**System Identification 5SMB0**

**Assignment**

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Part 1: Understanding saturation and Butterworth filter.

F(q) is a Butterworth filter. This filter attenuates frequencies that are above a specific cut-off frequency. This frequency can be determined using the Bode diagram.

The Bode diagram shows the filter's frequency response, as shown in Fig. 1, and It consists of magnitude and phase plots. This magnitude plot shows a 2.19 rad/sec cut-off frequency at -3dB. This frequency changes to Hertz by dividing π, resulting in 0.7 Hz.

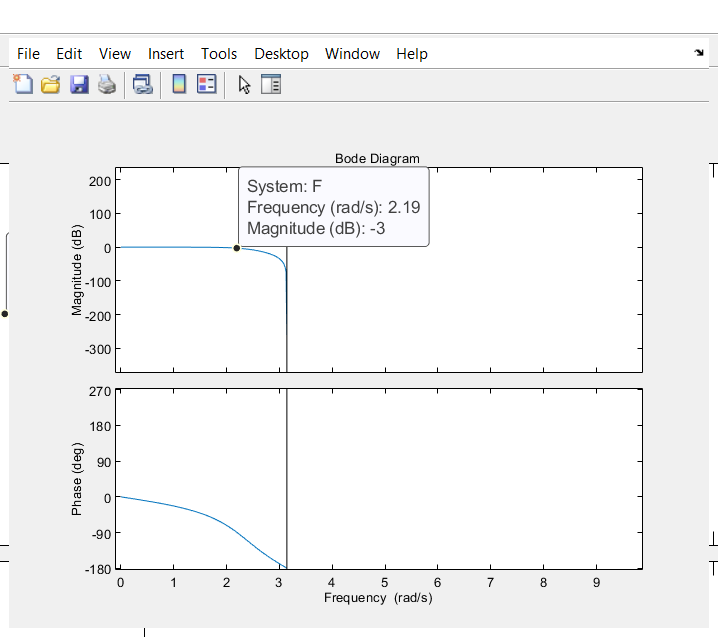


Fig. 1 Bode Diagram of a Butterworth filter F

The saturation block bound a signal between lower and upper limits. These limits are -M and M values, equal to -3 and 3, shown in Fig. 2. Moreover, these bounds are essential to work within the safe operational limits of the system. In addition, the signal excites the assignment\_sys\_18(r) system from t=-50 to t=50 to find the bounds explained.

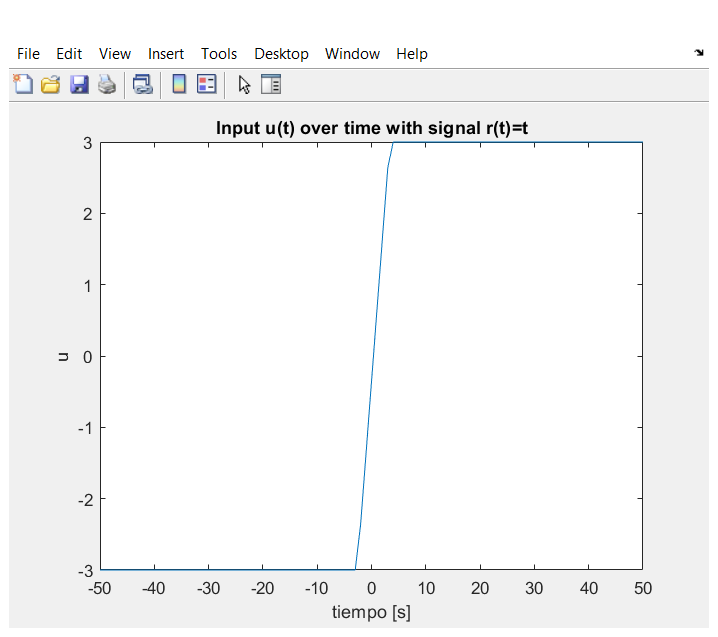


Fig. 2 Input signal u(t) excited with a signal r(t)=t

Relevant MATLAB commands for part 1:

SYS = tf(NUM,DEN,TS)

bode(SYS)

Part 2: Nonparametric identification.

The task is to design an input signal r(t) with specified characteristics, obtaining an accurate knowledge of the system in a limited number of frequencies. These characteristics are input length and the number of frequencies. Therefore, considering the amplitude range between -3 to 3 and the cut-off frequency of 0.7 Hz generates a sum-of-sinusoids signal of 128 frequencies of length 1024, shown in Fig. 3. This signal expression is below:

Fig.3 shows the Bode plot of the identified system. This identified system is an unbiased empirical transfer function estimate (ETFE) with no smoothing operation, directly from input and output signals. Moreover, there are two resonance peaks at frequencies around 0.64 and 1.55 rad/s. While the behaviour of high-frequencies increases in magnitude and phase from the cut-off frequency at 2.19 rad/s of the Butterworth filter.

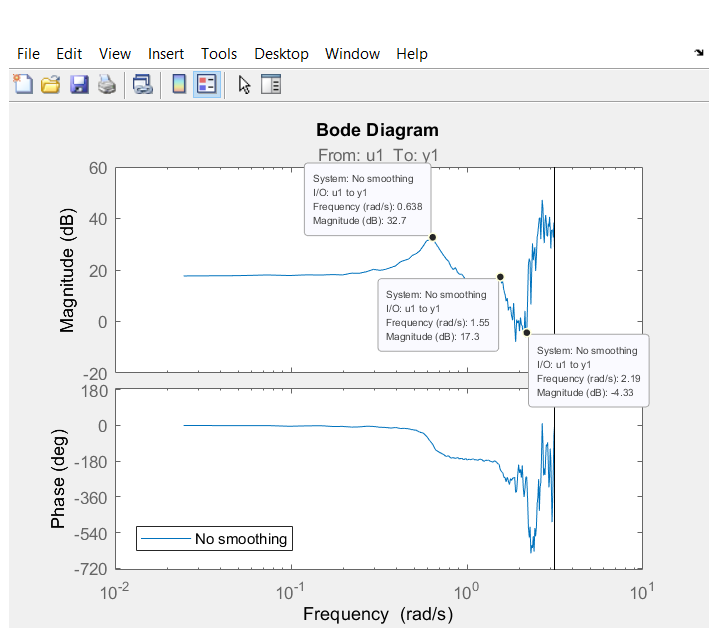


Fig. 3 Bode Diagram of Go(q)

The expression for the estimating noise spectrum is below, and Fig. 4 shows its magnitude. In addition, the noise signal v and the input signal u are uncorrelated, which is assumed.

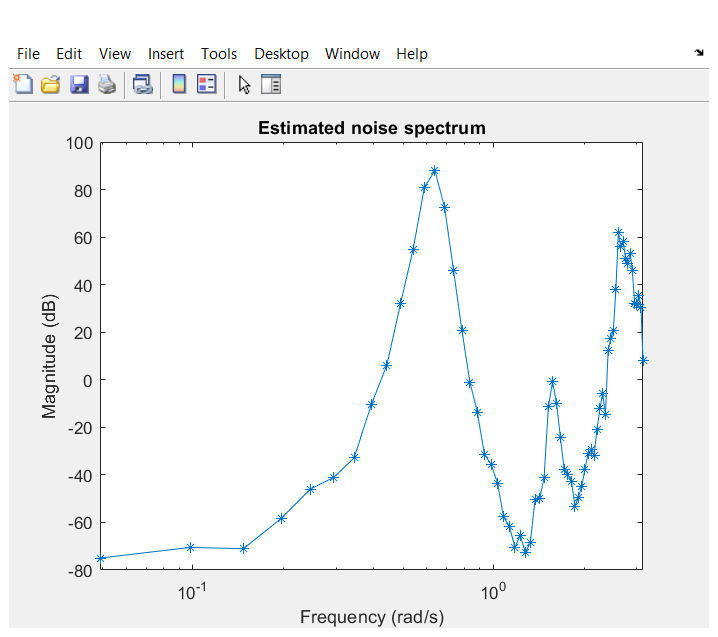
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Fig. 4 Magnitude of the estimated noise spectrum

Relevant MATLAB commands for part 2:

U = idinput(N,TYPE,BAND,LEVELS,SINEDATA)

DAT = iddata(Y,U,Ts)

G = etfe(DATA,M,N)

[Pxy,F] = cpsd(X,Y,WINDOW,NOVERLAP,NFFT,Fs)

Part 3: Experiment design.

Designing an identification experiment relies on the spectrum of the input signals covering a wide frequency range. Therefore, the input signals must be sufficiently exciting, guaranteeing that the measured data contains information about the system to be modelled.

PRBS signal is a binary signal, bringing additional properties apart from white noise's spectral properties. These properties are amplitude-bound and maxima signal power, which improve the model estimates' accuracy. In addition, a higher signal-to-noise ratio at the output depends on the accuracy of the model estimates. Therefore, a PRBS signal is chosen instead of a Gaussian pdf signal for r(t).

The r signal is a pseudorandom, binary signal. This signal has a range between -3 to 3 and 3000 data points. In addition, its band is between 0 to B value, and the clock period of B is also known as Nc, where B is equal to 1/Nc. This clock period of the PRBS signal must be chosen equal to the sampling interval after decimation. In other words, the clock period is the number greater than one, where the frequency band required shows the maxima signal power.

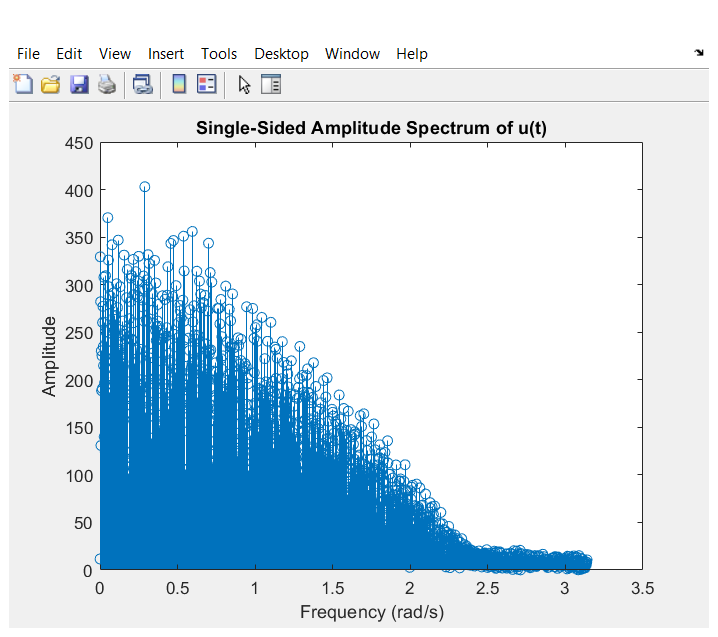
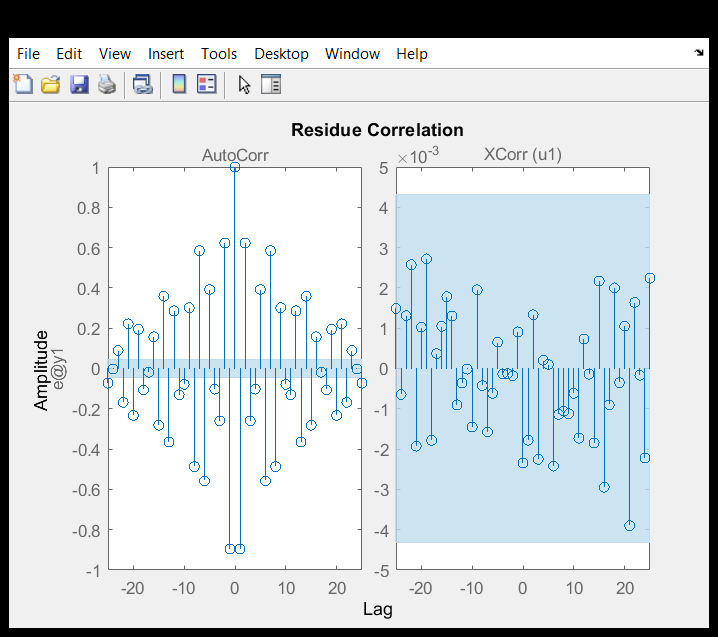
Deducing this frequency band is possible through Fig. 4, which shows where the signal is required to be maxima, and its value is around at 2.19 rad/s cut-off frequency. Moreover, a clock period (Nc) of 3 shows a negligible power in the frequencies around the cut-off frequency. Therefore, this clock period (Nc) chosen is at 2, and its B value is 0.5 shown in Fig.5.**

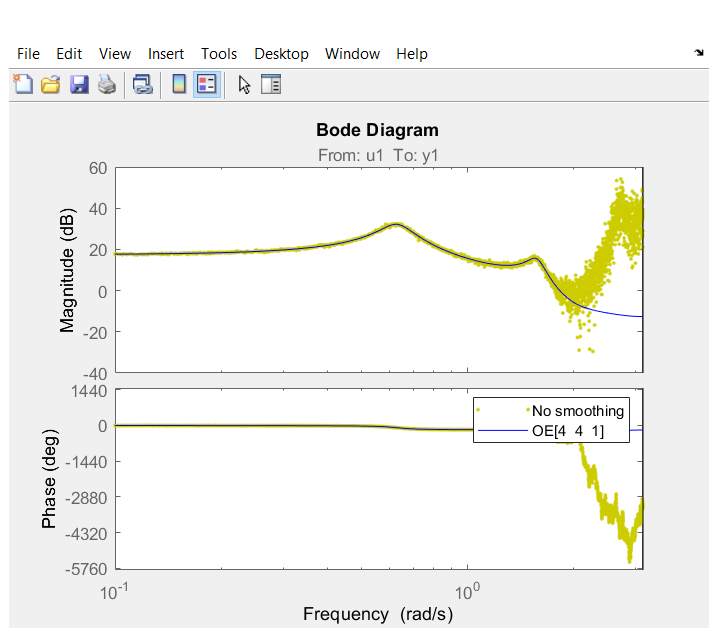
Fig. 5 Spectrum Φu (ω) of PRBS with basic clock period Nc=2

Relevant MATLAB commands for part 3:

U = idinput(N,TYPE,BAND,LEVELS)

Part 4: Parametric identification and validation.





FIT is the percentage of the measured output that was explained by the model (see formula above).

|  |  |  |  |
| --- | --- | --- | --- |
| [nb nf nk] | Percentage Fit [%] | RMSE | MAE |
| [4 4 1] | 91,9167 | 3,0817 | 2,4388 |
| [3 4 1] | 91,7452 | 3,1464 | 2,4956 |
| [5 4 1] | 91,9167 | 3,0817 | 2,4388 |
| [6 4 1] | 91,917 | 3,0817 | 2,4389 |

Relevant MATLAB commands for part 4:

[trainInd,valInd,testInd] = dividerand(Q,trainRatio,valRatio,testRatio)

NN = struc(NA,NB,NK)

V = arxstruc(ZE, ZV, NN)

NN = selstruc(V,0)

SYS = arx(DATA, ORDERS)

resid(DATA, SYS)

Part 5: Experimental verification of variance estimates.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Theorical variance OE | Monte Carlo OE variances initializing "randomly" | Monte Carlo OE variances initilizing median | Theorical variance BJ |
| b1 | 2,3919E-05 | 4,0784E-04 | 2,5337E-05 | 5,9472E-06 |
| b2 | 9,6024E-05 | 0,136025 | 9,3515E-05 | 2,9589E-05 |
| b3 | 1,9272E-04 | 0,280389 | 2,0335E-04 | 6,0078E-05 |
| b4 | 3,5979E-05 | 0,102875 | 4,2872E-05 | 9,8247E-06 |
| f1 | 1,3780E-06 | 0,028679 | 1,4988E-06 | 7,1658E-07 |
| f2 | 3,9799E-06 | 0,152323 | 3,0249E-06 | 2,0207E-06 |
| f3 | 3,7952E-06 | 0,164626 | 2,4865E-06 | 1,8948E-06 |
| f4 | 1,0941E-06 | 0,037659 | 9,2362E-07 | 5,5570E-07 |

Part 6: Estimation of a Box Jenkins model for minimum variance.

