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# Harmonic analysis of AC power supply using microcontroller

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***Abstract**: In recent years, the electrical harmonic pollution is getting more and more serious with the far ranging use of nonlinear components in electric and electronic devices. The presence of harmonics in power system is a major concern to power engineers for many years. Harmonic Pollution increases industrial plant downtimes and power losses. Harmonic of an electrical signal is the content of the signal whose frequency is an integer multiple of the fundamental system frequency. The cause of harmonic in a power system is from highly nonlinear devices. In power system, harmonic analysis is use to determine the impact of harmonic producing load on a power system. This technique is widely used for system planning, equipment design, troubleshooting, etc. The effect of harmonics on power system can be in the form of power efficiency reduction, overheating in wire, ageing of electrical insulation, etc. Several algorithms have been proposed on harmonic analysis and Fast Fourier transform (FFT) is the most widely used computation algorithm. FFT is an efficient algorithm used to compute Discrete Fourier transform (DFT). DFT uses a finite set of discrete-time sample of an analogue signal and produces a finite set of discrete-frequency magnitude spectrum values. This paper focuses on implementation of 240V, 50Hz power supply harmonic analysis on LPC2138 using FFT technique.*

***Keywords:** Electrical harmonic pollution; Fast Fourier Transform; LPC2138 microcontroller*

## I. Introduction

Due to the great increase in power electronics application, harmonics and their limitation have been a major concern and topic of research during the last decades.A power system operating under ideal conditionsis expected to be perfectly balanced, of a single frequency, and with sinusoidal current and voltage waveforms of constant amplitude. However, in practical power systems, this ideal operational mode is not encountered, since the network components, at a lesser or greater extent, have the undesirable effect of distorting the original sinusoidal waveforms. Nonlinear components and loads, such as power converters, flexible ac transmission systems (FACTS) devices, nonlinear saturation and hysteresis

in components with magnetic cores, fluorescent lamps and arc furnaces, among others, represent the main contribution to this effect, known as harmonic distortion. Adverse quality of power effects due to harmonic distortion are, for instance, interference with communication, control and protection systems, reduction of the equipment’s life span, and additional losses in the power system.The LPC2138 microcontroller is based on a 16/32 bit ARM7TDMI-S™ CPU with real-time emulation and embedded trace support, that combines the microcontroller with 32 kB, 64 kB, 128 kB, 256 kB and 512 kB of embedded high speed Flash memory. 10 stage butterfly analysis is chosen according to the sampling theory where in sampling frequency must be twice the maximum frequency component’. Maximum frequency that is displayed is 500Hz for digital implementation 512Hz is used.

One of the widely used computation algorithm for harmonic analysis is Fast Fourier Transform (FFT). In this project, a harmonic analyzer using FFT is being implemented on ARM7 core processor LPC2138. The supply voltage of 230V, 50 Hz is stepped down to 6V using a voltage divider in order to match the power rating of the processor input. The output from the processor is displayed on a graphic LCD, which is interfaced to the output ports of the processor. In order to improve the efficiency of harmonic analysis of AC power supply an opto thyrister (MOS3041) is added which functions as a relay

## II. Literature Review

A total harmonic distortion analyzer calculates the total harmonic content of a sine wave with some distortion, expressed as total harmonic distortion (THD). A typical application is to determine the THD of an amplifier by using a very-low-distortion sinewave input and examining the output.There are several types of distortion analyzers they are Fundamental suppression, heterodyne type, Tuned circuit, Spectrum analyzer. Harmonic analysis has been carried-out using frequency, time and hybrid time-frequency domain methods.

## III. Harmonic Calculation Using Fft Algorithm The Fast Fourier Transform (Fft) Can Be Used For

harmonic analysis because of its computational efficiency. FFT can be used to calculate the harmonic distortion and to separate even/odd/inter harmonics *etc*. Fourier analysis is used to convert time domain waveforms into their frequency components and vice versa. When the waveform is periodical, the Fourier series can be used to calculate the magnitudes and phases of the fundamental and its harmonic components. More generally the Fourier Transform and its inverse are used to map any function in the interval – to + ∞ in either the time or frequency domain into a continuous function in the inverse domain. The Fourier series therefore represents the special case of the Fourier Transform applied to a periodic signal. In practice data are always available in the form of a sampled time function, represented by a time series of amplitudes, separated by fixed time intervals of limited duration. When dealing with such data a modification of the Fourier transform, the DFT (discrete Fourier transform) is used. The implementation of the DFT by means of FFT algorithm forms the basis of the most modern spectral and harmonic analysis systems. DFT transforms a signal from the time domain to the frequency domain. This makes available the amplitude and phase of the fundamental and the harmonics present in the signal. The dc component is also available in the first bin. The Fast Fourier Transform (FFT) is the DFT's computational efficient implementation, its fast computation is considered as an advantage. With this tool it is possible to have an estimation of the fundamental amplitude and its harmonics with reasonable approximation. FFT performs well for estimation of periodic signals in stationary state; however it does not perform well for detection of sudden or fast changes in waveform e.g. transients or voltage sags. Fast Fourier transforms (FFT) is a faster version of discrete Fourier transform (DFT). The FFT utilizes some clever algorithms to do the same thing as the DFT, but in much less time. The finite, or discrete, Fourier transform of a complex vector with n elements is another complex vector Y with n elements

$$Y_k = \sum_{j=0}^{n-1} \omega^{jk} y_j,$$

Where ω is a complex *n*th root of unity:

$$\omega = e^{-2\pi i/n}.$$

**Lpc2138 Microcontroller**

The LPC2138 microcontroller is based on a 16/32 bit ARM7TDMI-S™ CPU with real-time emulation and embedded trace support, that combines the microcontroller with 32 kB, 64 kB, 128 kB, 256 kB and 512 kB of embedded high speed Flash memory. A 128-bit wide memory interface and a unique accelerator architecture enable 32-bit code execution at maximum clock rate. For critical code size applications, the alternative 16-bit Thumb® Mode reduces code by more than 30% with minimal performance penalty. Due to their tiny size and low power consumption, these microcontrollers are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. With a wide range of serial communications interfaces and on-chip SRAM options of 8/16/32 kB, they are very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit 8 channel ADC(s), 10-bit DAC, PWM channels and 47 GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers particularly suitable for industrial control and medical systems.

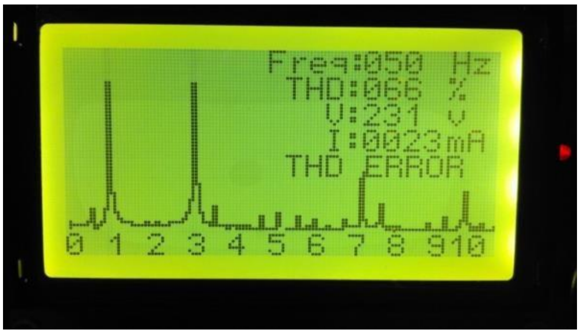
## IV. Working

The power supply section is to supply Vcc for the controller and graphic LCD. A 230V supply from the mains if fed to a step down transformer, 12-0-12, the signal will get downsized. This is then rectified using a full wave rectifier and smoothened using a capacitor. The output thus obtained is regulated using LM317 IC to get a 5V DC supply .The LPC2138 has a header of its own to convert the input to 3.3V which is its working voltage. In the voltage section of the circuitry provides the input for voltage harmonic analysis. At the same time an opto thyrister (MOS3041) act as relay is at ON condition. The signal to be analyzed is fed to the voltage transformer, 6-0-6. The output of transformer will be 12V peak-to-peak. This has to be converted into 3.3V for matching the requirements of the controller. For safe working, signal is made to 2V peak-to peak using voltage divider. Capacitor is used to prevent the disruptions on AC side by the DC bias given. Signal is then clamped to a reference of 1.7V using a voltage bias and identical clamping resistors. Output so obtained can then be given to the ADC channel of LPC2138 for harmonic analysis. Current section aims at providing input for current harmonic analysis. A 20:5A Current Transformer (CT) is used. Wire carrying the input current forms the primary whereas the secondary is a wire of many turns wound around a silicon former. A current which is reduced but proportional to the input current is produced at the output of the CT. The voltage drop by the current across the resistor which is very small is amplified using a differential amplifier. Input to the inverting terminal is the small voltage drop and that to the non-inverting terminal is 1.75V. Microcontroller LPC2138 is the brain of this project. Here we are calculating the rms voltage, rms current and total harmonic distortion. If any one of these calculated values violate the threshold value the relay will OFF then the supply to the device will break. The voltage and current signals to be analyzed are fed to the two channels of ADC which are pin 27 and 28 respectively. Reset operation is achieved by using a reset button connected to the pin 25 of the controller. Channels of ADC can be switched by using the ISP (pin 15). When pin 15 is grounded graphic LCD displays current harmonics and voltage harmonics otherwise. Graphic LCD is having a resolution of 128*64. The output is displayed on a graphic LCD which is interfaced to the controller through pin 35 to 48.

## V. Results And Observations

Output of the analyzer is being displayed on the graphic LCD. It is a plot between FFT magnitude and frequency. For each of the frequency samples the corresponding FFT magnitude is found out using implemented FFT algorithm.


Harmonics in normal supply




Harmonics in UPS

## VI. Conclusion

With the proliferation of non-linear loads, the issues of power harmonics are more apparent than ever. Controlling and monitoring industrial system designs and their effects on utility distribution systems are a potential problem for the industrial consumer. Hence a power harmonic analyzer is presented using LPC2138 ARM7 core processor. This harmonic analyzer is capable of analyzing harmonics in a single phase supply and represents the harmonics as a frequency spectrum. The proposed system provides a harmonic analyzer at much lower cost with improved system efficiency Suppress the magnitude/frequency of power variations. This method add solution to mitigate the power quality problems with decrease the liability of failure of electrical equipments and also avoids line loading and losses.

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