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Low-Cost Arbitrary Waveform Generator for Educational Environment Using ARM7

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ABSTRACT
This paper reports a new architecture for arbitrary function Generator generating any periodic function with desired frequency. Finally the system is implemented on an ARM-7. The Implementation is the main challenge in this work. In modern industrial detection and communication, a signal generator has gained increasing applications. Currently available signal generators are mainly based on the DDS technology. It is a kind of frequency synthesis technology which directly synthesizes waveform on the basis of phase. As the appearance of Advance Risc machine (ARM-7) chips, ARM-7 are used to realize DDS logic to meet different demand of the user. A harmonic signal generator with adjustable frequency, phase and harmonic proportion is designed in this paper.

KEY WORDS: - ARM 7, (DDS) Direct Digital Synthesizer (AWG) Arbitrary Waveform Generator, function generator

I. INTRODUCTION

This paper describes the design, implementation and operation in comparison for ARM & AVR controller. Analog-to-digital converters (ADC) and digital-to-analog converters (DAC) have to be characterized in static and dynamic regime. We have designed an arbitrary function generator based on direct digital synthesis (DDS).

And describe the function Generator for use Direct Digital Synthesizer (DDS) ordinary function Generator normally few waves generated and this function Generator you have take a design different type wave generate and this function generator we can interface with Personal Computer and operated. This use Direct Digital Synthesis (DDS).

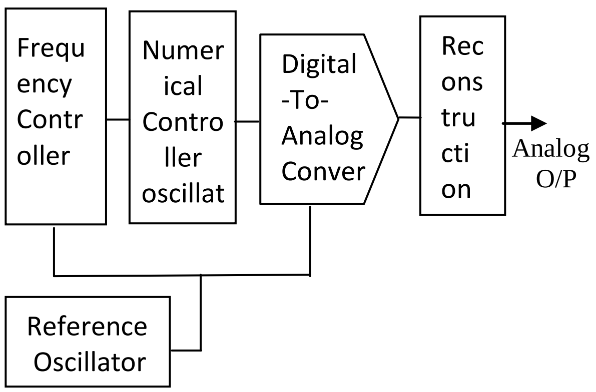
This signal generator is capable of generating single-tone sinusoidal (THD <; -80 dBc), two-tone sinusoidal, square wave, triangular and saw tooth waveforms in the frequency range from 0 to 10 kHz. The frequency stability achieved is 3.9 μHz (τ = 2 s) and the amplitude stability is 2.0 μV (τ = 2 s).

This design offers two significant advantages to educators: (1) it provides a low-cost instrument that can be used in undergraduate laboratories where more expensive commercial arbitrary function generators are not available; and (2) it is suitable for use as a student project. Function generator is connected to an audio amplifier and speaker.

A function generator is a device which produces simple repetitive waveforms. Such devices contain an electronic oscillator, a circuit that is capable of creating a repetitive wave form. (Modern devices may use digital signal processing to synthesize waveforms, followed by a digital to analog converter, or DAC, to produce an analog output). The most common waveform is a sine wave, but saw tooth, step (pulse),square, and triangular waveform oscillators are commonly available as are arbitrary waveform generators (AWGs). If the oscillator operates above the audio frequency range (>20 kHz), the generator will often include some sort of modulation function such as amplitude modulation (AM) frequency modulation (FM), or phase modulation (PM) as well as a second oscillator that provides an audio frequency modulation waveform.

II. DIRECT DIGITAL SYNTHESIZER

The idea behind Direct Digital Synthesis (DDS) is an electronic method for digitally creating waveforms and frequencies from a single Direct Digital Frequency Synthesis (DDFS or simply DDS), also known as Numerically Controlled Oscillator (NCO), is a technique which uses digital-data and mixed/analog-signal processing blocks as a means to generate signal waveforms that are repetitive in nature. Direct Digital Synthesizer (DDS) is a type of frequency synthesizer used for creating arbitrary waveforms from a single, fixed-frequency reference clock. Direct Digital Synthesizer consists of a frequency reference. The reference provides a stable time base for the system and determines the frequency accuracy of the DDS.



("DDS BLOCK DIAGRAM")

DDS technique consists in digital processing to generate signals at different frequencies and phases selectable by software, from a reference clock. The number of bits of the DDS and the desired output signal frequency is given by

$$f_o = \frac{\delta\varphi}{\delta t} = M\,\frac{f_{clock}}{2^N}\,,$$

Where *(δt* is the duration of a DDS time step (1/4) and *op* is the phase angle changing in one time interval *ot.* Considering that the tuning word *(M)* is the amount by which the phase accumulator increments on each DDS time step and that 2^N is the capacity of the phase accumulator, then *op* = *M* / 2^N (with *N* equal to the number of bits of the phase accumulator). Combining these results gives the frequency of the output sine wave. is the clock frequency, then the frequency of the output sine wave is equal to:

$$F_{out} = \frac{M \text{ X } F_{clk}}{2^N}$$

Above equation is known as the DDFS "tuning equation." The frequency resolution of the system equals. In a practical DDFS system, all the bits out of the phase accumulator are not passed on to the LUT, but are truncated, leaving only the first 13 to 15 MSBs. A DDS has many advantages over its analog counterpart, the phase-locked loop (PLL), including much better frequency agility, improved phase noise, and precise control of the output phase across frequency switching transitions. The output frequency of a DDS is determined by the value stored in the frequency control register

DDS output frequency settling time is determined mainly by the phase response of the reconstruction filter. The superior close-in phase noise performance of a DDS stems from the fact that it is a feed-forward system. The DDS technique has higher frequency resolution usually generators based on PLL have a limited frequency resolution in the order of $1{:}10^6$, total harmonic distortion (THD) of PLL generators typically has values of -40 dB in comparison with a THD better than -70 dB achievable by DDS devices. The DDS devices are software programmable and easy to use.

A. Analog function generator / (ADC)

Analog signal generators based on a sine wave oscillator were common before the inception of digital electronics, and are still used. There was a sharp distinction in purpose and design of radio-frequency and audio-frequency signal generator

A typical function generator usually comprises of a triangular waveform whose frequency can be controlled smoothly as well as in steps. This triangular wave is used as the basis for all of its other outputs. The triangular wave is generated by repeatedly charging and discharging a capacitor from a constant current source. This produces a linearly ascending or descending voltage ramp. As the output voltage reaches upper and lower limits, the charging and discharging is reversed using a comparator, producing the linear triangle wave. By varying the current and the size of the capacitor, different frequencies may be obtained.

Function generators, like most signal generators, may also contain an attenuator, various means of modulating the output waveform, and often the ability to automatically and repetitively "sweep" the frequency of the output waveform (by means of a voltage-controlled oscillator) between two operator-determined limits. This capability makes it very easy to evaluate the frequency response of a given electronic circuit.

More advanced function generators use Direct Digital Synthesis (DDS) to generate waveforms. Arbitrary waveform generators use DDS to generate any waveform that can be described by a table of amplitudes

B. Digital function generator / DAC

Digital Signal Generator is an easy-to-use, virtual signal generator. It can produce white noise signals, sine wave, square wave, trigon wave, beat wave, sweep sine wave and a signal defined by a windows WAV file.

The Digital Block is the heart of this digitally controlled function generator. Symmetry and frequency variation is direct result of the design of this block. In this design the emphasis was on simplicity and some target specifications at the top of the frequency variation were compromised in order to achieve greater simplicity.

This design achieves 28 frequencies in the range of 100Hz to 100 kHz. Whilst the 17 frequencies from the range 100Hz to 10 kHz are symmetry variable in five steps from 0.1 to 0.5 the last eight frequencies only managed to achieve symmetry variations 0.5 and 0.25. This is due to some limiting factors that will be discussed later. The table of achievable frequencies can be found at the end of this report. User inputs are also digitally processed in this function generator and sent out as digital signals to other parts of this function generator namely the amplifier module. Also a filter selector circuit is built in after the digital block. The user inputs controlling frequency and symmetry are also built into this control block.

Therefore it is clear that the digital block can be divided into 4 distinct blocks, each with its own functionality. These blocks are the control module, counter module, filter control module and 8-bit D/A. The D/A chosen is the DAC0801LCN. The interconnections will be discussed later but the thickness of the line indicates the number of bits in the bus lines. As the name suggests the control module takes user inputs, processes them and sends them out to the respective modules. The functionality module generates the count, varying between 0 to 255 in 256 steps or in 64 steps. The 8-bit D/A changes this count into a wave and the filter selector module selects which filter in the filter block to pass the signal through.

New high-speed DACs provide up to 16-bit resolution at sample rates in excess of 1 GS/s. These devices provide the foundation for an AWG with the bandwidth and dynamic range to address modern radio and communication applications. In combination with a quadrature modulator and advanced digital signal processing, high-speed DACs can be applied to create a full-featured vector signal generator with very high modulation bandwidth. Example applications include commercial wireless standards such as Wi-Fi (IEEE 802.11), WiMAX (IEEE 802.16) and LTE, in addition to military standards such as those specified in the Joint Tactical Radio System (JTRS) initiative. Also, broad modulation bandwidth allows multi-carrier signal generation, necessary for testing receiver adjacent channel rejection.

C. *Arbitrary waveform generators, or AWGs*

Arbitrary waveform generators are sophisticated signal generators which allow the user to generate arbitrary waveforms, within published limits of frequency range, accuracy, and output level. Unlike function generators, which are limited to a simple set of waveforms; an AWG allows the user to specify a source waveform in a variety of different ways. AWGs are generally more expensive than function generators, and are often more highly limited in available bandwidth; as a result, they are generally limited to higher-end design and test applications.

III. WHY ARM PROCESSOR USED

ARM used because this processor is risc design & more regions.

- ARM (Advanced Risc Machine) Microprocessor was based on the Berkeley/Stanford Risc concept
- ARM is programmable as little endian or big endian data alignment in memory.
- Originally called Acorn Risc Machine because developed by Acorn Computer in 1985
- Financial troubles initially plagued the Acorn Company but the ARM was rejuvenated by Apple, VLSI technology, and Nippon Investment and Finance
- Licenses ARM core designs to semiconductor partners who fabricate and sell to their customers.
- 4 bit field can shift an 8 bit data field into any one of 16 possible positions
- If necessary to use a complete 32 bit word, then break it up into four groups of 8 bits and use shift and add instructions to reassemble
- 18 data processing instructions of type: <Opcode> <dest reg.> <op1> <op2>
- ADC Add with Carry; ADD Add; AND Bitwise logical AND; BIC Bit Clear CMN Compare Negated; CMP Compare; EOR Exclusive OR; MOV Move; MVN Move Not; ORR Bitwise logical OR; RSB Reverse Subtract; RSC Reverse Subtract with Carry; SBC Subtract with Carry; SUB Subtract; TEQ Test Equivalence; TST Test and Mask
- Shift instruction fields are 5 bits, so shifts can accurately place in up to all 32 positions
- Shift instructions: LSL logical shift left, ASL Arithmetic shift left, LSR Logical shift right, ASR Arithmetic shift right, ROR Rotate right, RRX Rotate right with extend
- Use of Software Interrupt instruction (SWI) causes ARM to go into supervisor mode with private
- registers R13_svc and R14_svc as extras to allow OS kernel to protect the stack and link registers

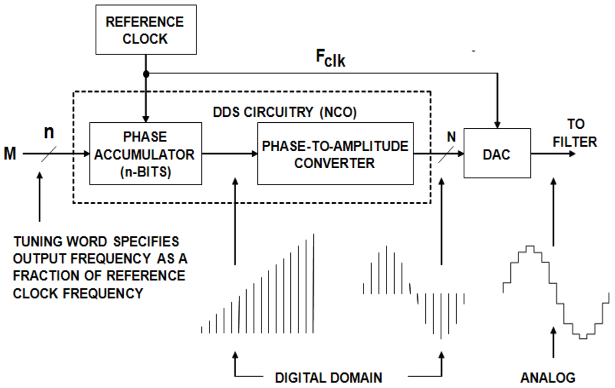
IV. WHY DIRECT DIGITAL SYNTHESIZER

Some advantages are as follows in support of Direct Digital Synthesizer:-

- The frequency is tunable with sub – Hertz resolution.
- The phase is digitally adjustable.
- Conceptually simple design & low part counts (these help keep cost down).
- No drift due to temperature changes or aging of components (as long as the clock is stable).
- Addition of arbitrary waveform generation is not conceptually difficult.

DDFS have capability that usually specified as the maximum sine wave output frequency. the sine waves can be generator at nearly half the clock frequency. Generated a square wave from a sine wave amplitude is less than 0. However, maintaining the fidelity of a square wave is harder because of the rich harmonic content – the post – processing circuitry (e.g. amplitude adjustment) needs to be of a higher bandwidth than for a single sine wave. Thus, it is not uncommon to see the square wave maximum frequency to be half or less of the sine wave maximum frequency. A similar comment applies for pulse generation, where the spectrum requirement can be even more demanding.

Some synthesizer provides specialized waveforms as added features. These are addition functions f(ξ) that are stored in the generator read only memory they can be useful for specialized task. Since these specialized waveform need to be generator accurately, their maximum output frequency will often be much less than the typical sine & square wave frequencies available from the generators.



("DDFS FUNCTION BLOCKS AND SIGNAL FLOW DIAGRAMS")

The main components of a DDFS are a phase accumulator, phase-to-amplitude converter (a sine look-up table), a Digital-to-Analog Converter and filter. A DDFS produces a sine wave at a given frequency. The frequency depends on three variables; the reference-clock frequency f_{clk} and the binary number programmed into the phase register (frequency control word, *M*), length of n-bit accumulator. The binary number in the phase register provides the main input to the phase accumulator.

V. PROBLM STATEMENT

Different problem statement for the describe the below in show.

A. Waves stability

The some problem function generator is wave's is not stable because resolutions change is wave's unstable and changes the amplitude so stability is not proper.

B. Environment effected

When a temperature is change for the environments so frequency phase & amplitude is change because due to the variation or the output and you have not aureate output waveform signal

C. The phase is adjustable

Some function generator use phase and amplitude adjustable used ring (nop) and that ring (nop) some time is automatic move and phase & amplitude is automatic change

VI. METHODOLOGY

The design of this waveform generator utilizes the theory of sampled-data systems. Sampling theorem states that a time-dependent function f (t) that is limited in bandwidth to f_m and sampled at a rate $f_s > 2f_m$ can be completely reconstructed from its samples. The waveform is a discrete time signal that processed all of the frequency components in the interval $0 < f < f_m$. Additional frequency components that are imposed by the sampling process appear in the interval $f > (f_s - f_m)$. Components are separated from the original frequency by a bandwidth of f_s - $2f_m$. If f(t) is sampled at a rate less than $2f_m$ samples per second, the undesirable components overlap the. Original components in the frequency spectrum, and consequently f(t) cannot be recovered from the original sampled signal. This phenomenon is known as aliasing. To reconstruct a function that has been sampled at the rate $f_s > 2f_m$, the sampled signal must be directed through a low-pass filter that has a cutoff frequency of f_m. The magnitude plot of the low-pass filter response must have a slope that is sufficiently steep in the cutoff region to reduce the magnitude of the lowest undesirable frequency component f_s - f_m to an acceptable level. Arbitrary function generator was designed to interface with a PC. This specific computer platform was chosen because it is very common in both industrial and scientific environments

VII. USER INTERFACE DESIGN

The arbitrary Waveform generated (AWG) had two modes of operation: command mode & Source mode. Source mode the AWG source the selected waveform specify frequency after the user start the waveform from the command mode. The command mode (which the AWG starts in at reset) the user navigates through a series of menus in order to setup the desired waveforms for sourcing set the frequency at which the AWG will source a waveform, or can select to start a waveform. When the user selects to change the frequency a prompt is shown at which the user enters the frequency in decimal from 0 to 9999 Hz. The frequency is not associated with any specific waveform. After the frequency is entered the AWG returns to the main menu. When the user selects to start the waveform she will be prompted for which waveform to Start and then that waveform will be initialized and source mode will be entered. The waveform may be stopped by pushing enter ('D') on the keypad returning the AWG to the main menu and the command mode.

VIII. THE OPERATION STAGE OF SYSTEM

The whole operation of the system can be listed as in the following steps:

- Training the ARM to obtain one and synapse weights which are appropriate to approximate the desired function.
- Applying pervious stage results to control unit of system that stores results in an internal memory assigned to this goal.
- Calculating desired frequency of wave and applying related number to the phase accumulator's input.

After initializing the system by related numbers, it goes to normal operation mode and generates the trained waveform by the specified frequency

IX. SYSTEM ANALYSIS

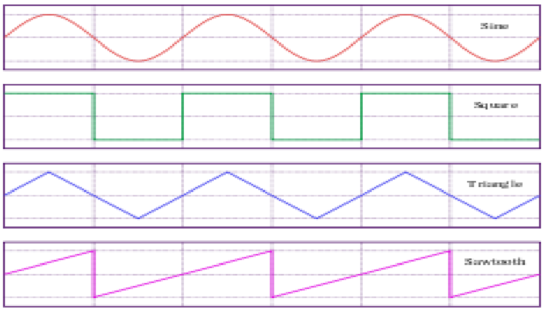
This system can be analysis waveform. This can be different type wave generated and check the phase amplitude & wave type this system used ARM-7 processor this processor is advance risc machine because this is reduced instruction set computer this is one pin 2 to 3 instruction and this is completed only one cycle for one instruction do not used more time. This is a high speed performance so this is used for the system. System is a stable, amplitude variation decreases, and high speed performance.AWG (Arbitrary Waveform Generator) this type waveform generated is easily can used look up table this table help for different type waveform generated because different type wave design for this system and easily to perform low coast and use for education lab. This is the computer interfacing and the this interfacing used you have online operate power plant, Pharmacy Company, any area for human is do not go that area so this generator used and operated for and give instruction. This can used hart bit sensor and see the hart bit wave oscilloscope. This system generated for saw tooth wave, triangular wave, squarwave and rectangular wave.

X. THE SYSTEM IMPROVMENT

The design of this project used for ARM-7. ARM-7 is the advance Risc machine and this processor take one cycle is completed instruction. The design of the AWG was limited partly by time which necessitated the use of code from previous labs which limited the way some of the parts of the AWG were implemented. The timer1 interrupt routine could be trimmed down quite a bit to provide less limitation on the maximum sample frequency. The minimum sample frequency could also be decreased by using a status register to count timer1 interrupts allowing samples to wait more than 65536 ticks before outputting. The user input system is also less than ideal. The menus could be implemented more cleanly so that there is a generic menu data type which can be loaded from Flash to specify each menu's contents while a state variable is used to indicate which menu the user is currently in. As it stands the AWG does not need this versatile menu system, but any additional menus would make the system easier to implement and control.

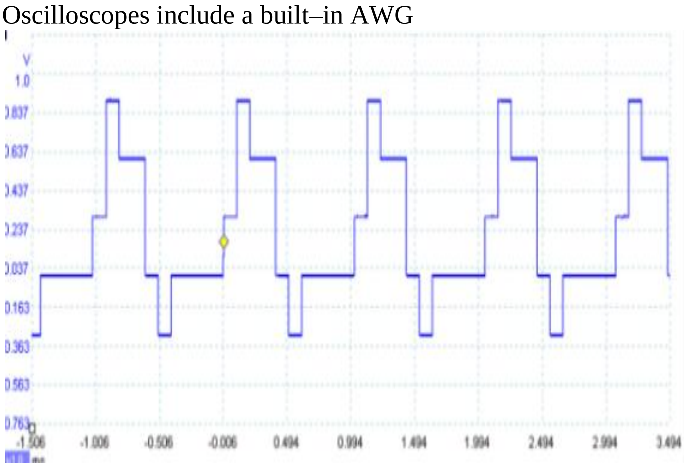
XI. CONCLUSION

This paper describes the design and operation of Low-Cost (AWG) Arbitrary Waveform Generator for Educational Environment using ARM-7 suitable for use in undergraduate laboratories as an analytical tool or as a student design project. Using custom software and a personal computer, this system can generate any function of time that can be represented. Describe of the analog & Digital function generator and whose is batter decided. This is used (DDS) direct digital synthesizer this explain the use ARM7 Processor this processor benefit for used this project. Analysis for the (DDS) direct digital synthesizer. This system generated for saw tooth wave, triangular wave, squarwave and rectangular wave



("DIFFERENT TYPE WAVE'S")

An arbitrary waveform generator (AWG) is an advanced signal generator that can generate a waveform of almost any shape. The generated waveform can then be inserted into the device you wish to test and then anal ysed as it progresses through the device to confirm correct operation, or to highlight a fault. Arbitrary waveform generators are often expensive and so are usually only found in high–end test equipment, however, several Pico Scope PC Oscilloscopes include a built–in AWG



("ARBITRARY WAVEFORM")

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