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The LC Oscillator Circuit Using Caprio Techniques

***Abstract**. The objective of this research is to analyze the LC oscillator circuit using Caprio technique, a relatively simple and symmetrical method. This circuit is a simple sinusoidal oscillator circuit. The improvement of the circuit was obtained with the Caprio technique, which optimizes parameters for improving total harmonic distortion. The proposed circuit is very simple and practical. The experiment showed total harmonic distortion decreased from 2.716 % to 1.898 %. The frequency output was about 286.7 kHz when the inductor (L3) had five turns of winding, agreeable with the predicted theory.*

***Streszczenie.** Celem niniejszych badań jest analiza układu oscylatora LC przy użyciu stosunkowo prostej i symetrycznej metody Caprio. Ten obwód jest prostym obwodem oscylatora sinusoidalnego. Udoskonalenie obwodu uzyskano dzięki technice Caprio, która optymalizuje parametry w celu poprawy całkowitego zniekształcenia harmonicznych. Proponowany obwód jest bardzo prosty i praktyczny. Eksperyment wykazał, że całkowite zniekształcenia harmoniczne zmniejszyły się z 2,716% do 1,898%. Częstotliwość wyjściowa wynosiła około 286,7 kHz, gdy cewka (L3) miała pięć zwojów uzwojenia, co było zgodne z przewidywaną teorią. (**Obweód generatora wykorztstującego technikę Caprio**)*

Keywords: LC Oscillator , Caprio Technique , Harmonic distortion
Słowa kluczowe: Oscylator LC, technika Caprio, zniekształcenia harmoniczne;

Introduction

Today, oscillator circuit designs are extremely popular. For example, the LC oscillator is a circuit made up of an inductor (L) and a capacitor (C) that are connected to each other [1-3]. An electric charge flows between the capacitor plates and the inductor, so the oscillator circuit can store electrical energy that will oscillate at a resonant frequency. The LC oscillators often generate radio frequencies for applications that require frequency modulation, such as in signal generators, radio transmitters, and for tuning in radio receivers. Hartley, Colpitts, and Clapp present an LC oscillator with an integrated MOSFET [4-5]. In the literature, it was found that there were researchers and presenters of sine waveform generator circuits using different active devices. For instance, Thanomsak Wongmeekaew [6] proposed a Fully-Balanced Current-Tunable Integrator [7-8] with the CAPRIO technique. This achieves optimal parameters for total harmonic distortion correction. Adison Leelasantitham [9] gives an analysis of a high-frequency[10], low-power CMOS low-pass-filter-based current-mirror sinusoidal quadrature oscillator in which the internal capacitor and conductivity of NMOS transistors and their negative resistance are caused by the electrical load, which is the resistance of the current circuit, and the circuit uses the capacitors and inductors that come from within the circuit.

This research presents the application of the Caprio technique to the LC Oscillator circuit based on research into the Caprio technique [11]. It was found to be highly linear and able to attenuate harmonic distortion and eliminate the dual-order harmonics from the circuit, which was developed into the LC circuit. The oscillator has been made, analyzed, and compared to the real circuit in the experiment.

The principle and design of the LC oscillator using the Caprio technique

The frequency of the LC oscillator circuit depends upon the value of the inductance and capacitance in the circuit. For resonance to happen in the LC oscillator circuit, there must be a frequency point where the value of the capacitive reactance (XC) is the same as the value of the inductive reactance (XL) and the frequency of the circuit can be written as in equation 1.

(1)
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

when L is inductance in Henries; C is capacitance in Farads; fr is frequency in Hertz

Total harmonic distortion (THD) is the ratio between the square root of the sum of squares of the second or more harmonic components and the fundamental frequency component in dB can be converted to a percentage as shown in Equation 2.

(2)
$$THD = \frac{\sqrt{H_{D2}^2 + H_{D3}^2 + H_{D4}^2 +}}{H_{D1}} \times 100\%$$

The Caprio technique shows a perspective current mode, differential input topology with very low input impedance and wide bandwidth. So equation (3) is a Volterra series analysis [6], the third-order intermodulation components (IM3) of the output voltage V_{out} at frequency f+2Δf.

(3)
$$IM3_{Cap} \approx \left|\frac{A_{in}^2}{8g_m^3 R_{ee}^3 V_T^2}\frac{f}{f_T}\right|$$

The parameters in equation (3) are as follows: Ain is the input amplitude, gm is the transconductance of the transistors, Ree is the emitter degeneration resistor, and the f_T is the cutoff. IIP3 can be solved from equation (3) by setting $IM3_{Cap}$ = 1 as follows

(4)
$$VIIP3_{Cap} \approx 2\sqrt{2V_T}\sqrt{\frac{g_m^3 R_{ee}^3 f_T}{f}}$$

where $VIIP3_{cap}$ shows the third-order input referred to as the intercept point voltage of Caprio's Quad. $VIIP3_{cap}$ can be further simplified as

(5)
$$VIIP3_{Cap} \approx \sqrt{\frac{f_T I_T^3 R_{ee}^3}{fV_T}}$$

where IT is the overall current consumption.

LC oscillator circuit using the Caprio technique

The LC oscillator does not use the Caprio technique shown in figure 1. This circuit consists of two MOSFETs (IRFP064N), three inductors, two capacitors, four resistors, and two diodes.

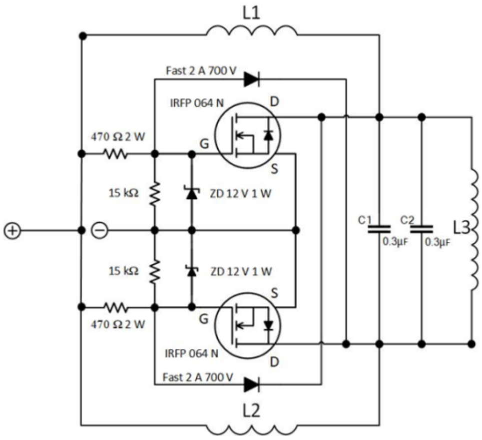

Fig.1. The LC oscillator without the Caprio technique.

Fig.2. The LC oscillator does without the Caprio technique with the prototype circuit board.

The LC oscillator using the Caprio technique in figure 2 consists of two N-MOSFETs, two P-MOSFETs, three inductors, two capacitors, five resistors, and two diodes.

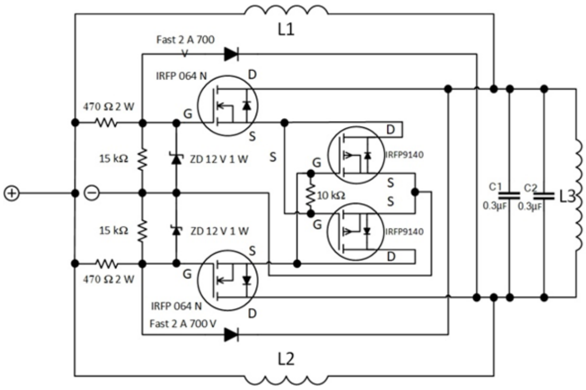

Fig.3. The LC oscillator does without the Caprio technique with the prototype circuit board.

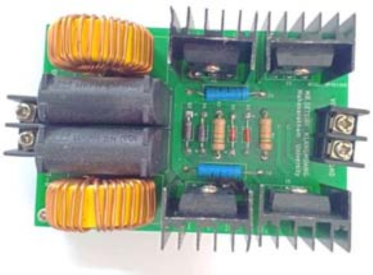

Fig.4. The LC oscillator does without the Caprio technique with the prototype circuit board.

Both circuits will change the inductor (L3) in figure 5 to measure how effectively the circuit performs, focusing mostly on the THD.

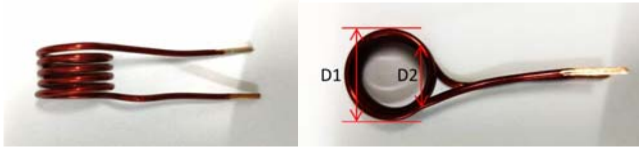

Fig.5. The LC oscillator does without the Caprio technique with the prototype circuit board.

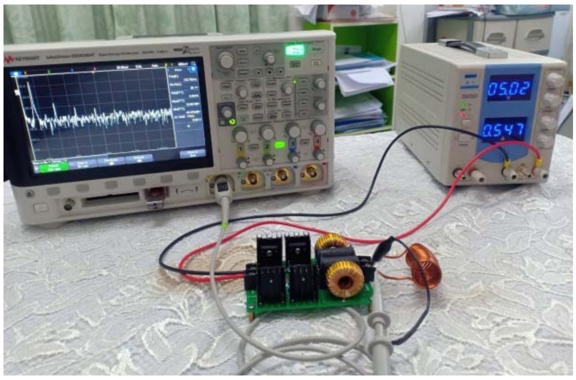

Fig.6. Frequency and THD measurements of the LC oscillator using the Caprio technique.

Experimental results

The proposed LC oscillator with the Caprio technique shown in Fig. 4 is set at a supply voltage of 5V. The elements of the circuit are L1 = L2 = 3 mH, C1 = C2 = 0.3 uF. The circuit uses two N-channel MOSFETs (IRFP064N) and two P-channel MOSFETs (IRFP9140). Table 1 shows the results of current, frequency output, and THD when the inductor (L3) was changed. A Keysight DSOX3024T oscilloscope was used to measure the frequency and THD of the circuit shown in figs. 7–12. Figure 13 shows the current response of the LC oscillator using the caprio technique.

Table 1. The frequency and THD of the LC oscillator with Caprio technique

No.	VIN (V)	I (A)	fr (kHz)	THD	L3 (number of turns)
1	5.02	2.098	286.7	1.898	5
2	5.02	1.273	227.5	1.415	7
3	5.02	0.967	193.7	1.188	10
4	5.02	0.645	152.8	0.962	15
5	5.02	0.572	139.7	0.930	17
6	5.02	0.54	133.3	0.937	20

The THD comparison of LC oscillators with and without Caprio is shown in table 2. The number of turns of the inductor (L3) is as follows: 5, 7, 10, 15, 17, and 20 turns to experiment with both circuits. The results in table 2 and fig. 14 show a decrease in the magnitude of the 2, 3, and 4 harmonics with the harmonic distortion being reduced. The inductor (L3) at 5 turns was the best whose THD decreased from 2.716 to 1.898, representing 30.1%.

Table 2. THD comparison of LC oscillators with and without Caprio.

No.	L3 (number of turns)	THD (caprio)	THD (without caprio)	(%THD) reduce
1	5	1.898	2.716	30.1
2	7	1.415	1.798	21.30
3	10	1.188	1.486	20.05
4	15	0.962	1.144	15.91
5	17	0.930	1.108	16.06
6	20	0.937	1.108	15.43

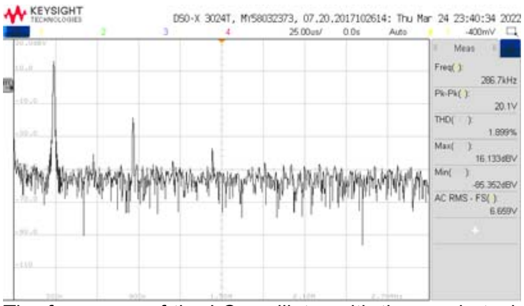

Fig.7. The frequency of the LC oscillator with the caprio technique, number of inductance L3 = 5 turns.

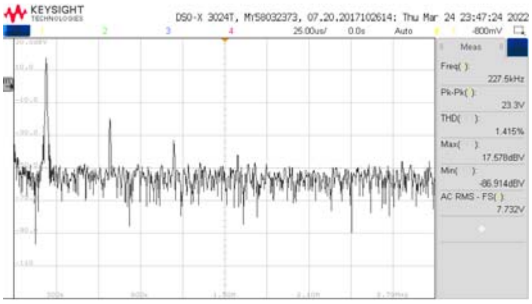

Fig.8. The frequency of the LC oscillator with the caprio technique, number of inductance L3 = 7 turns.

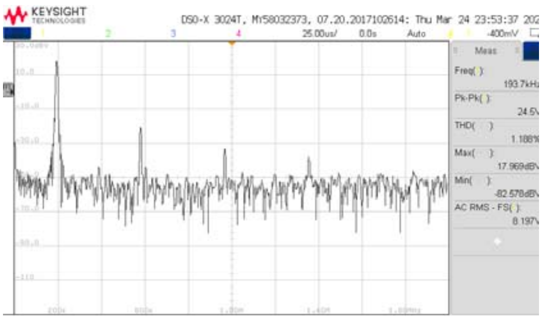

Fig.9. The frequency of the LC oscillator with the caprio technique, number of inductance L3 = 10 turns.

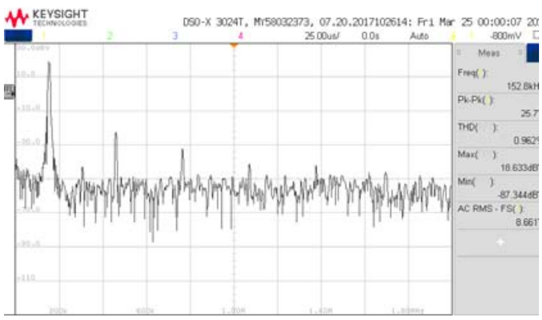

Fig.10.The frequency of the LC oscillator with the caprio technique, number of inductance L3 = 15 turns.

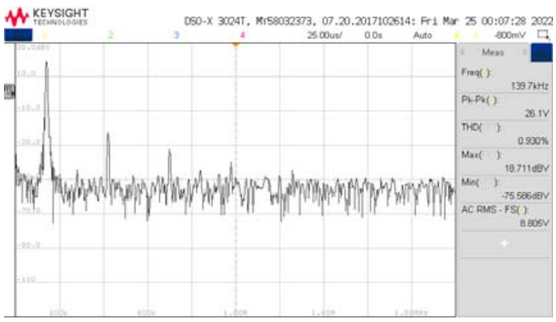

Fig.11.The frequency of the LC oscillator with the caprio technique, number of inductance turns L3 = 17

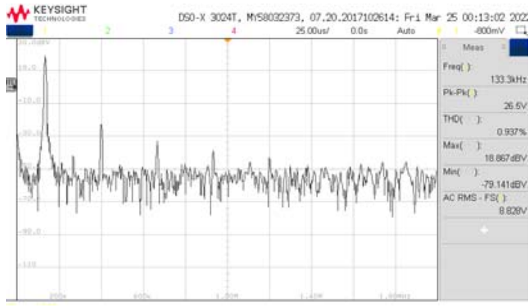

Fig.12. The frequency of the LC oscillator with the caprio technique, number of inductance L3 = 20 turns.

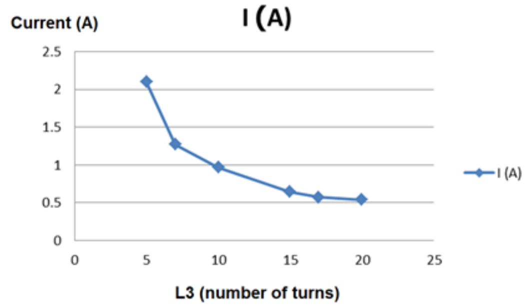

Fig.13. The current of the LC oscillator using the caprio technique when varying L3

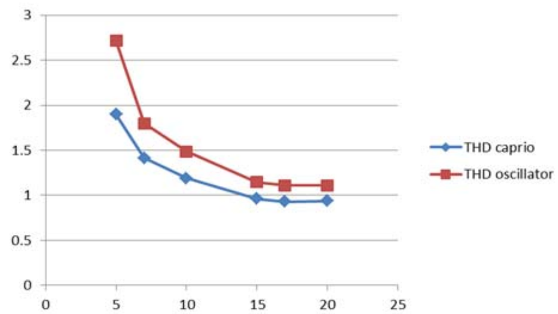

Fig.13. The current of the LC oscillator using the caprio technique when varying L3

Conclusions

From the study of the operation of the LC oscillator using the Caprio technique, it is a symmetrical circuit. The proposed circuit studies only the total harmonic distortion value. The inductor (L3) with a low number of turns has less total harmonic distortion than the inductor L3 with a large number of turns. The best experimental result for THD was decreased from 2.716% to 1.8988% when the number of inductor coils (L3) was adjusted to 5 turns of winding.

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