The Servo Control Apparatus Designed For Automatic Frequency Tracking in An E.N.D.O.R Electron-Nuclear Double Resonance Spectrometer

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The Servo Control Apparatus Designed For Automatic Frequency Tracking in An E.N.D.O.R Electron-Nuclear Double Resonance Spectrometer*

by

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SUMMARY

In the present work, a simple servo controlled, automatic frequency tuning apparatus was designed for matching impedance characteristics in ENDOR spectrometers in which frequency is swept through preset frequency intervals. It consists of r.f. signal source, parallel resonance tank circuit, r.f. detector, reference voltage regulator, amplifier and associated motor control subunits.

It has been observed that, when the signal frequency is swept through the 3-30 MHz band, the variable capacitor of the tank circuit was automatically tuned to the resonance frequency and the problems with impedance mismatches were, thus, partly eliminated.

INTRODUCTION

In general, in a closed control circuit, there is always some mechanical connection between the element to be controlled and those forming the other subunits of the control system as a whole. Therefore, by means of such a mechanical connection, the position of the elements can be stepwise or continuously controlled. So, the basic function of a servo control system is to provide this control process in a automatic fashion.

In a typical system, an input signal is applied to the system in which there is also a reference voltage whose characteristics can be set at will and when there exists a difference signal voltage

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between these two (error signal), it will be detected and amplified by proper subunits and is then simultaneously transferred to motor control unit. Thus, it provides necessary onset signal for the motor to give required motion. The motor turns in a direction such that it diminishes the error voltage and then comes to rest.

Servo control systems can be designed as D.C or A.C systems\textsuperscript{1,2,3} and in this work a D.C servo control system is described.

As it is well known from elementary electronics, the resonance frequency of a tank circuit which simply consists of a coil of inductance \( L \) and a capacitor \( C \), is approximately given by

\[
f = \frac{1}{2\pi} \frac{1}{\sqrt{LC}}
\]  

(1)

In a circuit which contains these elements in parallel, either \( L \) or \( C \) must be continuously tuned to or tracked with the resonance frequency of the signal source whose frequency is swept through certain band and which also feeds power to the \( (LC) \) combination. Otherwise, impedance mismatches that might be arose in some parts of the circuit would cause unwanted reflection signals to appear and also to interfere with measurements and thus, errors or mistakes would be unavoidable.

The purpose of designing such a circuit is to overcome the impedance mismatches encountered in sweep frequency systems, as it is common with almost all Endor\textsuperscript{4} experiments, and to provide sufficient R.F. power getting into the coil in which the sample is usually placed. Because, the Endor signals are proportional to the square of the R.F. field produced in the coil.

The unit described here does these functions through the pre-selected frequency intervals.

A simple block diagram of such a servo control system is shown in Figure 1 and detailed circuit diagram is shown in Figure 2.

**DESCRIPTION OF EXPERIMENTALLY DESIGNED FUNCTIONAL SUBUNITS**

a) Signal generator and parallel resonance circuit
Figure 1. A block diagram of a typical servo control system.

The signal generator used was a Heathkit Model 1G - 42 of which frequency can be manually swept thru 1-32 MHz frequency bands.

The capacitance of the variable capacitor in the tank circuit can be set to any value in between 4-360 pF. Therefore, with the given value of the inductance on the diagram the frequency band is found to be 3-30 MHz.

b) The R.F. detector

When design parameters are taken into account and for the error signal be accurately detected, the ripple factor $\Delta V$ must be chosen rather small.

Thus for $\Delta V = 10^{-3}$ Volt and from the relation given in references', if we take $f=10$ MHz, $R_L = 100$ k$\Omega$ we get for $C=1$ nF.

The error signal with magnitude $E_1$ is applied to the inverting input of succeeding operational amplifier and to this input is also applied the reference voltage and thus, forming a summing amplifier system.

c) The reference voltage source.

Throughout the present experiments, with the voltage values well below the $\pm 14.7$ V regulated, the frequency sweeps were justified.

The voltage $V_{ref}$ of the regulator subunit is simultaneously used with $E_1$ and is denoted as $E_2$ at the input of operational
Figure 2. The circuit diagram of the servo-control system.
amplifier. The reason for this was to provide necessary 0.7 V limit value at the output of the amplifier and which would onset the motion of the motor. When this condition is satisfied, the value of \( E_1 \) is kept constant and any value of \( E_1 \) other than 0.7 V limit value, would upset the stability and would provide an error signal causing the motor to turn.

d) The amplifier and motor control subunit

For the error signal provided by the R.F. detector is at low amplitude, it must be amplified to such a level that would cause motor to turn. The operational amplifier (MC 1741) circuit has been designed for this purpose and is used as both summing and amplifying subunit.

With the values of \( R_1 = R_2 = R = 10 \, \text{kΩ} \), the output voltage is shown to be \( E_0 = -K (E_1 + E_2) \) and where \( K = -\frac{R_c}{R} \) is the gain of the system and it has been so designed that the gain would assume any value between 0-100. For example, for the frequency sweep within the band of 3-9 MHz, \( E_1 = 250 \, \text{mV} \), \( E_2 = -255 \, \text{mV} \) and \( E = -K (E_1 + E_2) \leq 700 \, \text{mV} \) is obtained and this is the value of the signal that would cause the motor to turned on. When the gain is further increased, the sensitivity of the system increases also and other error signals with less amplitudes may be also zeroed.

Operation of the motor control system is based on the well known triggering actions of transistors and triacs. Actually designed control system is shown in Figure 2.

The output signal from the amplifier is applied through the resistor \( R_1 \) and for the input voltage greater than \(+700 \, \text{mV}\), transistors \( T_1 \), \( T_3 \), \( T_4 \) and \( T_5 \) would go to saturation and for those voltage values that are greater than \(-700 \, \text{mV}\) the transistor \( T_3 \) now goes to saturation. The current gain of all transistors is close to \( \beta = 125 \).

Depending upon the voltage values of zero or \(+15 \, \text{V}\) which appear on the resistors \( R_1 \) and \( R_{11} \), one of the two triacs (ITT TC 0640) takes command and provides necessary voltage to turn on the 110 V AC motor. When \( G_1 - V_{\text{ground}} = +15 \, \text{V} \), the triac on
the upper arm would turn the motor in one direction and when \( G_1 - V_{\text{ground}} = -15 \text{ V} \) the triac on the lower arm would turn it in the other direction, thus providing the capacitor to follow up those directional rotations.

The more details on the functional operation of the system may be found in the references cited at the end.

RESULTS AND DISCUSSIONS

With the servo control system whose characteristics and functional descriptions given here, it has been observed that the frequency bands of 3-9 MHz and 9-30 MHz were swept at an arbitrary rate of about 1 MHz/min and the capacitor \( C \) in the parallel resonance circuit followed the frequency sweep and thus was kept tuned to the signal frequency of the oscillator.

For any error signal with magnitude is equal or greater than \( \pm 700 \text{ mV} \), the motor control system provided sufficient drive to the motor. Therefore, by arranging the gain of the system, servo control can practically be achieved for any error signal amplitude provided the system should be prevented of going into oscillation due to high gain feedback loop. It was also observed that the functioning of the system was smooth regardless of the signal is modulated or unmodulated.

Although no continuous measurements of signal amplitude versus frequency, across the resonance circuit were made, but at some spot frequencies such as 3 MHz, 10 MHz, and 30 MHz, the checks showed that it is essentially the same as that of the signal generator, i.e. 250 mV. Through checks must be made when the actual working condition in the spectrometer is fulfilled, i.e. under full R.F. power 200 Watts applied to the Endor coil.

In practice, most of those similar but technologically advanced systems require large initial budget and then considerable maintenance costs which must be considered if one wishes to make an economical choice.

We, therefore, tried to lessen and succeeded in solving those aforementioned problems by using available electronic components in market. And, with this simple servo control system, we hope
to overcome the problems in the ENDOR spectrometer which is presently under construction in our department. We believe also that the unit described here would solve similar difficulties encountered with overhauser spectrometers.

It must be certainly possible to use the present unit within the other frequency bands and for various signal intensities provided that some minor modifications or adjustments be made in relevant subunits.

REFERENCES

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ÖZET

Bu çalışmada, frekansı belirli aralıktaki terk edilmiş ENDOR spektrometrelerinde çarşaf etilen impedans uyumuzsuzluklarını ortadan kaldırmak amacıyla tasarlanmış ve yapılmış, basit bir otomatik servo kontrol aygıtı tanımlanmıştır. Aygıt r.f. sinyal kaynağı, tank devresi, r.f. detektörü, referans voltaj kaynağı, yükseltgeç ve motor denetim altbıtımlarından oluşmuştur.

Sinyal frekânzi 3-30 MHz band aralığında terk edilmiş, tank devresindeki değişken sığannı rezonans frekansına otomatik uyum sağladığı gözlememiş ve böylece impedans uyumuzsuzluğundan doğan sorunlar kısmen önlenmiştir.
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