain is non-existent (See Appendix B, Figure 13). The gain being so low, is probably due to the capacitor's resistance being so low. Adjusting the values (See Appendix B, Figure 14) with

the aim of fixing the bandwidth and centre frequency, the respective values of bandwidth, centre frequency and gain is: 7.55MHz, 1MHz and 66 (See Appendix B, Figure 15). The bandwidth can be reduced, which in turn, should reduce the gain. To reduce the bandwidth to 3.8MHz the gain drops to 3 (See Appendix B, Figure 16). See testing table (Appendix B, Table 1) for complete tests. After completing around 20 complete tests (and many more tests with minor changes), the most notable of which are recorded, test 3 has the best values. Test 3 managed to have a centre frequency of 630KHz, a bandwidth of 2.7MHz and a gain of 46.3. It is not the most accurate on any of the values, however, it is the best of the values on average. The bandwidth covers the 1MHz centre frequency that it is meant to have and the frequency response is relatively flat between the -3db points (See Appendix B, Figure 17). The bandwidth is the lowest that was achieved out of the tests where the gain is close to 50.

Oscillator Design

The oscillator design is of a Colpitts configuration. The values of the inductor and capacitors need to be low to have an oscillation of around 1MHz. After a small amount of testing the values of 0.24mH and 150pF (per capacitor) produced the correct frequency (See Appendix C, Figure 1). An inverting amplifier with a gain of 0 is attached to the output, this ensures the output wave of the main amplifier is in the same phase as the original wave. A non-inverting amplifier is then used to decrease the signal down to a voltage of 100mV (See Appendix C, Figure 2). Unfortunately the output waveform is not a complete sine wave, however, it will function well enough (See Appendix C, Figure 3).

Final System

The final system is the combination of the amplifier and oscillator, the output of the oscillator is connected to the positive terminal of the amplifier (See Appendix D, Figure 1). The negative terminal of the amplifier is connected to ground. The final waveform of the circuit has been smoothed by the negative feedback to create a smoother sine wave than the wave that was output by the oscillator (See Appendix D, Figure 2). Measurements of the final circuit are taken and tabulated (See Appendix D, Figure 3 and Table 1).

Analysis

Through testing the amplifier design a few observations can be made. Starting with changing the input impedance: the higher the impedance, the lower the gain and the higher the filtering of the lower frequencies (defines the lower end of the curve more). The value of the input capacitance can manipulate the centre frequency, decreasing the capacitance increases the centre frequency and decreases the gain. The ratio between R_E and R_{E1} determines the amount of negative feedback and gain. If $R_E < R_{E1}$ the gain is increased and the effect of the negative feedback is reduced. The higher R_E gets the lower the gain. Reducing the value of the centre tapping capacitor also increases the effect of the negative feedback and reduces gain. C_4 affects the centre frequency, the higher the capacitance the lower the centre frequency and gain. The main issue when trying to tune the circuit was retaining the gain while getting the correct bandwidth and centre frequency.

Analysing the results from the final test and comparing them against the specifications show a few differences. The oscillations from the oscillator are not centred over 0V (See Appendix D, Figure 4), this causes issues when the signal is amplified. The final signal's peak to peak voltage has been correctly amplified by a factor of ~ 45 . However, since the input voltage was purely negative, the output voltage is now purely positive. This causes the maximum peak voltage to be $\sim 8.9V$ and the minimum $\sim 3.9V$ (See Appendix D, Figure 5). This gives a sine wave oscillating over a centre voltage of $\sim 6.4V$. Other than that issue, the circuit functions as per the final amplifier. The bandwidth could be tuned much more effectively using tuning circuits as shown under the research section. This would make it much easier to fix the centre frequency and reduce the bandwidth to the 300KHz desired.

Evaluation

In the selected design, there was a large sacrifice of centre frequency for gain. Overall that didn't matter too much as the bandwidth covered the intended centre frequency and bandwidth. The curve between the -3db points was shallow so most of those frequencies were amplified to a similar value. The oscillations inputted into the amplifier needed to be better centred over 0V. This would have fixed the final waveform being centred around $\sim 6.4V$. The bandwidth and centre frequency could have been improved significantly if a tuning circuit was included in the design.

Conclusion

Reflecting on the specifications laid out in the assignment, there could have been a vast improvement in the circuit design. Potentially, test 1 could have been used if tuned circuits were involved in its design. The tuned circuit would have a resonant frequency of the required centre frequency. The framework to produce a circuit that can fulfil the specification is present in this paper. If more of the theories found in the research were applied to the design the specifications could be achieved.

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(not all references are cited and used in the research section, some references were used for reading around the subject for further education)

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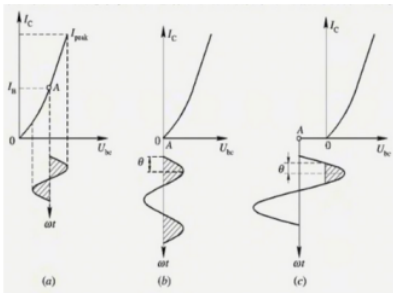
Appendix A - Research

Table 1

Class	Efficiency	Distortion	Conduction angle	Linearity
A	25 - 50%	Minimal	360	High
B	78.5%	Cross-over (Medium - High)	180	High
AB	50 - 60%	Medium	$360 < \alpha < 180$	High
C	80%	High	90	Low

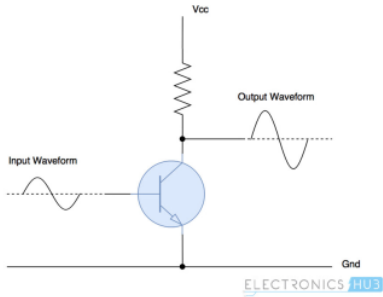
(Keylink Microwave, 2022)

Figure 1



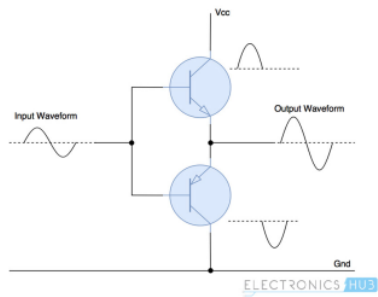
(Keylink Microwave, 2022)

Figure 2 - class A



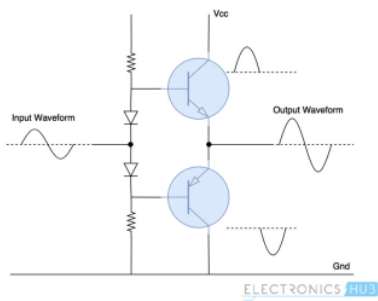
(Teja, 2021)

Figure 3 - class B



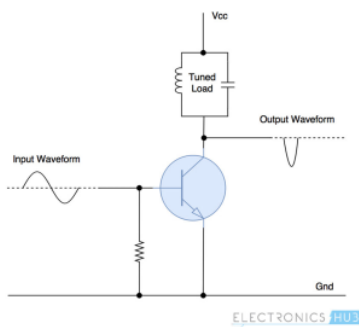
(Teja, 2021)

Figure 4 - class AB



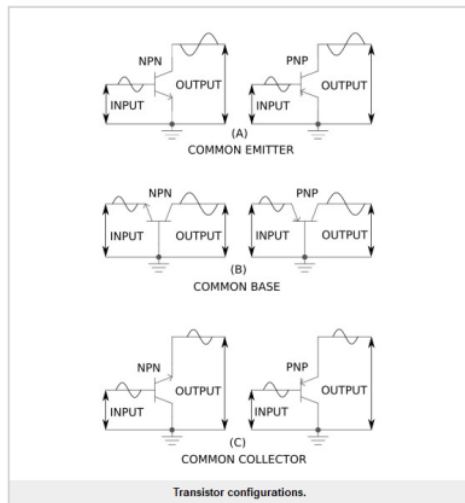
(Teja, 2021)

Figure 5 - class C



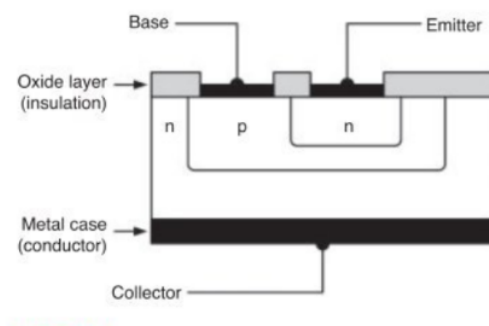
(Teja, 2021)

Figure 6



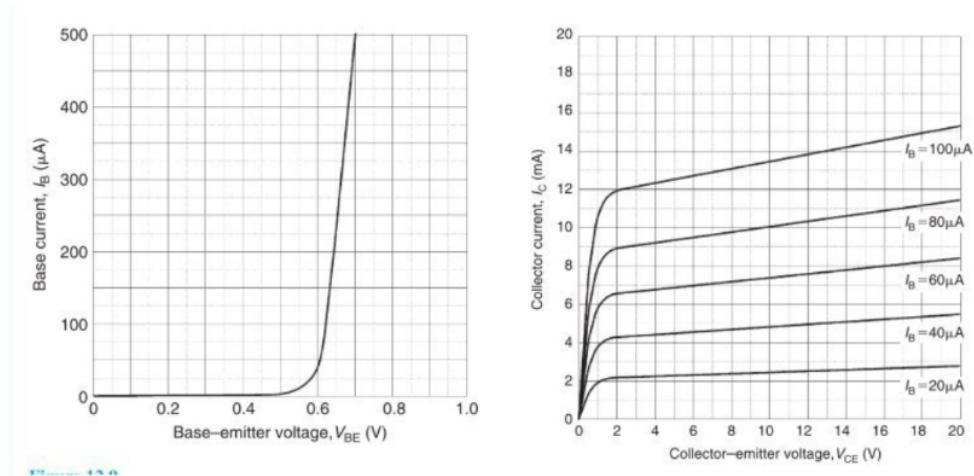
(ECStudioSystems, 2019)

Figure 7



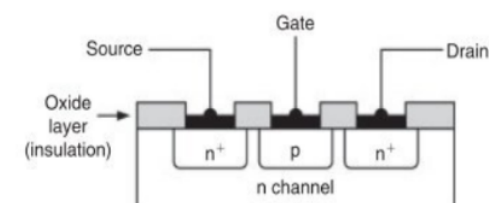
(Bird 2014, 164 - 170)

Figure 8



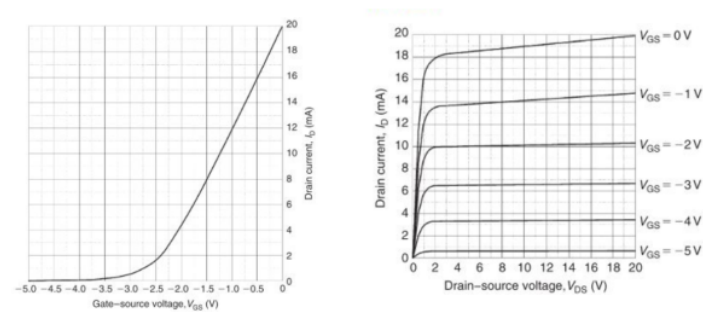
(Bird 2014, 164 - 170)

Figure 9



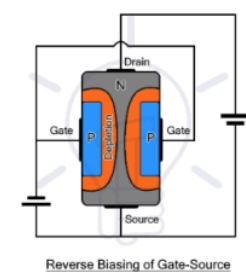
(Bird 2014, 173)

Figure 10



(Bird 2014, 173)

Figure 11



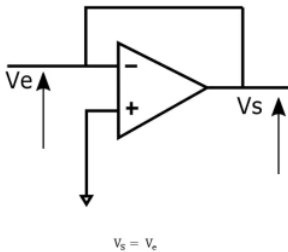
(electricaltechnology, 2020)

Table 2

BJT	FET
BJT stands for Bipolar Junction Transistor.	FET stands Field Effect Transistor.
The current flow is due to the flow of majority as well as minority charge carriers.	The current flow is due to the flow of majority charge carriers.
Current flow is due to both electrons and holes, therefore name bipolar transistor.	The current flow is due to either electrons or holes, therefore, named unipolar transistor.
There are two types of BJT i.e. NPN and PNP.	The two types of FET are JFET and MOSFET, each with N-channel and p-channel as well.
BJT construction is comparatively easier.	The FET construction is comparatively difficult.
The 3 terminals are named emitter, base and collector.	The 3 terminals of FET are Source Gate and Drain.
There are 2 PN junction in BJT.	There are no PN junctions.
It is a current-controlled current device.	It is a voltage-controlled current device.
The B-E junction is forward biased and the B-C junction is reversed biased.	The Gate voltage is reversed biased while the drain voltage is maintained higher than the source.
The BJT has very simple biasing.	The FET biasing is a little difficult.
The emitter and base cannot be interchanged or swapped.	The drain and source can be interchanged since the drain should be more positive.
BJT has a very high gain.	FET has a comparatively low gain.
The input impedance is very low in the range of 1K ohms.	The input impedance is very high in the range of 100M ohms.
The output impedance is very high thus high gain.	The output impedance is very low thus low gain.
There is current flow at its base terminal.	There is negligible current at its base terminal.
BJT has an offset voltage requirement.	FET does not require offset voltage.
Dependent on input current, it consumes high input energy at normal operation.	Dependent on input voltage, it consumes less energy in normal operation.
BJT consume high power thus not energy efficient.	FET consumes less power thus energy efficient.
BJT has a comparatively low switching speed.	FET has a comparatively very high switching speed.
BJT generates noise in the system.	FET is very noiseless.
BJT is cheaper than FET.	FET is costlier than FET.
The size of BJT is larger than FET.	The FET has a more compact and smaller size than BJT.
BJT has a negative temperature coefficient.	FET has a positive temperature coefficient.
Suitable for low input current application.	Suitable for low input voltage application.

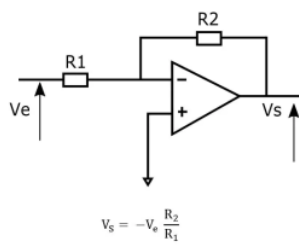
(electricaltechnology, 2020)

Figure 12



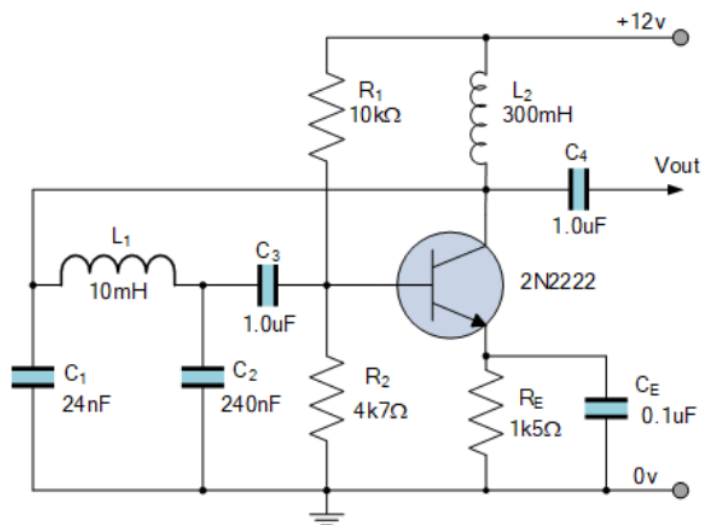
(meneu, 2016)

Figure 13



(meneu, 2016)

Figure 14



(Electronic Tutorials, 2022)

Appendix B - Amplifier Design

Figure 1

$$\begin{aligned}V_{CC} - V_C &= I_q \times R_L \\12 - 6 &= 0.002 \times R_L \\ \frac{6}{0.002} &= R_L = 3000\Omega\end{aligned}$$

$$\begin{aligned}\text{assuming } I_C &= I_E \\ R_E &= \frac{V_E}{I_E} = \frac{1.2}{0.002} \\ R_E &= 600\Omega\end{aligned}$$

Figure 2

$$\begin{aligned}h_{fe} &= \frac{I_C}{I_B} \\ I_B &= \frac{I_C}{h_{fe}} = \frac{0.002}{105} = 0.000019A\end{aligned}$$

Figure 3

$$\begin{aligned}I_{R1 \& R2} &= I_B \times 10 = 0.00019A \\ R_1 &= \frac{V_{CC} - V_B}{I_{R1}} = \frac{10.1}{0.00019} = 53157\Omega \\ R_2 &= \frac{V_B}{I_{R2}} = \frac{1.9}{0.00019} = 10000\Omega\end{aligned}$$

Figure 4

V_{CC}	12V
V_C	6V
V_E	1.2V
V_B	1.9V
I_q	2mA
I_C	2mA
I_E	2mA
I_B	19mA
$I_{R1 \& R2}$	190mA
R_L	3000 Ω
R_E	600 Ω
R_1	53157 Ω
R_2	10000 Ω

Figure 5

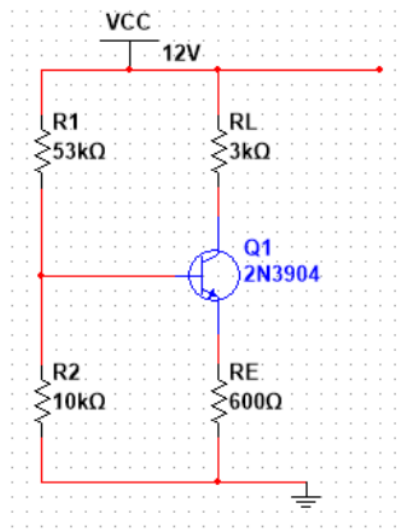


Figure 6

$$X_c = \frac{1}{2\pi(f_c \times C)} = \frac{1}{2\pi(1 \times 10^6)(1)} = 0.000000159F$$

Figure 7

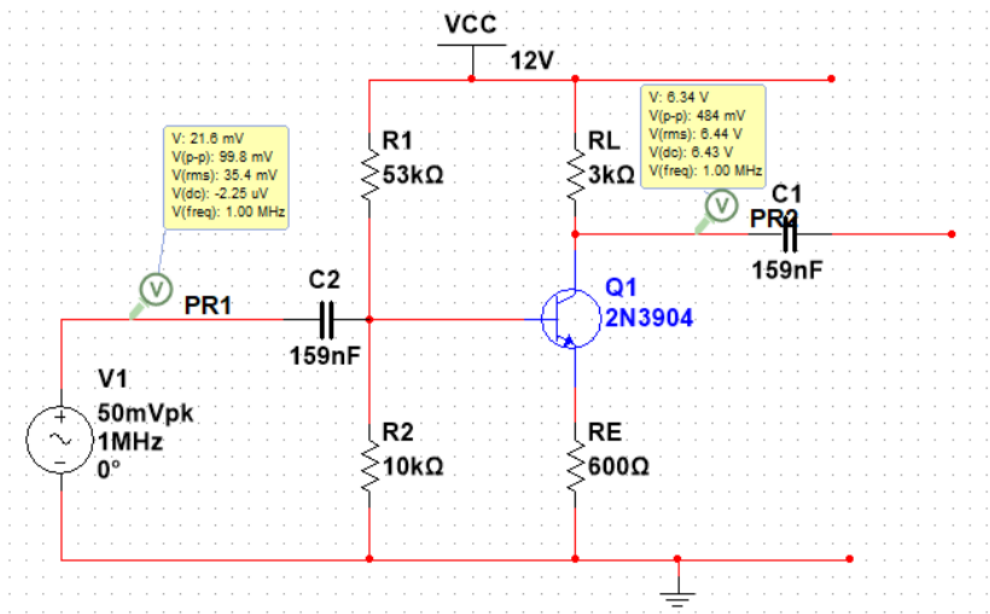


Figure 8

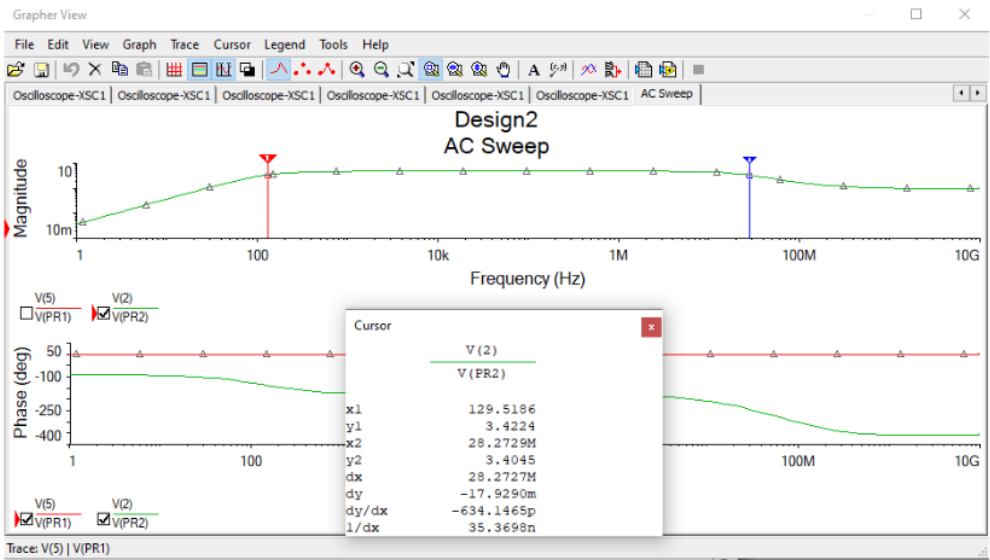


Figure 9

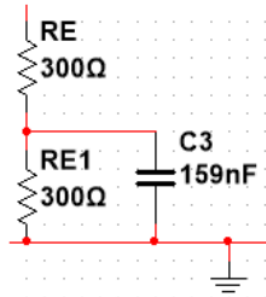


Figure 10

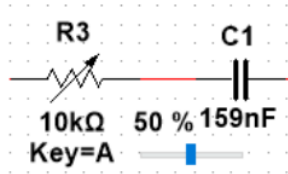


Figure 11

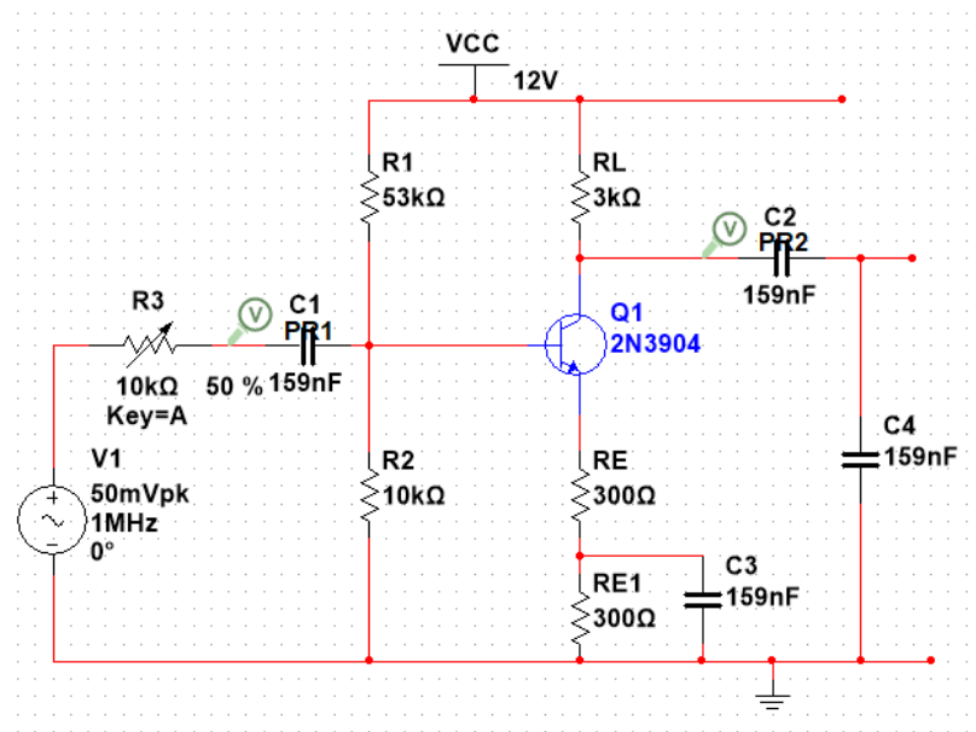


Figure 12

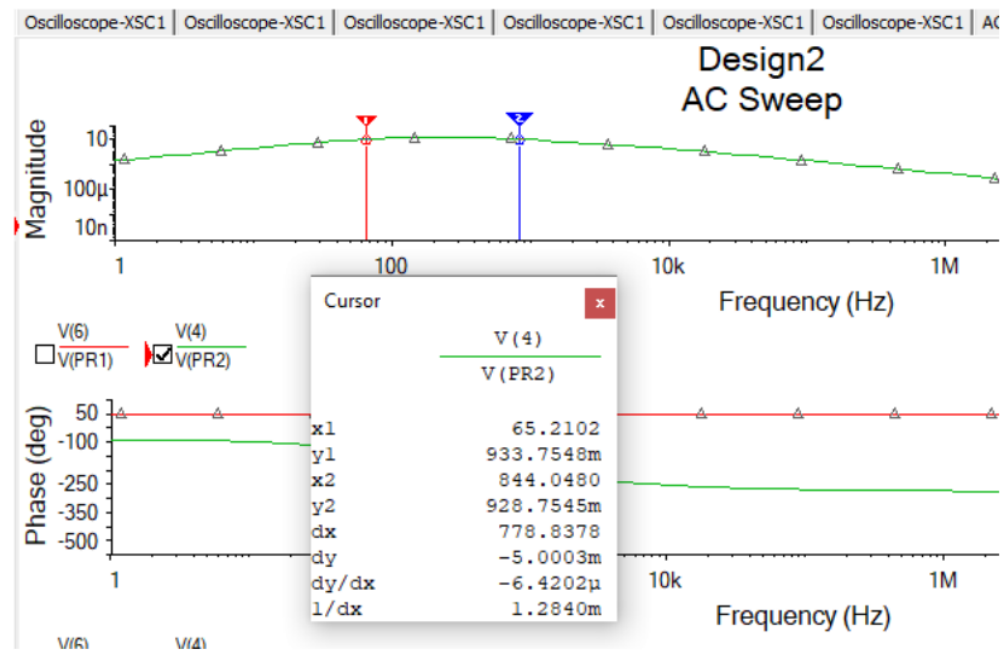


Figure 13

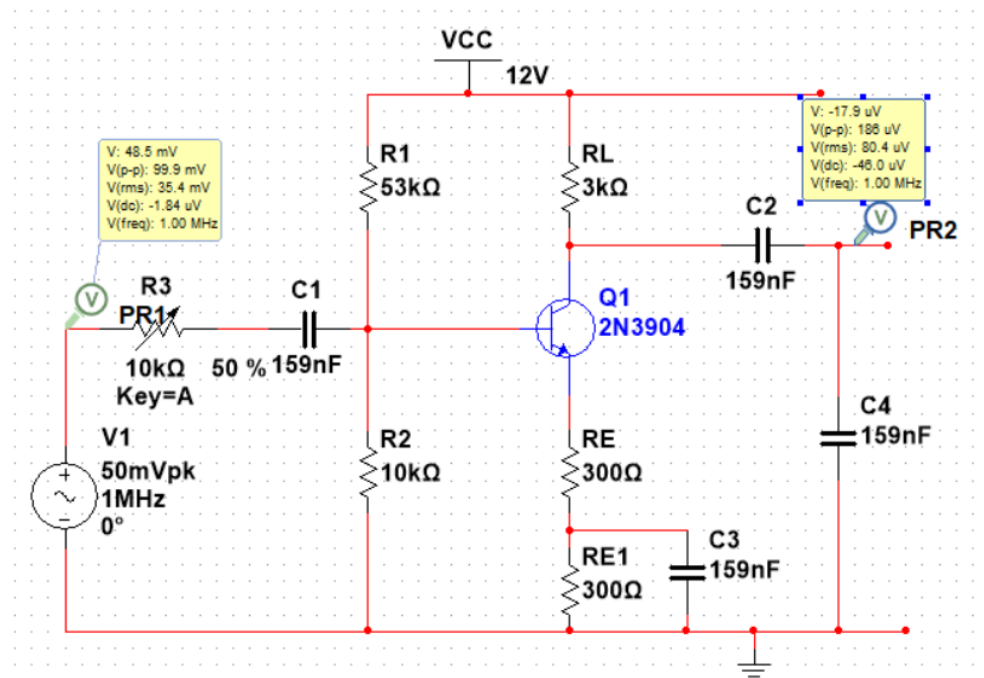


Figure 14

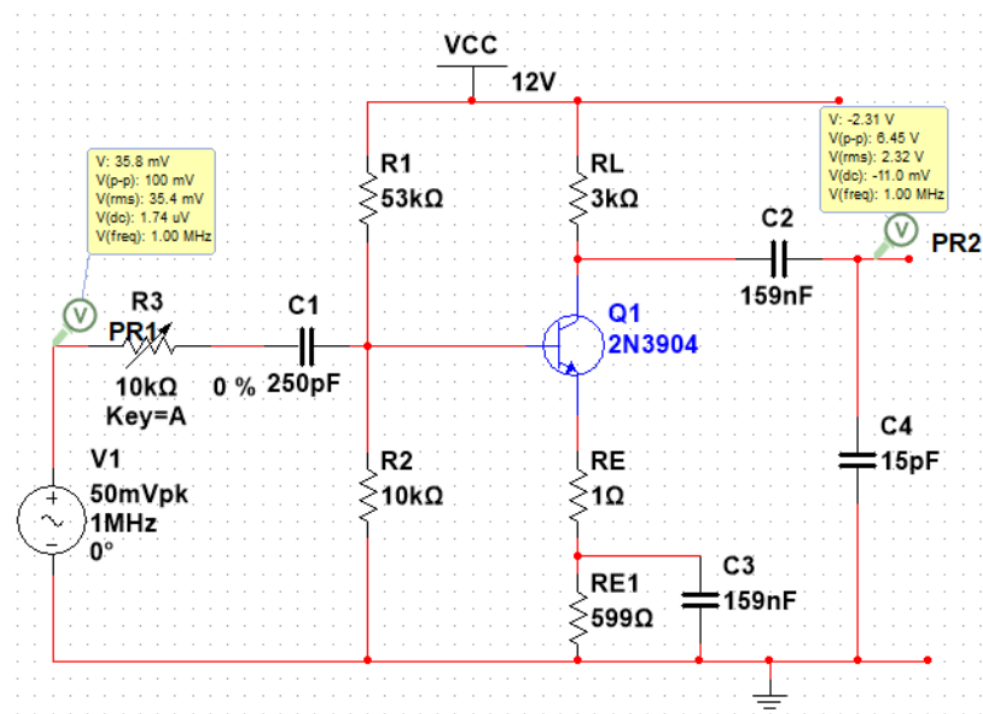


Figure 15

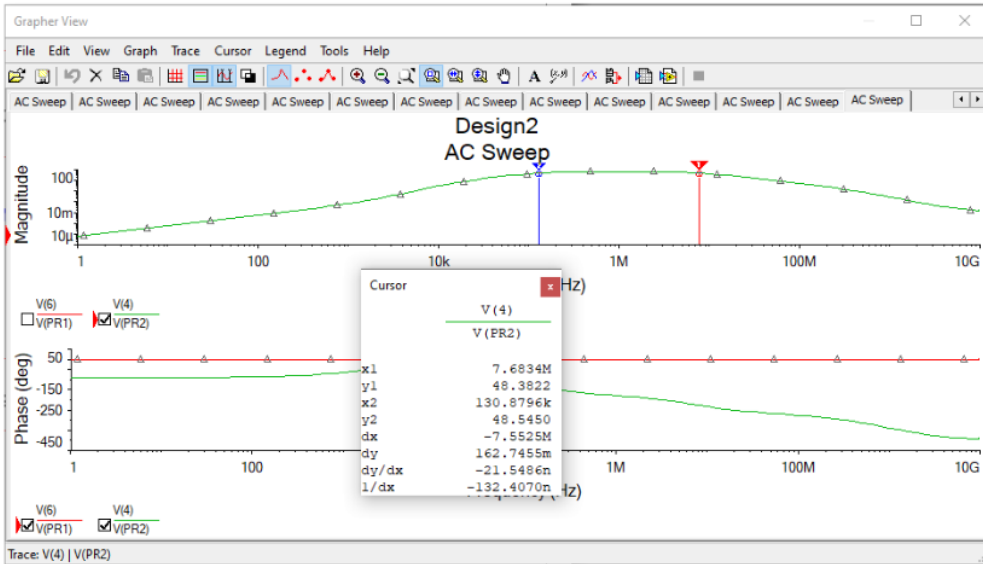


Figure 16

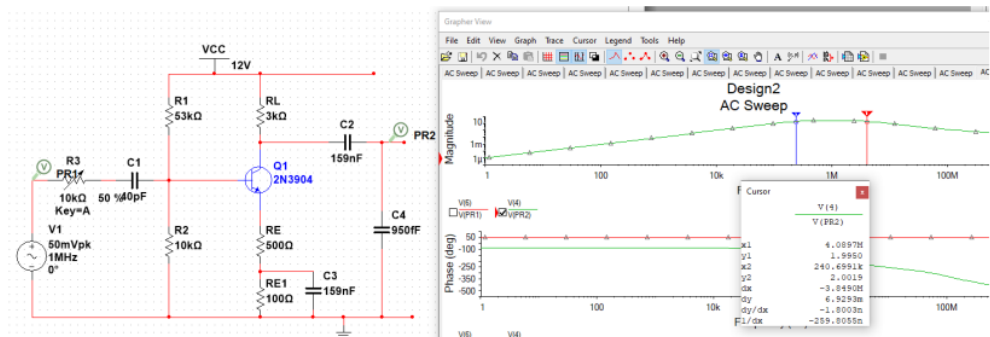


Figure 17

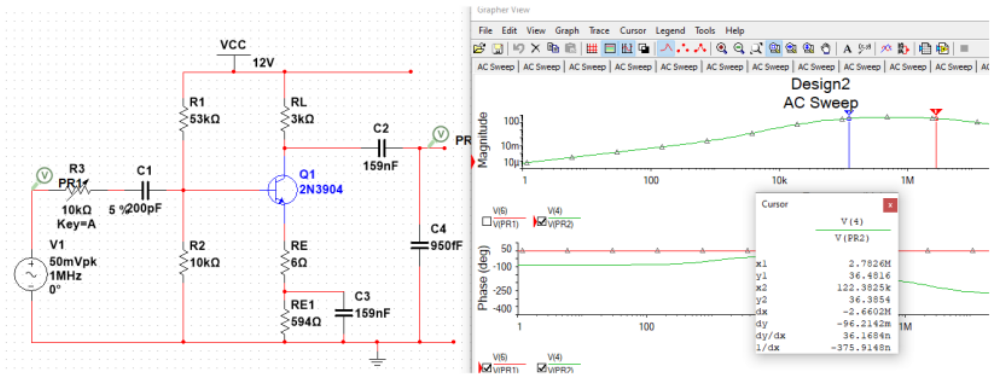


Table 1

	Default	T1	T2	T3	T4	T5
Variable Resistor Value (Ω)	5k	0	5K	500	400	500
C ₁ Value (F)	159n	250p	40p	200p	200p	80p
R _E Value (Ω)	300	1	500	6	6	6

R_{E1} Value (Ω)	300	599	100	594	594	594
C_4 Value (F)	159n	15p	950f	950f	950f	950f
Centre Frequency (Hz)	398	1M	1M	630K	630K	1M
Bandwidth (Hz)	779	7.55M	3.8M	2.7M	3.2M	4.9M
Gain	Negative	64.5	17.6	46.3	50.2	28.3

Appendix C - Oscillator Design

Figure 1

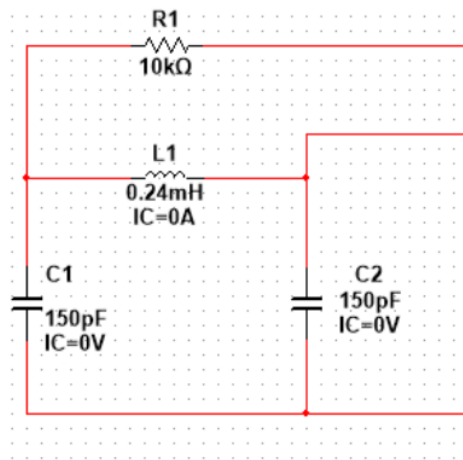


Figure 2

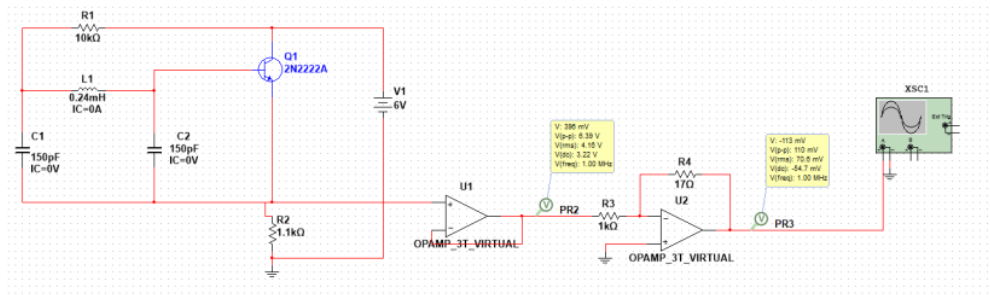
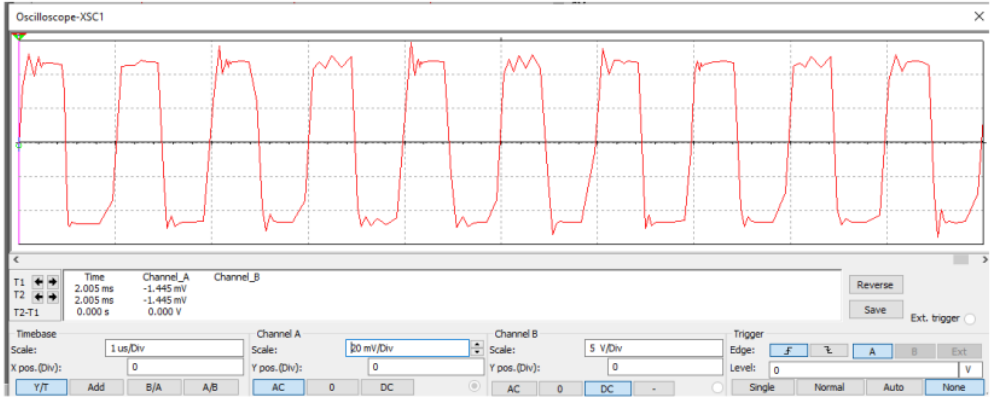


Figure 3



Appendix D - Final Design

Figure 1

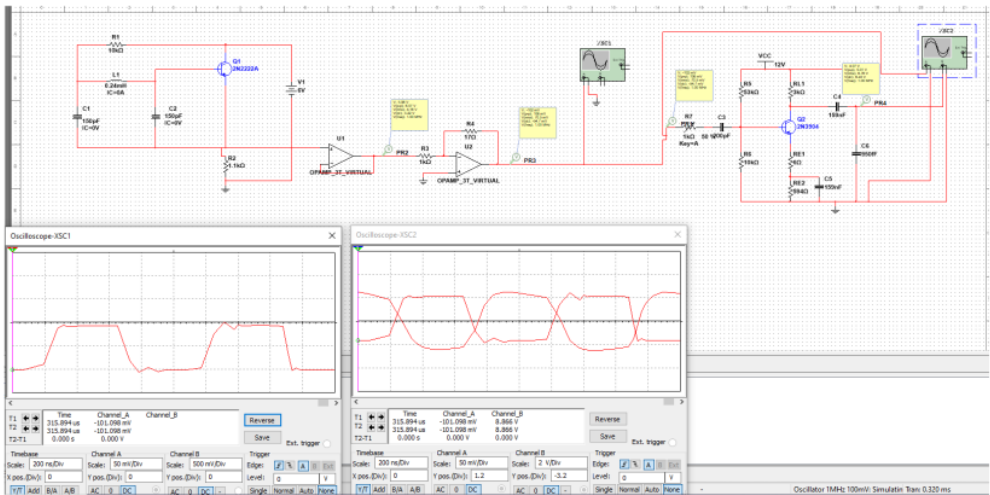


Figure 2

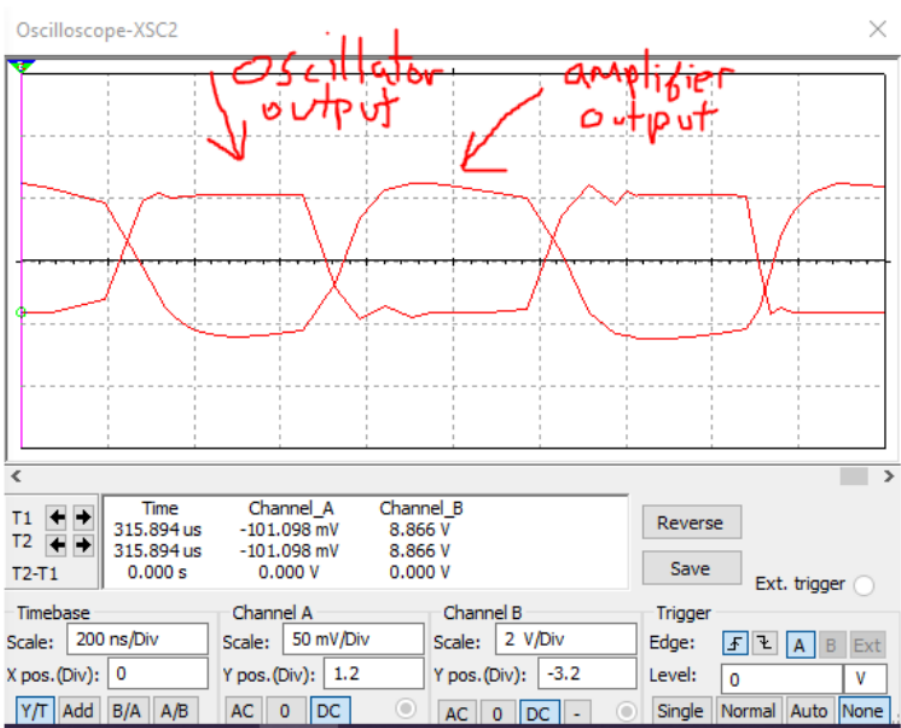


Figure 3

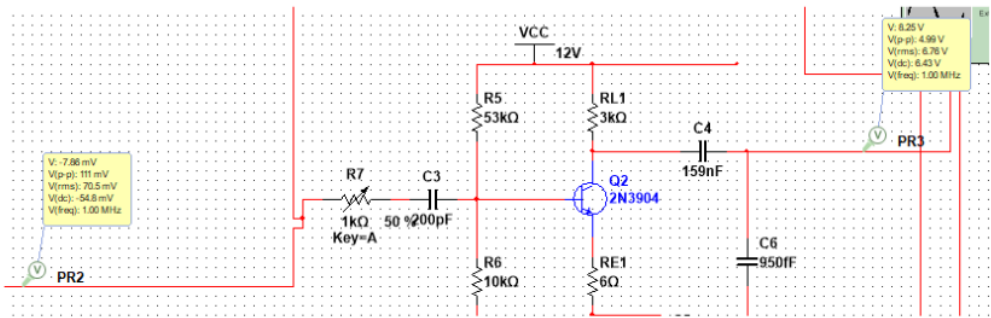


Figure 4

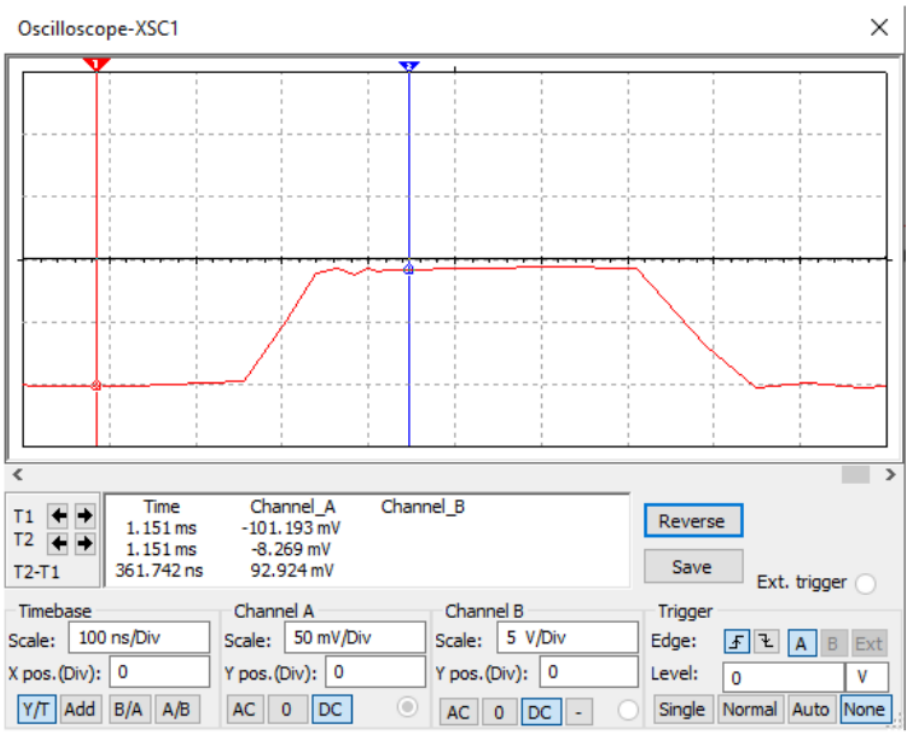


Figure 5

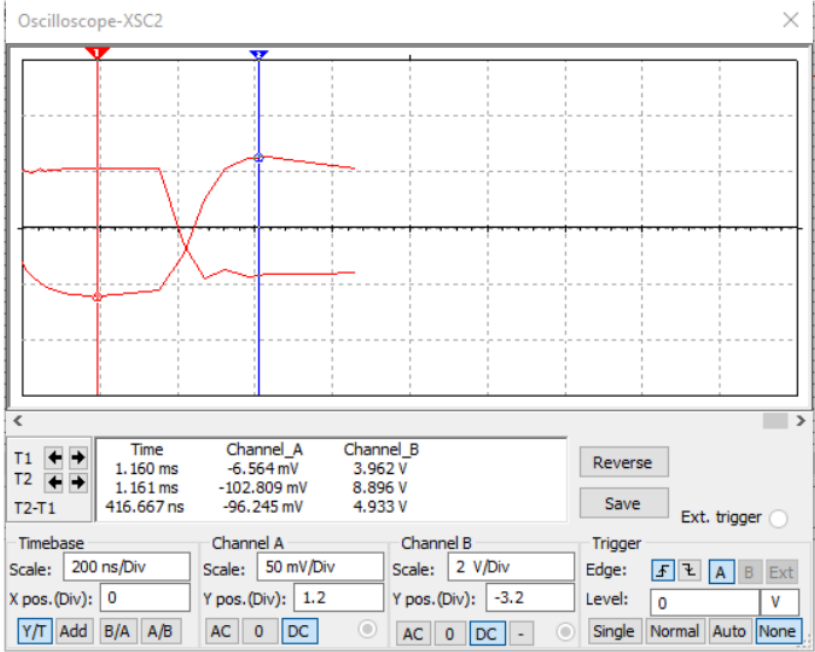


Table 1

	Oscillator Output	Amplifier Output
V	-7mV	8.25V
V _{p-p}	111mV	4.99V
V _{rms}	70.5mV	6.76V
F	1MHz	1MHz

FINAL GRADE

GENERAL COMMENTS

Instructor

70/100

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GRADING FORM: CSG-RUBIC

WILLIAM UTTING

0

RESEARCH-INFORMED LITERATURE



There was evidence of considerable further reading and research from highly credible and reliable sources. Your interpretation and understanding of the additional research was exceptional and demonstrated a deep underlying appreciation of the subject. Your references were consistently applied to a high level of competency and your reference list was extensive for this assignment.

18/20

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was reasonably extensive. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was demonstrated to a limited degree. You have demonstrated some critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes, however your explanations need to be more detailed and written with a greater emphasis on critical evaluation rather than description.

14/20

ANALYSIS



Your explanation of the design process was good and the conclusions showed that you can interpret quantitative and qualitative data, although this was

12/20

often descriptive. You could have evaluated the results and specified whether they concurred with theory suggesting reasons for any discrepancies. You have however demonstrated good analytical skills and your approach to the task was logical. Arguments made in the conclusions were mostly valid and demonstrated a good understanding of the topic. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory.

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally good. You used the resources available appropriately when designing the circuit and you used appropriate options for testing and evaluating the circuit performance. You managed to design an efficient circuit that functioned within the specification and achieved this by only asking for assistance when appropriate. Your results were comprehensive and allowed for a good conclusion to be attempted.

13/20

SKILLS FOR PROFESSIONAL PRAC.



Your written report was reasonably well presented in terms of content and layout and was mostly structured in a coherent way, however you should endeavour to use the available word count more effectively in future. You need to be much more selective with where you put diagrams and graphs, only put those essential for the explanation in the report, the rest can be referred to in the appendix.

13/20

