A SIMPLE LOW COST FUNCTION GENERATOR CONTROLLED BY ANDROID APPLICATION

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Abstract
An elementary, low cost function generator controlled by Android application is described in this paper. The controlled function generator is based on the ESP32 general purpose development board and AD9833 – programmable waveforms generator - module, capable generating frequencies 0 - 12.5MHz of sine, triangle or square wave signal.
The Android application is developed using MIT App Inventor – an intuitive, visual programming environment, while the communication between the hardware and application has been based on Bluetooth technology. Such realization significantly reduced the hardware complexity and the price of the device.
The realized function generator is unipolar, but it can be bipolar with slightly additional modifications. It was developed for laboratory testing purposes.

Keywords: function generator, bluetooth, MIT App Inventor, ESP32 board, AD9833 programmable function generator, sine wave, Android, direct digital synthesis - DDS.

INTRODUCTION

Function generator is one of numerous laboratory devices uses for frequency excitation, test equipment, defect detection, semiconductor component testing, equipment testing in cellular and wireless systems, broadcasting, television and radio systems etc [1]. It is almost inevitable device in every laboratory. The standard function generator is a complex device whose price amounts a few hundred dollars.

Some of the standard waveforms produced by the function generator are the sine wave, square wave and triangular wave. The newer function generators can produce additional cardiac pattern wave, Gaussian pulse waves and arbitrary waves [2].

There are mainly two types of function generators - analog and digital [2, 3, 4]. Analog are based on pulse integrated circuits while digital function generators utilize digital technology to generate the waveforms. Most versatile and most widely used technique for digital function generators is to use direct digital synthesis – DDS [1, 2]. DDS uses a phase accumulator, a look-up table containing a digital representation of the waveform, and a DAC [5]. Digital function generators offer high levels of accuracy and stability and also provide a high spectral purity and low phase noise. A DDS based digital function generator can also be swept over a much wider frequency range than an analogue function generator. It can also perform a number of other functions such as phase continuous frequency hopping because of the action of the direct digital synthesizer.

This paper describes a programmable digital function generator with standard outputs, controlled by Android application via bluetooth connection. All of the controls are implemented in the application in order to reduce the cost of the device. The hardware of the device consists of only AD9833 module [5] and ESP32 development board [6].

HARDWARE ARCHITECTURE

The proposed device is very simple and inexpensive, based on AD9833 versatile, easy to use direct digital synthesis waveform generator on a chip [5]. The output frequency and phase are software programmable, allowing easy tuning the frequency from 0.1Hz to 12.5MHz. The frequency registers are 28 bits wide. With a 25 MHz clock rate, the frequency resolution of 0.1Hz can be achieved while with a 1MHz clock rate, the AD9833 can be tuned to 4mHz resolution. The AD9833 has a 3-wire SPI serial interface operating at clock rates up to 40MHz and is compatible with DSP and microcontroller standards.

The internal circuitry of the AD9833 direct digital synthesis chip consists of the following main sections: a numerically controlled oscillator (NCO), frequency and phase modulators, SIN ROM, a 10-bit DAC, and a voltage regulator. The DAC generates an output voltage of typically $0.6V_{pp}$. The chip operates with a power supply from 2.3V to 5.5V.

With the addition of one SPI controlled digital potentiometer and an operational amplifier, the AD9833 module board, available on the market, was obtained, Fig. 1.

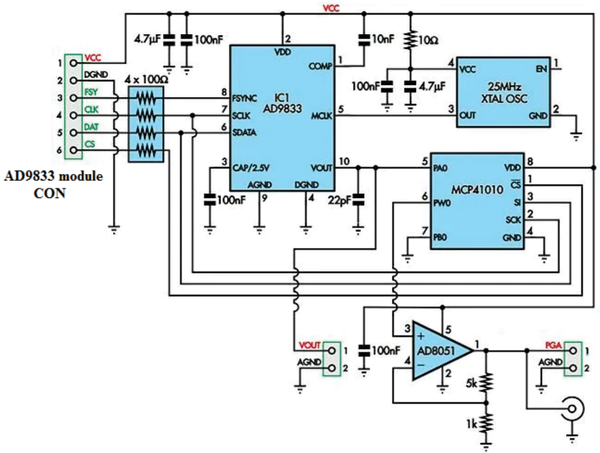

Fig. 1. *AD9833 module*

As can be seen in Fig. 1, the digital potentiometer MCP41010 [8] of 10KΩ-nominal resistance and 256-position has the role of the divider of the output voltage of AD9833. Its output is then amplified six time by operational amplifier AD8051. In such a way the programmable amplitude of the waveform generator was enabled.

The AD9833 module is connected to ESP32 development board which control the module.

ESP32 is a low-cost system on chip (SoC) microcontroller from Espressif Systems [6], It is a successor to ESP8266 SoC and comes in both single-core and dual-core variations of the Tensilica's 32-bit Xtensa LX6 microprocessor with integrated 2.4GHz Wi-Fi and dual-mode bluetooth connectivity. The microprocessor operates at 160 or 240MHz of the clock and performs up to 600 DMIPS. ESP32 integrates an antenna switch, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. As such, the entire solution occupies minimal printed circuit board (PCB) area. Typical ESP32 development board, Fig. 2, is based on ESP-WROOM-32 module available in the market.

Fig. 2. *ESP32 development board*

As can be seen from the Fig. 2, the ESP32 board consists of the following:

- ESP-WROOM-32 Module
- 30 I/O pins
- CP2012 USB to UART Bridge IC
- micro–USB connector (for power and programming)
- AMS1117 3.3V voltage regulator IC
- enable button (for reset)
- boot button (for flashing)
- power LED
- user LED connected to GPIO2
- some passive components

The ESP32 board is selected for control the AD9833 module via bluetooth connection of the board and Android application. In the Fig. 3 is shown a way of connection the ESP32 board to the AD9833 module. As can be seen, the communication between the ESP32 and AD9833 module is established by hardware SPI serial communication interface with two slave select lines, one FSY for AD9833 chip and second CS for MCP41010 digital potentiometer.

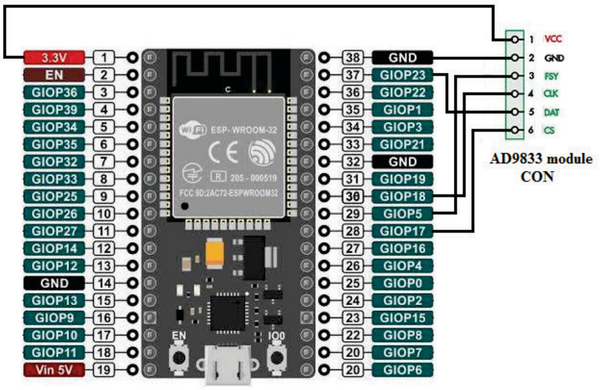

Fig. 3. Connecting the ESP32 board to the AD9833 module

The firmware for ESP32 board was developed under Arduino IDE using MD_AD9833.h library for programming AD9833 chip. This library provides access to all on-chip features.

THE CONTROL APPLICATION

To realization the control Android application was used an intuitive, visual programming environment that allows the creation of fully functional applications for Android phones or tablets, known as MIT App Inventor [7]. Blocks-based tool facilitates the creation of complex applications for significantly less time than traditional programming environments. Owing to that, the created control application is based on a relatively simple graphical code.

The MIT App Inventor consists of the Designer and the Block editor. The Designer serves for the application interface creation, while the Block editor lets the graphical programming of the application by putting blocks together.

In the Fig 4 is shown the appearance of the application interface to control the simple function generator. The application interface was created to Android mobile phone and consists of more buttons, text boxes, labels and one slider. By pressing the '*Connect*' button, after start the application, a list of available bluetooth devices appears. It is necessary to select the ESP32_FG device in order to establish connection between the mobile phone and the function generator. The function generator is initially turned off. After setting the frequency by entering the frequency value and then by pressing the button '*ENTER FREQ.*', it is necessary to select one of the three waveforms by pressing one of the three buttons with images of the waveforms.

The label below the waveforms selection buttons shows the selected waveform while the label below the text box for frequency entering shows the selected frequency value.

The amplitude of the selected waveform can be changed by changing the position of the slider. The amplitude is set in percent of full scale. There is a label with selected amplitude in percent below the slider, also.

Fig. 4. The function generator application interface on a mobile phone

When an excitation time limit is desired by the output of the function generator, a countdown timer can be used. This timer automatically turns off the function generator after the time specified in seconds has elapsed. The remaining operation time in seconds is displayed on the label below the button '*ENTER TIME*'. The described functionality does not have to be used if the time input button '*ENTER TIME*' is not used. All text labels in Figure 4 have built-in speech support.

Described application interface is very simple to control the function generator. The main disadvantage is the inability to adjust the offset of the selected waveform but this functionality is not support by the device hardware.

Fig. 5. *Block diagram of the application interface implemented in the MIT App Inventor*

Fig. 5 shows the graphical programming of the bluetooth application interface, implemented in the MIT App Invertor environment and based on the block diagram.

On the left side of the diagram are show blocks for the client initialization before and after list picking of the bluetooth devices. Then follows the blocks corresponding to the function generator off button and to the buttons for selecting one of three waveforms. This blocks send the corresponding data packets to the ESP32 development board via bluetooth, and have text to speech conversion support.

On the right side of the diagram are show two timer blocks used together with ‘*ENTER TIME*’ button for countdown time setting and turning off the generator after this time has expired. Next two blocks related to work with buttons ‘*ENTER FREQ.*’ for frequency entering and amplitude adjustment of the waveforms by the slider, respectively. Last three blocks have the text to speech conversion support.

As can be seen from Fig. 5, the application algorithm is relatively simple, intuitive and clear.

CONCLUSION

A simple low cost solution of the classic function generator was constructed for laboratory test purposes. The bluetooth based Android application for mobile phone or tablet replaces the necessary hardware box to adjustment the frequency, amplitude and to selection waveforms. For this purpose, an integrated, programmable DDS function generator - AD9833 module board, available on the market, was used as well as an ESP32 system-on-chip development board. Despite the advantages of the proposed solution compared to the conventional devices of this type, its main disadvantages are: inability to adjust waveform offsets and generated unipolar waveforms.

The mentioned disadvantages can be eliminated by slight modification the circuit of the AD9833 module and the Android application interface.

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