Microcontroller Based Direct Digital Synthesizer and FSK Modulator

Mahesh Bilagi, Manjunath Lakkannavar

Abstract- Many possibilities for frequency generation are open to a designer, ranging from phase-locked-loop (PLL)-based techniques or very high-frequency synthesis, to dynamic programming of digital- analog converter (DAC) outputs to generate arbitrary waveforms at lower frequencies. But DDS's ability to accurately produce and control waveforms of various frequencies and profiles has become a key requirement common to a number of industries. Whether providing lively sources of low phase-noise variable-frequencies with good spurious performance for communications, or simply generating a frequency stimulus in industrial or biomedical test equipment applications, convenience, compactness and low cost are important design considerations.

Keywords: - DDS and Digital to analog converter.

I. INTRODUCTION

Theoretical analysis of DDS technology gave an overview of the functioning of DDS; especially with respect to functionality and performance shift key generator developed using this technology embodies the power, flexibility and depth that this technology has to offer.

Nowadays the DDS technique is rapidly gaining acceptance for solving frequency (or waveform) generation requirements in both communications and industrial applications because single-chip IC devices can generate programmable analog output waveforms simply and with high resolution and accuracy.

Modern communications systems especially spread spectrum systems, are placing increasing demands on the resolution and bandwidth requirement of frequency synthesizer subsystem in order to gain analog improved performance. Today's spread spectrum applications require a frequency synthesizer that is capable of tunings to different output frequencies with extremely fine frequency resolution with the switching speed of the order of nanoseconds. The resolution requirements of many systems are so severe that they are surpassing the performance capabilities of conventional analog phase locked loop. Although limited by Nyquist criteria, DDS allows frequency resolution control on the order of milli-hertz or even nano-hertz of phase resolution control. The increasing availability of high speed DACs makes a direct digital approach to frequency synthesis and enticing alternative to conventional synthesizer.

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II. SYSTEM BLOCK DIAGRAM

2.1 MICROCONTROLLER AT89C52:

An 8-bit microcontroller with 8 Kilo bytes flash which provides the highly flexible and cost effective solution to many embedded control application. It is here used to accept the frequency from the keyboard, process it and present a 32-bit HEX value to the DDS. This is achieved through software programming.

2.2 DDS MODULATOR AD7008

The AD7008 direct digital synthesis chip is a numerically controlled oscillator employed a 32-bit phase accumulator, sine and cosine look-up tabled and a 10- bit D/A converter integrated on a single CMOS chip. The n bit value loaded to the AD7008 internally generates the frequency using the below given formula:

$f= (\Delta phase*fCLOCK)/2^n$, where $0 < phase < 2^{32}$

After internal processing the chip produces the output which is presented to the external environment through the pin I out. This output waveform can be observed on the CRO by connecting the Iout pin to one of the channels of the CRO.

2.3 KEYBOARD

It is used in the design to input the frequency. The 'key press' generates an interrupt to the processor (INT0), which initiates the rest of the process and finally produces the output corresponding to the input frequency.

2.4 LCD

LCD functions as a guide to the user, instructing the user to perform necessary actions by displaying the instructions on the LCD.

2.5 FUNCTIONAL DESCRIPTION

The system consists of two main components, the microcontroller AT89C52 and the DDS AD7008. The programmable peripheral interface, 82C55 is used to interface the microcontroller and the DDS chip. A keyboard and LCD display are interfaced to the microcontroller to provide the user inputs and guide the user respectively.

The system is reset on 'power on'. The user is guided to choose either of two modes of operations i.e., as a direct digital synthesizer or as a FSK modulator.

Mode 1: Direct digital synthesizer

The user is instructed to enter the required frequency on the keyboard. Each key press generates an interrupt to the microcontroller and the data is read into the microcontroller as explained in the keyboard operation. Once the user gives the input, the microcontroller generates the 32 bit value to be loaded into the frequency 0 register of DDS. This 32 bit value is now loaded into AD7008 through the programmable peripheral interface 82C55 in two cycles. The command register of AD7008 is chosen and configured for 16bit data bus mode. Now, frequency 0 register is selected by writing 0x08 in TC register.

The higher word of the 32bit data is first presented and the write pulse is given, at the falling edge of the write pulse the data is latched into the register. The lower word is then presented; simultaneously the TC register also loaded for frequency 0 register selections. The write pulse is given and at the falling edge of the write pulse, the entire 32 bit value is made available on the 32 bit parallel shift register of AD7008. at some time after the second falling edge of write pulse, the LOAD signal may go high.

The sine wave is now available at the IOUT pin of AD7008. Any frequency ranging 0-50MHZ can be realized using this setup successfully. To reduce the noise and distortions at higher frequencies active filters (using AD8031) can be implemented.

Mode 2: FSK Generator

FSK Generation requires that the user inputs 2 different frequencies to modulate the bits 0 and1. The user inputs the first frequency, say frequency 0 for bit 0 in a similar fashion as explained above. To enter the next frequency, the user needs to enter the mode selection button. Once this key is pressed, AD7008 is now configured for data to be entered into frequency 1 register. The timing diagram details remain the same but the TC register is now loaded with 0x09 instead. To generate the message signal for FSK We use a clock circuit using 555 timer with a frequency of 15Hz.

In the above two modes of operation the data can also be loaded into the 32 bit register from SRAM and FLASH memories by writing exhaustive LUTs for certain frequency ranges into the memories.

For successful implementation of the above, we need certain support circuitry.

A latch separates the data and address lines from the microcontroller with ALE signal. That apart, we also have bidirectional buffer that provides the extra current drive during read and write operations and sets the direction for read and write operations using NAND logic. We also have decoder for the addressing the devices as and when required. A more sophisticated 32-bit keyboard can also be interfaced with the system, for which communication can be provided by RS232 and MAX232 provisions made on the board.

The power supply considerations are taken care of by the voltage regulators. LM7912 and LM7905 provide 12V and 5V, respectively for the various chips as required.

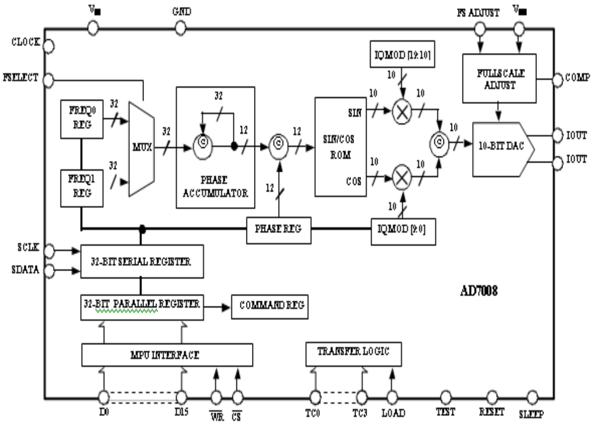
2.6 PRODUCT DESCRIPTION

The AD7008 direct digital synthesis chip is a numerically controlled oscillator employing a 32-bit phase accumulator, sine and cosine look-up tables and a 10-bit D/A converter integrated on a single CMOS chip. Modulation capabilities are provided for phase modulation, frequency modulation. In-phase and quadrature amplitude modulation techniques are suitable for QAM and SSB generation.

Clock rates up to 20 MHz and 50 MHz are supported. Frequency accuracy can be controlled to one part in 4 billion. Modulation may be effected by loading registers either through the parallel microprocessor interface or the serial interface. A frequency-select pin permits selection between two frequencies on a per cycle basis.

The serial and parallel interfaces may be operated independently and asynchronously from the DDS clock; the transfer control signals are internally synchronized to prevent metastability problems. The synchronizer can be bypassed to reduce the transfer latency in the event that the microprocessor clock is synchronous with the DDS clock.

A power-down pin allows external control of a power-downmode (also accessible through the microprocessor interface) The AD7008 is available in 44-pin PLCC.



III. CIRCUIT DESCRIPTION

The AD7008 provides an exciting new level of integration for the RF/Communications system designer. The AD7008 combines the numerically controlled oscillator (NCO), SINE/COSINE look-up tables, frequency, phase and IQ modulators, and a digital-to-analog converter on a single integrated circuit.

The internal circuitry of the AD7008 consists of four main sections. These are:

1. Numerically Controlled Oscillator (NCO) + Phase Modulator
2. SINE and COSINE Look-Up Tables
3. In Phase and Quadrature Modulators
4. Digital-to-Analog Converter

The AD7008 is a fully integrated Direct Digital synthesis (DDS) chip. The chip requires one reference clock, two low precision resistors and six decoupling capacitors to provide digitally created sine waves up to 25 MHz In addition to the generation of this RF signal, the chip is fully capable of a broad range of simple and complex modulation schemes. These modulation schemes are fully implemented in the digital domain allowing accurate and simple realization of complex modulation algorithms using DSP techniques.

Numerically Controlled Oscillator + Phase Modulator

This consists of two frequency select registers, a phase accumulator and a phase offset register. The main component of the NCO is a 32-bit phase accumulator which assembles the phase component of the output signal. Continuous time signals have a phase range 0 to 2π. Outside this range of numbers, the sinusoidal functions repeat themselves in a periodic manner. The digital implementation is no different. The accumulator simply scales the range of phase numbers into a multi bit digital word. The phase accumulator in the AD7008 is implemented with 32bits. Therefore in the AD7008, $2\pi = 232$. Likewise, the ΔPhase term is scaled into this range of numbers $0 \leq$□ΔPhase $\leq 232 - 1$.Making these substitutions into the equation above:

f=≤□Δphase x fCLOCK/2^32 where 0<Δphase<2^32

With a clock signal of 50MHz and a phase word of 051EB852 hex:

F=51EB852 x 50MHz/2^32=1.000000000931MHz

The input to the phase accumulator (i.e., the phase step) can be selected either from the FREQ0 Register or FREQ1 Register, and this is controlled by the FSELECT pin. The phase accumulator in the AD7008 inherently generates a continuous 32-bit phase signal, thus avoiding any output discontinuity when switching between frequencies. This facilitates complex frequency modulation schemes, such as GMSK.

Following the NCO, a phase offset can be added to perform phase modulation using the 12-bit PHASE Register. The contents of this register are added to the most significant bits of the NCO.

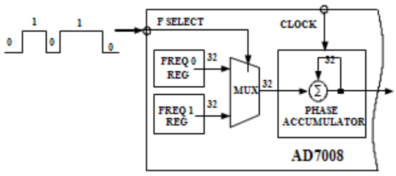
Sine and Cosine Look-Up Tables

To make the output useful, the signal must be converted from phase information into a sinusoidal value. Since phase information maps directly into amplitude, a ROM look up table converts the phase information into amplitude. To do this the digital phase information is used to address a Sine/Cosine ROM LUT. Only the most significant 12bits are used for this purpose. The remaining 20 bits provide frequency resolution an minimize the effects of quantization of the phase to amplitude conversion.

Digital-to-Analog Converter

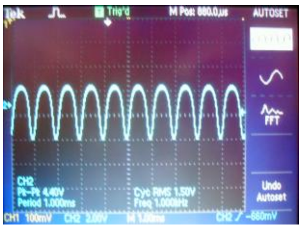
The AD7008 includes a high impedance current source 10-bit DAC, capable of driving a wide range of loads at different speeds. Full-scale output current can be adjusted, for optimum power and external load requirements, through the use of a single external resistor (RSET).

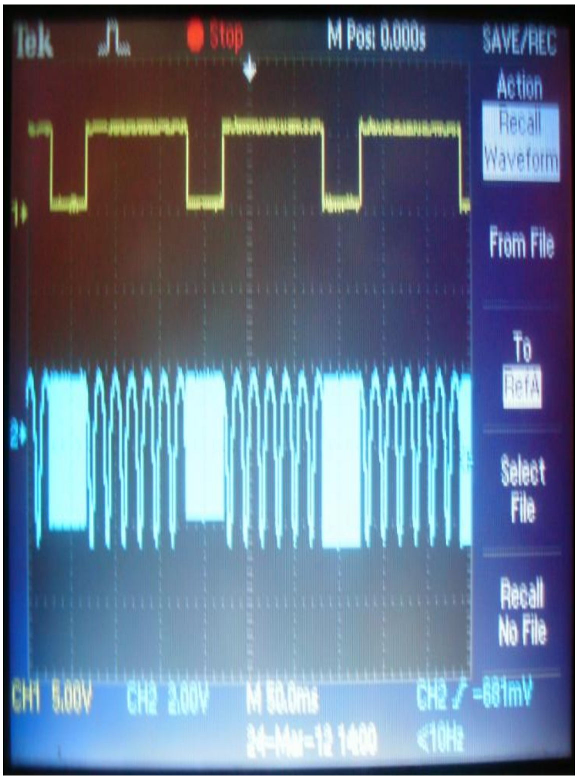
The DAC can be configured for single or differential-ended operation. IOUT can be tied directly to AGND for single-ended operation or through a load resistor to develop an output voltage. The load resistor can be any value required as long as the full-scale voltage developed across it does not exceed 1 volt. Since full-scale current is controlled by RSET, adjustments to RSET can balance changes made to the load resistor.



The AD7008 has three registers that can be used for modulation. Besides the example of frequency modulation shown above, the frequency registers can be updated dynamically as can the phase register and the IQMOD register. These can be modulated at rates up to 16.5 MHz. The example shown below along with code fragment shows how to implement the AD7008 in an amplitude modulation scheme. Other modulation schemes can be implemented in a similar fashion.

IV. RESULT





The above snap shot shows the output of the system as frequency synthesizer. The frequency entered through the keyboard is displayed on CRO.

Now, the mode of the system is changed by pressing the "MODE" button on the keyboard. The system functions as FSK generator. This allows the user to enter a second frequency.

V. CONCLUSION

A microcontroller based direct digital frequency synthesizer and FSK generator has been successfully designed tests and implemented. The DIRECT DIGITAL TECHNOLOGY has been successfully utilized using microcontroller to develop a highly accurate and precise system which provides a good operating frequency range. The correctness and liability of the subsystem have been scrutinized during the development stages. The overall system has been verified by producing frequencies with a high degree of accuracy and precision.

DDS based function generator are just beginning to appear in the market. These function generators offer substantial performance improvements, at reduced costs, over conventional analog function generators. As the costs of ASIC's RAM's and DAC's decline, while their speed and resolution increased, expect to see DDS based function generators soon replace their analog counterparts.

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