Design of Demodulation Circuit and Arduino Uno Microcontroller Syncronization for Capacitance Sensor

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Abstract

An AC signal is produced by oscillator or a similar circuit that includes demodulation. In addition to the demodulation circuit, there is also need interface circuit which include signal conditioning, signal processing and data acquisition. So that, the frequency can be read digitally. The purpose of this research was to create demodulation circuit in form of colpitts-crystal oscillator and microcontroller. This research carried out several stage. There are making colpitts-crystal oscillator, microcontroller synchronization, data retrieval and processing output. The DC voltage variations are 3.2 V, 9 V and 15.9 V and capacitor variations are 470 pF, 4.7 nF and 33 nF. Output data in form of frequencies measured by using oscilloscope. Futhermore, the data is tested for accuracy and precision. From the test result using 470 pF, 4.7 nF and 33 nF capacitors when given 3.2 V input voltage, the precision values were 91.35%, 93.06% and 96.17% and the accuracy value were 97.72%, 97.96%, and 98.17%. For 9 V input voltage, the precision values were 99.82%, 97.67% and 97.52% and the accuracy value were 99%, 98.90%, and 98.92%. Whereas 15.9 V input voltage, the precision values were 93.43%, 96.92% and 93.66% and the accuracy value were 98.08%, 98.75%, and 97.60%. From these data, it can be concluded that a good voltage value used in this ciecuit is 9 V with 470 pF capacitor where the precision value was 99.82% and the accuracy value was 99%.

Keywords: Demodulation Circuit, Frequency of Colpitts-Crystal Oscillator, Interface Circuit,

Abstrak

Sinyal AC dihasilkan oleh osilator atau rangkaian serupa yang mencakup demodulasi. Selain rangkaian demodulasi, juga perlu adanya interface circuit yang meliputi signal conditioning, signal processing dan sistem akuisisi data. Sehingga pembacaan keluaran nilai frekuensi dapat dilakukan secara digital pada monitor laptop. Tujuan dalam penelitian ini adalah membuat rangkain demodulasi berupa osilator Colpitts-Kristal dan menyikronkan mikrokontroler untuk digunakan pada sensor. Penelitian ini dilaksanakan beberapa tahap, yakni tahap pembuatan osilator Colpitts-Kristal, tahap sinkronisasi mikrokontroler, kemudian tahap pengambilan data dan pengolahan data hasil keluaran sinyal frekuensi. Variasi yang digunakan pada penelitian ini adalah tegangan masukan DC 3,2V, 9V dan 15,9V serta nilai kapasitor 470pF, 4,7nF dan 33nF. Setelah didapatkan data dari hasil pengukuran frekuensi menggunakan osiloskop dan hasil pengukuran frekuensi dengan sinkronisasi mikrokontroler, selanjutnya data tersebut diuji ketelitian dan keakuratannya. Dalam pengujian alat instrumentasi dilakukan perhitungan ketelitian dan keakuratan. Dari hasil pengujian dengan menggunakan kapasitor 470pF, 4,7nF dan 33nF saat diberi tegangan masukan 3,2V, nilai ketelitian berturut-turut adalah 91,35%, 93,06%, 96,17% dan nilai keakuratan berturut-turut adalah 97,72%, 97,96% dan 98,17%. Untuk tegangan masukan 9V, nilai ketelitian berturut-turut adalah 99,82%, 97,67%, 97,52% dan nilai keakuratan berturut-turut adalah 99%, 98,90% dan 98,92%. Sedangkan pada tegangan masukan 15,9V, nilai ketelitian berturut-turut adalah 93,43%, 96,92%, 93,66% dan nilai keakuratan berturut-turut adalah 98,08%, 98,75% dan 97,60%. Dari data tersebut dapat disimpulkan bahwa nilai tegangan yang baik digunakan pada alat instrumen ini adalah 9V dengan kapasitor 470pF. Dimana nilai ketelitiannya 99,82% dan nilai keakuratannya 99%.

Kata Kunci: Rangkaian Demodulasi, Frekuensi Osilator Colpitts-Kristal, Interface Circuit

1. Introduction

In most cases, the percentage change of the output score of inductance, capacitance, resistance (LCR) is very high. Commonly, the big change of the score can be measured using accurate LCR meter. However, in the case of the small percentage change of LCR score such as 100 ppm or even lower then it will be difficult to use common LCR meter. The type of LCR meter with resolution and high secitivity only may be used in laboratory test while in the industry using very sensitive *interface circuit* (Goes dan Meijer, 1996). In addition for what have been proposed by van der Goes and Meijer is that the measurement of such magnitude of physics which then changed into DC voltage can be used by using demodulation circuit. The demodulation circuit for instance is signal booster and oscillator which change the measurement into DC voltage (Aslam and Boon Tang, 2014).

Oscillator is the circuit that produces the periodic wave in its input by giving DC voltage as the input. The repetitive input voltage is not required except to synchronize the oscillation in several applications. The output signal can be sinusoidal or non-sinusoidal. Such oscillator changes the electrical energy from power supply of DC into the periodic wave form (Floyd, 2012). The output signal often used in the application is sinusoidal signal because it has many types of oscillator that can be used as you wish. From those types of oscillator each of them has its own strengths and weaknesses.

Based on the previous paragraph, it is necessary to make demodulation circuit that can change magnitude of physic into frequency score. Beside the demodulation circuit, it is necessary to have interface circuit including *signal conditioning, signal processing* and data acquisition system. Simply, this interface circuit is used to connect the hardware on the demodulation circuit and the software in the laptop. Therefore, the output reading of frequency score can be conducted digitally.

2. Methods

2.1 The Circuit-Making Stage of Colpitts-Crystal Oscillator

Colpitts oscillator is a feedback oscillator circuit which consists of an LC lowpass circuit. The requirement for oscillation is 0° phase shift through of feedbacks. On the collpits-crystal, the crystal behaves as a series of resonance series if placed as feedback. The crystal seems to have inductance (L), capacitance (C), and resistance (R). (Poole, 2016). Crystal oscillator is used to produce frequencies with a high level of stability. Crystal on the oscillator are made of quartz. This material has the ability to convert electrical energy into mechanical energy in the form of vibration or vice versa (Barmawi, 1985)

. Making a colpitts oscillator circuit by adding 12 MHz crystal aims to make the sinusoidal output signal more stable. The oscillator used feedback LC oscillator which is a sinusoidal output signal. The components used in the circuit are batteries, resistors, capacitors, crystals and potentiometers. Oscillator circuit is simulated in the application Multisim National Instrument 13.0 in accordance with the Figure 2.1. Various input voltage of DC in the form of battery is given those are 3.2V, 9V and 15.9V. In the oscilator the score of *C2* and *C3* are varied with the capacitor score of 470pF, 4.7nF and 33nF in order can be detected the difference of the frequency score output. The *Output* of oscillator colpitts-crystal is connected with pin 5 on microcontroller arduino uno. Arduino uno is microcontroller board based on Atmega328. This board has 14 digital pins inputs or outputs where 6 pins can be used as PWM outputs, 6 pins can be used analog input, other pins are for 16 MHz crystal oscillator, USB connection and reset button (Durfee, 2011)

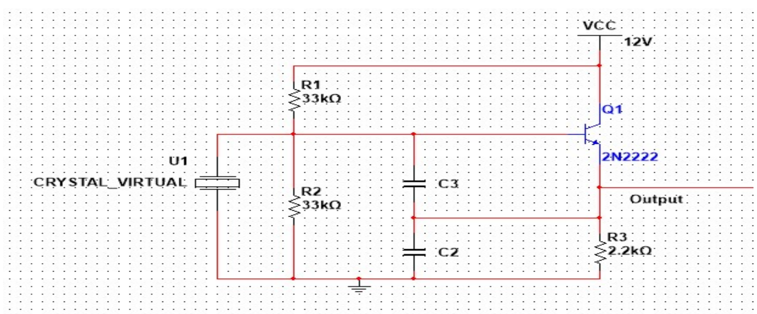

Figure 2.1 Circuit diagram of colpitts-crystal oscillator circuit using NI Multisim 13.0 application
Source: Kikkert, C.J., 2009

2.2 Data collection and Data Processing Stage

The next stepof this research is data collection and processing of frequency output score displayed on laptop monitor. The output data result is collected on each variant used then process them based on the variant. The data processing is conducted by testing the data in the form of precision and accuracy of such instrumentation circuit. Therefore from this processing data the effective instrumentation circuit can be detected. The precision of such instrumentation system can be calculated using the following equation where *f* is frequency:

$$\text{Absolute Error } (\Delta) = \left[\frac{\sum f - \bar{f}}{n(n-1)}\right]^{\frac{1}{2}} \tag{2.1}$$

$$\text{Eror (I)} = \frac{\Delta}{\bar{f}} \text{ x } 100\% \quad (2.2)$$

$$\text{Precision} = 100\% - \text{I} \quad (2.3)$$

$$\%\ \text{Error Accuracy} = 1 - \left|\frac{\text{Score expected} - \text{Nilai measured}}{\text{Score expected}}\right| \quad (2.4)$$

$$\%\ \text{Accuracy} = 100\% - \text{Error Accuracy} \quad (2.5)$$

3. Result and Discussion

3.1 Data Analysis and Discussion

Precision and accuracy of data obtained from testing instrumentation. Precision is the score of the accuracy of data while accuracy is the proximity of the sensor output to the actual value. The actual value of this research is the frequency of the osciloscope. The precision and accurancy equation can be seen in sub-chapter 2.2. The precision and the accuracy value of each variable can be seen in the tables 3.1. and 3.2.

Tabel 3.1 The Calculation Result of Precision

Voltage Input in DC (V)	Capacito	Absolute Error	Error (%)	Precision (%)
3,2	470pF	9.84	8.65	91.35
	4,7nF	7.07	6.94	93.06
	33nF	3.50	3.83	96.17
9	470pF	0.09	0.18	99.82
	4,7nF	1.26	2.33	97.67
	33nF	1.35	2.48	97.52
15,9	470pF	6.30	6.57	93.43
	4,7nF	1.94	3.08	96.92
	33nF	7.72	6.34	93.66

Tabel 3.2 The Calculation Result of Accuracy

Input Voltage in DC (V)	Capacitor	Score expected (in oscilloscope	Score Measured	Error Accuracy (%)	Accuracy (%)
3,2	470pF	50.05	114	2.28	97.72
	4,7nF	49.82	101.76	2.04	97.96
	33nF	49.98	91.45	1.83	98.17
9	470pF	50.16	50	1.00	99.00
	4,7nF	49.37	54.22	1.10	98.90
	33nF	50.63	54.54	1.08	98.92
15,9	470pF	49.98	96	1.92	98.08
	4,7nF	50.11	62.86	1.25	98.75
	33nF	50.85	121.84	2.40	97.60

Discussion

The data obtained from frequency value are processed into a graph of the frequency relationship with time. Figure 3.1 is graph when the DC input is 3.2 V. The x-axis in the graph is time (s) and y-axis is frequency (Hz). Through this graph, the distribution of data for each capacitor variation is displayed. 470 pF capacitors have poor data distribution which is having many peaks with different heights. Data distribution can also be seen from the precision of the test data in table 3.1. The precision value for 470 pF capasitor is the lowest of all values, namely 91.35% with higher error 8.65%. Meanwhile, figure 3.1 shows good data distribution when using 33 nF capasitor where the error is below 5%, which is 3.83%.

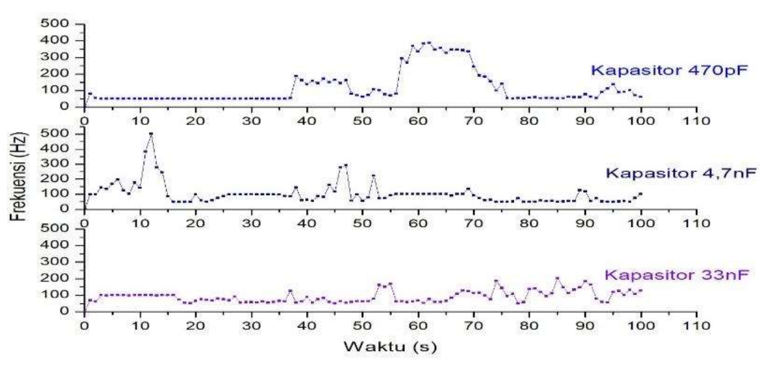

Figure 3.1 Graph of frequency score with input voltage DC 3.2V

After that, the graph for voltage variant 9V is shown by the Figure 3.2. This graph depicts the data distribution on each variant of capacitor score. Capacitor with 470pF has good data distribution. It also can be seen from the testing precision score on table 3.1. The precision score for capacitor 470pF is the highest from all variants that is 99.82% with lowest error score 0.18%. The last graph is the relationship graph of frequency against time on input voltage

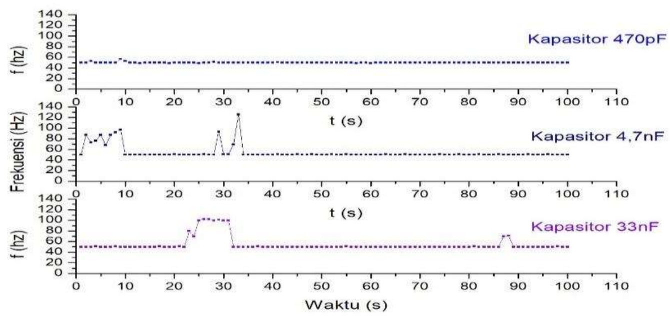

Figure 3.2 Graph of frequency score with input voltage DC 9V

variant 15.9V. Capacitor with score 470pF and 33nF has less good data distribution. Many culminations with different height produced. This data distribution also can be seen from the precision score of data testing on table 3.1. The precision score of capacitor 470pF is the lowest from all variant that is 93.43% with the highest error score 6.57%. In the capacitor 33nF the precision score is 93.66%. In the other hand, the figure of graph 3.3 the data distribution is good in which it is used capacitor 4.7nF with error score under 5% that is 3.08% and the precision score is 96.92%.

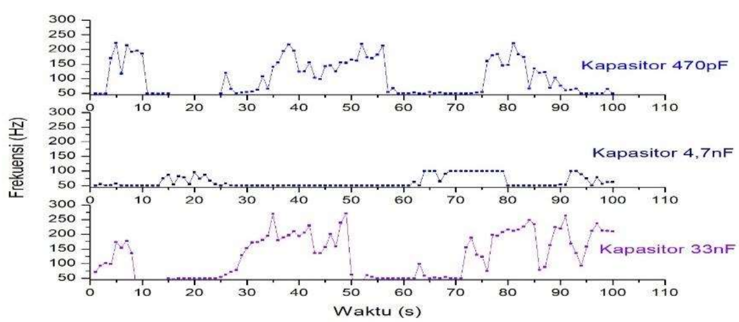

Figure 3.3 Graph of frequency score with input voltage DC 15.9V

According to the result of precision testing, it is known that when using input voltage 3.2V the lowest result is when using capacitor 470pF with error score 8.65% and the precision score is 91.35%.therefore, if want to use input voltage with range score of 3.2V it is better to not use capacitor 470pF but using capacitor 33nF because it has error score only 3.5% and the precision score is 96.17%. When the input voltage is 9V, the highest precision score is 99.82% when use capacitor 470pF. While in input voltage 15.9V, the highest precision score is 96.92%

when use capacitor 4,7nF. The error score above 5% from table 3.1 is for the precision testing occur when the input voltage 3.2V and 15.9V. therefore the precision score also can be obtained by using input voltage score 9V, the precision score from the result of instrumentation tool testing is in highest range 99.82% up to 97.52% with lowest error level that is in range 0.18% up to 2.48%. The occurrence of instability data distribution when using input voltage 3.2V and 15.9V is caused by the noise produced by the environment during the process of instrumentation tool testing. Meanwhile, the stability of data distribution obtained using input 9V is due to the less noise produced in environment that influences the data. The noise occurs due to the environment condition and different time of data collection. In addition, input voltage 9V use one battery DC as the source, contrarily in input voltage 3.2V and 15.9V which is the result of voltage battery series of DC 1.5V and 9V. From this series circuit on voltage battery of DC 1.5V and 9V produce disturbing *noise* toward the stability of data distribution when using input voltage 3.2V and 15.9V.

In the table 3.2, the accuracy table is in the range 97.6% up to 99%. According to the result of the accuracy testing, when the input voltage is 3.2V the highest accuracy score is 98.17% with error accuracy 1.83% when using capacitor 33nF. In addition, using the same input voltage score, the lowest accuracy score is when using capacitor 470pF that is 97.72%. When the voltage is raised become 9V and 15.9V, the accuracy score is changed on each variable. The highest accuracy score is when using capacitor 470pF that is 99%. On the contrary, when the input voltage is 15.9V, the highest accuracy is using capacitor 4,7nF. None error accuracy score over 3% from all variables of data tested, but the highest error accuracy score is occurred when using input voltage 3.2V that is 2.28% and the input voltage of 15.9V that is 2.40%. Therefore, according to the accuracy testing of this instrumentation tool, input voltage 9V which has highest accuracy score is in the range score of 99% up to 98,92%. Form both testing, the input voltage score 9V is the input voltage recommended by the writer due to the highest range of precision and accuracy.

4. Conclusion

The conclusion obtained from the current research is that using score of input voltage 9V, the precision score of testing result of instrumentation tool testing is in highest range9.82% with capacitor score 470pF and low error level that is 0.18%. The accuracy testing of instrumentation tool with input voltage 9V also have highest accuracy score 99% with capacitor score 470pF. Therefore according to both tests, the input voltage 9V is the input voltage with highest precision and accuracy range.

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