ISSN: 2985-4393

Development of Colpitts-Hartley Oscillator Training Kit

Nor Aizam Muhamed Yusof [1,a)]

[1]*Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim, Kedah, Malaysia*

[a)] *Corresponding author: aizam@ptsb.edu.my*

Abstract. Oscillator circuits play a vital role in communication systems, particularly in generating high-frequency signals for various electronic applications. This project focuses on the design and development of a Colpitts-Hartley Oscillator as an educational training kit to support effective teaching and learning of oscillator principles. The integration of both Colpitts and Hartley configurations allows students to explore the behaviour of sinusoidal oscillations generated by the LC tank circuit in a structured and guided manner. However, students frequently encounter challenges when assembling Colpitts-Hartley oscillators manually in laboratory sessions due to the complexity of the circuitry. These difficulties often result in inaccurate connections, inconsistent measurements, and unreliable experimental outcomes, limiting students' practical understanding of oscillator operation. To address this problem, this research was to design and test a dedicated Colpitts-Hartley oscillator training kit that simplifies circuit implementation while maintaining experimental accuracy. The results demonstrated that the kit successfully produced sinusoidal oscillations with frequencies aligning closely with theoretical, calculations and simulations, proving its reliability for hands-on learning. In conclusion, the Colpitts-Hartley oscillator training kit enhances students' ability to understand and experiment with oscillator circuits effectively, offering a practical solution to overcome challenges faced in traditional laboratory practices.

Keywords: Colpitts-Hartley oscillator; communication system; electronic application; high frequency signals

1. INTRODUCTION

One of the main topics addressed in classes on electronic circuits is the oscillator. Students study signal generation and its uses, including the use of LC and RC oscillators. But as of right now, there aren't many interactive teaching and learning resources that are especially geared towards LC oscillators, primarily the Colpitts and Hartley varieties, especially those that use operational amplifiers [1]. A hybrid form of LC oscillator, the Colpitts-Hartley oscillator creates a steady and continuous sinusoidal waveform by fusing components of the Hartley and Colpitts designs. In this setup, the Colpitts section uses a voltage divider composed of two capacitors to offer capacitive feedback, while the Hartley section contributes an inductive feedback network utilizing two inductors or a tapped inductor. The combination creates a balanced and effective feedback loop, allowing the oscillator to maintain consistent oscillation at a desired resonant frequency. This oscillator is especially suitable for high-frequency applications such as RF signal generation due to its simplicity and frequency stability [2][3].

In operation, the transistor or operational amplifier in the circuit amplifies the signal, and the feedback network ensures that a portion of the output is returned to the input in phase. This positive feedback is critical for sustaining oscillations [4]. The oscillation frequency is determined by the values of the inductors and capacitors used in the LC tank circuit, calculated by the formula: $f = 1 / (2\pi * \sqrt{(L * C)})$ where 'L' represents the inductance in Henrys, 'C' represents the capacitance in Farads, and 'f' is the resonant frequency in Hertz [5].

The Colpitts-Hartley oscillator is commonly used in educational training kits, communication systems, and signal generator circuits, making it a valuable learning tool for students and a practical component in electronic design [6][7]. The development of this study centers on creating a simple, user-friendly, and safe Hartley-Colpitts oscillator training kit, designed to serve as a practical teaching aid and reference tool for lecturers during the teaching and learning process. By offering an accessible and cost-effective solution, this training kit aims to strengthen students' understanding of high-frequency oscillator circuits within the field of electrical and electronic engineering [8][9].

Nima and Omar [4] was developed a tool kit with an oscillator circuit. The proposed design is developed through a three-phase approach. Firstly, a theoretical analysis is conducted based on fundamental oscillator principles, including the application of oscillation conditions to determine appropriate values for the capacitor (C) and inductor (L) components. Secondly, the circuit is simulated using LTSpice IV software to verify its performance. Finally, the validated design is implemented in a practical setup using the IC OP-AMP 741, along with passive components such as resistors, capacitors, and inductors. The output is then observed and analyzed using an oscilloscope and a frequency generator.

Furthermore, according to Fuada and Syifaul [5] discussed the design and implementation of a virtual lab featuring analog oscillators, covering four practical digital oscillator topics, the Wien Bridge oscillator, Colpitts oscillator, Hartley oscillator, and Astable Multivibrator. This interactive media allows users to modify resistor, inductor, and capacitor components, enabling a plug-and-play approach from the RLC configuration to a physical toolkit or trainer kit. The resulting output signals can be observed and analyzed using measuring instruments such as a frequency counter and oscilloscope.

In addition, Bui Thu Cao [1] introduced an improved analytical approach aimed at enhancing the accuracy of oscillation frequency calculations in the high-frequency domain. The study proposed incorporating parasitic capacitors into the design process to refine the analysis method. Results demonstrated that this approach yields oscillator frequencies that are more accurate and stable compared to other existing methods, particularly in high-frequency applications.

This project specifically addresses the challenges faced in polytechnic laboratories, where students often struggle with assembling Colpitts and Hartley oscillator circuits due to their complexity. Unlike previous studies that mainly focused on theoretical explanations or separate circuit setups, this project demonstrates a more effective approach by integrating both Colpitts and Hartley oscillators into a single, compact training kit. The structured design not only simplifies circuit assembly but also enhances safety, accuracy, and hands-on learning. With its support for multiple frequency ranges, accessible waveform outputs, and dedicated testing points for real-time analysis, the project offers a practical and comprehensive solution that directly addresses the limitations faced in polytechnic laboratories. [10][11].

The main purpose of this study is to develop a Colpitts-Hartley Oscillator as a practical educational tool for teaching and learning. Section 2 explains in detail the methodology used in this study. The practical experiment and simulation results will be presented in Section 3. Finally, Section 4 concludes the finding of study.

2. Research Methodology

This section provides a detailed explanation of the proposed methodological framework on how to design, fabricate and testing the Colpitts and Hartley oscillator tool kits based on IC OP-AMP 741 for learning material of circuit electronics course in Electrical Engineering Department, Politeknik Tuanku Sultanah Bahiyah.

2.1. The schematic circuit design of Colpitts-Hartley

The development of the Colpitts-Hartley oscillator training kit involves several key stages, as illustrated in the block diagram of the study methodology shown in Figure 1. Each oscillator section is designed to demonstrate signal generation using inductor-capacitor (LC) feedback networks, enabling students to observe frequency variation based on component values. The actual oscillation frequency corresponds to the resonant frequency of the LC tank circuit, calculated using the formula:

$$\frac{1}{2\pi\sqrt{LC}} \tag{1}$$

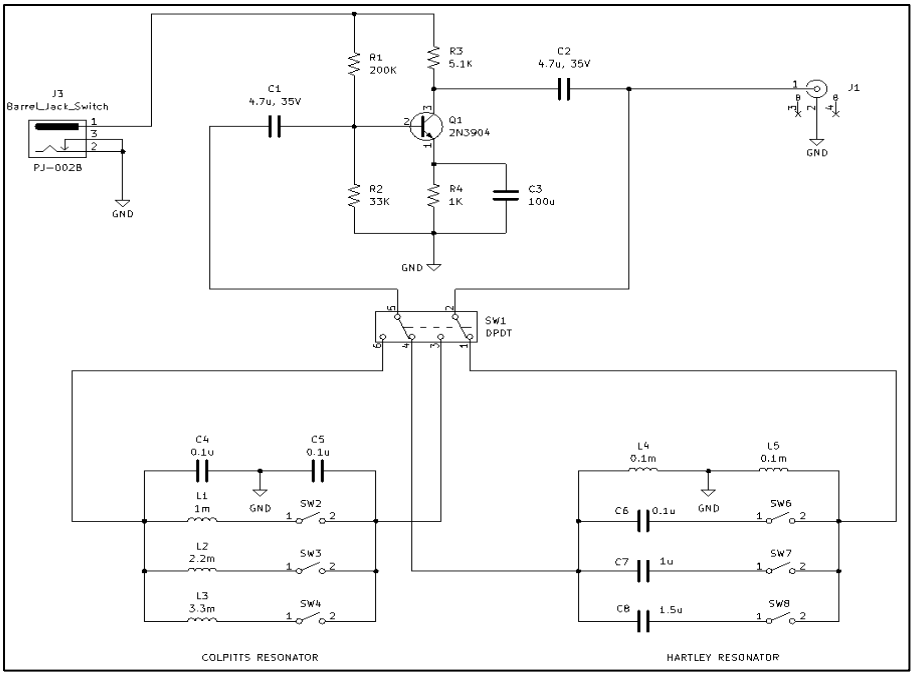

Figure 1. PCB Pattern Layout of Colpitts-Hartley Oscillator

Figure 1 shows The Colpitts-Hartley circuit generates smooth sinusoidal waveforms by utilizing positive feedback within an LC (inductor-capacitor) resonant network. In a Hartley oscillator, feedback is provided through either a tapped inductor or a pair of series-connected inductors (tank-circuit). Conversely, the Colpitts oscillator derives its feedback from a capacitive voltage divider. Both configurations employ a transistor or operational amplifier to amplify the signal, ensuring continuous and stable oscillations.

2.2 Electronic Components Essential for Circuit Functionality and Performance

This training kit is designed through a structured selection of suitable RLC component values and the calculation of the anticipated output frequency based on established formulas. The components utilized are thoughtfully categorized into active, passive, and testing elements.

a. Active Components

Bipolar Junction Transistors (BJTs) such as the BC547 and 2N2222 are used as the core amplification stage in both the Colpitts-Hartley oscillators, providing the necessary gain to sustain oscillations by compensating for energy losses in the LC network. Additionally, operational amplifiers (Op-Amps) like the LM741 are incorporated as alternative components to demonstrate different oscillator configurations, offering signal amplification, buffering, and improved waveform stability. These active components play a crucial role in maintaining consistent and reliable oscillator performance within the training kit.

b. Passive Components

Inductors with values of 1mH, 1.32mH, and 2mH are essential components in the Colpitts oscillator circuit, functioning primarily to provide feedback and determine the oscillation frequency. When combined with capacitors in the LC tank circuit, these inductors form a resonant circuit that defines the output frequency based on the values of both inductance and capacitance. By selecting different inductor values, users can observe how the frequency of oscillation changes, making them vital for hands-on experimentation and understanding frequency control in oscillator design.

Capacitors with values of 0.01µF, 0.047µF, and 0.1µF are used in the Colpitts-Hartley circuit to facilitate feedback and tune the oscillation frequency. By adjusting or selecting different capacitor values, the resonant frequency of the circuit can be varied, allowing students to explore how component selection influences oscillator behaviour. This makes capacitors a key element in understanding and experimenting with frequency control in Hartley oscillator configurations.

Resistors ranging from 1kΩ to 100kΩ are fundamental components in the Colpitts-Hartley oscillator circuit, serving multiple essential functions including biasing, stabilization, and load balancing. In transistor-based oscillator circuits, fixed resistors are used to set the correct biasing conditions for the active device such as a BJT or op-amp, ensuring that it operates in the appropriate region of its characteristic curve for amplification.

c. Measurement and Testing Components

The oscilloscope is one of the most important diagnostic instruments used in conjunction with the Colpitts–Hartley oscillator training kit. Its primary function is to visualize and analyze electrical waveforms in real time, allowing users to better understand how the oscillator operates.By connecting oscilloscope probes to different test points in the circuit such as the LC tank circuit or the amplifier stage, students can directly observe the behaviour of signals across each component. This provides insight into how the frequency, amplitude, and waveform shape are influenced by the chosen component values and circuit configuration.

2.3 Printed Circuit Board Design

The printed circuit board (PCB) is a critical element in the development of the oscillator training kit, as it provides the physical platform for assembling and interconnecting all electronic components. This training kit integrates both the Hartley and Colpitts oscillator designs, utilizing a tapped inductor (Hartley configuration) and a capacitive voltage divider (Colpitts configuration) to establish the desired oscillation frequency. When designing the PCB layout, several key considerations must be followed to ensure reliable performance and frequency stability:

a. Components Placement

Inductors, capacitors, and active devices (such as transistors or operational amplifiers) should be positioned with short and direct connections. This minimizes parasitic inductance and capacitance, which can otherwise introduce interference or cause frequency drift.

b. Grounding Strategy

Implementing a solid ground plane is essential to reduce noise, improve signal integrity, and maintain circuit stability. A well-designed ground system ensures that high-frequency signals remain clean and free from distortion.

c. Thermal and Mechanical Stability:

Proper spacing and secure mounting of components ensure that the oscillator operates consistently under different environmental conditions without physical or thermal stress affecting performance.

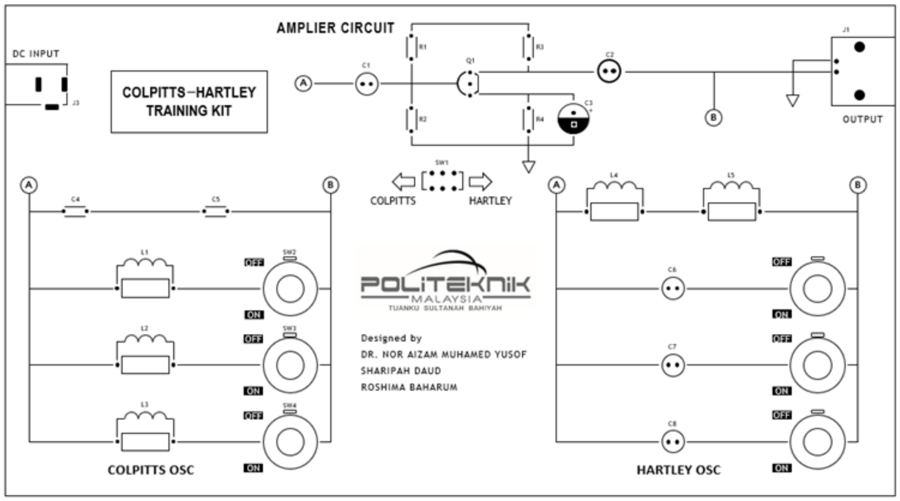

Figure 2. The Top View of Colpitts-Hartley Oscillator Printed Circuit Board

When laying out the PCB, it is best to keep signal paths short especially around the tank circuit since longer traces can cause performance issues. Adding decoupling capacitors near the power pins of the active component helps filter out power supply (12V) noise. Using high-quality inductors and capacitors will also go a long way in keeping the oscillator stable. Before sending the design off for manufacturing, running a simulation can help catch any issues. And for added flexibility, including adjustable components like variable capacitors or tunable inductors can make it easier to fine-tune the oscillator once the board is built as shown in Figure 2.

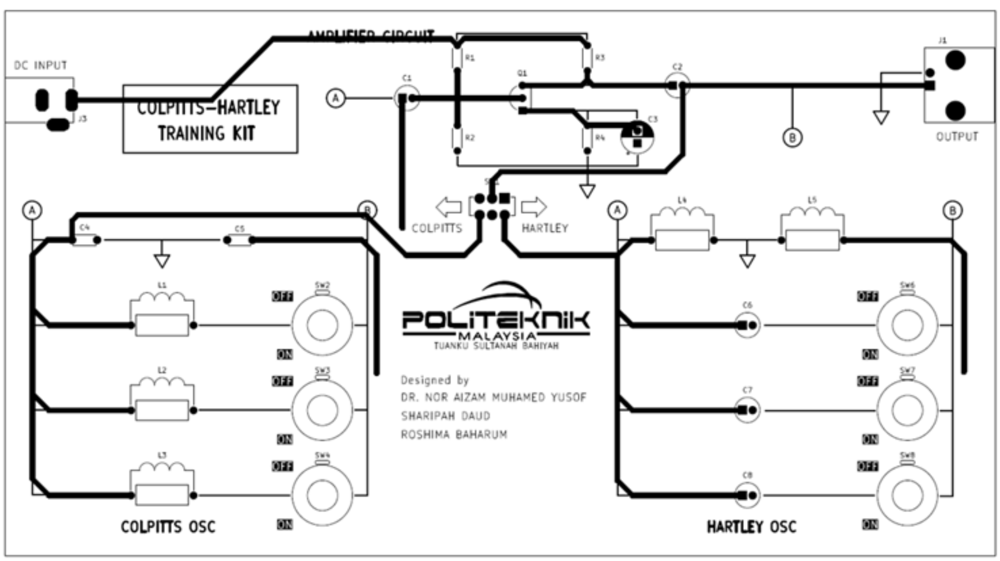

Figure 3. PCB Pattern Layout of Colpitts-Hartley Oscillator

Figure 3 shows the PCB drawing for Colpitts-Hartley Oscillator training kit includes a compact and well-organized layout designed for educational purposes. When designing the PCB for a Colpitts-Hartley Oscillator, the focus is on placing and connecting a few key components that make the circuit work reliably. The main part of the oscillator is the tank circuit, which sets the frequency. Th includes a tapped inductor from the Hartley side and two capacitors in series from the Colpitts side. Depending on your design, the tapped inductor can either be a single coil with a center tap or two smaller inductors connected in a row.

Figure 4. Prototype of Colpitts-Hartley Training Kit

Figure 4 shows the PCB layout has been completed. The next step is to validate the design to ensure it is error-free and ready for manufacturing. In the first stage, the Design Rule Check is performed to ensure that the PCB layout complies with the fabrication constraints, such as minimum trace widths, spacing between components, and the correct placement of pads. This step helps identify any layout violations that could lead to manufacturing defects or operational failures. The second stage, Electrical Rule Check, verifies the integrity of the electrical connections and the correctness of the circuit topology. This involves checking for issues such as unconnected nets, short circuits, and incorrect or missing connections between components. By rigorously conducting these validation steps, potential problems are addressed early, ensuring the PCB design is robust, reliable, and ready for a successful transition to the manufacturing phase. This validation process typically involves two main stages:

a. Simulations

Circuit simulations are carried out to verify that the designed layout performs as expected. These simulations allow the designer to check signal flow, frequency response, and overall circuit behavior before physical fabrication, reducing the risk of costly mistakes.

b. Design Rule Checks (DRC)

A DRC is performed using PCB design software to automatically detect layout issues such as trace spacing violations, incorrect pad sizes, or overlapping components. This step ensures that the design adheres to industry manufacturing standards and avoids fabrication errors.

After successful validation, the finalized PCB layout is exported as Gerber files. These files serve as the format for PCB fabrication, containing precise information about copper traces, drill holes, solder masks, and component placements. The Gerber files are then submitted to a PCB manufacturer for production. The outcome is illustrated in Figure 4, which demonstrates how careful validation and preparation translate into a professional-quality circuit board ready for use in the oscillator training kit.

3. RESULTS

This section presents and analyzes the results obtained from the proposed Colpitts-Hartley Oscillator Training Kit. The main objective is to confirm that the training kit successfully generates the expected sinusoidal waveforms, while enabling students to explore and understand the operational principles of each oscillator type.

a. Calculation Result for Hartley Oscillator

For the Hartley oscillator, the output is anticipated to exhibit a stable sinusoidal oscillation produced by its LC resonant circuit. The frequency of oscillation is primarily determined by the inductance of the tapped coil and the capacitance within the tank circuit. By adjusting these component values, observable changes in frequency occur, thereby reinforcing the fundamental relationship between resonance and component selection. The frequency that generated by the tank depends on L_1, L_2 and C_1 value as shown in Figure 5.

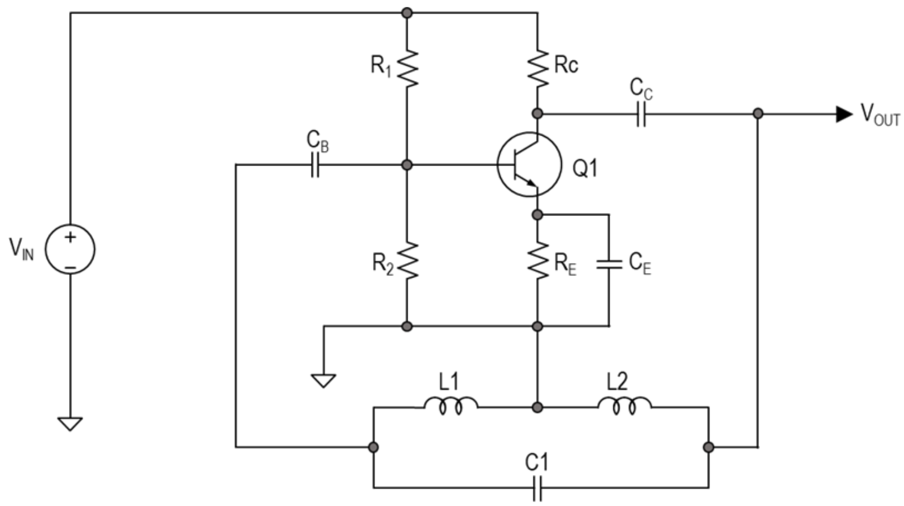

Figure 5. Hartley Oscillator Schematic Circuit

In theoretical the resonant frequency can be calculated by:

$$f_r = \frac{1}{2\pi\sqrt{L_T C_1}} \tag{2}$$

where,

$$L_T = L_1 + L_2 \tag{3}$$

Thus, varying the values of C_1 are 0.01μF, 0.047μF and 0.1μF. The result obtained listed as Table 1.

Table 1. Calculated and Simulated Resonant Frequency by Varies Capacitance

L_1	L_2	L_T	C_1 (μF)	Calculated (KHz)	Simulation (KHz)
			0.01	136.47	135.77
0.1mH	0.1mH	0.2mH	0.047	62.95	62.84
			0.1	43.16	43.06

The results in Table 1 present a comparison between the calculated resonant frequencies and the simulated resonant frequencies of the Hartley oscillator for different capacitor values, while keeping the inductance constant at L_1 = 0.1mH, L_2 = 0.1mH, L_T = 0.2mH.

The comparison between the calculated and simulated results of the Hartley oscillator as shown in Table 1, a very close match, with only slight deviations of less than 1%, confirming the accuracy of the theoretical formula. As expected, the oscillation frequency decreases when the capacitor value increases, demonstrating the inverse relationship between capacitance and frequency in LC circuits. For instance, the frequency drops from about 136.47 kHz at 0.01 μF to around 43.16 kHz at 0.1 μF. These results validate that the oscillator design performs reliably, producing stable sinusoidal outputs consistent with both theory and simulation.

b. Practical Result for Hartley Oscillator

A practical using a Hartley oscillator prototype was conducted to demonstrate the fundamental principle of how this circuit is able to generate a stable sinusoidal waveform through the combination of an inductor (L) and a capacitor

(C) in a resonant tank. The purpose of this experiment (refer to Figures 6a-6c) is to practically assess the effect of varying capacitor values on the output frequency and to verify the stability of the generated waveform, while also linking the theory of LC resonance with real-world applications.

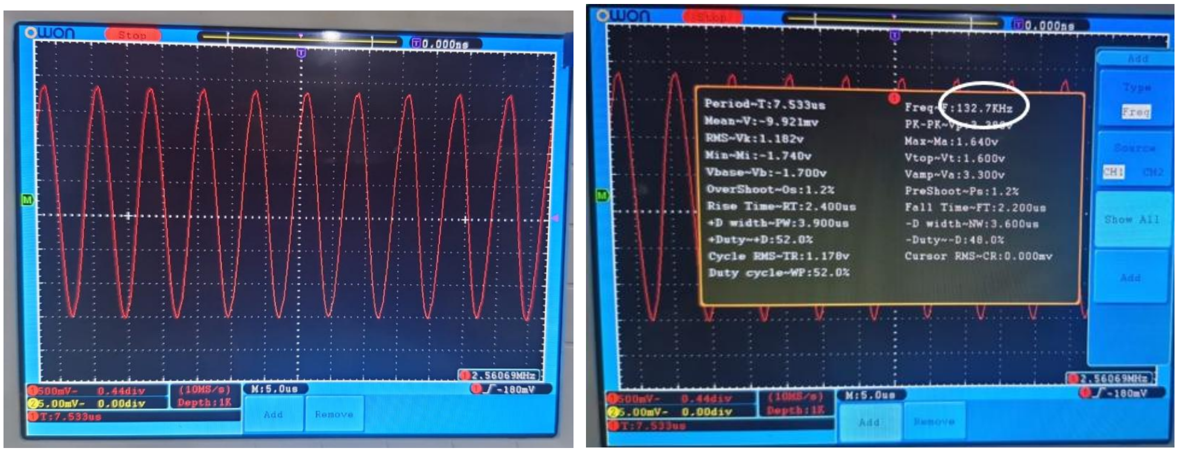

Figure 6 (a). Hartley resonant frequency of 132.7 kHz when C1 = 0.01 µF

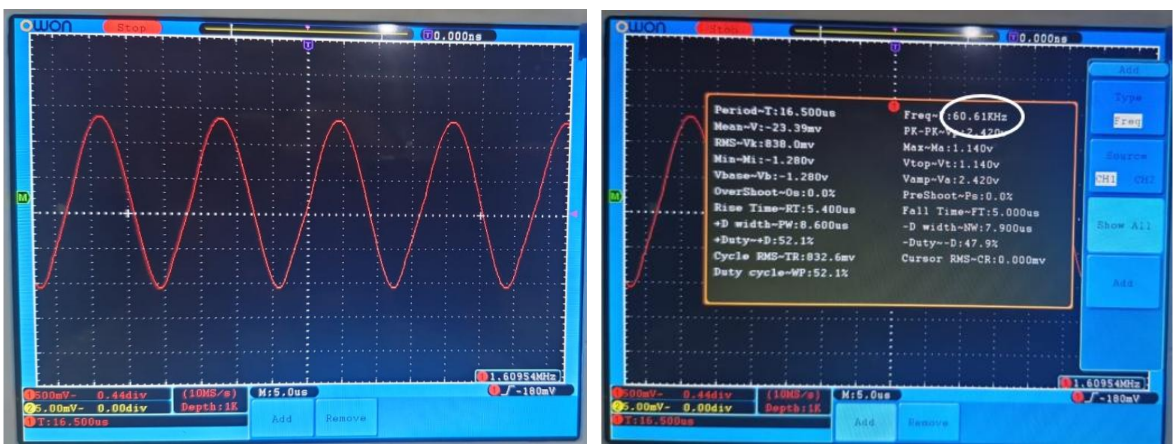

Figure 6 (b). Hartley resonant frequency of 60.61 KHz when C1= 0.047µF

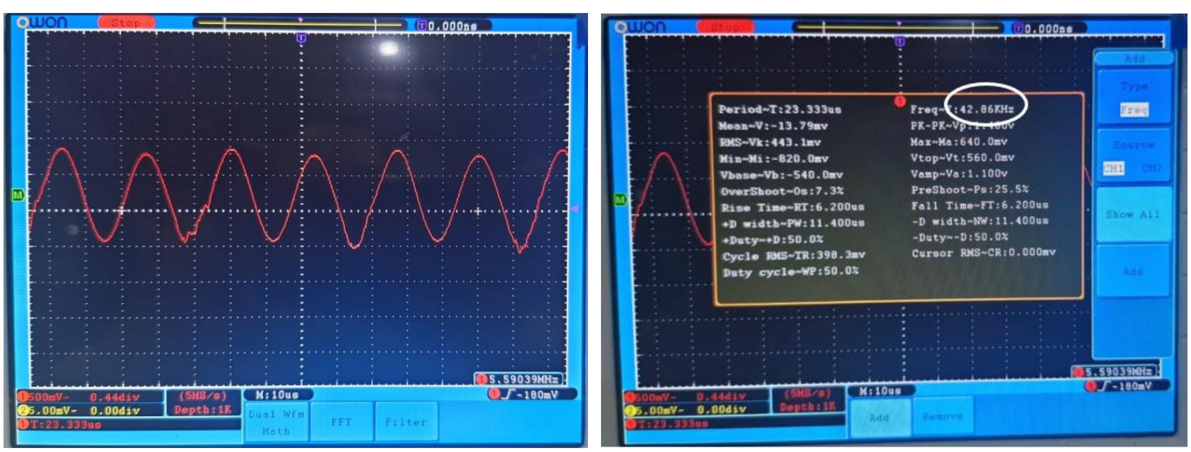

Figure 6 (c). Hartley resonant frequency of 42.8KHz when C1= 0.1µF

The practical Hartley oscillator demonstrates in Figure 6(a) – 6(c), a clear inverse relationship between its resonant frequency and the capacitance value in its tank circuit. When the capacitance C1 is set to 0.01 µF, the circuit achieves a resonant frequency of 132.7 kHz. As the capacitance increases to 0.047 µF, the frequency drops to 60.61 kHz, and further increases in C1 to 0.1 µF result in a lower frequency of 42.8 kHz. This trend occurs because the resonant frequency in an LC circuit is determined by the formula in (2). Increasing the capacitance (C) causes the denominator to grow, thereby reducing the overall frequency. The practical results confirm the theoretical expectation, illustrating that by varying the value of C1, the output frequency of the Hartley oscillator can be precisely controlled. Such behavior is fundamental for applications where frequency tuning is required, and it also reinforces the importance of component selection in oscillator design.

c. Calculation Result for Colpitts Oscillator

In the Colpitts oscillator, the output is expected to be a smooth and steady sine wave. This happens because the circuit uses a capacitor divider together with an inductor to set the oscillation frequency. The way these components work together controls how fast the circuit oscillates, making the frequency stable and predictable.
The frequency generated by the tank depends to C_1, C_2 and L_1 value as shown in Figure 7.

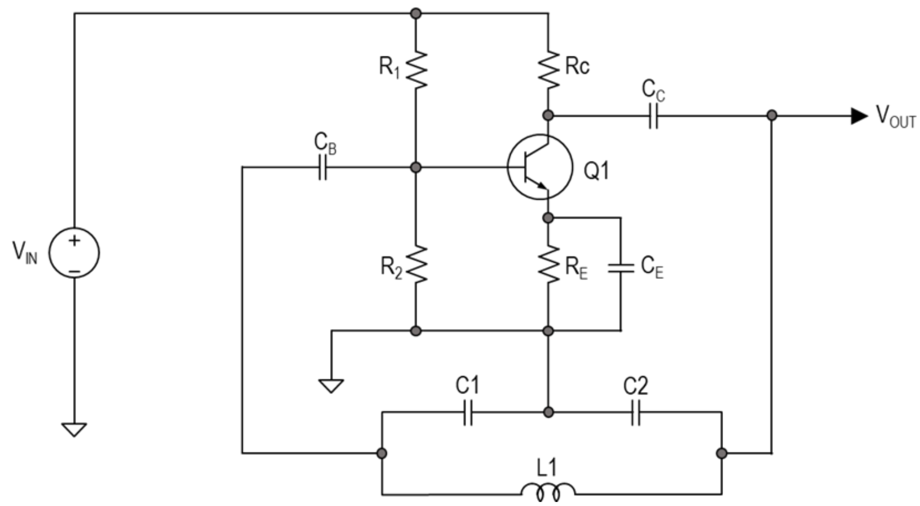

Figure 7. Colpitts Oscillator Schematic Circuit

In theoretically the resonant frequency can be calculated by:

$$f_r = \frac{1}{2\pi\sqrt{L_1 C_T}} \tag{4}$$

where,

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \; or \; C_T = \frac{C_1 C_2}{C_1 + C_2} \tag{5}$$

Thus, by using the values of L_1 are 1mH, 1.32mH and 2.2mH. The result obtained listed as Table 2.

The calculated and simulated results for the Colpitts oscillator shown in Table 2, very close result, with frequency differences of less than 1%, proving that the theoretical design matches practical simulation.

Table 2. Calculated and Simulated Resonant Frequency by Varies Inductance

L_1 (mH)	C_1	C_2	C_T	Calculated (KHz)	Simulation (KHz)
1.0	0.1uF	0.1uF	50nF	22.51	22.41
1.32				19.59	19.49
2.2				15.17	15.15

The results Table 2 also confirm that the oscillation frequency depends on the values of the inductor (L1) and the capacitor divider (C1 and C2). As the inductance increases, the frequency decreases, demonstrating the inverse relationship between inductance and resonant frequency. For example, with L1 = 1.0mH, the frequency is about 22.5 kHz, but when L1 is increased to 2.2mH, the frequency drops to around 15.1 kHz. This trend validates that the Colpitts oscillator produces stable sinusoidal outputs consistent with both theory and simulation.

d. Practical Result for Colpitts Oscillator

Practical analysis of the Colpitts configuration is necessary to gain a detailed understanding of the effects of changing the inductor value on frequency tuning, and to ensure that the LC resonance theory can be practically demonstrated, refer to Figures 8(a) - 8(c). This analysis is also needed to assess the stability of the generated sinusoidal waveform and to measure how much the frequency can be adjusted without compromising signal quality.

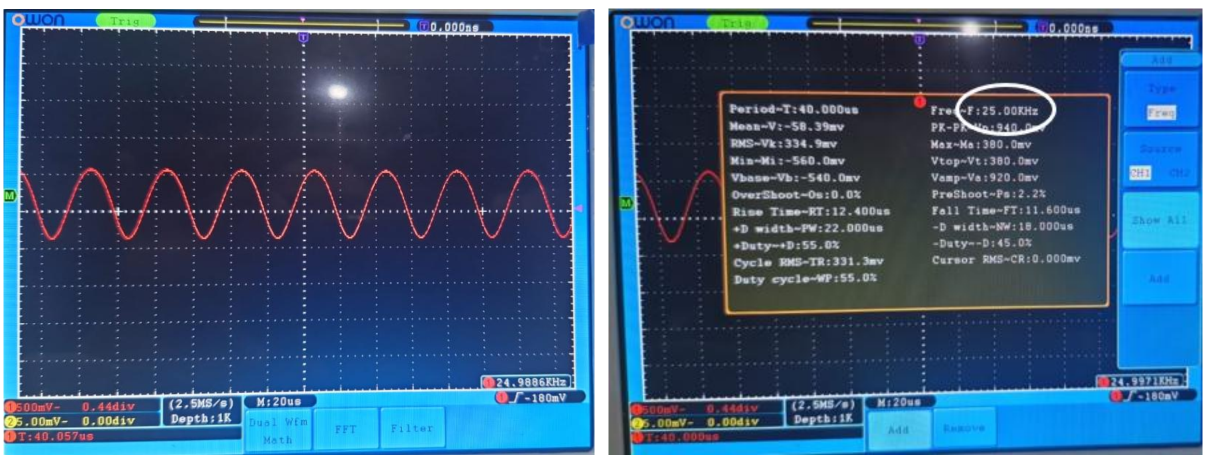

Figure 8 (a). Resonant frequency of 25 kHz when L = 1mH

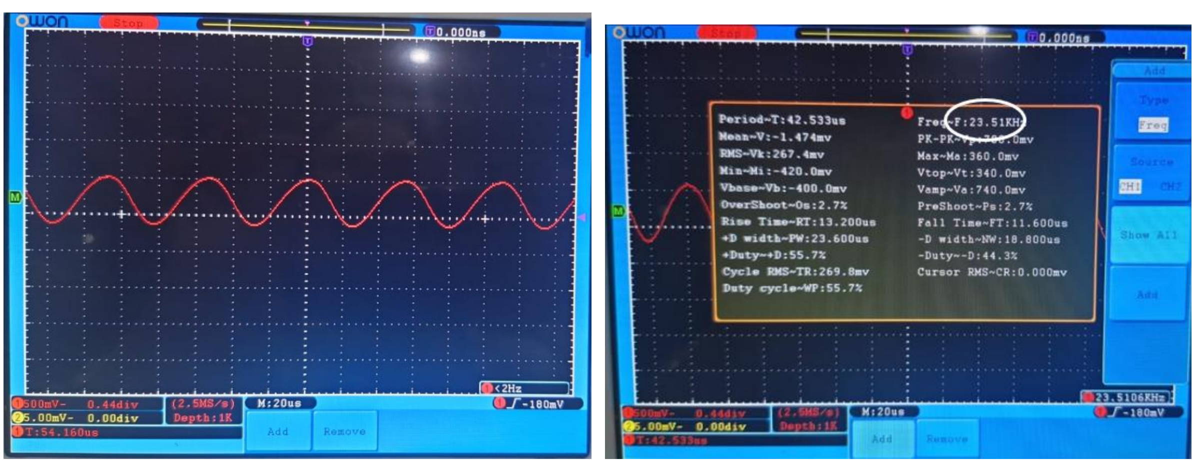

Figure 8 (b). Resonant frequency of 23.5 kHz when L = 1.32mH

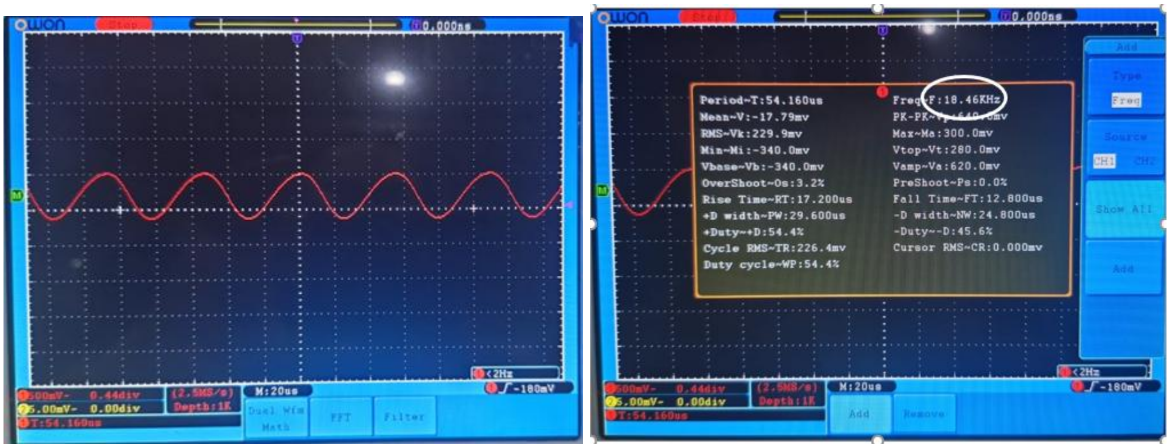

Figure 8 (c). Resonant frequency of 18.46 kHz when L = 2.2mH

From the experimental results, refer Figure 8(a) to 8(c) shows that as the inductance (L) increases in the oscillator circuit, the resonant frequency decreases. For example, when L = 1mH, the frequency is 25 kHz; increasing L to 1.32mH lowers the frequency to 23.5 kHz, and further increasing L to 2.2mH results in a frequency of 18.46 kHz. This demonstrates the inverse relationship between inductance and resonant frequency, consistent with the formula (4), where increasing L causes the frequency to drop.

4. DISCUSSION

The results for the Hartley oscillator reveal a strong correlation between calculated values, simulation outputs, and practical measurements, as summarized in Table 3. When the capacitance of C1 is increased from 0.01 µF to 0.1 µF, the oscillation frequency correspondingly decreases from 136 kHz to 43 kHz. This trend clearly demonstrates the fundamental inverse relationship between frequency and the product of inductance and capacitance ($f \propto 1/LC$) inherent in LC oscillator design. The consistency across theoretical, simulated, and measured data underscores the reliability of the Hartley oscillator's operational principles and its suitability for educational and practical applications.

Table 3. Comparison Calculated, Simulated and Practical Result by Varies Capacitance

L_1	L_2	L_T	C_1 (µF)	Calculated (KHz)	Simulation (KHz)	Practical (KHz)
68uH	68uH	13.6mH	0.01	136.47	135.77	132.7
			0.047	62.95	62.84	60.61
			0.1	43.16	43.06	42.6

Despite the close agreement, practical frequency readings are observed to be slightly lower, approximately 1–3% than those predicted by theory and simulation, such as 132.7 kHz versus 136.47 kHz at a capacitance of 0.01 µF. These minor discrepancies can be attributed to real-world factors like component tolerances, stray or parasitic capacitance, wiring lengths, and instrument loading effects. Nonetheless, the overall data affirms that the Hartley oscillator exhibits stable and predictable performance, with its real-world behavior closely mirroring theoretical expectations. This validation supports the effectiveness of the Hartley oscillator for both demonstration and hands-on experimentation in electronics education.

Table 4. Error analysis for Hartley Oscillator

C1 (µF)	Calculated (KHz)	Practical (KHz)	Absolute Error (KHz)	% Error (Practical vs Calculated_
0.01	136.47	132.7	-3.77	-2.76
0.047	62.95	60.61	-2.34	-3.72
0.1	43.16	42.6	-0.56	-1.3

Based on Table 4, the error analysis Hartley oscillator shows only small deviations between the calculated and practical frequencies, with error rates of –2.76% at 0.01 µF, –3.72% at 0.047 µF, and –1.30% at 0.1 µF. These negative errors indicate that the measured practical frequencies are slightly lower than the theoretical values. The small differences are mainly due to real-world factors such as component tolerance, stray capacitance, and resistance in the inductor, which slightly reduce the oscillation frequency. Overall, the low error rates demonstrate that the Hartley oscillator closely follows theoretical predictions and provides stable, reliable performance.

Table 5. Comparison Calculated, Simulated and Practical Result by Varies Inductance

L_1 (mH)	C_1	C_2	C_T	Calculated (KHz)	Simulation (KHz)	Practical (KHz)
1.0	0.1uF	0.1uF	50nF	22.51	22.41	25.00
1.32				19.59	19.49	23.51
2.2				15.17	15.15	18.46

Referring to Table 5, the results for the Colpitts oscillator demonstrate good agreement between the calculated and simulated frequencies, with differences of less than 1%, confirming the accuracy of the theoretical formula. The practical measurements are slightly higher than both the calculated and simulated values, which can be attributed to factors such as parasitic capacitance, component tolerances, and measurement limitations. As the inductance (L1) increases from 1.0 mH to 2.2 mH, the resonant frequency decreases from about 25.0 kHz to 18.46 kHz in practice, validating the inverse relationship between inductance and frequency. Overall, the results confirm that the Colpitts oscillator produces stable sinusoidal outputs, with practical results following the same trend as theoretical and simulated values, even with minor deviations.

Table 6. Error analysis for Colpitts Oscillator

L1 (mH)	Calculated (KHz)	Practical (KHz)	Absolute Error (KHz)	% Error (Practical vs Calculated)
1	22.51	25	2.49	11.06
1.32	19.59	23.51	3.92	20.01
2.2	15.17	18.46	3.29	21.69

Based on Table 6, the Colpitts oscillator shows practical frequencies consistently higher than the calculated values, with error rates increasing as the inductance rises. At L_1 = 1mH, the error is relatively small (11.06%), but it grows to 20.01% at 1.32mH and further to 21.69% at 2.2mH. This trend suggests that the circuit is highly sensitive to real-world factors such as component tolerances, stray capacitances, and parasitic inductance that are not fully captured in the theoretical calculations. The results indicate that while the Colpitts oscillator follows the expected inverse relationship between inductance and frequency, the practical implementation tends to oscillate at slightly higher frequencies, with larger deviations compared to the Hartley oscillator.

The increasing error with higher inductance values suggests that the Colpitts configuration is particularly vulnerable to the cumulative effects of parasitic and component variations, especially in the presence of larger inductors. Stray capacitance from circuit wiring, PCB layout, and external sources can combine with the intended capacitance, shifting the resonant frequency upward. Similarly, parasitic inductance and resistance inherent in physical components and connections further distort the circuit's behaviour, leading to higher-than-expected frequencies. While the Colpitts oscillator still demonstrates the expected inverse relationship between inductance and frequency, the magnitude of the deviation highlights the practical challenges in achieving accurate frequency control. Compared to the Hartley oscillator, which shows smaller and more predictable errors, the Colpitts design requires greater attention to component selection, layout, and construction to minimize these discrepancies and ensure reliable performance in real-world applications.

6. CONCLUSION

The experimental investigation of the Hartley and Colpitts oscillators validates the fundamental theoretical principles of LC oscillators, while also emphasizing the influence of real-world component tolerances and circuit limitations. For the Hartley oscillator, a comparison between calculated, simulated, and practical results reveals strong consistency, with minor error rates ranging from –1.30% to –3.72%. These slight discrepancies, where practical frequencies are somewhat lower than theoretical predictions, are primarily due to stray capacitance, inductor resistance, and variations in component tolerances. Nonetheless, the consistently low error rates confirm that the Hartley oscillator delivers a stable and reliable sinusoidal output that closely aligns with its theoretical design.

In contrast, the Colpitts oscillator displays larger deviations between calculated and practical values, with error rates ranging from 11.06% to 21.69%. Unlike the Hartley design, the practical frequencies observed in the Colpitts oscillator are consistently higher than their theoretical counterparts. This discrepancy is likely attributed to the increased sensitivity of the Colpitts configuration to capacitor tolerances, parasitic capacitances, and variations in the inductor. Nevertheless, despite these higher error rates, the Colpitts oscillator reliably produces the expected sinusoidal waveforms and clearly demonstrates the correct inverse relationship between inductance and oscillation frequency.

Overall, both oscillators successfully validate their theoretical models and deliver clean sinusoidal outputs. The Hartley oscillator proves to be more accurate and stable, while the Colpitts oscillator highlights the impact of practical non-idealities on frequency determination. Collectively, these results underscore the importance of accounting for parasitic effects and component quality when designing and implementing LC oscillators in real-world applications.

REFERENCES

[1] Bui Thu Cao, “An Advanced Analysis Method of Colpitts Oscillator Circuit”, *Journal of Science and Technology*”, pages 71, vol 5, 2024, doi: https://doi.org/10.46242/jstiuh.v71i5.5012

[2] M. Azadmehr, I. Paprotny and L. Marchetti, “100 years of Colpitts Oscillators: Ontology Review of Common Oscillator Circuit Topologies”, *IEEE Circuits and Systems Magazine*, vol. 20, no. 4, pp. 8 – 27, 2020.

[3] K. A. Humood, O. A. Imran and A. M. Taha, “Design and Simulation of High Frequency Colpitts Oscillator Based on BJT Amplifier”, *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 1, pp. 160-170, 2020.

[4] Nima Safaei, Omar Smadi, Arezoo Masoud and Babak Safaei, "Design and Fabrication of LC-Oscillator Tool KitsBased Op-Amp for Engineering Education', *Indonesian Journal of Electrical Engineering and Computer Science* Vol. 1, No. 1, pp. 88 ~ 100, 2016.

[5] Fuada, Syifaul. " Pengujian Trainer Oscilator Wien Bridge dengan Menggunakan Osciloskop dan Frekuensi Counter", *Prosiding SENTIA 2014 - Politeknik Negeri Malang*, A-32 – A36, 2014.

[6] Ilias Chlis, Domenico Pepe,and Domenico Zito, "Comparative Analyses of Phase Noise in 28 nm CMOS LC Oscillator Circuit Topologies: Hartley, Colpitts,and Common-Source Cross-Coupled Differential Pair", *The Scientific World Journal*, 2014, doi: http://dx.doi.org/10.1155/2014/421321.

[7] Chingyei Chung; Shouyen Chao, "Robust Colpitts and Hartley Oscillator Design", *2014 IEEE International Frequency Control Symposium (FCS)*, 2014, doi: 10.1109/FCS30536, 2014.

[8] Abdelhafid Es-saqy, Abata Maryam, Said Mazer, "Comparative Study Between Hartley and Colpitts VCO for 5G MM-Wave Band Applications", *7th Mediterranean Congress of Telecommunications (CMT),* 2019, doi: 10.1109/CMT.2019.8931343.

[9] M.J. Hemmati, A. Hakimi, "A CMOS Quadrature VCO with Optimized Colpitts Topology for Low-Voltage Applications", *Microelectronics Journal*, vol. 72, pp. 32-39, 2018.

[10] S.L Jang, J.C. Hou, B.S. Shih, G.Z.Li, “Low-phase noise 8.22 GHz GaN HEMT Oscillator using a Feedback Multi-Path Tansformer”, *Wiley Journal*, pp. 1-5, 2018.

[11] Marius Voicu, Domenico Pepe and Domenico Zito, “Phase Noise Analysis of Colpitts and Hartley CMOS Oscillators”, *ISSC 2013*, LYIT Letterkenny, 2021.