Microcontroller Based Phase Locked Loop for Automatic Resonance Frequency Tracking

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5/2012 - 9/2014
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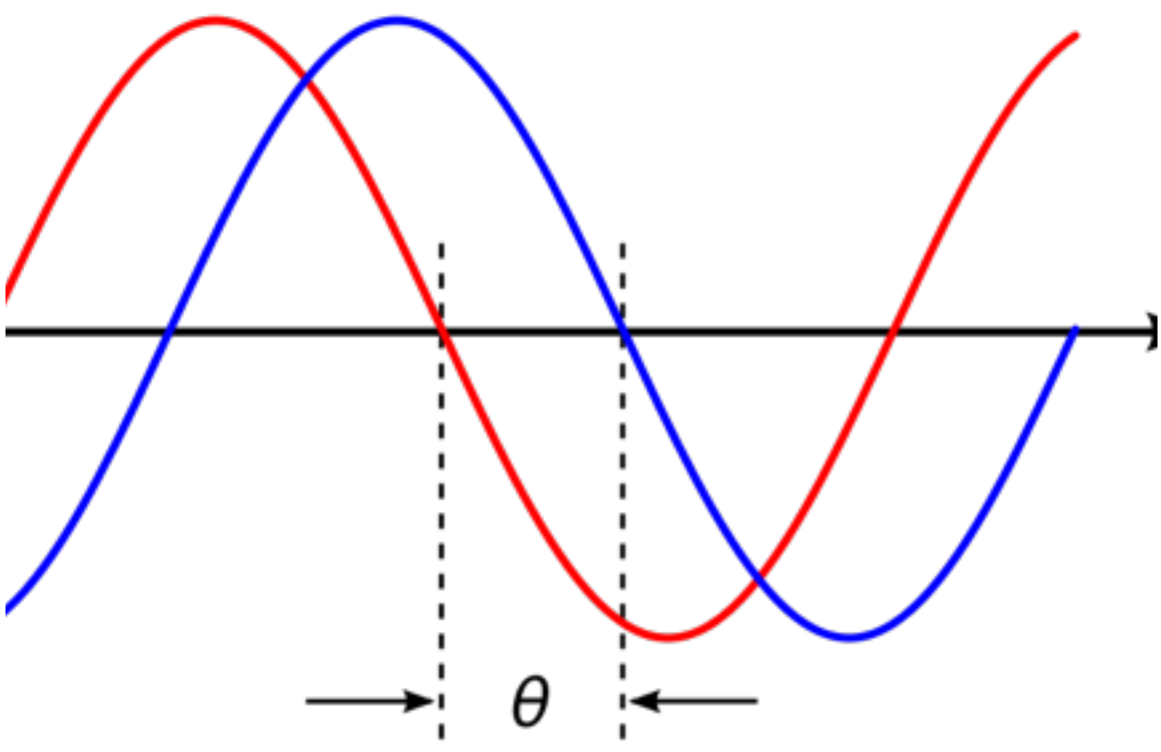
Abstract— This paper presents an approach for a low cost microcontroller based method of phase control of a resonant circuit (tank). The primary utilization of this system that will be presented here is it's use in a resonant inverter to provide self-tuning to the tank's resonant frequency. This is a common practice in a number of applications that require a controlled AC source such as induction heating and lighting ballasts. Traditional solutions for accomplishing this task include using a monolithic PLL such as the common CD4046, mixed signal or to perform digital phase control in an FPGA or DPS platform. The goal of the approach presented in this paper is to bring the convenience of analog along with the stability and flexibility inherent in digital control to a low cost, simple to program, microcontroller platform for control of resonant circuits operating at frequencies <200kHz.



1. Introduction

Resonant inverters [RI] in the 20-100kHz range are commonly used in applications such as induction heating, ultrasonic generators, ballasts for lighting, and resonance transformers used for power transmission and tesla coils. The RI in these devices supply an AC voltage to a resonant circuit or tank. By using the tank voltage or current as a feedback component compared to original AC input signal, the phase angle of the circuit can be calculated. Controlling the phase angle relationship between voltage and current in these systems is important for a variety of reasons. In this paper the target application will be induction heating, in which phase control provides the advantage of self tuning to the tank resonant frequency over varying work load conditions, and protection against inverter non zero voltage switching operation.

Analog monolithic phase locked loop ICs such as the common CD4046 and real time implementation of digital phase control in an FPGA or DPS platform are typical solutions in all of the above applications where some type of phase or frequency control is required. Both options come at a cost with their own advantages and disadvantages. The goal of the approach presented in this paper is to bring the convenience of analog along with the stability and flexibility inherent in digital control to a low cost, simple to program, microcontroller platform for control of resonant circuits operating at frequencies <200kHz.

2. Review of Phase-locked loop Fundamentals

Although it is not the goal of this paper to go into depth explaining phase-locked loop (PLL) systems, a basic review will be given to enhance understanding of the topics discussed.

PLL Overview: A PLL is a servo system, an automatic device that uses error-sensing negative feedback to correct the performance of a mechanism. The main function of a PLL is to generate an output clock whose phase and frequency (not always 1:1) are locked to that of the input reference clock. It’s operation is based around the idea of comparing the phase of two signals. The information about the error in phase or the phase difference between the two signals is then used to control the frequency of the loop. A primitive PLL system is shown below in Figure 2.1, the system consists of three basic blocks: a phase detector or comparator (PD), low-pass filter (LPF), and voltage controlled oscillator (VCO). Each component is connected forming a closed-loop feedback system.

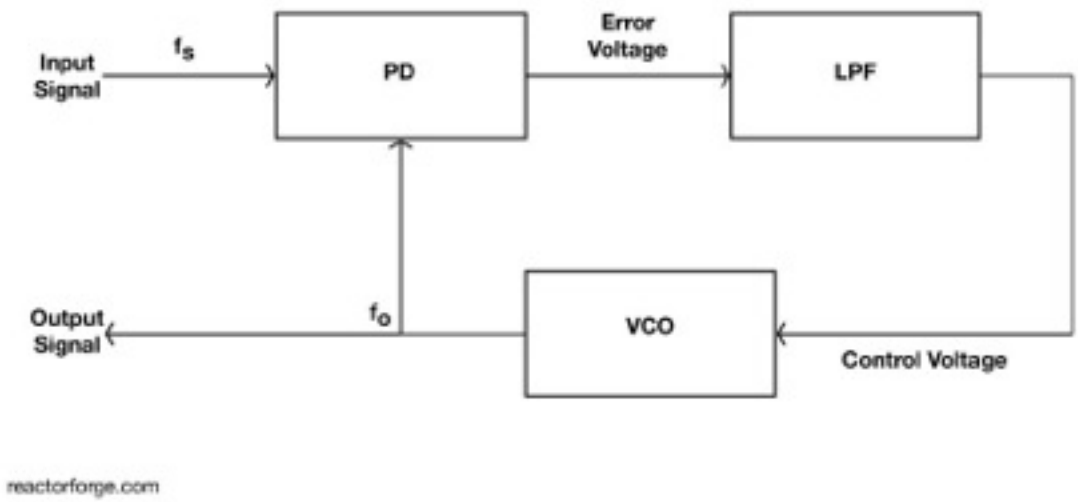


Figure 2.1 PLL Block Diagram

Phase Detector (PD): Also called a Phase Comparator, this circuit block within the PLL compares the phase the input and VCO (f_o) signals and generates a voltage according to the phase difference between the two signals.

Low Pass Filter (LPF): Also called a loop filter, this is used to filter the error voltage output from the phase comparator. It is removes high frequency components and noise. It also governs many of the characteristics of the PLL including bandwidth, lock range, response time, and its stability.

Voltage Controlled Oscillator (VCO): The voltage controlled oscillator is the circuit block that generates the output frequency. It's output frequency is proportional to the input dc control voltage from the LPF.

PLL Operation: The VCO generates a frequency (f_o) that is fed to the PD, this frequency is also output to the external circuit requiring the phase locked signal. The external circuit sends a reference signal (f_s) back to the PD as well. The PD compares the phase of these two signals, the resulting difference is the error voltage. This error signal passes through the LPF where ripple is removed. Depending on the damping strength of this filter the resulting control signal can be more stable with a slow response to phase changes or less stable but quicker to respond.