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PHYSICAL SYSTEM ANALYSIS USING MATLAB

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Abstract - *An important parameter of any system is its stability which is defined with the help of poles. If the transfer function of a system is available its poles and zeros can be find out easily. Then it is also possible to define delay and gain parameters of the system. The transfer function is usually derived using either poles and zeros or numerators and denominators. Here the transfer function of a physical system is derived using input and output streams. Any Physical system like motor, filter etc., is fed with the input signal, with help of "stm32f407" processor and thus we got the corresponding output using ADC that fed to computer via UART. In this contribution high pass filter used as a physical system, fed with square wave as a input signal and obtained the corresponding output. After importing these input and output streams in MATLAB the transfer function is plotted, thus defining various parameters of the system.*

***Key Words*: STM32f407, Cortex M4 and FTDI, IDENT tool.**

1. INTRODUCTION

Using physical system analysis transfer function of system is derived. Transfer function helps us to define various parameters like stability, gain, delay etc. Stability is an important parameter of a system, which is defined by poles, if poles are present at left half of s-plane then system is stable system otherwise unstable or partially stable. Similarly delay is also defined. Delay can be removed by changing the values of component. In this contribution to determine transfer function input and output stream are used. These input and output streams are determined as per figure(2).

Stm32F407 discovery board consist of Cortex M4 processor working at a frequency of 168 MHz, which can be programmed as per the requirement through KEIL software. It has 40 pins, 16 stream DMA (Direct Memory Access) controller with FIFOs (First In First Out) algorithm and input/output ports with interrupts capability. DMA can store readings simultaneously even when the program is running. This is a advantage of stm32f407 processor. In stm32f407 processor the sampling frequency can also be defined.

Using PE6 pin as a GPIO (General Purpose Input Output) pin and PC1 pin for reading analog output of the system using ADC (Analog to Digital Convertor).PC10 and PC11 pins are used as a UART (Universal Asynchronous Receiver/Transmitter) pins. PC10 pin is used as data transmitter and PC11 is used as data receiver port.

FTDI stands for "Future Technology Device". It is used as a single chip USB, to transfer serial data asynchronously .We have employed FT232 as FTDI. FT232 is a 6 pins board. Out of 6 pins, we are using 3 pins, Rx(receiver), Tx(transmitter) and GND(ground). Here we have utilized first order HPF (High Pass Filter) as our physical system.

FTDI supports data transfer rate from 300 baud to 3 Mega baud. In our program, a baud rate of 115200 is used. UART interface support 7 or 8 data bits, 1 or 2 stop bits.

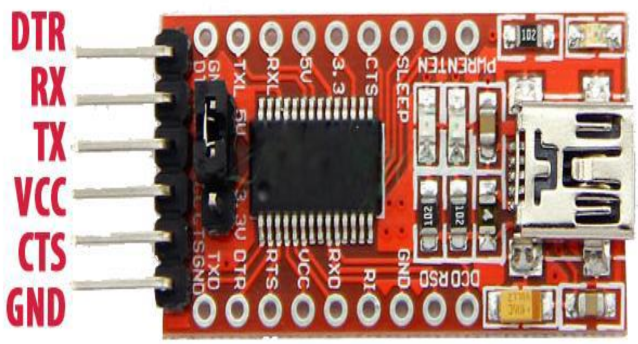

Figure1. FT232 pin diagram

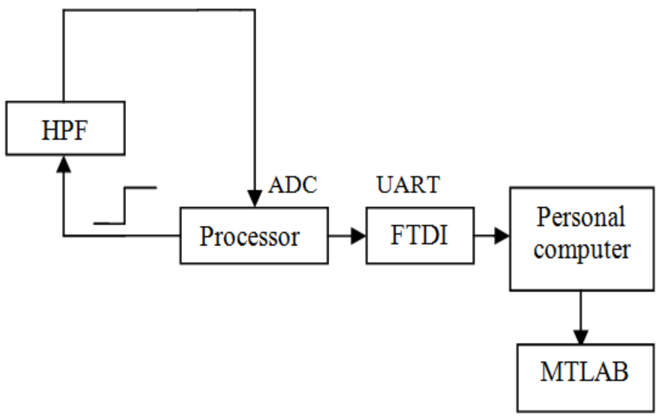

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Figure 2. Basic block diagram representation

2. INTERFACING

The input stream is fed to HPF through PE6 pin and the corresponding output is recorded using ADC that is in build to the STM32F407 processor. The input and output streams are transferred to the computer via UART. Here FT232 based FTDI is used for interfacing stm processor with computer that convert UART to USB. The transmit (Tx) and receive(Rx) pin of FTDI are connected with pin PC11 and PC10 of the STM board respectively. The received readings can be seen on computer screen via hyper terminal. These input and output stream are imported in MATLAB[1].For the purpose of plotting the streams, only 500 readings of these streams are utilized. Both input and output streams are plotted with respect to time in MATLAB. Using system identification tool (ident), the transfer function of first order high pass filter is determined. In system identification tool poles and Zeros can be defined as per our requirement, if higher order transfer function is required then change the number of poles to get the corresponding output. With the help of derived transfer function, step response is plotted.

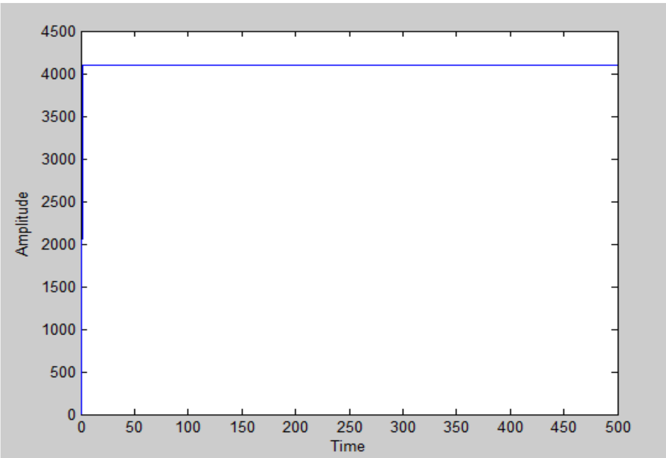


Figure 3. Input of high pass filter

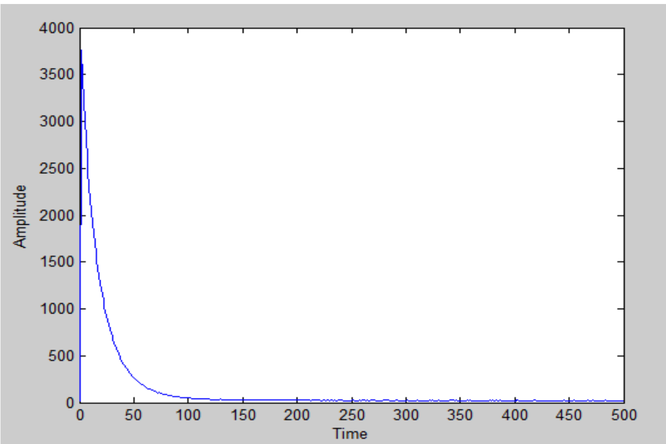


Figure 4. Output of high pass filter

3. TRANSFER FUNCTION

Transfer functions are used to calculate the response y(t) of a system to a given input signal x(t).Here t used for time[2].

In a simple system, the output y(t) may be governed by a second order differential equation

$$a_2 \frac{d^2 c}{dt^2} + a_1 \frac{dc}{dt} + a_0 c = y(t) \quad (1)$$

The properties of time-invariant linear systems can be expressed by a rational algebraic polynomial. Transfer function of a linear time invariant system can be determined from the system differential equation by taking the one-sided Laplace transformation and ignoring all initial values [3].

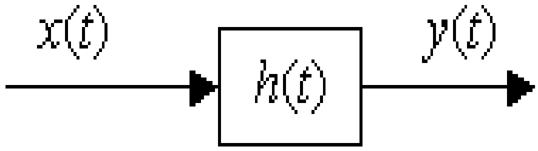


Figure 5. Block representation of transfer function

$$F(s) = \int_0^\infty f(t)\, e^{-st} dt \quad (2)$$

In the Laplace integral the time domain function f(t) is unambiguously assigned to a complex function F(s), which is called Laplace transformation. For the sake of completeness it has to be mentioned that the inverse Laplace transformation,

$$F(t)= L^{-1}\{F(s)\} \quad (3)$$

provides infinite number of solutions F(t), fitting the function F(s)[4]. The transfer function in Laplace transformation is defined as

$$G(s)= \frac{Y(s)}{X(s)} \quad (4)$$

Transfer Function of high pass filter is defined as

$$H(s)= \frac{R}{R+\frac{1}{sC}} \quad (5)$$

And its standard form is

$$H(s)= \frac{RCs}{RCs+1} \quad (6)$$

Where, ζ=RC time constant of high pass filter.

Important parameters of transfer function are poles and zeros. Here location of pole is defined as

$$S_{\infty}=-\frac{1}{RC} \tag{7}$$

and location of zeros as

$$S_0=0 \tag{8}$$

In this contribution value of R=1000Ω and C=10μF. With the help of these values, pole is defined at -100. When input and output stream are used to determine transfer function, pole is found to be at -74.54.
The derived transfer function from input and output streams is

$$G(s)=\frac{0.8704s+0.5013}{s+74.54} \tag{9}$$

Transfer function which is derived from values of R and C is

$$H(s)=\frac{0.01s}{0.01s+1} \tag{10}$$

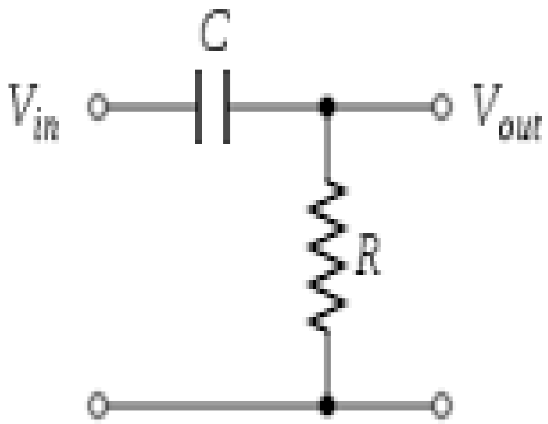
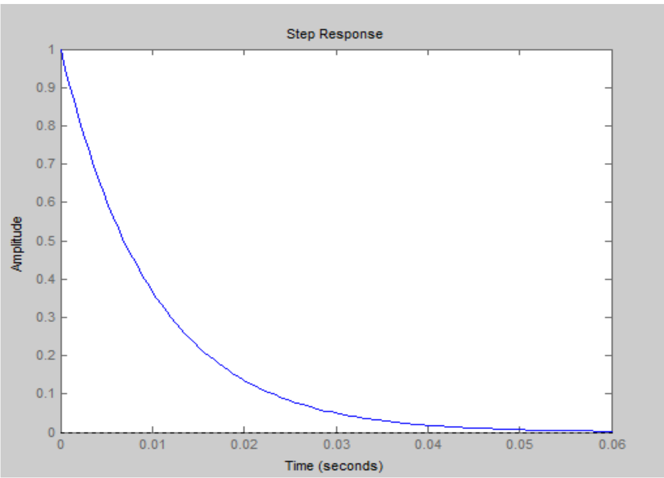
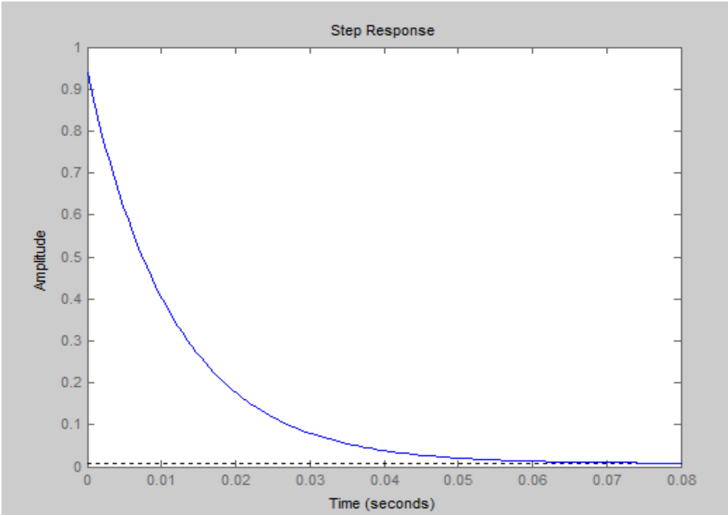


Figure 6. High Pass filter



(a)



(b)

Figure 7 comparison between (a) & (b). (a) plotted from H(s) transfer function coefficient and, (b) plotted from G(s) transfer function coefficient. (b) reaches zero after having some delay with respect to (a).

4. CONCLUSION

Viewing the transfer function to be the basic requirement to define a system, we started with a filter and plotted its transfer function. Some other authors used other method like state space analysis[5] to reach transfer function, but here, we rather concentrated on input and output stream of the filter. In practically derived transfer function we get a pole at -74.54, so we say that our system is stable. When practically and numerically plotted step response are compared we found that numerically plotted step response is having some delay arising due to components used. Analysis and removal of this delay and testing a more complex physical system will be further task to be performed.

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