

PSDE 4004 Assignment 1

by Thomas Wood

FILE	15329_THOMAS_WOOD_PSDE_4004_ASSIGNMENT_1_152836_1100676 327.DOCX (2.02M)		
TIME SUBMITTED	16-DEC-2017 10:00AM (UTC+0000)	WORD COUNT	3386
SUBMISSION ID	80300683	CHARACTER COUNT	19902



HNC ELECTRICAL AND ELECTRONIC ENGINEERING

PSDE 4004 ELECTRONICS - ASSIGNMENT 1



DECEMBER 4, 2017

THOMAS WOOD
WORD COUNT:- 3030

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Introduction

Amplifiers and oscillators are utilised repeatedly within electronics due to their abilities to provide and control signals. Therefore, these electronics are readily available in abundance, and it is therefore important that the correct component is chosen for a particular application; as designing a circuit without the most suitable component is not desirable. In order to ensure the components chosen are suitable, a gauge for the key aspects of each component must be understood. In order to do this each form of oscillator and amplifier readily available will be researched and compared in order to provide the most influential and helpful information when deciding upon the most suitable component(s).

Research

Amplifiers have several different uses within electronic circuits, one common use of an amplifiers is to increase/decrease the voltage or current within a circuit. Another use for an amplifier is to match the impedance of a circuit, this is commonly known as impedance matching, Frenzel states 'impedance matching is most simply defined as the process of making one impedance look like another.' (2011).

Amplifiers are segregated into different classes; in all there are many different classes, for this task Class A, B and C are analysed;

- Class A

Class A amplifiers are the simplest form of amplifier, the wave form that is outputted from the amplifier conducts through a full 360°. This means that this amplifier must produce a larger output signal than that of the input signal as they are of the same waveform. Class A amplifiers are very desirable as they are the simplest amplifier to design, they have a high-frequency response as the active device is always on and therefore does not need time to be turned on. Class A amplifiers also have no distortion as the signal is only amplified and not changed. Although the Class A amplifier has many merits it also has its downfalls, these being; high cost due to large power supply, poor efficiency and also poor frequency response due to transformer coupling.

- Class B

Class B amplifiers utilise an assortment of two different transistors in order to operate, the transistors are constructed in such a way that when the input is conducting on its positive half cycle the positive transistor is turned on and the negative transistor is turned off. When the negative half cycle is produced the vice versa occurs and the negative transistor is turned on and the positive transistor is turned off. The two half waveforms are then combined together in order for the full waveform to be produced, as a result of this technique this amplifier has around 70% efficiency and is therefore more efficient than class A. However, Class B amplifiers has one main disadvantage which is the high distortion that occurs in the output signal (Anon., 2015), which can be unacceptable in certain applications such as audio applications. Class B amplifiers are not as expensive as class A amplifiers.

- Class C

Class C amplifiers are the most efficient, however they are non-linear, and this means that the output waveform doesn't have a full 360 degrees. This amplifier works by having a heavy bias that means that the transistor only conducts for around 90 degrees of the positive cycle. This signal can be converted back into a 360 degree waveform through the use of a 'LC resonant circuits in its collector circuit.' (2016). Class C amplifiers are often utilised in RF (radio frequency) circuits, this is due to its high efficiency and high frequency capabilities. Class C amplifiers are the relatively inexpensive compared to Class A amplifiers.

There are many types of harmonic/sinusoidal oscillators available, three of these type of oscillators are;

- Tuned circuit oscillators
- RC oscillators
- Crystal oscillators

Each of the different types of oscillators have their own particular benefits, in order to understand this research needs to be carried out into each oscillator type. Each of these oscillators produce an AC signal.

Tuned circuit oscillators

This particular form of oscillator uses a tuned circuit (Figure 1); this allows this particular oscillator to be utilised in high frequency applications. An example of one application for this oscillator is signal generators. Due to the feedback within this oscillator the stability of its oscillation is dependent upon the phase shift of the feedback, if the feedback is in-phase with the oscillations then the stability will be high.

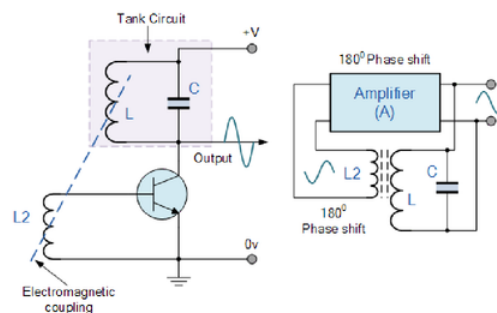


Figure 1 - Tuned oscillator circuit (Anon., 2016)

RC oscillators

This particular form of oscillator utilises an organisation of resistors and capacitors in order to produce regenerative feedback. There is three stages to the oscillation each of these stages have a 60° phase shift. Which in turn can be utilised in order to produce a complete 360° and therefore produce a waveform. RC oscillators were widely used within Morse code, due to its extremely low cost, however it is often found that the stability of oscillation within this oscillator are not very good.

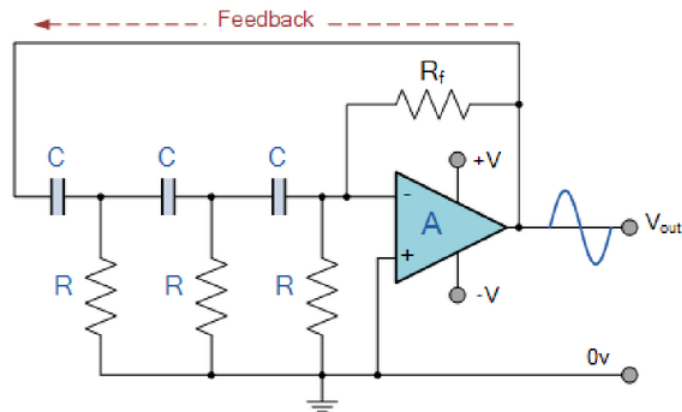


Figure 2 - RC oscillator circuit (Anon., 2016)

Crystal oscillators

This particular oscillator has a very high level of frequency stability, this is achieved by utilising the 'piezo-electric effect'. The piezo-electric effect produces mechanical vibrations that can be defined as oscillations. The crystal oscillator can also obtain very high frequency operation. An application of this oscillator is a TV, as such crystal oscillators are normally of low cost, and a high stability of oscillation.

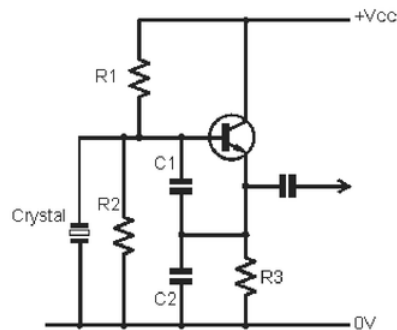


Figure 3 - Crystal oscillator circuit (Poole, n.d.)

Choice of active device:

In order to construct an amplifier certain components are desirable, however there are several different components that could be utilised. Each individual components has its merits and disadvantages. The components that could be utilised are:

- Bipolar transistor (BPT)

A BPT or bipolar transistor is a form of transistor; it has a large gain bandwidth and shows good performance at high frequencies. The transistor has a good voltage gain but subsequently a low voltage drop. The BPT can also be utilised within most power applications whether they be low power or high power. The only real disadvantages of a BPT is its low thermal stability and its low switching frequency.

- FET (Field effect transistor)

A FET or field effect transistor is another type of transistor. A FET has low power consumption and also has high input impedance. The FET is a majority charge carrier which therefore means it does not emit that much noise. The main disadvantages of a FET is its poor performance at higher frequencies due to internal capacitance of feedback and its low gain bandwidth.

- IC (Integrated Circuit)



Figure 4 - Integrated Circuit (Solarbotics, n.d.)

An IC or integrated circuit can be utilised to function in the same way as many different semi-conductors. An IC has very low power consumption and can be easily repaired, it is most suitable for small signal operations. However the IC can only handle a low amount of power and also does not have the capabilities of being utilised in a PNP assembly

Feedback can be useful within electronic circuits, when used properly feedback from electronic circuits can allow a specific control to be made of the output from the circuit. An example of a feedback system can be seen in Figure 5.

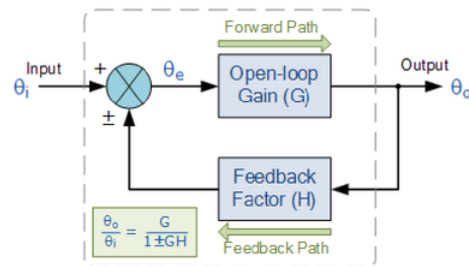


Figure 5 - Feedback on a simple electronic circuit

There are two main types of feedback, these types are positive and negative;

Positive feedback - positive feedback is utilised in order to give part of the output back to the input, this is done so that the output is increased, this in turn produces oscillations. The feedback itself is in phase with the input which then increases the output. A common use for positive feedback is within oscillators.

Negative feedback - negative feedback is utilised in order to stabilise the gain of an amplifier, this is achieved by taking part of the output and giving it back to the input in order to decrease the output, the same feedback is utilised a positive feedback however with negative feedback it is out of phase and therefore reduces the output. A common use for negative feedback is within most amplifiers.

Design method, choices and calculations

Designing of Amplifier

In order to design and produce the amplifier for this task, an understanding on how to design an amplifier was needed, after conducting research into this matter, a step-by-step guide for designing an amplifier was produced. Due to the simplicity of the A class amplifier it was decided that this type would be produced. The 'step to step' (Coates, 2007) guide can be seen below;

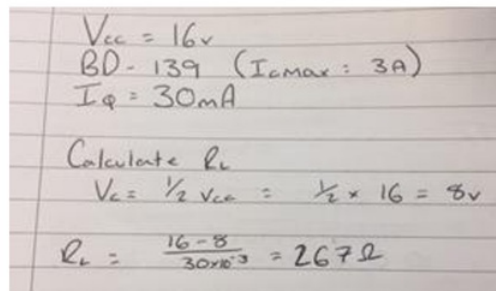
1. DC conditions
2. AC conditions
3. Applying the gain
4. Applying the bandwidth

Each one of these steps need to be carried out in order to produce the amplifier, to begin with the DC conditions needed to be met.

The DC conditions within the amplifier circuit are the four resistors (R_L , R_E , R_1 and R_2) in order to determine the values of the resistors, the following calculations are utilised;

In order to calculate R_L the following formula is utilised; $\frac{V_{CC}-V_C}{I_Q}$

An example of this formula being used can be seen within Figure 6;



Handwritten calculations on lined paper:

$$\begin{aligned} V_{CC} &= 16V \\ \text{BD-139 } (I_{Cmax} &= 3A) \\ I_Q &= 30mA \\ \text{Calculate } R_L \\ V_C &= \frac{1}{2} V_{CC} = \frac{1}{2} \times 16 = 8V \\ R_L &= \frac{16-8}{30 \times 10^{-3}} = 267\Omega \end{aligned}$$

Figure 6 - Calculations carried out in order to find value of R_L

In order to calculate R_E the formula utilised is; $R_E = \frac{V_E}{I_Q}$

In order to calculate R_1 the formula utilised is; $R_1 = \frac{V_{CC}-V_B}{I_{R1}}$

In order to calculate R_2 the formula that is used is; $R_2 = \frac{V_B-0}{I_{R1}}$

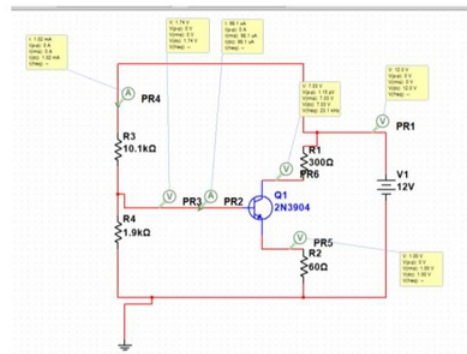


Figure 7 - Amplifier design DC components

There were also more steps within the guide, one of these steps was to decide upon a suitable transistor that could be utilised as the active device within the amplifier; In order to decide upon the transistor that would be the most suitable for the amplifier that was going to be created, requirements were needed. The first requirement for the transistor was that it had to be a NPN type transistor. This means that the transistor needs to be a bipolar type. This is crucial as the voltage within the amplifier circuit needs to be given to the collector leg of the transistor and then given out by the emitter leg of the transistor. The transistor must also be available within 'multisim' so that the circuit can be built and tested. The requirements for the transistor were;

- Supply voltage of 16v
- NPN transistor
- $I_{C_{max}}$ minimum of 300mA
- H_{FE} = minimum of 150

Ultimately after conducting some research into the various amplifiers available it was decided that the BD-139 transistor was suitable for this application.

The AC conditions within the amplifier circuit are the three capacitors, in order to determine the values of the capacitors calculations are undergone, C_1 , C_2 and C_3 are calculated in the same way. This calculation is as follows:

$$C = \frac{1}{2 \pi f X_c}$$

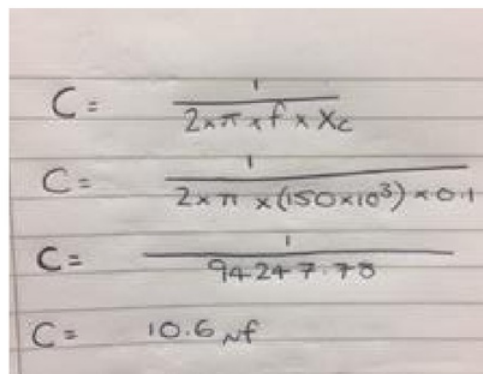
C = Capacitance

X_c = Capacitive reactance

f = Frequency

Figure 8 shows this formula being utilised in order to calculate the values of C_1 , C_2 and C_3 .

Figure 9 shows the amplifier design after adding the capacitors to the circuit, the waveform has also been taken from the circuit by utilising an oscilloscope.



The image shows handwritten calculations on lined paper. The first line is the formula $C = \frac{1}{2\pi f X_c}$. The second line shows the formula with values: $C = \frac{1}{2\pi \times (150 \times 10^3) \times 0.1}$. The third line shows the denominator calculated: $C = \frac{1}{94.247.78}$. The final line shows the result: $C = 10.6 \text{ nf}$.

Figure 8 - Capacitor calculations

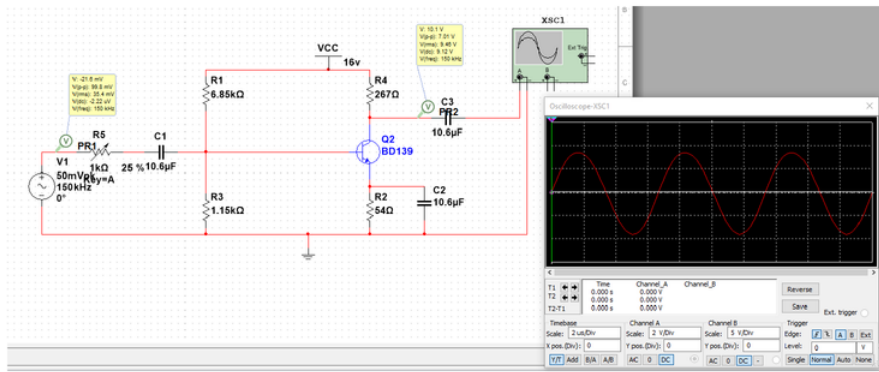


Figure 9 - Amplifier with AC and DC conditions

Designing of Oscillator

It was decided that a RC oscillator would be the type of oscillator produced, the RC oscillator works by utilising an assortment of resistors and capacitors in ladder like assortment. As a result of this assortment each 180° is produced utilising three stages of 60° phase shift.

Therefore in order to design the oscillator the values of the capacitors and resistors within the circuit are needed, in order to determine these an educated capacitor value is produced and then utilised within this calculation.

For this particular calculation the capacitor value that was chosen is 0.8nF;

$$R = \frac{1}{2 \times \pi \times \sqrt{6} \times (150 \times 10^3) \times (0.8 \times 10^{-9})} \quad R = \frac{1}{1.847}$$

Therefore, $R = 541.5 \, \Omega$

By utilising this formula the values of the resistors can be determined, it was found that slight adjustments to the values had to be made in order to achieve the desired output.

Ultimately through trial and error with the oscillator circuit and its RC values Figure 10 was produced, although the output V_{rms} was below the specified value it was deemed acceptable.

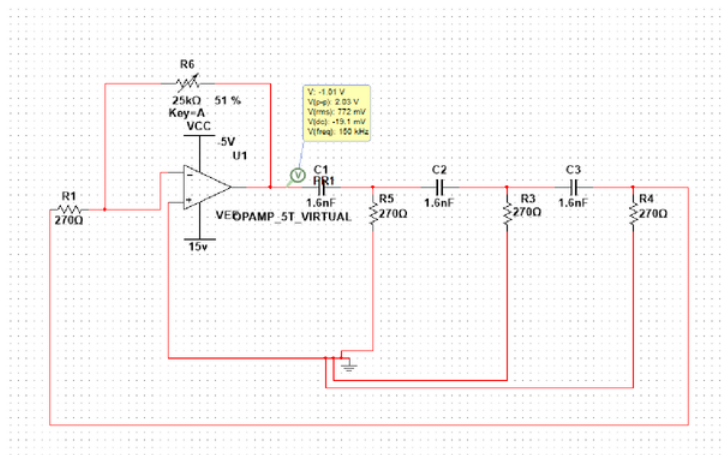


Figure 10 - Oscillator circuit

Having designed and built the oscillator circuit the last thing to do is analyse its oscillations by utilising the oscilloscope (Figure 11 and Figure 12).

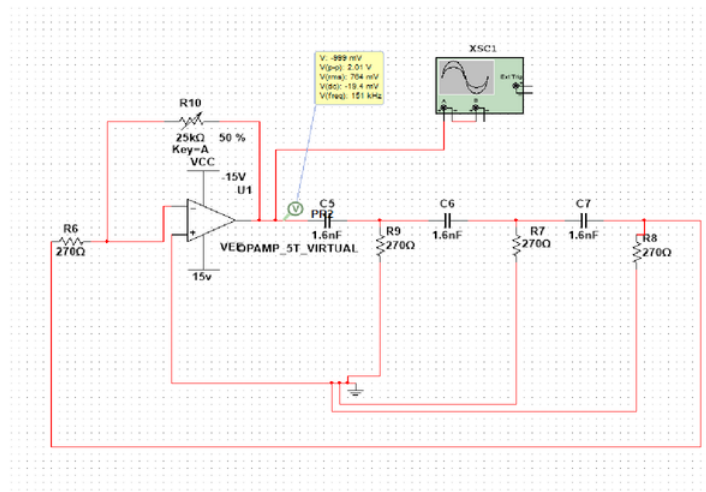
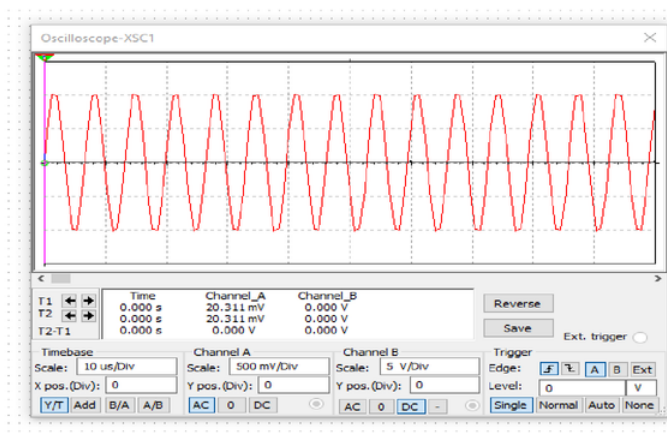


Figure 11 - Oscillator circuit with oscilloscope connected



Testing and improving design

Having built the amplifier the next step was to fine tune the amplifier and improve its design, in order to do this the first thing that was to be done was to ensure the gain of the amplifier was correct this is achieved by splitting the R_E resistor. The resistors value is 54Ω therefore in order to split it the two resistor values must add up to 54Ω . Therefore to begin with a combination was utilised. The first combination that was utilised was the use of two 27Ω resistors. By then testing the circuit a conclusion was able to be drawn up on what kind of values are needed for each resistor. By then utilising a trial and error method the values of 8Ω and 46Ω were found to give the required gain of 20.

Following achieving the appropriate gain the next step is to achieve the required bandwidth, in order to do this the value of C_1 needs to be modified and also C_4 needs to be added to the circuit. In order to determine the values of both capacitors the input and output impedance must be found; the output impedance of this amplifier is equal to R_L which is therefore 267Ω . However in order to determine the Input impedance a variable resistor is utilised, this resistor is utilised within the circuit in order to reduce the V_{out} , when the V_{out} is reduced to exactly half of what V_{out} originally was, the input impedance is equal to the value of the variable resistor. In this particular circuit the input impedance was 250Ω . The calculations to find the values of C_1 and C_4 are shown in Figure 13. Figure 14 shows the amplifier with the correct gain and the capacitor values that were calculated.

Handwritten calculations on lined paper:

$$Z_i = R_{\text{resistance when } V_{out} = \frac{1}{2} V_{out}}$$
$$Z_i = 250\Omega$$
$$Z_{out} = R_L = 267\Omega$$
$$C_1 = \frac{1}{2\pi \times (100 \times 10^3) \times 250}$$
$$C_1 = 5.99\mu F$$
$$C_4 = \frac{1}{2\pi \times (100 \times 10^3) \times 267}$$
$$C_4 = 3.14\mu F$$

Figure 13 - Capacitor calculations

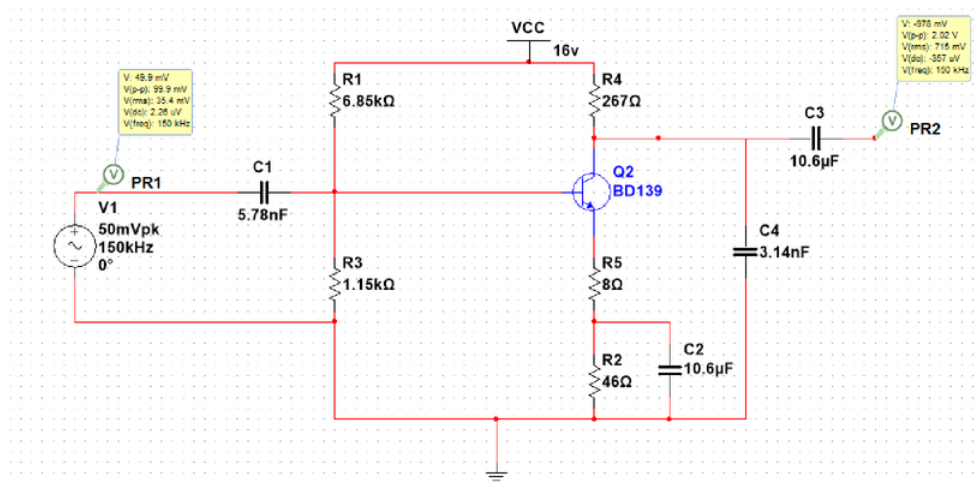


Figure 14 - Amplifier circuit with gain of 20 and C4

Having completed the amplifier the next step was to measure the bandwidth of the circuit in order to do this an AC sweep needed to be undergone of the circuit. By doing this the bandwidth of the circuit can then be analysed by utilising the high and low frequencies (Figure 16) and the centre frequency (Figure 15).

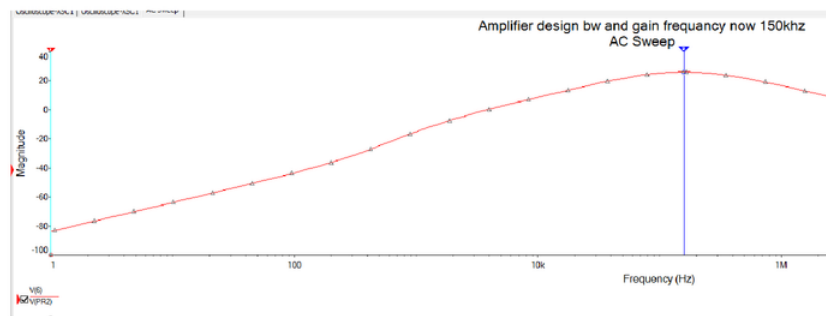


Figure 15 - Centre frequency of amplifier

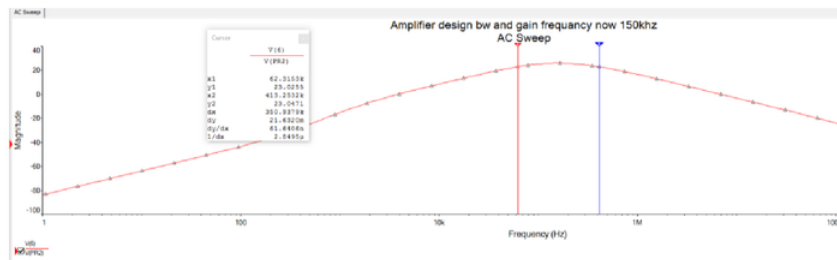


Figure 16 - Low and High frequency of amplifier

After producing both circuits the next thing to do is to combine the two circuits, in order to combine the circuits an op amp is needed (Figure 17), in order to reduce the output from the oscillator down to the desired input of 50mV into the amplifier circuit.



Figure 17 - Final assembly of oscillator and amplifier circuit

Having completed the final assembly of the circuits it is important that tests are carried out in order to determine whether the final assembly functions correctly, the first collaboration of the circuit was working partly however although there was a 50mV input to the amplifier the output from the amplifier was not amplified. This can be seen in Figure 19 within the annexe.

Having looked at the circuit the first thing that was noticed was that the VCC of the amplifier had been automatically changed to -15v because that is what was stated within the oscillator circuit, this value was therefore changed to the desired supply voltage of 16v. After doing this the gain was still not the desired gain of 20, therefore it was decided that the R_L resistor be split again in order to achieve the desired gain.

After splitting the resistor for the correct gain it was found that the centre frequency was incorrect therefore in order to rectify that the capacitor values of C1 and C4 were lowered,

this therefore gave the circuit a centre frequency of 158kHz (Figure 18). The final circuit can be found within the annexe (Figure 20).

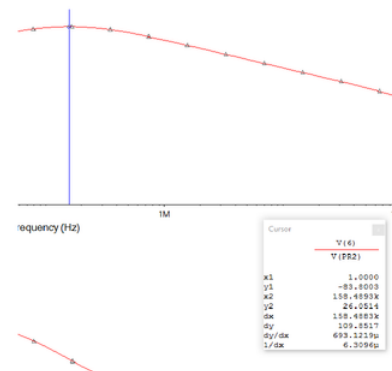


Figure 18 - Centre frequency of final circuit

Conclusion

Amplifiers have many different characteristics and it is important that these characteristics are understood before designing a circuit. An amplifier not perfectly tuned or suited to a certain circuit can cause re-occurring problems and can therefore lead to circuit damage. Therefore, it is important that a good knowledge is built on the different classes of amplifier and their each individual characteristics, by understanding the amplifiers capabilities a more prominent and advantageous circuit can be designed and built with utter confidence on the end circuit/product.

Similarly to amplifiers the correct oscillator design should be chosen for a particular application. If an oscillator is not chosen correctly then it can lead to distortion at certain frequencies and ultimately makes the oscillator invalid. This can therefore cause more problems within a circuit and in due course lead to invalid signals being analysed or circuit failure. It is therefore important to choose the correct components before having to rectify a problem.

Knowing how to manipulate a circuit can benefit heavily in circuit design. This is evident when introducing feedback within a signal circuit. Feedback itself can allow control over all aspects of a circuit whether it be the input signal or the output signal. The efficiency of a circuit can also be improved through the use of feedback, this evident as 'the gain is stabilised, the distortion of a circuit is reduced and also there is a reduction in the noise of the circuit' (Anon., 2016) therefore improving the signal.

It is also evident that when designing a circuit it is extremely important that extensive testing is carried out; this should be important as without extensive testing a circuit is definitely not built in the perfect manner. By testing a circuit it can allow a circuit to be slightly altered until the circuit cannot become any more efficient or reliable. However with ever-growing technology circuits will only become more efficient and more reliable.

Reference list

Works Cited

Anon., 2015. *UKessays*. [Online]

Available at: <https://www.ukessays.com/essays/engineering/a-power-amplifier.php>

[Accessed 6 December 2017].

Anon., 2016. *ElectronicsTutorial*. [Online]

Available at:

<http://webcache.googleusercontent.com/search?q=cache:th3OZxiQsXYJ:www.electronics-tutorials.ws/amplifier/amplifier-classes.html+&cd=13&hl=en&ct=clnk&gl=uk>

[Accessed 7 December 2017].

Coates, E., 2007. *Learnabout-electronics*. [Online]

Available at: www.learnabout-electronics.org

[Accessed 11 December 2017].

Frenzel, L., 2011. *Electronic Design*. [Online]

Available at: <http://www.electronicdesign.com/communications/back-basics-impedance-matching-part-1>

[Accessed 4 December 2017].

Poole, I., n.d. *Radio-Electronics*. [Online]

Available at: [http://www.radio-](http://www.radio-electronics.com/info/circuits/transistor_crystal_oscillator/crystal_oscillator.php)

[electronics.com/info/circuits/transistor_crystal_oscillator/crystal_oscillator.php](http://www.radio-electronics.com/info/circuits/transistor_crystal_oscillator/crystal_oscillator.php)

[Accessed 10 December 2017].

Solarbotics, n.d. *Solarbotics*. [Online]

Available at: <https://solarbotics.com/product/74hc595/>

[Accessed 7 December 2017].

STMicroelectronics, 2008. *STMicroelectronics*. [Online]

Available at: <http://docs-europe.electrocomponents.com/webdocs/135f/0900766b8135f82f.pdf>

[Accessed 13 December 2017].

Annexe

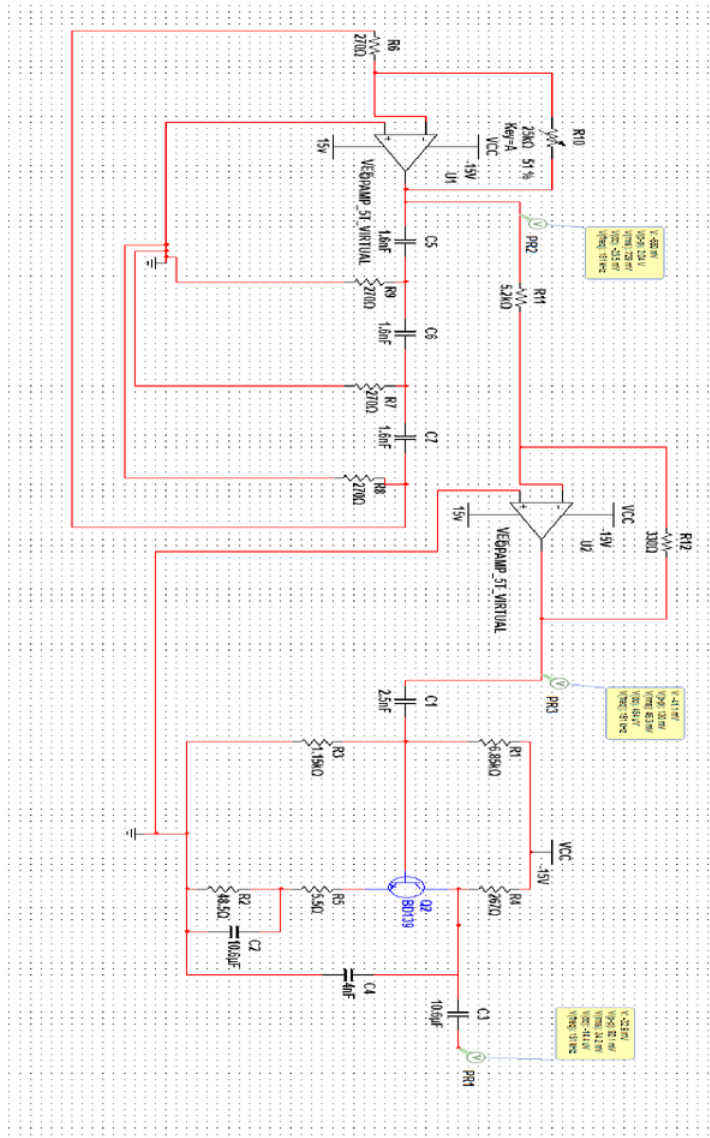


Figure 19 - Combined circuit without amplification

Figure 20 - Final circuit

1 Electrical ratings

Table 2. Absolute maximum ratings

Symbol	Parameter	Value				Unit
		NPN		PNP		
		BD135	BD139	BD136	BD140	
V_{CB0}	Collector-base voltage ($I_E = 0$)	45	80	-45	-80	V
V_{CE0}	Collector-emitter voltage ($I_B = 0$)	45	80	-45	-80	V
V_{EB0}	Emitter-base voltage ($I_C = 0$)	5		-5		V
I_C	Collector current	1.5		-1.5		A
I_{CM}	Collector peak current	3		-3		A
I_B	Base current	0.5		-0.5		A
P_{TOT}	Total dissipation at $T_J \leq 25^\circ\text{C}$	12.5				W
P_{TOT}	Total dissipation at $T_{AMB} \leq 25^\circ\text{C}$	1.25				W
T_{stg}	Storage temperature	-65 to 150				$^\circ\text{C}$
T_J	Max. operating junction temperature	150				$^\circ\text{C}$

Table 3. Thermal data

Symbol	Parameter	Max. value	Unit
$R_{\theta JA}$	Thermal resistance junction-case	10	$^\circ\text{C/W}$
$R_{\theta JA}$	Thermal resistance junction-ambient	100	$^\circ\text{C/W}$

Figure 21 - Data Sheet 1 for BD-139 (STMicroelectronics, 2008)

2 Electrical characteristics

(T_{case} = 25 $^\circ\text{C}$ unless otherwise specified)

Table 4. On/off states

Symbol	Parameter	Polarity	Test conditions	Value			Unit
				Min.	Typ.	Max.	
I_{CBO}	Collector cut-off current ($I_E = 0$)	NPN	$V_{CB} = 30\text{ V}$ $V_{CB} = 30\text{ V}, T_C = 125^\circ\text{C}$		0.1	10	μA
		PNP	$V_{CB} = -30\text{ V}$ $V_{CB} = -30\text{ V}, T_C = 125^\circ\text{C}$		-0.1	-10	μA
I_{EBO}	Emitter cut-off current ($I_C = 0$)	NPN	$V_{EB} = 5\text{ V}$			10	μA
		PNP	$V_{EB} = -5\text{ V}$			-10	μA
$V_{CE(sat)}^{(1)}$	Collector-emitter sustaining voltage ($I_B = 0$)	NPN	$I_C = 30\text{ mA}$				V
			BD135	45			V
			BD139	80			V
		PNP	$I_C = -30\text{ mA}$		-45		V
$V_{CE(sat)}^{(1)}$	Collector-emitter saturation voltage	NPN	$I_C = 0.5\text{ A}, I_B = 0.05\text{ A}$			0.5	V
			BD135				V
			BD139				V
		PNP	$I_C = -0.5\text{ A}, I_B = -0.05\text{ A}$			-0.5	V
$V_{BE}^{(1)}$	Base-emitter voltage	NPN	$I_C = 0.5\text{ A}, V_{CE} = 2\text{ V}$			1	V
			BD135				V
			BD139				V
		PNP	$I_C = -0.5\text{ A}, V_{CE} = -2\text{ V}$			-1	V
$h_{FE}^{(1)}$	DC current gain	NPN	$I_C = 5\text{ mA}, V_{CE} = 2\text{ V}$	25		250	
			$I_C = 150\text{ mA}, V_{CE} = 2\text{ V}$	40			
			$I_C = 0.5\text{ A}, V_{CE} = 2\text{ V}$	25			
		PNP	$I_C = -5\text{ mA}, V_{CE} = -2\text{ V}$	25		250	
			$I_C = -150\text{ mA}, V_{CE} = -2\text{ V}$	40			
			$I_C = -0.5\text{ A}, V_{CE} = -2\text{ V}$	25			
$h_{FE}^{(1)}$	h_{FE} groups	NPN	$I_C = 150\text{ mA}, V_{CE} = 2\text{ V}$	63	160	250	
			BD135-10				
			BD135-16/BD139-16	100			
		PNP	$I_C = -150\text{ mA}, V_{CE} = -2\text{ V}$	63	160	250	
			BD140-10				
			BD136-16/BD140-16	100			

1. Pulsed; pulse duration = 300 μs , duty cycle 1.5%

Figure 22 - Data Sheet 2 for BD-139 (STMicroelectronics, 2008)

PSDE 4004 Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

72/100

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GRADING FORM: CSG-RUBIC

THOMAS WOOD**72****RESEARCH-INFORMED LITERATURE**

There was evidence of extensive further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was very good and demonstrated a deep underlying appreciation of the subject. Your references were appropriate to the task and your reference list was of an appropriate length for this assignment. You should however include more in-text citations.

7**KNOWLEDGE AND UNDERSTANDING**

The knowledge and understanding of the subject demonstrated by this assignment was generally very good. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was very good. Your research and explanation was particularly good and extended your knowledge well beyond that contained in the course notes.

22

ANALYSIS

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- Your analysis of the task was generally satisfactory, both in class and as shown in this assignment. You have demonstrated some analytical skills and your approach to the task was logical. You carried out a short analysis and a short conclusion. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory.

15

PRACTICAL APPLICATION AND DEP.

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- Your explanation of the design process was good, however the conclusions lacked some detail. You could have evaluated the use of the various components, specified whether the solution met the specification and suggested ways to improve the solution. You have however demonstrated good analytical skills and your approach to the task was logical.

22

SKILLS FOR PROFESSIONAL PRAC.

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- Your written report was generally good and contained most of the required detail, although it lacked the depth of explanation required. Avoid the use of photographs of hand-written notes.

6