DESIGN AND DEVELOPMENT OF LOW COST FLIGHT TERMINATION SYSTEM ENCODER BASED ON DDS AD9850 FOR FLIGHT VEHICLE

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Abstract

FTS (flight termination system) is a system that used to terminate a mission on the air vehicle such as; rocket, aircraft, and UAV (unmanned air vehicle). FTS is basic safety on the rocket launch for anticipation mission fail. FTS consists 2 systems; encoder system (in transmitter system) and decoder system (in the receiver system). This research just focused on the FTS encoder with generates the sine waveform as signal tone. The method transmitted FTS signal by using radio transceiver HT (handy-talky) with frequency VHF and the audio frequency as the FTS signal tone. The encoder system can generate the audio frequency from 20 Hz till 20 KHz as sine waveform by use DDS method. The experiment results shown that the DDS AD9850 can generate the sine waveform from 0 Hz till 40 MHz depend on the frequency given.

Key Words: FTS, Encoder, DDS Method, Sine Waveform, Audio Frequency.

Nomenclature

DDS	:Direct digital synthesis
F_{out}	: Frequency Output
CLKIN	: Clock Input
W_clk	: Word Clock
Fq_ud	: Frequency Update
Gnd	: Ground
Vcc	: Voltage Input

1. INTRODUCTION

Mastery in aerospace technology especially rocket technology becomes Indonesia has diplomatic bargain with another countries. Some countries that had have ability in rocket technology especially for satellite launch vehicle (SLV), such as USA, China, Russia, and India [7]. Indonesia country had begun mastery rocket technology since 1963 and LAPAN has focused research on SLV technology since 2010. There are some development countries have tried hard to mastery SLV (satellite launch vehicle) technology.

Commonly SLV consists 3 stages, first and second stages are motor rocket, and the third stage consists some satellites which are going to orbit. The safety area of the launching SLV must be attention to the regulation SLV's company first. SLV must consist of the system which can terminate the mission if not on the track. Some methods could be applied to terminate the SLV mission; such as the SLV will be bombed in the air or SLV will be controlled from ground station to safety area [8].

FTS (flight termination system) is the system which can terminate the mission of air vehicle such as; rocket, UAV, etc [9]. This system could be controlled from ground station, by transferring the secret command. FTS consist 2 parts, the first part is transmitter system and the second part is receiver system. The transmitter system is on the ground station position which has task to send the command to the receiver system. The receiver system is on the air vehicle which has task to do the action if get command from the transmitter system. The command data must be secreted, nobody knows the data except the person who has responsibility on the task FTS procedure. The command data of the FTS system is not text data, but the frequency data. The frequency data is more accurately than the text data. The FTS system must be fast in the response due to the air vehicle fastly.

In this research would be focused on the part of the FTS transmitter system or encoder system. To send the frequency data, the frequency carrier VHF (very high frequency) would be used. The HT (handy talky) has two kinds of frequency, VHF 30MHz-300MHz [4] and UHF (ultra high frequency) 300MHz-3GHz [3]. The HT can broadcast the audio frequency of the person, 20Hz-20kHz [8]. To detect the audio frequency as a signal command from the FTS transmitter, the IC LM567 can do well. Before LM567 process the frequency input, this frequency must be filtered by band pass filter. The tone audio

frequency can be generated the sine wave. To generate sine wave, there are some method can be used, such as a microcontroller with some passive circuit, function generator, counter, oscillator, DDS (direct digital synthesis), etc. The easy of the change the tone frequency input and the stable sine wave must be considered. The DDS system is easy way to generate sine wave and change it. The chip IC DDS AD9850 could be used to generate the sine wave or square wave from frequency 1Hz till 40MHz. In the research of the design FTS transmitter system, the focused on the using the DDS AD9850 as the generate tone audio frequency with the sine waveform.

2. DDS AD9850 METHOD

DDS (direct digital synthesis) is a type of frequency synthesizer used for creating arbitrary waveforms from single, fixed frequency reference clock [1]. The application of DDS are as signal generation, local oscillators in communication systems, mixers, modulators [2], sound synthesizer, function generators, and as part of a digital phase-locked loop [3]. The DDS method could be built from a simple circuit (resistor, capacitor, and inductor) as like in Fig. 2-1 [6] or in one chip IC as like in Fig. 2-2 that is DDS AD9850 [1]. To implement the DDS method in software, it needs four passive components; resistor, capacitor, inductor, and potentiometer. The sine wave looks up table as a list of numerical values of one sine period stored as constant.

The chip IC AD9850 is a highly integrated device that uses advanced DDS technology coupled with an internal high speed, high performance DAC (digital to analog converter) and comparator to complete the form, clock generator function and programmable frequency synthesizer digitally. The AD9850 can generate a spectrally pure, frequency/phase programmable, analog sine wave, when it is referenced to an accurate clock source. The output sine wave can be used directly as frequency source or converted to a square wave for clock generator application.

DDS is very useful in digital techniques for instrumentation and communication systems which can be made digitally-controlled method of generating multiple frequencies from reference frequency source. The basic DDS architecture is shown in Fig. 2-3. In that architecture, a stable clock drives a PROM (programmable-read-only-memory), this function stores one or more integral number of cycles of a sine wave or other arbitrary waveform). Each memory location save the counter step based on the address, the analog output signal is generated by DAC as the corresponding digital amplitude. The DAC determines to the spectral purity of the final analog output signal. DDS system is based on a sampled data system, thus all the issues involved in sampling must be considered, such as filtering, aliasing, quantization, etc.

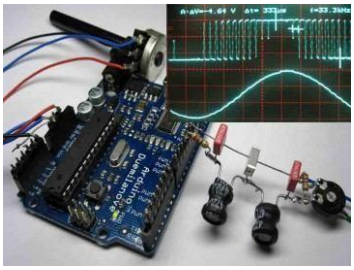


Figure 2-1 Arduino Sine Wave Generator with Simple Circuit of DDS Method [6)]

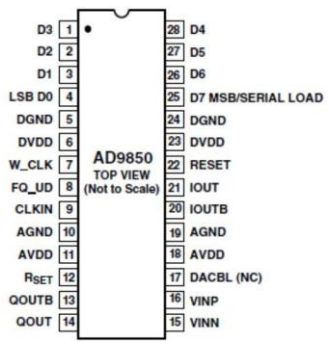


Figure 2-2 DDS IC AD9850

The DDS chip IC (integrated circuit) AD9850 has two methods to control it, serial or parallel method. In the serial method, it just needs 6 pins connections, Vcc, Gnd, Clkin, W_clk, Fq_ud, serial data, and Reset. Meanwhile in the parallel method, there are 14 pins reach 8 bits for data, another pin for; Vcc, Gnd, Clkin, W_clk, F_ud, and reset. The AD9850 uses digital synthesis (DDS) technology directly which generates a frequency sine wave or square wave. An internal 10-bit high speed DAC converts the digital sine wave to analog form. An on-board high speed comparator translates the analog sine wave into output square wave. Fig. 2-3 shows the basic fundamental block diagram of AD9850 and signal flow. Eq. (1) shows the relationship of the output frequency, reference clock, and tuning word of the AD9850.

$$f_{out} = (\Delta Phase x CLKIN) / 2^{32} \qquad (1)$$

Where :
Phase is the 32-bit tuning word value.
CLKIN is the input reference clock frequency in MHz.
Fout is the output signal frequency in MHz.

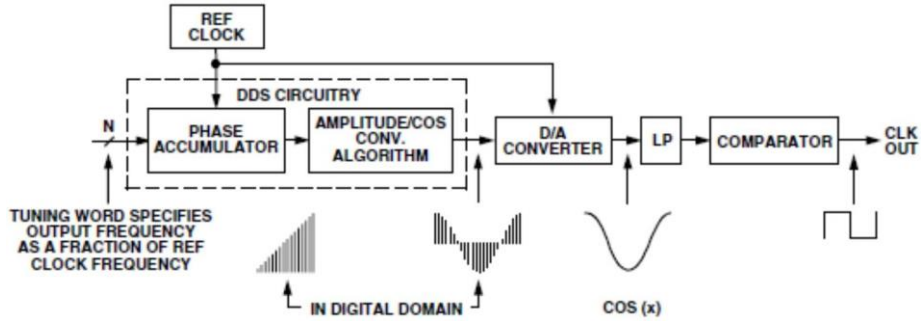


Figure 2-3 The Basic DDS Diagram and Signal Flow AD9850 [1]

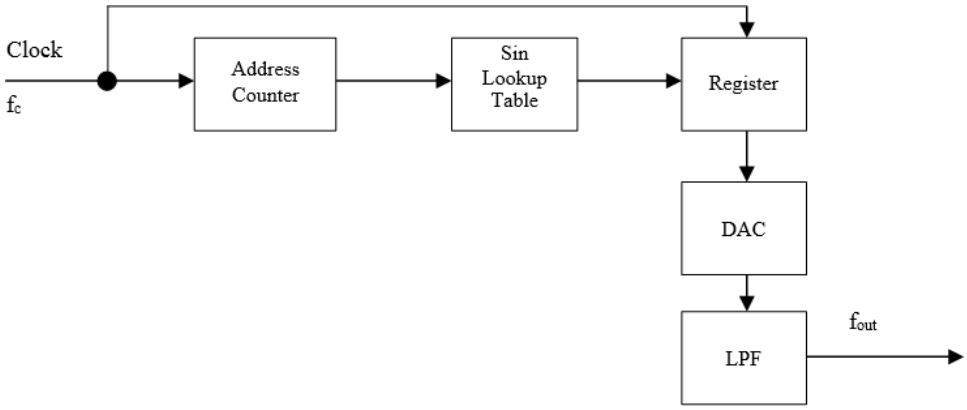


Figure 2-4 The Basic Fundamental DDS System

3. ENCODER DESIGN BASED ON DDS AD9850

3.1. Circuit DDS AD9850

The chip IC AD9850 is the IC which can generate sine wave or square wave based on DDS method. This IC still need some passive electronic components, such as resistor, capacitor, and crystal. The AD9850 can drive an output frequency resolution of 0.0291 Hz with using reference clock is 125 MHz. Fig. 3-1 shows the DDS circuit with IC AD9850 and some support components, clock reference, and filter circuit. The serial data is as setting frequency and phase from microcontroller or computer can

be connected in pin D7.

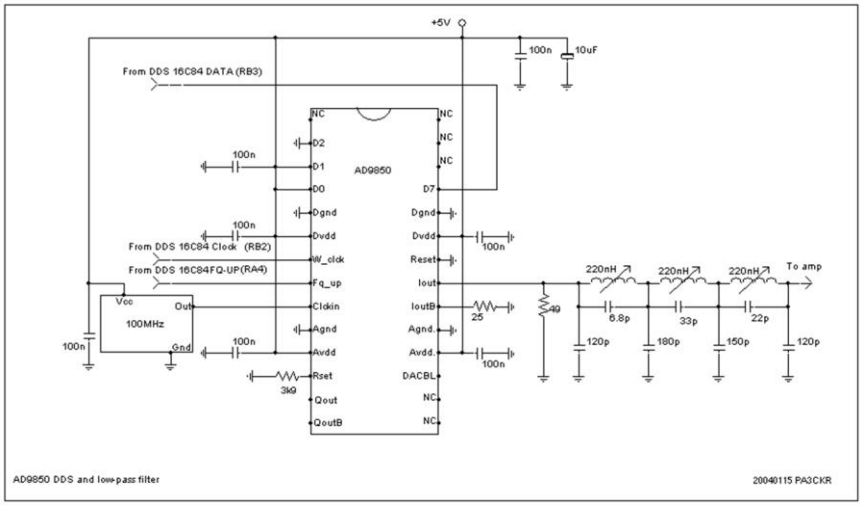


Figure 3-1 Schematic DDS AD9850 [10)]

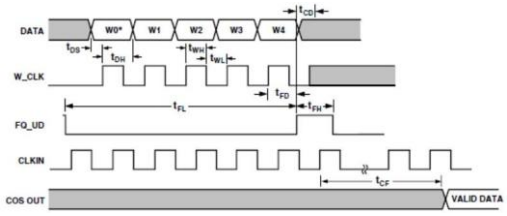
3.2. Programming DDS AD9850

There are two methods for program DDS AD9850, parallel or serial method. The AD9850 has 40 bits register which is used to program the 32 bits frequency control word, 5 bits for phase modulation word, and the last bits for power-down control. The register can be programmed via parallel or serial mode. In the parallel mode, the register is programmed via 8 bits bus data, 40 bits need 5 iterations from 8 bit word. FQ_UD and W_CLK pins as signals are used to address and load registers. The rising edge of FQ_UD loads 40 bits control data word for the IC and resets the address pointer registers number 1. Then W_CLCK rising edges load 8 bits data on words [7:0] and move the pointer to next register. W_CLCK edges are ignored after 5 loads until either a reset action or FQ_UD rising edge the address pointer to first register.

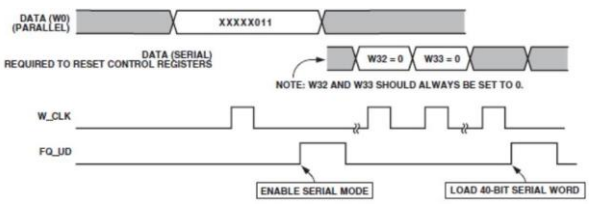
In serial mode, the rising edges of W_CLK shift the first bit data to Pin 25 [D7] for 40 bits of programming information. After 40 bits are shifted, the FQ_UD pulse is needed to update the output frequency or phase. Table 3.1. shows the function assignments of the data and control words. Fig 3.2. shows the timing diagram of the updating output frequency and/or phase for parallel mode and serial mode, in series.

Table 3-1 8 Bits Parallel Load Data/Control Word Functional

Word	Data[7]	Data[6]	Data[5]	Data [4]	Data[3]	Data[2]	Data[1]	Data[0]
W0	Phase b4 (MSB)	Phase b3	Phase b2	Phase b1	Phase b0 (LSB)	Power down	Control	Control
W1	Freq b31 (MSB)	Freq b30	Freq b29	Freq b28	Freq b27	Freq b26	Freq b25	Freq b24
W2	Freq b23	Freq b22	Freq b21	Freq b20	Freq b19	Freq b18	Freq b17	Freq b16
W3	Freq b15	Freq b14	Freq b13	Freq b12	Freq b11	Freq b10	Freq b9	Freq b8
W4	Freq b7	Freq b6	Freq b5	Freq b4	Freq b3	Freq b2	Freq b1	Freq b0 (LSB)



a. The Timing Diagram for Parallel Mode



b. The Timing Diagram for Serial Mode

Figure 3-2 The Timing Diagram to Program AD9850 [4]

4. EXPERIMENT RESULT AND DISCUSSION

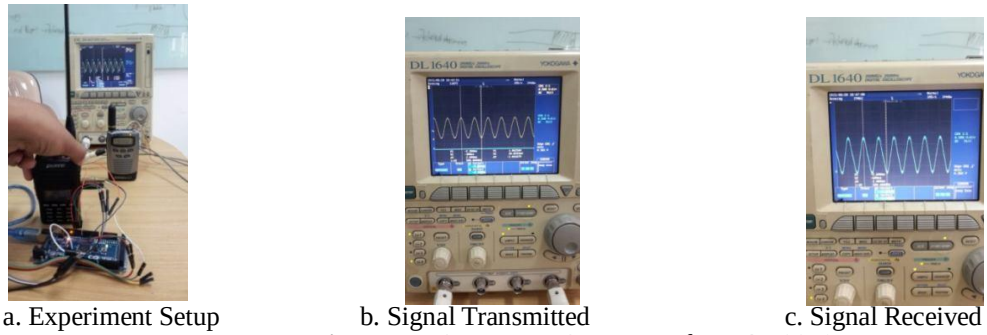
Generating sine wave from DDS AD9850 is controlled by arduino mega2560 and the serial mode for DDS AD8950 is chosen. The setting some parameters of DDS AD9850 via programming arduino mega2560 that the AD9850 can generate the sine wave from 1Hz till 40MHz. The arduino 2560 is common microcontroller board for many applications in electronics area. To program this board, the connection from the board to computer is via USB cable and connection from arduino to DDS AD9850 via pin. The high level language C++ is used to make program for arduino 2560. Fig. 4-1 shows the experiment setup of generating sine wave from DDS AD9850 with frequency 500Hz. The block diagram is for serial mode, it functions to generate sine wave for DDS AD9850 can be seen in Fig. 4-2. There are 2 handy-talkies which are used with frequency 344.000Hz, 1 is transmitter and the other for receiver. The sine wave is transmitted by handy-talky via the microphone in transmitter part. Meanwhile the receiver part of sine wave data is form the loudspeaker output. The handy-talky is the common tools as communication for far distance. Due as the handy-talky can transmit and receive the audio frequency. The human being voice frequency is between 20Hz till 20kHz. Therefore, in this research the audio frequency is chosen. In commonly that the audio frequency is also called as tone signal. In many fields that the tone signals can give some benefit, such as for Morse signal. As shown in Fig. 4-1.a is the input signal with frequency 500Hz and Fig. 4-3.a is also the output which has the same frequency 500Hz. The sine wave with yellow color is the input and sine wave with blue color is the output. The Fig. 4-1.b. is more detail about the sine wave of the input and Fig. 4-1.c. is the output.

The output of DDS AD9850 is sine wave or square wave depends on the setting of the output. In the sine wave, the output phase is 180^0, 90^0, 45^0, 22.5^0, 11.25^0, and any combinations. The reference clock for AD9850 is 125MHz, based on Eq. (1) to get the delta phase for frequency 500 Hz as follow. The value 25769 will be converted to binary for control the AD9850 generate sine wave 500 Hz. The process programming of the arduino mega 2560 based on the block diagram on Fig. 4-2. The first step that the microcontroller must make initialization of the pin input-output arduino mega2560 which is connected to the AD9850, then calculation delta phase based on the value frequency given. The fellow code of arduino is the code for programming mega 2560 for generating sine wave from the IC AD9850.

```
void sendFrequencyb(double frequency)
{
  int32_t freqb = frequency * 4294967295/125000000;
  for (int bb=0; bb<4; bb++, freqb>>=8)
  {
    tfr_byteb(freqb & 0xFF);
  }
  tfr_byteb(0x000);
  pulseHigh(FQ_UDb);
}
```

DDS AD9850 can generate many kinds frequency recurring by change the frequency commands in the loop of the program. The Fig. 4.3 shows 2 kinds of the frequency output from AD9850, 300Hz and 1300Hz.

$$\Delta Phase = (f_{out} * 2^{32}) / CLKIN$$
$$\Delta Phase = (500 * 4294967296) / 12500000 \qquad (4.1)$$
$$\Delta Phase = 25769.8 \approx 25769$$



a. Experiment Setup b. Signal Transmitted c. Signal Received

Figure 4-1 Generating Sine Wave from AD9850

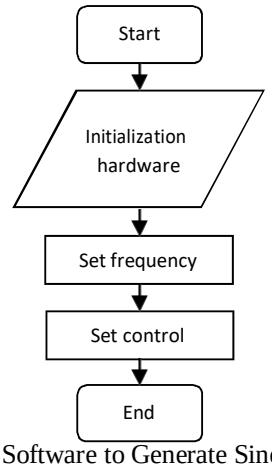


Figure 4-2 Block Diagram Software to Generate Sine Wave from AD9850

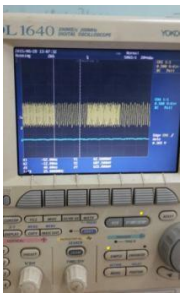


Figure 4-3 DDS AD9850 Generates 2 kinds of frequency

5. CONCLUSION AND FUTURE WORKS

The AD9850 is the chip IC which can generate sine wave or square wave from frequency 1Hz until 40MHz with DDS method. The FTS encoder with tone frequency can be build from DDS AD9850, 1Hz till 20KHz. The chosen audio frequency in this FTS system, due to the transceiver is handy-talky with VHF (very high frequency) or UHF (ultra high frequency) frequency. The input of frequency signal can be connected to microphone of handy-talky. Meanwhile the output of receiver signal can be connected to the speaker pin of AD9850.

To avoid jamming from another people who doesn't have responsibility, so the FTS encoder can be driven from many kinds of the frequency, such as two or three kind frequencies.

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