http://elec3004.com

An Introduction to
Systems: Signals & Controls

Welcome!

ELEC 3004: **Systems**: Signals & Controls
Dr. Surya Singh

Lecture 1

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February 29, 2016

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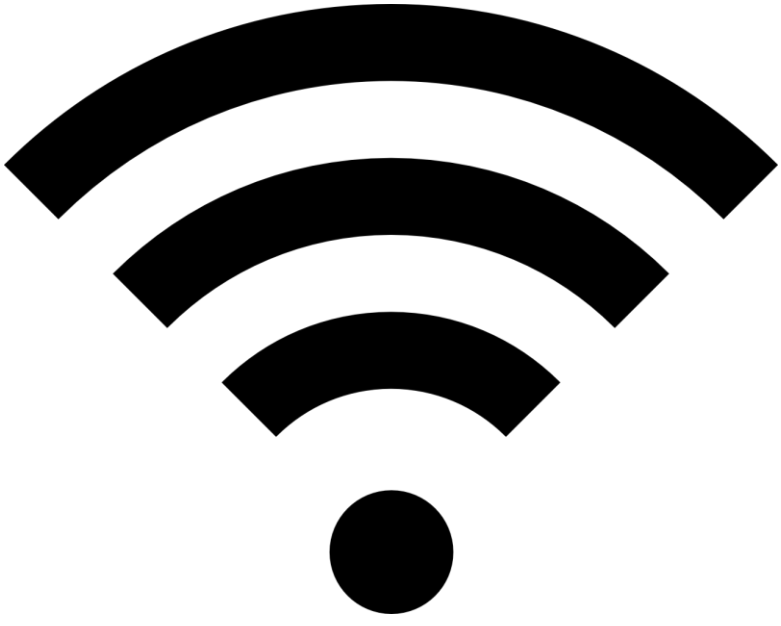
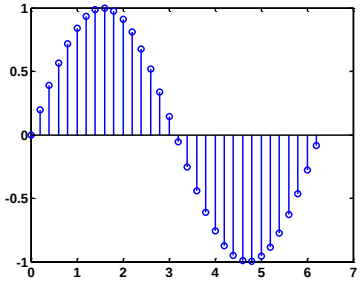


M3 TO CORONATION DR
Toowong
CLEARANCE
AHEAD 5.0 m
NORTH
QUAY
M3 PACIFIC
Logan
Gold Coas
CLEARANCE
5.2m

What's a Signal?

≡ *A set of data or* ***information***



- Can be a function of in **space** and/or **time**
- Various types: electrical, economics, dating, etc.
- Data → "information" is a process of understanding its structure/ forms:

$$\sin(\omega t)$$

What is a System?

≡ A **process** (function) by which information (signals) are modified so as to extract additional information from them

- Systems modify the signal(s) to yield a new result (also a signal)
- Can be of various forms: electrical, mechanical, etc.

Systems Can Be Simpler Than You Think

- B747
  - level flight,
  - 40000 ft, 774 ft/sec …

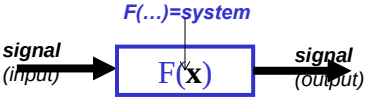
$$\begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} -.003 & .039 & 0 & -.322 \\ -.065 & -.319 & 7.74 & 0 \\ .020 & -.101 & -.429 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} u - u_w \\ v - v_w \\ q \\ \theta \end{bmatrix} + \begin{bmatrix} .01 & 1 \\ -.18 & -.04 \\ -1.16 & .598 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \delta_e \\ \delta_t \end{bmatrix}$$

  - u, w: horizontal/vertical velocity
  - q, θ: orientation & pitch rate
  - δe, δt : elevator and thrust commands

Source: Boyd, Stanford EE263 Lecture 14 (Slide 14-4)

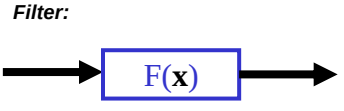
Signals and Systems Together

- A **signal** can be seen as that which goes in and out of a **system**

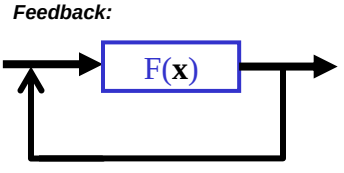


Signals and Systems Together

- A **signal** can be seen as that which goes in and out of a **system**
- **Signal Processing / "Filters" :** can be seen as a open-loop system



- **Feedback Control:** can be viewed as the case where the output signal **shapes** the input signal



Introducing ELEC3004/7312

Website: http://robotics.itee.uq.edu.au/~elec3004/

http://elec3004.com

http://openplatypus.org

Schedules and Locations:

- **Lectures:**
  - **Mondays** from **2:05 -- 3:30 pm**

    &

  - **Thursdays** from **2:05 -- 3:30 pm**

  - Here! ☺

- It starts at 2:05 – **Relax!**

Schedules and Locations: **Tutorials**

- **Tutorials:** **EVEN Weeks (Starting on Week 2)** [~60 min]
  - Five parallel sessions -- **Please come to your assigned one**.
  - Alternate attendance is at tutor discretion and must be arranged in advance

- Sessions are:
  - **Monday 10:00a--11:00** in Priestley (67) - 342
  - **Monday 4:00p--5:00** in Priestley (67) - 342
  - **Tuesday 8:00a--9:00** in Gordon Greenwood (32) - 211
  - **Tuesday 4:00p--5:00** in Gordon Greenwood (32) - 211
  - **Thursday 8:00a--9:00** in Michie Building (9) - 211

- ~ 1 hour (unless extra time is needed)

Schedules and Locations: **Labs**

- **Prac / Lab Sessions: ODD Weeks (Starting Week 3)**
  - Five parallel sessions -- **Please come to your assigned one**.
  - Alternate attendance is at tutor discretion and must be arranged in advance

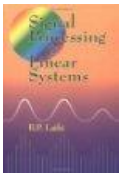
- Sessions are:
  - **Monday 10:00a--12:00** in Hawken - Room S202
  - **Monday 4:00p--6:00** in Hawken - Room S202
  - **Tuesday 8:00a--10:00** in Hawken - Room S202
  - **Tuesday 4:00p--6:00** in Hawken - Room S202
  - **Thursday 8:00a--10:00** in Hawken - Room S202

- ~ 2 hours (unless less time is needed)

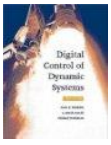
Lecture Schedule:

Week	Date	Lecture Title
1	29-Feb	Introduction
	3-Mar	Systems Overview
2	9-Mar	Systems as Maps & Signals as Vectors
	10-Mar	Data Acquisition & Sampling
3	16-Mar	Sampling Theory
	17-Mar	Antialiasing Filters
4	23-Mar	Discrete System Analysis
	24-Mar	Convolution Review
0	30-Mar	Holiday & Holiday
	31-Mar	Holiday
6	13-Apr	Digital Filters
	14-Apr	Digital Filters
7	20-Apr	Digital Windows
	21-Apr	FFT
8	27-Apr	Discrete Systems Analysis
	28-Apr	Feedback
9	4-May	Introduction to Feedback Control
	5-May	Servoregulation/PID
10	11-May	Introduction to (Digital) Control
	12-May	Digitial Control
11	18-May	Digital Control Design
	19-May	Stability
12	25-May	Digital Control Systems: Shaping the Dynamic Response & Estimation
	26-May	Applications in Industry
13	1-Jun	System Identification & Information Theory
	2-Jun	Summary and Course Review

Reference Texts:



B. P. Lathi
Signal processing and linear systems
1998
TK5102.9.L38 1998



G. Franklin, J. Powell, M. Workman,
Digital Control of Dynamic Systems
1990
TJ216.F72 1990 and [UQ Ebook]

João Hespanha
Linear Systems Theory
2009
[UQ Ebooks]

- Yes!

You may use the Internet!!

- Khan Academy
- Wikipedia
- YouTube
- & **Google Scholar** Too!

- This field is vast & there are countless references present

The Point of the Course

- Introduction to terminology/semantics
- An appreciation of how to frame problems in a linear systems engineering context
- Modeling and learning assumptions/when to trust the model
- Ability to identify critical details from the problem

➔ It's a **shortcut** …
Once you see that a system is **"linear"**
you can then apply the raft of
"linear systems" tools
(time & frequency analysis) to them
without having to do all the analysis from scratch

Not the Point of the Course

- Get good grades
- Just do homework
- Memorize pointless facts
- Rote "learning" of material with no comprehension
- Ask yourself, is the wonder still there?

Lots of Stuff To Cover…

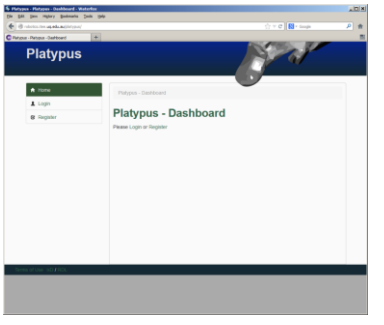
- Systems
- Signal Abstractions
- Signals as Vectors / Systems as Maps
- Linear Systems and Their Properties
- LTI Systems
- Autonomous Linear Dynamical Systems
- Convolution
- FIR & IIR Systems
- Frequency domain
- Fourier Transform (CT)
- Fourier Transform (DT)
- Even and Odd Signals
- Likelihood
- Causality
- Impulse Response
- Root Locus
- Bode Functions
- Left-hand Plane
- Frequency Response
- Discrete Time
- Continuous Time
- Laplace Transformation
- Feedback and Control
- Additional Applications
- Linear Functions
- Linear Algebra Review
- Least Squares
- Least Squares Problems
- Least Squares Applications
- Matrix Decomposition and Linear Algebra
- Regularized Least Squares
- Least-squares
- Least-squares applications
- Orthonormal sets of vectors
- Eigenvectors and diagonalization
- Linear dynamical systems with inputs and outputs
- Symmetric matrices, quadratic forms, matrix norm, and SVD
- Controllability and state transfer
- Observability and state estimation
- And that, of course,
  Linear Systems are Cool! ☺

Assessment

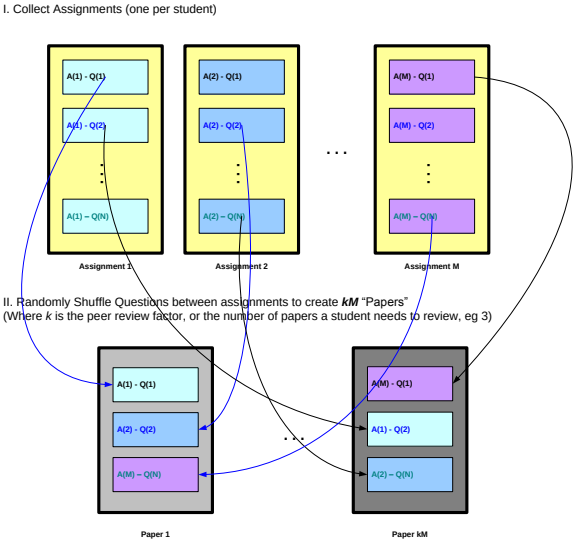
Assessment Task	Due Date	Weighting
Problem Set 1	24/03/2016 23:59	20%
Online Quiz	22/04/2016 23:59	EXTRA CREDIT
Problem Set 2	29/04/2016 23:59	20%
Problem Set 3	27/05/2016 23:59	20%
Final Examination	Examination Period	40%

Platypus: Peer-review for Deliberate Practice/Learning

- **Peer-Review**
  - A **key** part of Engineering is being able to critically evaluate peer work (and give **good** feedback on it)
  - We **will** help teach you good habits of peer feedback
- **Question** (not Assignment) based random shuffling

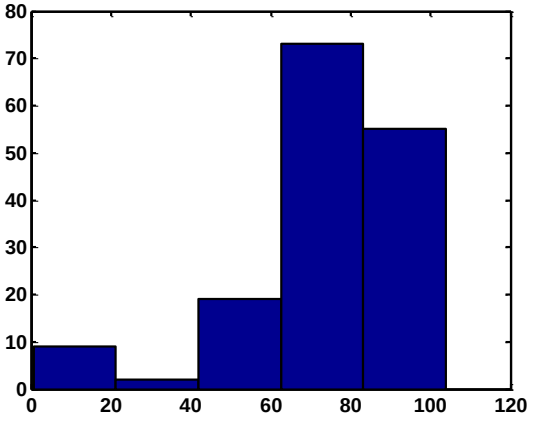


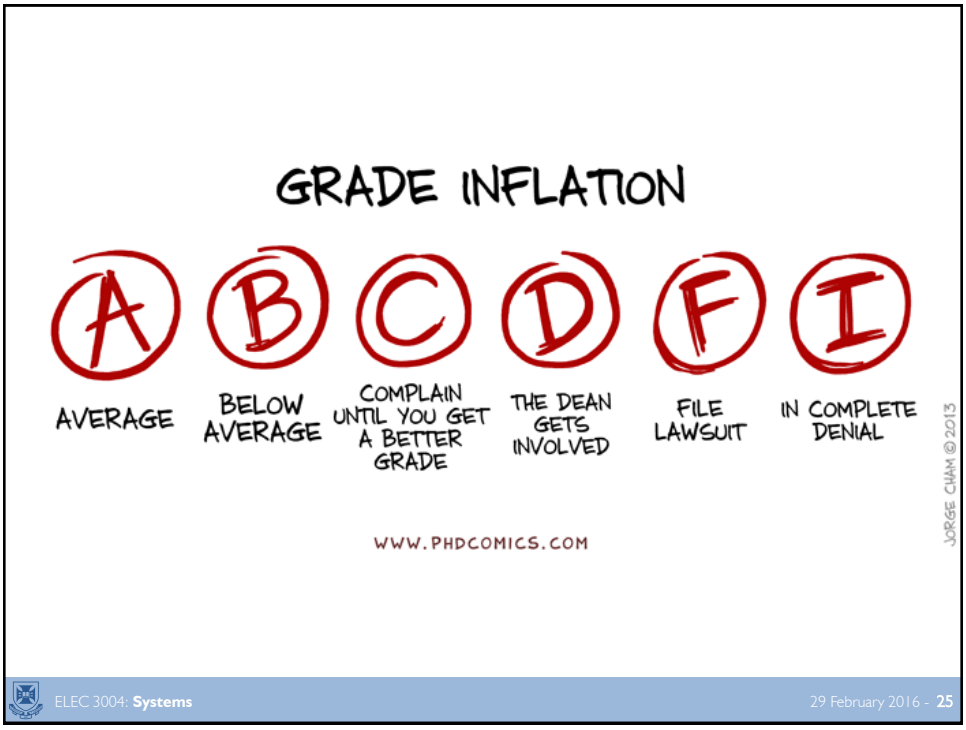
Platypus: How does it work?



Last Year's Grade Statistics

- ~ 45 % received >5
- Worry about **learning**, not about marks





Information: Size and Rate

A short novel	1 megabyte	1,000,000
All undergraduate textbooks	100 MB	100,000,000
An iPod	100 GB	80,000,000,000
A library floor of academic journals	100 GB	100,000,000,000
Print collections of Library of Congress	10 TB	10,000,000,000,00

Copying notes by hand	32 bits/second	32 bps
Speaking	230 bits/sec.	230 bps
Reading text	360 bits/sec	360 bps
Home internet connection	1-10 Mb/sec.	5,000,000 bps
Single optical fiber	40 Gb/sec.	40,000,000,000 bps

A short novel ≅ 1 Mbyte
- 70 hours to copy
- 6 hours to read
- Less than 10 seconds to download

Taken from: *http://burikmodeldesign.com/search/How_Many_Bytes.htm*

I need a "7" for a Job!

The New York Times | http://nyti.ms/1jTJavh

SUNDAYREVIEW | OP-ED COLUMNIST

How to Get a Job at Google

FEB. 22, 2014

Thomas L. Friedman

MOUNTAIN VIEW, Calif. — LAST June, in an interview with Adam Bryant of The Times, Laszlo Bock, the senior vice president of people operations for Google — i.e., the guy in charge of hiring for one of the world's most successful companies — noted that Google had determined that "G.P.A.'s are worthless as a criteria for hiring, and test scores are worthless. ... We found that they don't predict anything." He also noted that the "proportion of people without any college education

Changes from 2015

1. Three Assignments Instead of Five
2. Online Quiz ("Mid-Semester" Review/Recap)
3. Labs remain optional
   1. Concepts still overlap with class
   2. May be assessed on Assignments/Final Exam
4. No State-Space Control "crammed" in the end
5. I am still inspired by, but little less of, Boyd's EE263: *Introduction to Linear Dynamical Systems*

E-mail

- **elec3004@itee.uq.edu.au**

- Casper!
  - https://casper.ceit.uq.edu.au/courses/elec3004/

- [That's it!]
- {Not the instructors/tutors personally}

Communications: Help Us Help You!

- **Think carefully before using `email`**

- Please keep communication concise and polite

- Let me know if there are problems
  - During tutorials, before and after lectures
  - Tutors/student reps
  - **Office Hours: 4-6pm Thursday**

Source: O'Brien, *Ruthless Compassion*

What I expect from you

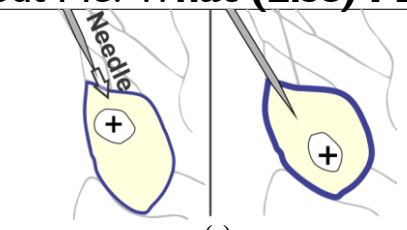
- Lectures:
  - Participate - ask questions
  - Turn up (we're adults – no attendance marks)
  - Take an interest in the material being presented
  - Assignments to be submitted on time please
- Tutorials:
  - Work on questions before tutorials
  - Use tutorials to clarify and enhance
- Labs:
  - Work on pre-lab before laboratory
  - Focus on understanding (as well as data capture)

Source: O'Brien, *Ruthless Compassion*

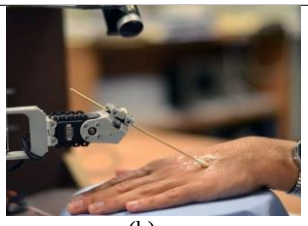
Some Philosophy

- Let's start with Why …
- To learn something is to teach it
  - The function of a teaching is not so much to cover the topics, but more to discover them
- It is actually **more** work for us!
  - We have to teach you how to reflect & then assess this as well as how to do the assignment
- It helps you understand it by giving you a different perspective
- We're a community
  - You (alone) can't do everything … that's why we work together
  - The notion of "free speech" ➔ Trust emerges → efficiency (η)

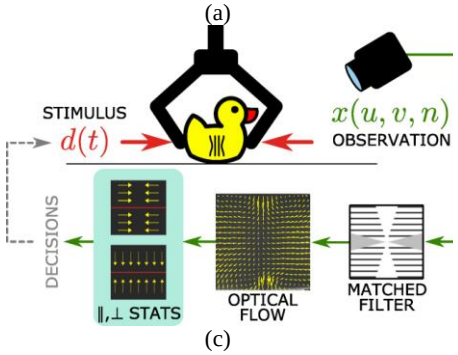
About Me: **What (Else) I Do**



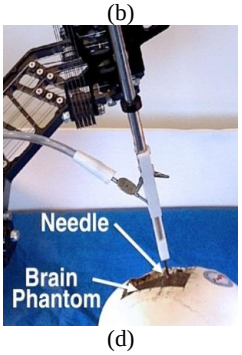
(a)



(b)

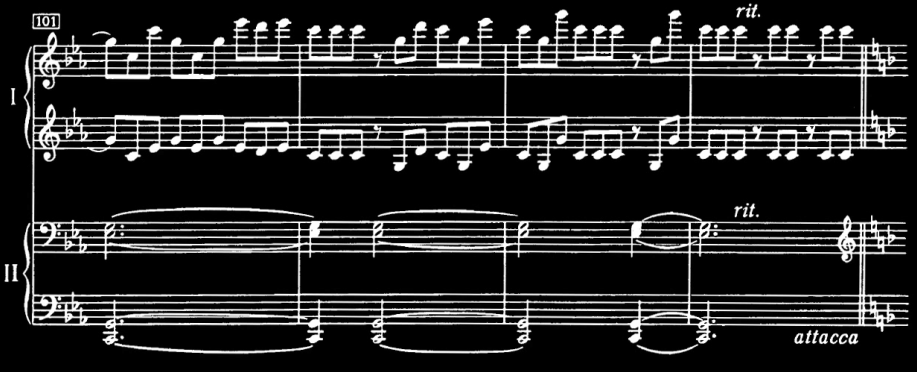


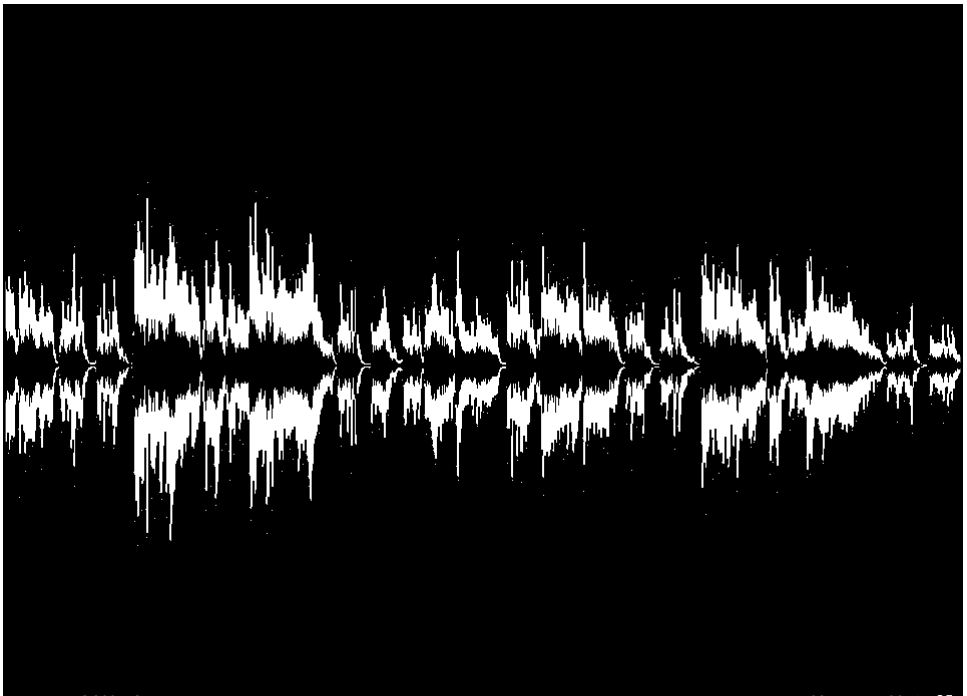
(c)

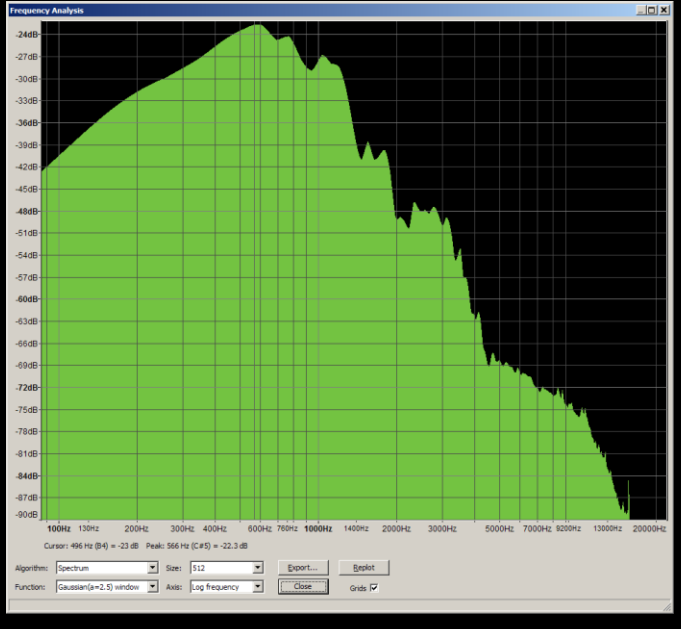


(d)

(a) Lesion targeting **(b)** DermBot **(c)** Visual Deformable Object Analysis **(d)** Neurosurgical Robotics






Frequency Analysis
-24dB
-27dB
-30dB
-33dB
-36dB
-39dB
-42dB
-45dB
-48dB
-51dB
-54dB
-57dB
-60dB
-63dB
-66dB
-69dB
-72dB
-75dB
-78dB
-81dB
-84dB
-87dB
-90dB
100Hz 130Hz 200Hz 300Hz 400Hz 600Hz 760Hz 1000Hz 1400Hz 2000Hz 3000Hz 5000Hz 7000Hz 9200Hz 13000Hz 20000Hz
Cursor: 496 Hz (B4) = -23 dB Peak: 566 Hz (C#5) = -22.3 dB
Algorithm: Spectrum
Size: 512
Export...
Replot
Function: Gaussian(a=2.5) window
Axis: Log frequency
Close
Grids