Microcontroller Based Phase-Locked Loop for Automatic Resonance Frequency Tracking

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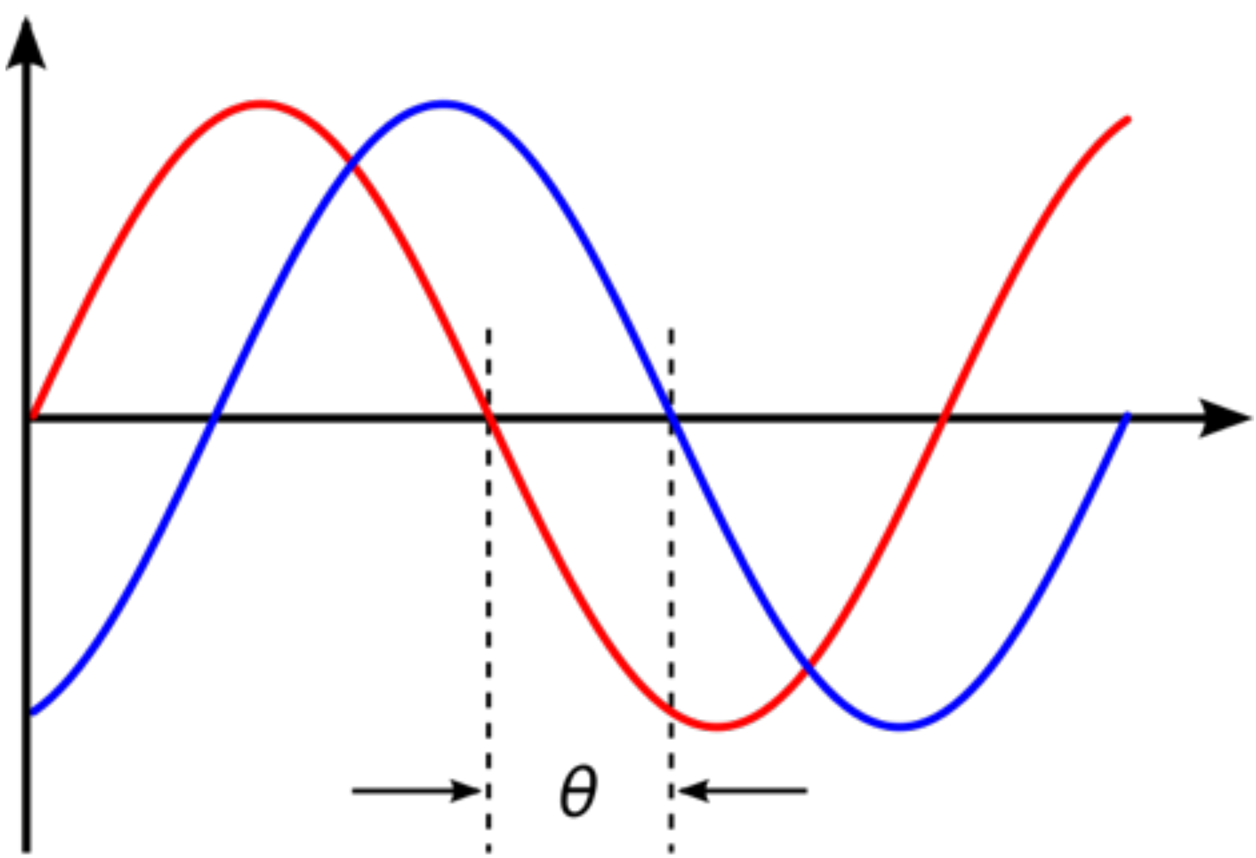
Abstract— This paper presents an approach for a low cost microcontroller based method of phase control of a resonant circuit (tank). The primary utilization of this system that will be presented here is it's use in a resonant inverter to provide self-tuning to the tank's resonant frequency. This is a 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 operation, or to perform pure digital phase control in software using an FPGA, DSP or other platforms. The approach presented in this paper aims to bring the convenience of analog along with the stability and flexibility possible in digital control to a low cost, simple to program, microcontroller platform for control of resonant circuits operating at frequencies <200kHz.



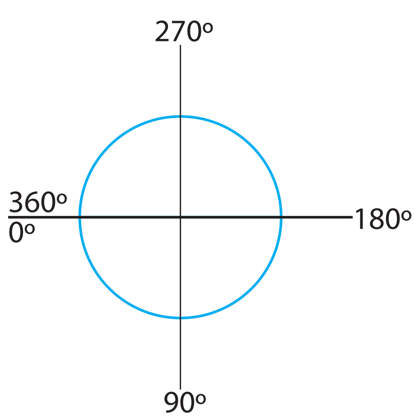
1. Introduction

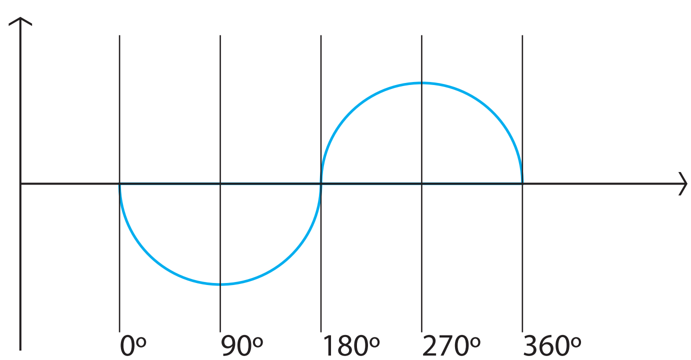
Resonant inverters (RI) in the 20-100kHz range are commonly used in applications such as induction heating, ultrasonic generators, ballasts for lighting, and resonance transformers like those found in wireless power transmission devices or tesla coils. The RI in these devices supplies an AC voltage to a resonant circuit (tank). By using a combination of signals including the tank and inverter voltage or current, the phase angle of the circuit can be calculated. For example, comparing the inverter output voltage to the inverter current or tank voltage will yield a phase measurement of the tank circuit. 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 angle awareness provides the advantage of performing 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 software are typical solutions used in the above applications where some type of phase or frequency control is required. Both options come with their own advantages and disadvantages. The the approach presented in this paper aims to bring the convenience of analog along with the stability and flexibility possible in digital control to a low cost, simple to program, microcontroller platform for phase control of resonant circuits operating at frequencies <200kHz.

2. Understanding Phase

Phase denotes the particular point in the cycle of a wave relative to it's origin or another wave, measured as an angle in degrees. Just as a circle's circumference is divided into 360 degrees, the period of a wave (one complete cycle) is also divided into 360 degrees. A sine wave can be thought of as a circle divided in half and rotated so that the halves are side by side. The period begins at 0° and ends at 360° just as a full revolution on the circle. Figure 3.1 Phase Illustration



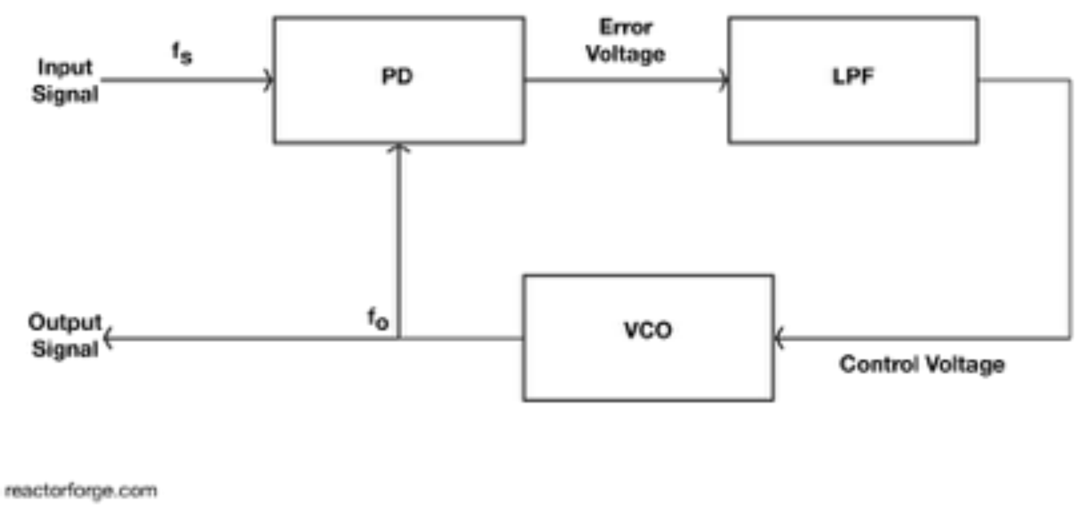


3. Phase-locked loop Fundamentals

Although it is not the goal of this paper to provide an in-depth explanation of phase-locked loop (PLL) systems, a basic understanding of them is of key relevance. Therefor a brief definition of the basic systems will be presented to facilitate understanding of the topics discussed herein.

PLL Overview: A PLL is a servo system, an automatic device that uses error-sensing negative feedback to correct the performance of a circuit. The main function of a PLL is to generate an output clock whose phase and sometimes frequency 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 used to control the frequency of the loop. A typical analog PLL system is shown below in Figure 3.1, 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 3.1 PLL Block Diagram



Phase Detector (PD): Also called a Phase Comparator, this circuit block within the PLL that compares the phase of the input or reference signal (f_s) and the VCO output (f_o). It then generates a pulsed voltage who's characteristics vary 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 PD. It removes high frequency components and noise, outputting a near DC voltage. The LPF also governs many of the characteristics of the PLL including bandwidth, lock range, response time, and stability.

Voltage Controlled Oscillator (VCO): The voltage controlled oscillator is the circuit block that generates the output frequency (f_o). 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 determines characteristics such as duty cycle in the error voltage it outputs. This error signal passes through the LPF where it is converted to a low ripple, near DC voltage. 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.

WIP…

References

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