Control SystemToolbox



release 1.3

The CST User Guide

Fifth Edtion October 2005

Gnu GPL 2002-2005 Loreto Parisi

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About Control System Toolbox for TI-89

Control System Toolbox (CST) for TI-89 is a suite of specialized functions and programs for Systems Control and Tuning created by **Loreto Parisi** from June 2002 for the TI-89 personal calculator.

F1+ F2 Tools A19e	:+ F3+ F4+ braCa1cOtherP	FS F6 r9ml0Clea	ν UP
cst∖cs	t()		
MAIN	DEGAUTO	FUNC	0/30

After installing (see *How To Install* on page 10), to run the program on your calculator, types *CST/cst()* from folder *MAIN* and wait few seconds.



This is the main screen of cst(). You can see several menus, in which you can find all the function you need to work with state space, linear and non – linear models, etc., grouped in a logical order.



If you have trouble to use any function, you can choose help() from *Other* menu (*F6*), to run the useful on- line help tool, which can be used instead of this reference guide to obtain instant help. Note that this is a standalone program so you can recall it typing CST/help() from *HOME*.

F1+ F2+ F3+ F4+ F5+ Systems Analysis Dynamics Data Tools	F6+ Other
1:ss2tf(A,B,C,D,iu) 2:tf2ss(SYS) 3:tf(NUM,DEN)	ΟL
4:tf(SYS) 5:zpk(Z,P,G) 6:c2d(<u>SYS,T</u> c)	οx
7:d2c(SYS,Tc)	
02002-2005 Loreto Par: cst Degauto Func	isi

To recall menus you can use *Function-keys* instead of arrow keys. Then to choose a function, simply select it typing the number or the letter on the left, or use the arrow keys to navigate in the menu.

Disclaimer

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You should have received a copy of the GNU General Public License along with this program; if not, write to the Free Software Foundation, Inc., 59 Temple Place - Suite 330, Boston, MA 02111-1307, USA.

The Open Source Philosophy

If you have an apple and I have an apple and we exchange apples then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas.

This is our way of thinkin'...

How To Get Help

• *Consult the new CST Guides:* The **CST Start Guide** will guide you through the installation of CST.

The CST Reference Guide will guide you through all CST functions.

The **CST User Guide** will guide you using CST with complete examples. <u>http://web.tiscali.it/loretoparisihome</u> and go to *Downloads*.

• Get In Touch:

To get more help about CST *for TI-89* and/or to send comments, questions and suggestions, you can contact me at

Loreto Parisi

Email: <u>loreto parisi@yahoo.it</u> CST Home: <u>http://web.tiscali.it/loretoparisihome</u>

• *Send Feedback:* <u>http://web.tiscali.it/loretoparisihome</u> and go to *Feedback*.

How To Install

Use your linking software to send the program CSTxxx.89G on the calculator. All the files are automatically placed in the folder CST. Once installation has occurred, do not move, delete, or rename any of the functions and programs or pictures in the folder CST. All files included in folder CST are necessary to cst() to work right. For a list of files included in this folder, see *Contents*. For further notice please see **Note**.

Install CST	
(F1+) F2+ (F3+) F4+ F5 Tools Al9ebra Calc Other Pr9ml0 Clean Up	Once sent CST to your device, please run <i>cst\install()</i> from HOME.
cst\install()	
MAIN DEGAUTO FUNC 0/30	
F1+ F2+ F3+ F4+ F5 F6+ Too Control System Toolbox for TI-89 CST INSTALL TOOL v1.3 Press enter to install CST GnuGPL 2003-2005 Loreto Parisi loreto.parisi@tiscali.it http://web.tiscali.it/loretoparisihome Cst\install() CST ODEGAUTO F1+ FUNC 0/20	CST Install Tool starts. Please confirm pressing Enter now.
F1+ F2+ F3 F4 F5+ F6+ F7+5: Tools 200m Trace Regraph Math Draw Fen: Control System Toolbox Step 1+ Executing once all functions Enter=DK GnuGPL 2005 Loreto Parisi CST DEGRUTO FUNC	The first step is to executing once all functions to improve performances. Please press Enter.
F1+ F2+ F3 Tools[zoom Trace Re\$raph Math Draw Fen : ■Control System Toolbox■ CST Install Tool 1.3 ▶ Executing	Please wait while executing once all functions. This will take few minutes. The progress bar indicates the Install Tool is working.
<u>GnuGPL 2005 Loreto Parisi</u> CST DEGAUTO FUNC	<i>Please don't break execution during this time.</i>

F1+ F2+ F3 F4 F5+ F6+ F7+3: ToolsZoomTraceRegraph[MathDraw[Fen]:: Control System Toolbox Control System Toolbox Step 2+ All functions will be archivid Enter=DK GnuGPL 2005 Loreto Parisi CST T DEGAUTO FUNC	The second step is to archive all executed functions. Please press Enter.
(F1+)F2+)F3 F4 F5+)F6+)F2+(0) Tools/Zoom/Trace/Regraph/Math/Draw/Pen(0) ■Control System Toolbox■ CST Install Tool 1.3 • Executing • Archiving • Archiving • GnuGPL 2005 Loreto Parisi	Please wait while archiving all functions This will take few minutes. The progress bar indicates the Install Tool is working. <i>Please don't break execution during this</i> <i>time</i> .
	Now it's time to execute once and
Fiv F2v F3 F3v F6v F6v F6v F6v F6v F6v F6v F6v F6v F6	archive the programs. Press Enter will run the program. Then simply quit. Choose Enter to run <i>bodex()</i> , then press $F1 \rightarrow 1$ to exit.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 • Control System Toolbox • Control System Toolbox • Archiving GSTEPO • Now starts 9step(). • PRESS F7 to exit. • R Enter=OK • GnuGPL 2005 Loreto Parisi • GNUGPL 2005 Loreto FUNC	Choose Enter to run <i>gstep()</i> , then press F7 to exit.
F1+ F2+ F3 F4 F5+ F6+ F2+(%) ToolsZoom[Trace[Regraph[Math]Draw[Pen]*: Control System Toolbox= Archiving FEEDBACK() Mow starts feedback(). FRESS F4 + 1 to exit. A <u>Enter=OK</u> <u>ESC=CANCEL</u> GnuGPL 2005 Loreto Parisi CST 0 BAD AUTO FUNC	Choose Enter to run <i>feedback()</i> , then press F4 \rightarrow 1 to exit.

F1+ F2+ F3 F4 F5+ F6+ F7+ F3 • Control System Toolbox • Control System Toolbox • Archiving NYQUISTO • Now starts nyauisto. • PRESS F4 to exit. • R Enter=OK • GnuGPL 2005 Loreto Parisi CST © DEGAUTO	Choose Enter to run <i>nyquist()</i> , then press F4 to exit.
F1+ F2+ F3 F4 F5+ F6+ F7+ ³ : ToolsZoomTraceRegraph[Math]Draw[Pen]:: Control System Toolbox Archiving RLOCUSO Now starts rlocusO. PRESS F5 to exit. A <u>Enter=OK</u> <u>ESC=CANCEL</u> GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	Choose Enter to run <i>rlocus()</i> , then press F5 to exit.
F1+ F2+ F3 F4 F5+ F6+ F2+ ³ ToolsZoomTraceRegraphMathDrawPen: Control System Toolbox= Archiving EREBRO Now starts errorO PRESS ENTER to exit. A <u>Enter=OK</u> <u>ESC=CANCEL</u> GnuGPL 2005 Loreto Parisi CST 0 RAD AUTO FUNC	This will execute and install the Error Management System, <i>error()</i> .
F1+ F2+ F3 F4 F5+ F6+ F2+ ³ ToolsZoomTraceRegraphMathDrawFen:: Control System Toolbox= CT Testall Tool 1 Error Management installed. A Enter=DK ESC=CANCEL GnuGPL 2005 Loreto Parisi CST 0 RAD AUTO FUNC	The Error Management System was installed.
F1+ F2+ F3 F4 F5+ F6+ F2+ ToolsZoom[Trace[Regraph[Math]Draw[Pen]>: Control System Toolbox= Archiving CSTO Mow starts cstO. FRESS F6 + 5 to exit. FRESS F6 + 5 to exit. FRESS F6 + 5 to exit. A CEnter=OK CESC=CANCEL GnuGPL 2005 Loreto Parisi CST RAD AUTO FUNC	Choose Enter to run <i>cst()</i> , then press $F6 \rightarrow 7$ to exit.

F1+ F2+ F3 F4 F5+ F6+ F7+ 50 ToolsZoom TraceResraph MathDraw Pen: Control System Toolbox Archiving HELPO Now starts helpO PRESS F6 + 5 to exit. PRESS F6 + 5 to exit. PRESS F6 + 5 to exit. PRESS F6 + 5 to exit. Control System Toolbox Archiving HELPO PRESS F6 + 5 to exit. Archive Starts helpO Archive Starts helpO Arch	Choose Enter to run <i>cst()</i> , then press F6 \rightarrow 7 to exit.
F1+ F2+ F3 F4 F5+ F6+ F7+ F8+ Too Control System Toolbox Hinstallation successed. Eurrent Release: 1.3 FOrum CST type cst\cstO GnuGPL 2003-2005 Loreto Parisi Toreto.parisi@tiscali.it http://web.tiscali.it/loretoparisihome Run CST now ? W#3+ Enter=0K ESC=CANCEL GnuGPL 2005 Loreto Parisi USE € AND > TO OPEN CHOICES	Congratulations! Control System Toolbox <i>for TI-89</i> installation successed. To run <i>cst()</i> just now, choose Yes and press Enter. Enjoy the journey!

Note.

From release 1.3, CST needs the tool LZT to perform symbolic calculations (i.e. Laplace and Zeta transforms). To install LZT please follow instructions we provide in the following section **Install LZT**. We also raccomend to read the LZT readme file.

LZT r7 Author: Jiri Bazant Email: <u>georger@razdva.cz</u> Home: <u>http://www.razdva.cz/georger/</u>

This powerful tool needs any kernel like DoorsOS, UniOS or KerNO. We provide KenNO r3.1 from CST r1.3 as its convenient installation. To install KerNO please follow instructions we provide in the following section **Install KerNO**. We also raccomend to read the KerNo readme file.

KerNO r3.1 Author: Greg Dietsche E-Mail: <u>mailto:calc@gregd.org</u> Home: <u>http://calc.gregd.org/</u>

Install KerNO	
F1+ F2+ F3+ F4+ F5 F6+ Tools[#19ebra[Calc]0ther Pr9mi0[Clean UP] hw3patch()] Main RAD AUTO FUNC 0/30	First, we have to install the hw3patch(), for Hardware Version up to 3. Transfer the patch to TI-89, then run it from <i>main</i> .
	HW3Patch 1.00 Author: Kevin Kofler Copyright (C) 2004 Kevin Kofler. All rights reserved. Home: http://tigcc.ticalc.org.
F1+ F2+ F3+ F4+ F5 F6+ Tools[A13ebra]Calc[0ther]Pr3m0[Clean UP] kerno() MAIN BAD AUTO FUNC 0/30	Now, we can install the kernel. Transfer KerNo to TI-89, then simply run it from <i>main</i> .
F1+ F2+ F3+ F4+ F5 F6+ Tools(#13ebra(ca)c)[0ther Pr3ml0(clean UP)] KerN0 v3.1 KerN0 installed Enter=0K	KerNO is now installed in TI-89 memory.
	KerNO r3.1 Author: Greg Dietsche E-Mail: <u>mailto:calc@gregd.org</u> Home: <u>http://calc.gregd.org/</u>

Install LZT	
	After installing a kernel, we can install LZT release 7 (current).
F1+ F2+ F3+ F4+ F5 F6+ ToolsAl9ebraCalcOtherPr9mIDClean Up	Send <i>lztR7.89g</i> to TI-89 and run <i>install</i> from <i>lzt</i> folder.
F1* F2* F3* F4* F5 F6* ToolslatedeedCateInthextRevention Enterson Enterson Enterson Laplace & 2 transform # Enterson Enterson Dutput form Rational fce. # Addit.solu. d(h(t),t)= 0 # 2 transform # Enter=BK ESC=CANCEL Izt\install() USE # AND # TO OPEN CHOICES	Choose output options for Laplace and Zeta transforms: We will use 0 as derivative of the Heavside's Step and rational fce as output forms.
1: Archive 2: Don't archive 1zt\install() Type DR USE +>t+ CENTERI DR CESCI	Now we will choose Archive to improve performances of <i>lzt</i> and to save space in RAM memory, archiving <i>lzt</i> in Flash ROM memory.
	LZT r7 Author: Jiri Bazant Email: <u>georger@razdva.cz</u> Home: <u>http://www.razdva.cz/georger/</u>

Systems	
F1+ F2+ F3+ F4+ F5+ F6+ Systems Analysis Dynamics Data Tools Other 1: $ss2tf(A, B, C, D, iu)$ 0 1: $ss2tf(A, B, C, D, iu)$ 2: $tf(2ss(SYS))$ 3: $tf(NUM, DEN)$ 0 L 3: $tf(SYS)$ 0 L 4: $tf(SYS)$ 0 X 5: $zpk(Z, P, G)$ 0 X 6: $c2d(SYS, Tc)$ 0 X 7: $d2c(SYS, Tc)$ 0 X 0: CST DEGAUTO FUNC	The <i>Systems</i> menu (F1) contains all the functions to build the model, using state-space or transfer function and to perform conversions from one representation to another, even from continuous time to discrete time model.
F1+1 F2+1 F3 F4 Y F5+1 F6+1 F2+18:: State Space to Transfer Function A: B: C: D: Input: Delay: Enter=0K ESC=CANCEL G2002-2005 Loreto Parisi	ss2tf(A,B,C,D,iu) Gives transfer function W(s)=C(sI-A) ⁻¹ B+D from state-space $\dot{x} = Ax + Bu$, y = Cx + Du, relating to input iu (it works on MIMO systems, but only one input at time). Delay τ is the Time Delay e ^{-τs} .
F1+ F2+ F3 F4 F5+ F6+ F7+ F1+ Tools Contrace Re3raph Math Draw Pen+ Pen+ <t< td=""><td><i>tf2ss(SYS)</i> Convert transfer function SYS in the state- space representation $\dot{x} = Ax + Bu$, y = Cx + Du, using the observability canonical form. Delay τ is the Time Delay e^{-τs}.</td></t<>	<i>tf2ss(SYS)</i> Convert transfer function SYS in the state- space representation $\dot{x} = Ax + Bu$, y = Cx + Du, using the observability canonical form. Delay τ is the Time Delay e ^{-τs} .
F1+ F2+ F3 F4 F5+ F6+ F7+33 F3+ ToolsZoom Trace[Regraph[Math]Draw Pen]:: Transfer Function Num:	<i>tf(NUM,DEN)</i> Calculates transfer function, where NUM and DEN are LIST of coefficients of numerator's and denominator's polynomial: NUM={ $b_0,b_1,,b_n$ }, DEN={ a_0,a_1,a_n }, so $W(s) = \frac{b_0 s^n + b_1 s^{n-1} + + b_n}{a_0 s^n + a_1 s^{n-1} + + a_n}$. Delay τ is the Time Delay e ^{-τs} .
F1+ F2+ F3 F4 F5+ F6+ F7+ Siii) Tools/200m/Trace/Regraph/Math/Draw/Pen/sti Transfer Function Siii) Siii) W(s): Delay: 0 Siii) Siii) Center=0K CESC=CANCEL Siii) 02002-2005 Loreto Parisi TYPE + CENTER1=0K AND CESCI=CANCEL Siii)	<i>tf</i> (<i>SYS</i>) Calculates transfer function from a rational expression in s Delay τ is the Time Delay $e^{-\tau s}$.

F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Taals/Zaam/Trace/Restrach/Math/Mrau/Penk: Zero-Pole-Gain Transfer Function Zeros:	<i>zpk</i> (<i>Z</i> , <i>P</i> , <i>G</i>) Calculates transfer function W(s) in the zeros-poles-gain representation, where Z, P are LIST of zeros of numerator and denominator (poles), while G is NUM and represents constant gain K. Control's Toolbox v.1.16 author: Francesco Orabona E-mail: <u>bremen79@infinito.it</u> Home: <u>http://web.genie.it/utenti/b/bremen79/</u>
F1+ F2+ F3 F4 F5+ F6+ F7- \$	<i>c2d</i> (<i>SYS</i> , <i>T_c</i>) Converts continuous time model SYS to the discrete time model, using sample time $_{Tc}$ and different methods: HE (Linear Hold Equivalence), TU (Bilinear Tustin), BE (Bilinear Backward Eulero), FE (Bilinear Forward Eulero). Can use function tconst(SYS) to determinate sample time T_c . Use function sampler(A,B, T_c) to use ZOH method. Can save the resulting discrete time model Wd(z) as current discrete transfer function W(z).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools/2000/Trace/Bestrach/Math/Drau/Penk: Discrete to Continuous Time Model W(z):	$d2c(SYS,T_c)$ Converts discrete time model SYS (in z) to the continuous time model, using sample time T _c and different methods: HE (Linear Hold Equivalence), TU (Bilinear Tustin), BE (Bilinear Backward Eulero), FE (Bilinear Forward Eulero).Can use function tconst(SYS) to determinate sample time T _c . Can save the resulting continuous time model Wd(s) as current continuous transfer function W(s).

Control System Toolbox *for TI-89* – The CST User Guide 5th Edition

Analysis	
F1+ F2+ F3+ F4+ F5+ F6+ Systems AndIvsis Dynamics Data Tools Other 1: poly(A) 2: pzmap(SYS) 1: 3: damp(SYS) 1: 4: dcgain(SYS) 1: 4: dcgain(SYS) 1: 6: tconst(SYS) 1: 7: tmax(A) 84 peak(SYS) 84 peak(SYS) 1: 0: 2002-2005 Loreto 0: 2002-2005 Loreto 0: USE +>14 + LENTERI DR LESCI	The <i>Analysis</i> menu (F2) contains all the tools to analyze the model you have created with Systems' tools. You can also analyze different models, using different SYS at time. This will not change current transfer function.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools[Zoom[Trace[Re9raph[Math]Draw]Pen]*: C <td><i>poly(A)</i> This function calculates characteristic polynomial of matrix A, as $p(s)= sI-A$, where \cdot is determinat of a matrix.</td>	<i>poly(A)</i> This function calculates characteristic polynomial of matrix A, as $p(s)= sI-A $, where $ \cdot $ is determinat of a matrix.
F1. F2. F3 F4 F5. F6. F7. ToolsZoom TraceRegraph Math Draw Pen:: Poles and Zeros of W(s) W(s): Enter=DK ESC=CANCEL V1.2.2 02002-2003 Loreto Parisi CST DEGAUTO FUNC	<i>pzmap(SYS)</i> This function calculates poles and zeros of given transfer function SYS, where poles are zeros of denominator of SYS.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3::: Tools[Zoom[Trace[Re9raph[Math]Draw]Pen]*: Image: Construction of the second damping of the	damp(SYS) Calculate natural frequencies ω_{nh} and damping factors ζ_h for transfer function SYS, where $\omega_{nh} = \sqrt{\alpha_h^2 + \omega_h^2}$ and $\zeta_h = \frac{-\alpha_h}{\omega_{nh}}$ for eigenvalue $\lambda_h = \alpha_h + j\omega_h$.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 ToolsZoom[Trace[Re9raph[Math]Draw]Pen]*: D.C. Gain of H(s) D.C. Gain of H(s) W(s):	<i>dcgain(SYS)</i> Calculates d.c. gain G for transfer function SYS, as $G=\lim_{s\to 0} W(s)$.

F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools Tools Comparent Partician Compa	<i>gain(SYS)</i> Calculates constant gain K for transfer function SYS, as $K=\lim_{s\to 0} s^{n_0-m_0}W(s)$, where n_0 and m_0 are multiplicity of zero roots for denominator and numerator.
F1+ F2+ F3 F4 F5+ F6+ F2+ F3 ToolsZoomTraceRegraphMathDraw[Pen]*: Image: Constants Image: Constants Image: Constants Sampling time and time constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s): Image: Constants Image: Constants Image: Constants Image: Constants W(s):	<i>tconst(SYS)</i> Calculates sample time T _c and time constants τ_i , τ_h , and T _h , where $\tau_i = -\frac{1}{\lambda_i}$, $\tau_h = -\frac{1}{\alpha_h}$ and $T_h = \frac{2\pi}{\omega_h}$, while T _c = 0.1min{ τ_i , τ_h , T _h }.
F1+ F2+ F3 F4 F5+ F6+ F2+ F3 ToolsZoomTraceRegraphMathDraw[Pen]:: C O M T O I Resunance Peak and Frequency M(s): C I	<i>peak(SYS)</i> This function uses a proprietary numerical algorithm to calculate resonance peak $M_p=max_{\omega}$ $M(\omega)$, where $M(\omega)= W(s) _{s=j\omega}$ and relating frequency f_r , which is $M(2\pi f_r)=M_P$.
F1+ F2+ F3 F4 F5+ F6+ F7+ ³ ;; Tools[Zoom[Trace[Re9raph[Math[Draw]Fen]::] Max time constant A: Time? Continouos + < <u>Enter=DK</u> <u>ESC=CANCEL</u> B2002-2003 Loreto Parisi CST DEGAUTO FUNC	$\frac{tmmax(A)}{Calculates maximum time constant for characteristic polynomial of matrix A, in continuous or discrete time, where \tau_{max} = \frac{1}{\min(-\Re\lambda_i)} (continuous time) and \tau_{max} = \frac{1}{\min(\ln \lambda_i)} (discrete time).$
(F1+ F2+ F3 F4 F5+ F6+ F7+3:: ToolsZoom[Trace[Regraph[Math]Draw]Pen[:: Mag and Phase Margin W(s): Delay: 0 (Enter=OK ESC=CANCEL) 02002-2005 Loreto Parisi CST DEGAUTO FUNC	$\begin{array}{l} \textit{margin(SYS)} \\ \text{Calculates Mag and Phase Margins.} \\ K_m = 1 / \left W(i\omega_m) \right \ (Mag Margin) \\ \omega_m: \angle W(i\omega_m) = -180^{\circ} \\ \varphi_m = 180^{\circ} - \left \varphi_c \right \ (Phase Margin) \\ \omega_c: \left W(i\omega_c) \right = 1 \\ \varphi_c = \angle W(i\omega_c) \ (Critical Phase) \\ \tau_c = \varphi_m / \omega_c * \pi / 180^{\circ} \ (Critical Time Constant) \end{array}$

F1+ F2+ F3 F4 F5+ F6+ F7+ Sii	feedback(sys)
ToolsZoomTraceRe9raph MathDrawPen ::	Performs the analysis and design of the
Feedback Control System	closed loop control system of process
W(s):	SYS.
Delay: 0	Delay τ is the Time Delay e ^{-ts} . Please see
Enter=OK ESC=CANCEL	Feedback Control Systems section.
<u>02002-2005 Loreto Parisi</u> CST DEGAUTO FUNC	

Dynamics	
F1+ Systems/Analysis Dynamics Data[Tools]Other 1:trim(A, B, C, D, u0) 2:linmod(f, y, x, u,) 3:bodex(SYS) 4:nyquist(SYS) 5:rlocus(SYS) 6:step(SYS) 7:pstep(SYS) 8:gstep(w_1(t)) 02002-2005 Loreto Parisi TYPE OR USE ++t+ CENTERI OR CESCI	The <i>Dynamics</i> menu (F3) contains functions concerning dynamics of system for input, output and linearization of a non- linear model, frequency analysis with Bode and Nyquist diagrams and Root Locus yet.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ Steady State parameters Steady State parameters Steady Steady </th <td><i>trim</i>(<i>A</i>,<i>B</i>,<i>C</i>,<i>D</i>,<i>u</i>₀) This function calculates the steady state x_0, relating to input u_0 for state-space $\dot{x} = Ax + Bu$, $y = Cx + Du$.</td>	<i>trim</i> (<i>A</i> , <i>B</i> , <i>C</i> , <i>D</i> , <i>u</i> ₀) This function calculates the steady state x_0 , relating to input u_0 for state-space $\dot{x} = Ax + Bu$, $y = Cx + Du$.
Linear model at x0,00 State equ: Dutput equ: State vars: Dutput vars: Steady State x0: Constant input u0: Evalutate? Yes + Save state space No + <u>Enter=DK</u> CST D DEGAUTO FUNC	<i>linmod</i> (f , y , x , u , x_0 , u_0) This function calculates linear model for non–linear model assigned in terms of input equations f, such as f={f ₁ (x,u),,f _n (x,u)} and output equations y, such as y={y ₁ (x,u),,y _n (x,u)}, relating to constant input u ₀ and steady state x ₀ . The jacobian matrixes can be evalutated in x ₀ , u ₀ and the state-space can be saved, or can be calculated in a symbolic way, before being evalutated.
F1+ F2+ F3 F4 F5+ F6+ F7+ Si Tools Zoom Trace Regraph Math Draw Pen:: Bode 8 U.2.2.3 by 92BROTHERS W(s): Delay: 0 W min: AUTO W max: AUTO Enter=OK ESC=CANCEL 0 0 0 0 0 0 0 0 0 0 0 0 0	 bodex(SYS) This program, made by 92BROTHERS, plots Bode diagrams of phase and magnitude and offers several tools to work with the plottoed diagrams. BodeX v.2.2.3 Copyright © 2000 92BROTHERS Email: 92brothers@infinito.it Home: http://www.92brothers.net/

F1+ F2+ F3 F4 F5+ F6+ F7+ F3: ToolsZoom TraceRegraph(Math)Draw/Pen(*: NYQUIST DIAGRAM W(3):	nyquist(SYS) Plots Nyquist diagram of SYS Control Toolbox v1.16 Author: Francesco Orabona E-mail: <u>bremen79@infinito.it</u> Home: <u>http://web.genie.it/utenti/b/bremen79/</u>
F1+ F2+ F3 F4 F5+ F6+ F7+ S:: Tools Zoom Trace Regraph Math Draw Pen:: Root Locus W(s): Min Gain: Max Gain: Step: <u>Enter=OK</u> <u>ESC=CANCEL</u> 02002-2005 Loreto Parisi TYPE + CENTERJ=OK AND CESCI=CANCEL	 <i>rlocus(SYS)</i> Plots the Root Locus of SYS Max, min gain are the extremes of the gain list. Porting for CST: Loreto Parisi Control Toolbox v1.16 Author: Francesco Orabona E-mail: <u>bremen79@infinito.it</u> Home:<u>http://web.genie.it/utenti/b/bremen79/</u> <i>step(SYS)</i>
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: Tools/Zoom/Trace/Response Step Response W(s): Amplitude U: 1 Delay: 0 CEnter=OK CESC=CANCEL 02002-2005 Loreto Parisi CST DEGAUTO FUNC	This tool calculates the step response for SYS, as $U^*w_{-1}(t) = L^{-1}(W(s)U/s)$, with amplitude U. Needs the tool LZT to perform symbolic calculation of Laplace direct and inverse transformation. LZT r7 Author: Jiri Bazant Email: <u>georger@razdva.cz</u> Home: <u>http://www.razdva.cz/georger/</u>
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ F3+ F7+ F3+ F3+ F7+ F3+ F3+	<i>pstep(SYS)</i> Calculates characteristic parameter of step response for transfer function SYS, such as T_e , T_a , T_s , T_p and s. Step response $w_{-1}(t)$ can be specified or calculated with step(SYS). Needs the tool LZT to perform symbolic calculation of Laplace direct and inverse transformation.

(F1+) F2+) F3 F4 F5+) F6+) F7+\$33 Tools Zoom Trace ResPaph Math Draw Pen:<: Step Response Image: Step Response: Image: Step Respon:	<i>gstep(w_1(t))</i> This tool plots the step response w_1(t) calculated with step(SYS) or specified directly. Can use pstep(SYS) to evalutate w_1(t) around its typical parameters.
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Notes.

1. About *pstep(SYS)*. Calculates time domain parameters of the step response for transfer function SYS, such as T_e , T_a , T_s , T_p and s, where T_e is the Elongation Time, T_r is the Raise Time, T_s is the Delay Time and s is the elongation.

Data	
$\begin{array}{c c} F1* & F2* & F3* & F4* & F5* & F6* \\ \hline Systems[Analysis] Dynamics Data Tools [Dther] \\ \hline 1 \pm U(\leq) \\ 2 \pm U(\leq) \\ 3 \pm \omega_{-}1(\pm) \\ 4 \pm \text{State Space} \\ 5 \pm 1W(\pm\omega) \\ 4 \pm \text{State Space} \\ 5 \pm 1W(\pm\omega) \\ 6 \pm 2W(\pm\omega) \\ 7 \pm \text{mag}(SYS, \omega0) \\ 8 \pm \text{phase}(SYS, \omega0) \\ 8 \pm \text{phase}(SYS, \omega0) \\ 8 \pm \text{phase}(SYS, \omega0) \\ \hline 0 \pm 2002 \pm 2005 \\ \text{Loreto Parisi} \\ \text{TYPE DR USE } \leftrightarrow \pm 1 \pm \text{CENTERJ DR LESC} \end{array}$	The <i>Data</i> menu (F4) gives access to current transfer function $W(\bullet)^1$, its discrete model $Wd(\bullet)$, the step response w-1(•), the current state space and magnitude and phase of $W(\bullet)$. ¹ According to current Time Domain Settings (see Other menu)
Image: State	W(s) [W(z)] Displays the current transfer function. SYS refers to it in all calculations of current session of CST, once you've calculated it with one of the tools of Systems menu.
State State Transfer Function >Wd(z)= 1 z + 1.	Wd(z) [Wd(s)]The discrete transfer function Wd(z)[Wd(s)], obtained by c2d(SYS),Tc)[d2c(SYS,Tc)] using the current transferfunction W(s) [W(z)] or bysampler(A,B,Tc) using the current statespace.
(ST DEGAUTO FUNC ST DEGAUTO FUNC ST	w_1(t) [w_1(k)] Shows the current step response obtained with step(SYS).
State Space A= -1 B= 1 CST DEGRUTO FUNC 120088	State Space It displays the current state space, as defined from one of tools of System menu.

F1+ F2+ F3 F4 F5+ F6+ F7+ F3::: Tools[Zoom[Trace[Re9raph[Math]Draw]Pen]:: -<	$/ W(\omega) /$ Displays magnitude of transfer function $W(\bullet)$ in Laplace domain (for $W(s)$) and even in domain Z (for $W(z)$).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3:: Tools[Zoom[Trace[Regraph[Math]Draw[Pen]::] Phase Ph	$\angle W(\omega)$ Displays phase of transfer function W(•) in Laplace domain (for W(s)) and even in domain Z (for W(z)).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ Tools/Zoom/Trace/Regraph/Math/Draw/Pen/-: <	$mag(SYS, \omega_0)$ Calculates magnitude of SYS in Laplacedomain (for W(s)) and even in domain Z(for W(z)), relating to ω_0 .
(F1+ F2+ F3 F4 F5+ F6+ F7+3;;) Tools[Zoom[Trace[Re9raph[Math]Draw]Pen]:: Phase in w0 ZW(iw): w0: Center=OK CESC=CANCEL 02002-2005 Loreto Parisi CST DEGAUTO FUNC	phase(SYS, ω_{θ})Calculates phase of SYS in Laplace domain(for W(s)) and even in domain Z (for W(z)), relating to ω_0 .

Tools	
$\begin{array}{c ccccc} F1* & F2* & F3* & F4* & F5* & F6* \\ Systems[Analysis]Dynamics]Data[Tools]Other] \\ \hline 1 & Cpoles(Cx) \\ \hline 2 & band(SYS) \\ 3 & polyz2s(Cx) \\ 3 & polyz2s(Cx) \\ 4 & routh(Cx) \\ 5 & routh(Cx) \\ 5 & routh(Cx) \\ 5 & routh(Cy) \\ 6 & pade(n, t) \\ 7 & eigenv(A) \\ 8 & spectre(A) \\ \hline 0 & 2002-2005 & Loreto & Parisi \\ CST & DEGAUTO & FUNC \\ \end{array}$	The <i>Tools</i> menu (F5) offers several useful functions to complete the analysis of the model you're working and to give more detailed information about it. Moreover presents different tools for discrete systems and finite state systems.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: Tools[Zoom[Trace[Re3raph Math]Draw[Pen]::] Poles Poles Poles Poles Poles Poles Enter::: Enter:::: Esc:::: Esc::::: Esc::::: Esc::::: Esc::::: Esc::::: Esc::::::::: Esc::::::::: Esc::::::::::::::::::::::::::::::::::::	<i>cpoles(Cx)</i> It calculates zeros of polinomyal given as LIST of coefficients, Cx.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools[Zoom[Trace[Re9raph[Math]Draw]Pen]** <t< td=""><td>polyz2s(Cx) This tool calculates the continuous polynomial q(s), relating to discrete polynomial p(z), assigned in terms of its coefficients LIST, Cx, using the formula $q(s) = (s-1)^n p(z) _{z=\frac{s+1}{s-1}}$</td></t<>	polyz2s(Cx) This tool calculates the continuous polynomial q(s), relating to discrete polynomial p(z), assigned in terms of its coefficients LIST, Cx, using the formula $q(s) = (s-1)^n p(z) _{z=\frac{s+1}{s-1}}$
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools[Zoom]Trace[Re9raph Math]Draw[Pen]:: <	band (SYS) This function uses a numerical algorithm and several preexistent formulas to calculate bandwith of system with transfer function SYS. It calculates f_i , f_s , where $B=[f_i,f_s]$, f_r (resonance frequency) and M_p (resonance peak).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: Tools[Zoom[Trace[Re9raph Math]Draw[Pen]::] Routh Matrix of P(s) Routh Matrix of P(s) Cx: Routh Matrix of P(s) Routh Matrix of P(s) Cx: Enter::DK ESC::CANCEL @2002-2005 Loreto Parisi CST DEG AUTO FUNC	<i>routh(Cx)</i> It calculates the Routh matrix for polynomial assigned with its coefficients LIST, Cx.

F1+ F2+ F3 F4 F5+ F6+ F7+51 Tools[200m]Trace[Re3raph[Math]Draw[Pen] Routh Criterion W(s): Parameter: Enter=0K G2002-2005 Loreto Parisi CST DEGAUTO FUNC	<i>routhc(Cx)</i> Applies Routh Criterion to parametric W(s) to obtain Routh conditions using the specified parameter.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ Tools[Zoom[Trace[Re3raph]Math[Draw]Pen]** Delay Pade Approximation Order:	$pade(n, \tau)$ Calculates the delay Padè approximation. Resulting delay transfer function can be saved as the current continuous transfer function W(s).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ Tools Tools Contrace Regraph Regraph Contract Contra	<i>eingev(A)</i> It calculates eigenvalues and eigenvectors of matrix A.
F1+ F2+ F3 F4 F5+ F6+ F7+51 Tools/200m/Trace/Regraph/Math/Draw/Penix: Spectral Decomposition of matrix A A:	<i>spectre(A)</i> This tool calculates the spectral decomposition of matrix A, even in the continuous (e^{At}) and in the discrete time (A^k), relating to real eigenvalues and complex eigenvalues. ¹
F1+ F2+ F3 F4 F5+ F6+ F7- \$!!! TableZaamiTraceIRe@raphiMathInrauIPeni:: Hold Equivalence A:	<i>sampler</i> (<i>A</i> , <i>B</i> , <i>T_c</i>) This function performs the discrete time conversion of continuous time model with state-space $\dot{x} = Ax + Bu$ at sample time T _c , using the ZOH (Zero Order Hold) method. It permits to use sample time T _c calculated with function tconst(SYS) for current transfer function SYS. It can save the resulting discrete transfer function Wd(z).

F1+ F2+ F3 F4 F5+ F6+ F7+ F1+ Tools Zoom Trace Re3raph Math Draw P0+ Polynomial to Coefficients Polynomial to Coefficients Var:	<pre>poly2cof(expr,var) Gives the LIST of coefficients of the polynomial given in expr in the variable var. Control's Toolbox v.1.16 Author: Francesco Orabona E-mail: bremen79@infinito.it Home:http://web.genie.it/utenti/b/bremen79/</pre>
F1+ F2+ F3 F4 F5+ F6+ F7+ 511 Tools/Zoom/Trace/Re9raph/Math/Draw/Pen/*:	 <i>rts2poly(roots)</i> Builds the polynomial with roots assigned as LIST. Author: Chadd L. Easterday Email: <u>easterday@mindspring.com</u>
<u>@2002-2003 Loreto Parisi</u> CST ∎D∎DEGAUTO FUNC	
F1+ F2+ F3 F4 F5+ F6+ F7+ F1+ Tools[200m]Trace[Regraph[Math]Draw[Pen]::] Laplace Transformation f(t):	<i>laplace(f(t))</i> Performs Laplace Transformation of f(t) Needs the tool LZT to perform symbolic calculation. LZT r7 Author: Jiri Bazant Email: <u>georger@razdva.cz</u> Home: <u>http://www.razdva.cz/georger/</u>
F1+ F2+ F3 F4 F5+ F6+ F7-15:11 ToolsZoom/Trace/Regraph/Math/Draw/Pen/:: - - - - Inverse Laplace Transformation - - - - - F(s): - <td< th=""><td> <i>ilaplace(F(s))</i> Performs Inverse Laplace Transformation of F(s). Needs the tool LZT to perform symbolic calculation. LZT r7 Author: Jiri Bazant Email: georger@razdva.cz Home: <u>http://www.razdva.cz/georger/</u> </td></td<>	 <i>ilaplace(F(s))</i> Performs Inverse Laplace Transformation of F(s). Needs the tool LZT to perform symbolic calculation. LZT r7 Author: Jiri Bazant Email: georger@razdva.cz Home: <u>http://www.razdva.cz/georger/</u>
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ Tools/Zoom/Trace/Regraph/Math/Draw/Pen/*: Zeta Transformation F(k):	<pre>zeta(f(k)) Performs Zeta Transformation of f(k) Needs the tool LZT to perform symbolic calculation. LZT r7 Author: Jiri Bazant Email: georger@razdva.cz Home: <u>http://www.razdva.cz/georger/</u></pre>

F1+ F2+ F3 F4 F5+ F6+ F7+ 5 Tools Zoom Trace Regraph Math Draw Pen :: Inverse Zeta Transformation F(z): Enter=OK ESC=CANCEL 02002-2005 Loreto Parisi CST DEGAUTO FUNC	<i>izeta</i> (<i>F</i> (<i>z</i>)) Performs Inverse Zeta Transformation of F(<i>z</i>). Needs the tool LZT to perform symbolic calculation. LZT r7 Author: Jiri Bazant Email: <u>georger@razdva.cz</u> Home: <u>http://www.razdva.cz/georger/</u>
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Notes.

¹ About *spectre(A)* The spectral decomposition of matrix A is

$$e^{At} = \sum_{i=1}^{\mu} u_i e^{\lambda_i t} v_i^T + \sum_{h=1}^{\nu} (u_{ha} \quad u_{hb}) e^{\alpha_h t} \begin{pmatrix} \cos \omega_h t & \sin \omega_h t \\ -\sin \omega_h t & \cos \omega_h t \end{pmatrix} \begin{pmatrix} v_{ha}^T \\ v_{hb}^T \end{pmatrix}$$
(continuous)

$$A^{k} = \sum_{i=1}^{\mu} u_{i} \lambda_{i}^{k} v_{i}^{T} + \sum_{h=1}^{\nu} (u_{ha} \quad u_{hb}) \rho_{h}^{k} \begin{pmatrix} \cos\theta_{h}k & \sin\theta_{h}k \\ -\sin\theta_{h}k & \cos\theta_{h}k \end{pmatrix} \begin{pmatrix} v_{ha}^{T} \\ v_{hb}^{T} \end{pmatrix}$$
(discrete)

relating to real μ eigenvalues λ_i and 2υ complex eigenvalues $\lambda_h = \alpha_h \pm j\omega_h = \rho_h e^{\pm j\theta_h}$ and the relating eigenvector u_i and $u_h = u_{ha} \pm u_{hb}$.

Other	
F1+ F2+ F3+ F4+ F5+ F6+ Systems Analysis Dynamics DataTools Other 1:Quick Load (2:Quick Save 3:File 4:Settings 5:Help 6:About 7:Exit 02002-2005 Loreto Parisi CST DEGAUTO FUNC	The <i>Other</i> menu (F6) gives tools to manage files, the current working session, the Settings, to access to on-line help tool with help(), some information about CST, and the way to exit CST.
F1+ F2+ F3 F4 F5+ F6+ F7+ S: ToolsZoomTraceRe3raphMathDrawPen:: Load session Press Enter to load a saved session. <u>Enter=DK ESC=CANCEL</u> VI.Z.J <u>B2002-2003 Loreto Parisi</u> CST TRAD AUTO FUNC	<i>Quick Load</i> Loads the current working session (i.e. transfer functions W(s) and W(z),State space, w_1(t), Tc, step response parameters,etc.) previously saved. It overwrites all the existing values for the current session. Be careful.
Fit F2+ F3 F4 F5+ F6+ F7+ ⁵ Tools 200m Trace Regraph Math Draw Pen :: Save session Press Enter to save current session. Enter=OK ESC=CANCEL VI.2.3 B2002-2003 Loreto Parisi CST B RAD AUTO FUNC	<i>Quick Save</i> Saves the current working session (i.e. transfer functions W(s) and W(z),State space, w_1(t), Tc, step response parameters,etc.).
C O N T R O L SYSTEM T O O L B O X 1.3 G2002-2005 Loreto Parisi CST DEGAUTO FUNC	<i>File</i> The File toolbox gives access to the File & Session Management. Here you can load and save the current working session, the State Space, the Transfer Function, the Step Response and bode diagram obtained with bodex(SYS). There are three menus Load, Save and Exit. Exit menu (F3) brings to the previous toolbox.

F1+ F2+ F3 F4 F5+ F6+ F7+(5) Tools Zoom Trace Regraph (Math Draw Pen)-: Settings Time Domain DOMANTOTED Display Digits FLOAT 1+ Results	Settings It permits to modify some settings of the calculator, such as the display digits, the angle, the format of results and to switch the current Time Domain: Continuous to work with continuous time model W(s) or Discrete to work with discrete time model W(z) in the same working session.
Systems Analysis Dynamics Data Tools Dther Systems Analysis Dynamics Data Tools Dther CONTROL SYSTEM TOOLBOX HELP 1.3 02002-2005 Loreto Parisi CST DEGAUTO FUNC	<i>help()</i> Starts the help tool. To get help, simply choose a function from one of the menus and you'll get some information about it.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ Too Control System Toolbox for TI-89 ** + Current release r1.3 May 2005 + Contacts Ioreto.Parisi@tiscali.it + CST Support & Up3rades http://web.tiscali.it/loretoparisihome 02002-2005 Loreto Parisi. Esteration Enter=0K ESC=CANCEL 02002-2005 Loreto Parisi CST 0 DEGAUTO FUNC	<i>About</i> Gives the current version of CST for TI- 89, the way to contact the author and to obtain support and upgrades.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3:: Tools[Zoom[Trace[Re9raph[Math]Draw]Pen]::	<i>Exit</i> To close Control System Toolbox for TI- 89. All previous settings of the calculator will be restored. Prompts for non-saved working session.

File	
Eit F2+F3 C O N T R O L SYSTEM T O O L B O X 1.3 02002-2005 Loreto Parisi CST DEGRUTO FUNC	The <i>File</i> toolbox gives access to the File & Session Management. Here you can load and save the current working session, the State Space, the Transfer Function, the Step Response and bode diagram obtained with bodex(SYS). There are three menus Load, Save and Exit. Exit menu (F3) brings to the previous toolbox.
Fi F2+F3 Load Sove(Exit 1: Session 2: State Space 3: Transfer Function 4: Step Response 5: Bode diagram V1.2.3 0 X V1.2.3 0 2002-2003 Loreto Parisi CST RAD AUTO FUNC	<i>Load</i> The Load menu (F1) permits to load the current working session, the State Space, Transfer Function, Step Responde and bode diagrams from the specified path.
F1+ F2+ F3 F4 F5+ F6+ F7+Sii ToolsZoom Trace Regraph Math Draw Pen: Load session Press Enter to load a saved session X Enter=DK CESC=CANCEL VI.2.3 B2002-2003 Longto Parisi CST B2 RAD AUTO FUNC	<i>Load Session</i> Loads the current working session (i.e. transfer functions W(s) and W(z),State space, w_1(t), Tc, step response parameters,etc.) previously saved. It overwrites all the existing values for the current session. Be careful.
F1+) F2+) F3 F4 F5+) F6+) F7+(5;) Load State Space A:	<i>Load State Space</i> To load state space matrixes A,B,C,D from specified path. Please use absolute path. For example, if your dynamic matrix A is stored in main as dyn, you have to input dyn in A input field and main as path. All matrixes should be in the same path.
F1+ F2+ F3 F4 F5+ F6+ F7- \$!! ToolsZoom Trace Re3raph Math Draw Pen :: Load Transfer Function SYS:	<i>Load Transfer Function</i> Permits to load Transfer Function from specified path.

F1+ F2+ F3 F4 F5+ F6+ F7+ F3: ToolsZoom/Trace/Regraph/Math/Draw/Pen::: <t< th=""><th>Load Step Response Permits to load the Step Response from specified path.</th></t<>	Load Step Response Permits to load the Step Response from specified path.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: Tools/Zoom/Trace/Re#raph/Math/Draw/Pen/*: <	Load Bode diagram This tools permits to load a picture stored in CST folder. It's aid is in displaying Bode plots, created with bodex() first, and estimating the diagrams in a assigned frequency ω_0 .
Five F2 F3 Lood Sove Exit 1: Session 2: State Space 3: Transfer Function 4: Step Response v1.2.3 02002-2003 Loreto Parisi CST RAD AUTO FUNC	<i>Save</i> The Save menu (F2) permits to save the current working session, the State Space, Transfer Function, Step Responde into a specified path.
F1+ F2+ F3 F4 F5+ F6+ F7+ ⁵ ;; ToolsZoomTraceRegraphMathDrawPenP:: Save session Press Enter to save current session. Enter=OK ESC=CANCEL V1.2.3 B2002-2003 Loreto Parisi CST B RAD AUTO FUNC	<i>Save session</i> Saves the current working session (i.e. transfer functions W(s) and W(z),State space, w_1(t), Tc, step response parameters,etc.).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ TableZoom/TraceleadranblMathINtaulEcol. Save State Space Save State Space A name:	<i>Save State Space.</i> Permits to save current State Space into the specified path, using given names.

F1+ F2+ F3 F4 F5+ F6+ F7+ F3: Tools/Zoom/Trace/Regraph/Math/Draw/Pen(*: Save Transfer Function Save Transfer Function Save Transfer Function SYS name: Path: Please specify absolute path. @2002 Loneto Parisi @2002 Loneto Parisi	Save Transfer Function. To save current transfer function into the specified path, using given name. The current SYS results from Data menu (F4).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: Tools/200m/Trace/Regraph/Math/Draw/Pen/::	Save Step Response. To save currrent step response into the specified path, using give name. The current step results from Data menu (F4).

Controller	
F2* $(F3*) F4* (F5*)$ Controller Network[Data[Tools[Dther]1: Design2: Tuning0 L3: CustomM4: P0 X6: PI0 X6: PI0 X6: PI0 X6: PD7: PID84Lead NetworkGnuGPL 2005 Loreto ParisiTYPE DR USE +>14 + CENTERI DR CESCI	The <i>Controller</i> menu (F1) is intented to design and tuning the control system.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3:: Tools Tools Controller Design L Controller Design L L L PChoose Controller R(s) Enter=0K ESC=CANCEL X GnuGPL 2005 Loreto Parisi USE + AND + T0 DPEN CHOICES C	The <i>Controller Design</i> wizard will guide you throught the full design of the network's controller. First step is to choose the <i>network structure</i> from the following types: Custom (i.e. user defined), P, PI, PD, PID, Lead, Lag and Lead-Lag networks.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3:: ToolsZoom Trace Restraph Math Draw Pen<::	<i>Custom Network</i> Defines your own custom network's controller R(s).
F1+ F2+ F3 F4 F5+ F6+ F7+ F3::: Tools/200m/Trace/Regraph/Math/Draw/Pen/:: 0<	<i>P Controller</i> Defines a proportional controller R(s) = Kp.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: ToolsZoom Trace Restarb MathDraw Pen :: PI Controller KP: Ki: Enter=0K ESC=CANCEL GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	PI Controller Defines a PI controller R(s) as you give Kp and Ki or Kp and Ti: $R_{PI}(s) = \frac{K_P s + K_I}{s} = K_P \frac{1 + T_I s}{T_I s}$ where $T_I = \frac{K_P}{K_I}$

	PD Controller	
F1+ F2+ F3 F4 F5+ F6+ F7+3:: Too1sZoomTraceRe9raphMathDrawPen:: PD Controller	Defines a PD controller R(s) as you give Kp and Kd or Kp and Td:	
KP:	$R_{PD}(s) = K_P + K_D s = K_P (1 + T_D s)$	
GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	where $T_D = \frac{K_D}{K_P}$	
	DID Controllor	
F1+1 F2+1 F3 F4 1 F5+1 F6+1 F7+15:: PID Controller KP: Ki: Ki:	Defines a standard PID controller as you give Kp, Ki, Kd or Kp, Ti, Td: $R_{ppr}(s) = \frac{K_D s^2 + K_P s + K_I}{K_D s^2 + K_D s^2 + T_I s + 1}$	
	s r $T_{l}s$	
N: <u>Enter=OK</u> (ESC=CANCEL) GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	or a real PID controller specifing N: $R_{PID}(s) = K_P + \frac{K_I}{s} + \frac{K_D s}{1 + \frac{K_D}{K_P N} s} = K_P (1 + \frac{1}{T_I s} + \frac{T_D}{1 + \frac{T_D}{N} s})$	
	Direct Design	
ToolsZoomTraceRegraphMathDrawPen:	Defines a Lead, Lag or Lead-lag network directly from	
CONTROL 1:Direct 2:Nichols 1.3	transfer function's gain μ_R , time constant T and α parameter.	
GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC		
(F1+ F2+ F3 F4 F5+ F6+ F7+3)) ToolsZoomTraceRegraph(MathDrawPen)) Lead Network	<i>Lead Network</i> Defines a lead network R(s) as you give the gain μ_R , time constant T and parameter α :	
T:	$R(s) = \mu_R \frac{1+1s}{1+cT_R}$	
«: Please set #R>0,T>0, 0<«<1	Must be:	
	$\mu_R > 0, T > 0, 0 < \alpha < 1$	
<u>GnuGPL 2005 Loreto Parisi</u> TYPE + LENTERJEOK AND LESCJECANCEL	Usually, $\alpha = 0.1$ and $T = \frac{1}{\omega_c}$	
	Lag Network	
F1+ F2+ F3 F4 F5+ F6+ F7+S: ToolsZoomTraceRe9raphMathDrawPen::	Defines a lag network $R(s)$ as you give the gain μ_R ,	
La9 Network	time constant T and parameter α :	
Fin: [T: [$R(s) = \mu_R \frac{1+Is}{1+cT}$	
α: Please set μR>0,T>0, α>1	$1 + \alpha I s$ Must be:	
	$\mu_R > 0, T > 0, \alpha > 1$	
GnuGPL 2005 Loreto Parisi TYPE + CENTERJ=OK AND CESCJ=CANCEL	Usually, $T > \frac{1}{\omega_c} (T = \frac{10}{\omega_c})$	
Lead-Lag Network		
--	--	--
F1+ F2+ F3 F4 F5+ F6+ F7+ 3:: Lead*La3 Network #R: t1: t2: T1: T2: Please set #R>0,71>t12t2>T2>0 Enter=0K ESC=CANCEL GnuGPL 2005 Loreto Parisi TYPE + CENTERJ=0K AND CESCJ=CANCEL	Defines a lead-lag network R(s) as you give the gain μ_R , and time constants τ_1 , τ_2 , T_1 , T_2 : $R(s) = \mu_R \frac{(1 + \tau_1 s)(1 + \tau_2 s)}{(1 + T_1 s)(1 + T_2 s)}$ Must be: $\mu_R > 0, T_1 > \tau_1 \ge \tau_2 > T_2 > 0$ Usually, $T_1 T_2 = \tau_1 \tau_2, \tau_2 > \frac{1}{\omega_C} > T_2$	
F1+ F2+ F3 F4 F5+ F6+ F7+75 Tools/200m/Trace/Re3raph/Math/Draw/Pen/: CONTROL 1:Direct EM 2:Nichols BOX 1.3 GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	Nichols Design Defines a Lead, Lag or Lead-lag network using Nichols's standard networks parameters $\omega \tau$, $1/\alpha$ at ω_0 . In most cases ω_0 will be the critical frequency ω_C .	
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: Tools/200m/Trace/Re3raph/Math/Draw/Pen/: <t< th=""><td>Lead Network Defines a Lead network using Nichols's standard networks parameters $\omega \tau$, $1/\alpha$ at ω_0. $R(s) = \frac{1 + s\tau}{1 + s\alpha\tau}$</td></t<>	Lead Network Defines a Lead network using Nichols's standard networks parameters $\omega \tau$, $1/\alpha$ at ω_0 . $R(s) = \frac{1 + s\tau}{1 + s\alpha\tau}$	
Lag Network		
F1+ F2+ F3 F4 F5+ F6+ F7+3: Tools/Zoom/Trace/Re3raph/Math/Draw/Pen/:: La3 Network 0: 1/0: Center=DK CESC=CANCEL GnuGPL 2005 Loreto Parisi	Defines a Lag network using Nichols's standard networks parameters $\omega \tau$, $1/\alpha$ at ω_0 . $R(s) = \frac{1 + s\alpha\tau}{1 + s\tau}$	
C4-Y E2-Y E2 FM Y EE-Y E2-Y E2 Y E2-Y E2 <	Lead-Lag Network Defines a Lead-Lag network using Nichols's standard networks parameters $\omega \tau_1$, $1/\alpha_1$ for the lead and $\omega \tau_2$, $1/\alpha_2$ for the lag network at frequency ω_0 . $R(s) = \frac{1 + s\tau_1}{1 + s\alpha_1\tau_1} \frac{1 + s\alpha_2\tau_2}{1 + s\tau_2}$	

F1+ F2+ F3 F4 F5+ F6+ F7+ ⁸ :: Tools/200m/Trace[ReSraph/Math/Draw/Pen]:: Controller Tunin3 G(s): Delay: 0 PChoose Tunin3 Method Tunin3 F8 ZieSler-Nichols+ <u>Enter=OK</u> <u>ESC=CANCEL</u>	<i>Controller Tuning</i> The Controller Tuning wizard will guide you through the tuning of the network's controller R(s) for the given process G(s) and its delay. First choose the tuning method from ones avaiable: <i>Feedback Ziegler-</i> <i>Nichols, Feedforward Ziegler-Nichols, Optimal</i> <i>Control, Predictive Control</i> and <i>Adaptive Filtering.</i>
GnuGPL 2005 Loreto Parisi TYPE + LENTERJ=DK AND LESCJ=CANCEL F1+ F2+ F3 F4 F0015[Zoom[Trace[ReSraph[Math]Draw]Pen]: Feedback Zie3]er-Nichols Feedback Zie3]er-Nichols PController R(s) P+ PID Tuning Auto+ PID N: Enter=DK ESC=CANCEL	Feedback Ziegler-Nichols Uses the <i>Closed Loop Ziegler-Nichols</i> method to tune the controller for the feedback network. Choose the desidered structure for $R(s) - P$, PI or PID. Only for PIDs, choose the assignment method for gain and phase margins (Auto, assign Gain Margin or assign Phase Margin) and the parameter N if you wish to use
GnuGPL 2005 Loneto Parisi USE 4 AND 3 TO OPEN CHOICES Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Fod(s) Farameters Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols File Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Footroller Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols Feedforward Zie3ler-Nichols File Feedforward Zie3ler-Nichols	a real PID controller, instead of a standard PID controller. Feedforward Ziegler-Nichols Uses the Open Loop Ziegler-Nichols method to tune the controller for the approximate process (obtained from the step response using the areas method) $G_a(s) = \frac{\mu}{1+Ts}e^{-\tau s}$. Choose the structure (P, PI or PID) for R(s) and for PIs only the assignment method for the phase margin (Auto, assign Phase Margin).
Optimal Control ÞGa(s) Parameters µ: T: T: T: T: T: Timing ISE + ÞController R(s) PI + PID N: Center=0K VIEW - CENTERJ=0K AND LESCJ=CANCEL	Optimal Control Uses optimization methods to tune the controller R(s): ISE (<i>Integral Square Error</i>), ISTE (<i>Integral Square Time Error</i>) and IST ² E (<i>Integral Square Time² Error</i>). Kp, Ti and Td are defined by a table as follows: $K_p = \frac{a_1}{\mu} \theta^{b_1}, T_l = \frac{T}{a_2 + b_2 \theta}, T_D = a_3 T \theta^{b_3}$
Smith Predictive Control PG(s) N+(s): N-(s): D(s): Delay: 0 Save G(s) No ÷ MUSE Controller R(s) Custom ÷ Center=0K CST DEGAUTO	Smith Predictive Control Used to tune network's controllers for processes with postive real zeros or time delays. The process G(s) is given as $G(s) = \frac{N^-(s)N^+(s)}{D(s)}e^{-\tau s}$. The predictor P(s) and the network transfer function L'(s) for the given controller R(s) are $P(s) = \left(1 - \frac{N^+(s)}{N^+(-s)}e^{-\tau s}\right)\frac{N^-(s)N^+(-s)}{D(s)}$ and $L'(s) = (G(s) + P(s))R(s)$.

F1+ F2+ F3 F4 F5+ F6+ F7+S: ToolsZoomTraceRegraphMathDrawPen:: Adaptive Filtering HUse Compensator C(s) UNIXOD+ Enter=DK ESC=CANCEL	<i>Adaptive Filtering</i> Uses a pre-filtering technique (compensation of input signal) to improve static and dynamic behaviour. You have to choose the structure for the compensator C(s). We suppose you have defined it as a controller (custom, lead, lag or lead-lag) yet.
GnuGPL 2005 Loreto Parisi WSE € AND → TO DPEN CHOICES	
S S S S S S S S S S S S S S	<i>Custom, P, PI, PD, PID, Lead, Lag, Lead-Lag</i> Shows the controller defined for that structure. Note that you have to choose the controller first to perform the analysis, but it's possible to define (design or tuning) more controllers, then choose one of them as the current R(s).
CST DEGAUTO FUNC 1211189	

Network	
F1+ Controller F2+ Network Output Data Tools Other 1: Design 2: Analysis 3: 6(s) 4: R(s) 5: L(s) 6: F(s) 7: S(s) 84Q(s) GnuGPL 2005 Control Longton	The <i>Network menu (F2)</i> permits to design and analyse the control system, calculating gain and phase margins, and the network transfer functions.
F1+Y F2+Y F3 Y F4 Y F5+Y F6+Y F2+Y2; Network Design PProcess G(s): 5*100/(s*2+4:%s+25.) Delay: 0 Use None + PController R0(s) None + K(s) Custom + Center=0K Cesc=cancel GnuGPL 2005 Loreto Parisi TYPE + CENTERJ=0K AND CESC=CANCEL	<i>Network Design</i> Define the process $G(s)$ and its delay, the controllers $R_0(s)$ and $R(s)$.
$\begin{array}{c c} F1 + Y F2 + Y F3 Y F4 Y F5 + Y F6 + Y F2 + Y2; \\ \hline Network Design \\ \hline PProcess \\ G(s): [s+10)/(s^2+4, *s+25.) \\ Delay: [0] \\ Use 1: None \\ \hline None \\ R(s) [2: F(s)] \\ R(s) Custom + \\ \hline Center=DK \\ \hline Center=Center=DK \\ \hline Center=Center$	<i>Network Design</i> Use the inner loop transfer function F(s) as G(s) in the unstable processes control systems. Now you can tune the controller against the inner closed loop transfer function. See notes for more informations.
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Network DesignChoose the controller $R_0(s)$ betweencustom, proportional, lead or lag structures.Generally, use it to satisfy staticrequirements.
F1+Y F2+Y F3_Y F4 Y F5+Y F6+Y F2+Y2 Network Desi3n PProcess G(s) 1: Custon De1(2: P Use (3: PI PCon 4: PD R(s) 6: Lead CET 7: Lag Gnut 8: Lead - Lag TYPE DR USE ++1+ CENTER) DR CESC	<i>Network Design</i> Choose the controller R(s) between all structures avaiable to satisfy dynamic requirements.

	L(s)
	The network transfer function
Colculating	
	L(s) = R(s)G(s)
5 (a + 2, 1)(a + 10)	
2(2)	
s²·(s² + s + 100.)	
CST DEGAUTO FUNC PAUSE	
Kenny en year way as y so y	F(s)
รได้มีสระได้หายได้ได้ห้าง หรือกอย่างไม้อย	The network transfer function
Calculating	
▶F(s)=	$F(s) = \frac{R(s)G(s)}{1-1}$
5. (s + 2.1) (s + 16	$T(s) = \frac{1}{1 + R(s)G(s)}$
(s ² +.421 · s + 104.) · (s ² +.5	
CST DEGENTO FUNC IZO1644	
	S(s)
87 - 187 - 183 - 188 - 185 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186 - 186	The network transfer function
Calculating	
▶S(s)=	1
$a^{2}(a^{2}+a+100)$	$S(s) = \frac{1}{1 + R(s)G(s)}$
(2)	1 + N (3)O(3)
ls²+.421·s+104.j·ls²+.5	
CST DEGAUTO FUNC IZTURIA	
	Q(s)
「ディー」「ディー」「FB+」「FN+」「FS」「デルー」 していたきに、たからしない。「かっかっ」「ディー」「FS」「デルー」	The network transfer function
Calculating	
▶Q(s)=	R(s) $R(s)$ $R(s)$
005:0:(0+2+)(-2+-	$Q(s) = \frac{1}{1 + R(s)G(s)} = F(s)G(s)^{-1} = R(s)S(s)$
.000757(S+2.1)7(S+5)	1 + 11(5)0(5)
[s ² + .421 ⋅s + 104.]·[s ² + .5	
CST DEGAUTO FUNC PRUSE	
(set so trates to the tot	M(s)
1.41.81.61.61.01.01.01.01.01.01.01.01.01.01.01	The network transfer function
Calculating	
►M(s)=	M(s) = G(s)S(s)
5. (s+2.1) (s+10	
(s ² +.421·s+104.)·(s ² +.5	
CST DEGAUTO FUNC IZVIDAR	

1.2.1 (2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.	<i>Analysis</i> Performs an analysis of the defined control system, calculating the Gain and the Phase margins.
CST DEGAUTO FUNC PAUSE	

Notes.

About Network Design.

1. When G(s) is such an unstable process, we'll use a block model with a inner control loop, like the block diagram below.



And we'll tune R₁(s) to stabilize G(s) and R₂(s) against $F(s) = \frac{R_1(s)G(s)}{1 + R_1(s)G(s)}$ to satisfy

given requirements. To do so, first design $R_1(s)$ as usual. When the inner closed loop is stable, you can design $R_2(s)$ choosing in *Network Design* **Use** F(s) as new G(s) from the drop down menu.

Output	
$\begin{array}{c} F1* \\ Controller Network \\ \hline \\ $	The Output menu (F3) permits to perform a time domain analisys of the closed loop system against inputs, noises and measure noise.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+ Tootr/20000/Tradicles@kambledathInvaul@colit. Network Inputs Network Inputs Minput	Inputs To set the input $r(t)$, noise inputs $d(t)$ and $d^*(t)$, and measure noise input $n(t)$. To set a step input of amplitude K use K for $r(t)$. To set a sinusoidal measure noise, use $sin(\omega t)$ as $n(t)$.
ST RAD AUTO FUNC FUNC	yr(t), yd(t),yn(t) The output y time response against input r(t), noise input d(t) and measure noise input n(t).
CST RAD AUTO FUNC	ur(t), ud(t), un(t) The control variable u time response against input r(t), noise input d(t) and measure noise input n(t).
CST RAD AUTO FUNC	er(t), ed(t), en(t) The error e=r-y time response against input r(t), noise input d(t) and measure noise input n(t).

Notes.

About Output menu.

1. We assume a Closed Loop Control System block model like that below.



2. We assume the following transfer functions.

$$\begin{bmatrix} Y(s) \\ U(s) \\ E(s) \end{bmatrix} = \begin{bmatrix} F(s) & S(s) & -F(s) \\ Q(s) & -Q(s) & -Q(s) \\ S(s) & -S(s) & F(s) \end{bmatrix} \cdot \begin{bmatrix} R(s) \\ D(s) \\ N(s) \end{bmatrix}$$

where

$$F(s) = \frac{K(s)G(s)}{1 + K(s)G(s)},$$

$$S(s) = \frac{1}{1 + K(s)G(s)},$$

$$Q(s) = \frac{K(s)}{1 + K(s)G(s)},$$

and $Y^*(s) = M(s)D^*(s)$ where M(s) = G(s)S(s).

Data	
Controller Network Oddo Tools[Dther]	The <i>Data</i> menu (F3) shows detailed informations about the control system.
State State State Phase Margin > φm=33.2° > φc=1.1 rad/s > φc=-147.° > τc=.528 s	<i>Margins</i> Shows the Gain and Phase margins of the control system.

Tools	
Controller Network Data Tools Other Controller Network Data Tools Other Controller Network Data Tools Other Controller Network Data Tools Other Controller Network Data System Controller	The <i>Tools</i> menu (F4) permits you to perform a detailed analysis of transfer function SYS. You need to choose the current transfer fuction SYS first.

Other	
Controller Network Data Tools Other Controller	The <i>Other</i> menu (F3) shows some help, info and permits to exit the program.
F1+ F2+ F3 F4 F5+ F6+ F7+5: Tools200mTraceRegraphMathDrawPen:: Load session Press Enter to load a saved session. Enter=DK ESC=CANCEL V1.2.3 B2002-2003 Loreto Parisi CST DE RAD AUTO FUNC	Quick Load Loads the current working session (i.e. transfer functions of process, network and controllers, calculated margins, etc.) previously saved. It overwrites all the existing values for the current session. Be careful.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools200m[Trace[Re3raph[Math]Draw]Pen]:: C O M T P Save session Save session C O M T P Press Enter to save current session. C Esc=CANCEL VI.2.3 Image: Same control of the same current session. VI.2.3 Image: Same control of the same current session. VI.2.3 Image: Same current session. VI.2.3 Image: Same current session. VI.2.3	<i>Quick Save</i> Saves the current working session (i.e. transfer functions of process, network and controllers, calculated margins, etc.).
F1+ F2+ F3 F4 F5+ F6+ F7+ ⁵ ;; ToolsZoomTraceReBraph(MathDrawPen):: Not avaiable yet. Enter=OK GnuGPL 2005 Loreto Parisi	<i>Help</i> Shows some help.

F1+ F2+ F3 F4 F5+ F6+ F7+S:: Tools Zoom Trace Regraph Math Draw Pen:: Feedback Control Systems Design and Tuning of Control Systems PCurrent Release r1.0 GnuGPL 2005 Loroto Parisi	<i>About</i> Shows some info.
<u>(Enter=OK)</u> (ESC=CANCEL) GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	Exit
F1+ F2+ F3 F4 F5+ F6+ F7+ 53 ToolsZoomTraceRe9raph[Math]Draw[Pen]:: Feedback Control Systems Current session not saved. Exit without savin9? Enter=OK ESC=CANCEL	Exit the program. Unsaved session will be losed.
GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	

Examples 1 - First Order LPF	
F1+ F2+ F3 F4 F5+ F6+ F7+ 5000 Trace[Re3raph Math Draw Pen]: Transfer Function Num: 1 Den: [1:103 Delay: 0 Please insert coefficients as LIST ESC=CANCEL GnuGPL 2005 Loreto Parisi CST DEGAUTO	Considers a sample low pass filter, with transfer function $\frac{1}{1+10s}$. First of all, we'll define the current transfer function. From Systems menu (F1) choose function tf(NUM,DEN) (3) where NUM=1 and DEN={1,10}.
Calculating Calculating Delay=0 FW(s)= 1 s + 10 CST DEGAUTO FUNC 2003	This stores $\frac{1}{1+10s}$ as the current transfer function SYS.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools/200m/Trace/Re3raph/Math/Draw/Pen/:: Image: Constant Part of Parts Image: Constant Image: Constant Parts Image: Const	To get relating state-space, now we'll use function tf2ss(SYS), where SYS is the current transfer function, automatically filled in the input field.
State Space A= -10 B= 1 CST DEGAUTO FUNC MOUNT	After calculation of all matrixes, they will be the current state space.
F1* F2* F3 F4 F5* F6* F7* F3* Taals/Zaam/Trace/Restrach/Math/Draw/Peni:: Continuous to Discrete Time Model W(s): 1/(s+10) Sampling time: Hethod HE + Sampling time with tconst() ? M28+ Save Wd(z) as W(z) ? No + Enter=0K ESC=CANCEL GnuGPL 2005 Loreto USE € AND > TO OPEN CHOICES Parisi	If you need to obtain the discrete model of SYS, use c2d(SYS,Tc) where Tc is the sample time desidered. We'll use tconst(SYS) to get Tc and 'HE' (Hold Equivalence) transformation as method. We could save resulting Wd(z) as the current discrete transfer function W(z).

Image: State of the state	Here is the discrete time model with sample time Tc from tconst(SYS) and 'HE' (Hold Equivalence) method.
(2.1222) ▶Wd(z)= .005·(z+1) z905 ▶Sampling Time Tc=.01 CST DEGAUTO FUNC MOUSE	This is the discrete time model with sample time Tc from tconst(SYS) and 'Tustin' method.
Calculating Poles (-1/t) (-10.) ►Zeros (-1/t') () CST DEGAUTO FUNC MOUST	Now, we'll gonna calculate poles and zeros of SYS. From Analysis menu (F2) we'll choose pzmap(SYS) where SYS is the current transfer function.
Calculating Calculating ▶D.C. Gain of W(s) G=.1 IGIdB=-20. CST DEGAUTO FUNC MANUSE	With function dcgain(SYS) we have calculated the d.c. gain of SYS, which results –20 dB (0.1 linear).
Calculating ►Mp=.1 (Mp)dB=-20. dB ►fr=.159 Hz	In the same way, with function peak(SYS) we'll obtain the resonance peak MP (in this case it matches with previous d.c. gain G) and relating resonance frequency fr that results .159 Hz.

CST DEGAUTO FUNC PROBA	We can calculate the Bandwith B ₃ choosing band(SYS) from Tools menu (F5).
Calculating Ffi Ffs Calculate MP and fr with PeakO? Ffr Enter=DK CST DEGAUTO FUNC 2/30	As you can see, M _P and fr will results from peak(SYS) when band(SYS) fails.
$\begin{array}{c c} F1 \bullet & F2 \bullet & F3 & F4 & F5 \bullet & F6 \bullet & F7 \bullet ^3 \vdots \\ \hline Tools[200m]Trace[Regraph[Math]Draw[Pen] :: \\ \hline Bode& V.2.2.3 by 92BROTHERS \\ \hline W(s): $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $$	From Dynamics menu (F3) we'll going to plot Bode diagrams with function bodex(SYS), courtesy of 92BROTHERS. We'll use w and 0.01 and 100 as transfer function, ωmin and ωmax. Current SYS is showned in the W(s) input field.
F1+ F2+ F3+ F3+ F4+ F5+ F6+ EXIT 2000 MAG/PHASE INFO TOOLSFILE -20. db F1F(s) 120. db/d 120. db F1F(s) 120. db/d 120. db F1F(s) 120. db/d	The Mag Bode diagram. Use Get Point from Info (F4) to trace the plot and get a specific value for magnitude. You can even save this plot from File (F6).
EXIT Zoom MAG/PHASE INFD TODUS FILE EXIT Zoom MAG/PHASE INFD TODUS FILE -45.0 1. DEG AUTO FUNC	The Phase Bode diagram. Use Get Point from Info (F4) to trace the plot and get a specific value for phase. You can even save this plot from File (F6).

$\begin{array}{c c} F1 + F2 + F3 & F4 & F5 + F6 + F7 + 3 \\ \hline Tools[Zoom[Trace[Regraph[Math]Draw]Pen] :: \\ \hline $	We can calculate the step response using step(SYS). Set the amplitude (1 by default) and the time delay.
Step Response ▶w_1(t) 1/10 - € CST DEGAUTO FUNC	Here is the step response.
$\begin{array}{c c} F1+ F2+ F3 & F4 & F5+ F6+ F7+3:::\\ Tools/Zoom/Trace/Redrash/Math/Draw/Peni::Step Response Parameters \\ \hline W(s): 17(0-e^{(-10*t)/10} \\ w_1(t): 1/10-e^{(-10*t)/10} \\ Delay: 0 \\ w_1 with step()? ND + \\ Amplitude U: 1 \\ \hline Center=DK & CESC=CANCEL \\ \hline GnuGPL 2005 Loreto Parisi \\ TYPE + CENTERJ=DK AND (ESC)=CANCEL \\ \end{array}$	Then we could calculate the time domain step response parameters using function pstep(SYS). We can decide to use current step response or define a new one with step(SYS), for wich we will set the amplitude and time delay.
Step Response parameters Te= .07 sec Tr= .22 sec Ts= .3 sec s= 0. % Step Response parameters Step Response parameter	Here are the time domain step response parameters, Te, Tr, Ts, Tp and s.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 TableIstantFraceBookenhildsthingsulfanit Steady State parameters Steady State parameters 8: 1 Image: State parameters Steady State parameters 0: 0 Image: State parameters Steady State parameters 0: 0 Image: State parameters State parameters 0: 0 Image: State paramet	To get the steady state we'll use function trim(A,B,C, D,u0).

Calculating Calculating ▶Steady State [1/10] ▶Output [1/10] CST DEGAUTO FUNC PAUSE	Note that x0 and y0 matches with w-1(t).
Calculating Calculating ▶Real Eigenvalues [e ^{-10·t}] ▶Complex Eigenvalues 0 CST DEGAUTO FUNC PRUNE	With spectre(A) we'll obtain e^{At} in the Continuous Time Domain. Because of real pole, we have not complex expansion.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3::: Tools[Zoom[Trace[Regraph[Math]Draw[Pen]::: Settings Image: Settings Image: Settings Time Domain Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Settings Image: Setings <td>Now we will set the Time Domain to Discrete from Settings in Other (F6) menu.</td>	Now we will set the Time Domain to Discrete from Settings in Other (F6) menu.
Calculating ►Real Eigenvalues [(10.) ^k .cos(2.ɛ2·k)+(10.) ^k ► ►Complex Eigenvalues 0 CST DEGAUTO FUNC FROM	With spectre(A) we'll obtain A^{k} in the Discrete Time Domain. Because of real pole, we have not complex expansion.
F1+ F2+ F3 F4 F5+ F6+ F7+3:: Tools/Zoom/Trace/Begraph/Math/Drow/Pen:: Hold Equivalence A: 10 B: 1 Sampling Time: [01 Sampling Time with tconst() ? No + Save Wd(z)? No + <u>Enter=OK</u> <u>ESC=CANCEL</u> GnuGPL 2005 Loreto Parisi TYPE + CENTERJ=OK AND CESC]=CANCEL	Here we have obtained a discrete model of SYS, using ZOH method. We can save the resulting discrete transfer function as the current discretized transfer function.

CST DEGAUTO FUNC [2018]	Here are the Discrete time model of SYS.
$\frac{5}{2} + \frac{5}{2} + \frac{5}$	Now we will plot the Nyquist diagram to study the asimphtotic stability of SYS. Choose the ω range, the resolution and if the polar diagram must be symmetric against the real axe. nyquist(SYS) Control Toolbox v1.16 Author: Francesco Orabona E-mail: <u>bremen79@infinito.it</u>
CST DEGAPPROX PAR	Here is the Nyquist diagram. We can zoom, save and trace it.
F1+ F2+ F3 F4 F5+ F6+ F7+ F3 Tools/Zoom/Trace/Regraph/Math/Draw/Pen::: Root Locus W(s): 1/(s+10) Min Gain: 1 Max Gain: 1 Step: 1 Esc=CANCEL GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	We can now plot the Root Locus for SYS. We must set the range of gains and the plot's step. rlocus(SYS) Control Toolbox v1.16 Author: Francesco Orabona E-mail: <u>bremen79@infinito.it</u>
CST DEGAUTO FUNC	Here is the Root Locus of SYS. We can zoom, trace and get significant plot info from Data menu (F5).

Examples. 2 – Linearization.	
Now consider a non linear model:	First, we have to calculate the steady state
$\int \dot{x}_1 = x_2$	$[0]$ to result $x = \begin{bmatrix} 0 \end{bmatrix}$ for input $y = 0$
$\begin{cases} \dot{x}_2 = x_1 - x_2 \end{cases}$	x0. It results $x_0 = \begin{bmatrix} 0 \end{bmatrix}$ for input u0=0.
v = x	
To work with it, we need to linearize	
around a steady state x0 relating to	
constant input u0.	
Linearization State Equ: CONSTRUCTOR Dutput Equ: CONSTRUCTOR State Vars: CONSTRUCTOR Steady State X0: CONSTRUCTOR Constant Input u0: CONSTRUCTOR Evalutate? Yest Save State Space Yest CONSTRUCTOR CONSTRUCT	From Dynamics menu (F3) we choose linmod(f,y,x,u,x0,u0) where we have $f=\{x2,x1-x2 2+u1\}, y=\{x1\}, x=\{x1,x2\},$ $u=\{u1\}, x0=\{0,0\}$ and $u0=\{0\}$. We have decided to evalutate jacobian matrixex in x0 and u0 to save the state-space of obtained linearized model.
(3) (3) </td <td>Here the jacobian matrixes evalutated in (x0,u0).</td>	Here the jacobian matrixes evalutated in (x0,u0).
F1+1 F2+1 F3 F4 1F5+1 F6+1F2+15:: State Space to Transfer Function A: [[0051][4:00]] B: [[1011]] C: [[11:0]] D: [[101]] Input: [1 Delay: [0 (Enter=0K) (ESC=CANCEL) GnuGPL 2005 TYPE + LENTER]=0K AND LESC]=CANCEL	Now, we can get transfer function of this new model, that is a approximation of non-linear model above around x0 and u0.
Calculating FW(s) 1 s ² - 1. CST DEGAUTO FUNC PRUSS	Here is the linearized model transfer function. We can now procede to study this system in the usual way with our powerful tools.

Examples. 3 – 3 rd Order LPF.	
F1+ F2+ F3 F4 F5+ F6+ F7+3:: Tools[Zoom[Trace[Re9raph[Math]Draw]Pen:: Transfer Function Num: 1E7 Den: [/1010/300000/101000000> Delay: 0 Please insert coefficients as LIST <u>Enter=0K</u> <u>ESC=CANCEL</u> GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	Consider a 3 rd order low pass filter $W(s) = \frac{10000000}{s^3 + 1010s^2 + 30000s + 10100000}$
Calculating ►Delay=0 ►W(s)= 1.E7 s ³ + 1010 · s ² + 30000 · s + 101 CST DEGAUTO FUNC 20053	Calculating Calculating >State Space A= [0 0 -10100000] 1 0 -30000 0 1 -1010 CST DEGAUTO FUNC FMUSE
Calculating Calculating ▶Natural Frequency wn= (990.,101.,101.) ▶Damping Factor C= (1.,.099,.099)	Calculating Calculating ▶D.C. Gain of W(s) G=.99 IGIdB=086
F1+ F2+ F3+ F4+ F5+ F6+ EXIT 200M MAG/PHASE INFDITEDLSFILE 0. dB IF(s) 120. dB/d -20. dB IF(s) 120. dB/d -40. dB IF(s) 120. dB/d -80. dB IF(s) 120. dB/d 100. dB IF(s) 120. dB/d 101. dB IF(s) 120. dB/d 102. dB IF(s) 120. dB/d 103. dB IF(s) 120. dB/d 104. dB IF(s) 120. dB/d 105. dB IF(s) 120. dB/d	F17 F27 F37 F47 F57 F67 EXIT 200m/MAG/PHASE INFO TODLS FILE 0.0 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
Calculating ▶p(s)= sI-A 1= s^3+1.01ɛ3*s^2+3.ɛ4*s+1.0⊅	Calculating Coefficients (1. 1.01e3 3.e4 1.01e7)
CST DEGAUTO FUNC PAUSA	CST DEGAUTO FUNC PROUSE

Calculating Calculating ▶Routh Matrix [1 30000 1010 10100000 20000 0 <u>10100000 0</u> CST DEGAUTO FUNC MOUSE	Calculating Calculating ▶Conditions (1.,1.01E3, -9.9E3*(k-2.02) ▶Solutions (true, true, k<2.02, k>-1.01) CST DEGAUTO FUNC 20089
Calculating Poles (-1/t) (-99010 101. i -10) Eros (-1/t') () CST DEGAUTO FUNC MOUST	Simple Simpl
Steady State *Steady State [2.97 ±4] 1. ±3 .99 *Output [.99] CST	CST RAD AUTO FUNC PRUSE
Statistic Statistic Statistic Statistic Calculating Calculating ▶Tc=1.01c-4 ▶ti=(.001) ▶th=(.1) ▶Th=(.062)	<pre>Sampling Time Tc= 1.01E-4 +Wd(z)=</pre>
Calculating Calculating ►IW(iω) 1.ε7 √ω ⁶ + 9.6ε5·ω ⁴ - 1.95ε10·ω ² CST DEGAUTO FUNC 127083	$\frac{\left(\frac{1}{2}\right)\left(\frac{1}{$

Examples. 4 – 2 nd Order LPF.	
F1+ F2+ F3 F4 F5+ F6+ F7+ F3: ToolsZoom Trace Regraph (Math Draw Pen:::) Transfer Function Num: C12 Den: C1/1/1002 Den: C1/1/1002 Den: P1ease insert coefficients as LIST Enter=0K ESC=CANCEL GnuGPL 2005 Loreto Parisi TYPE + LENTER3=0K AND LESCI=CANCEL ESC=CANCEL	Consider a 2 nd order low pass filter $W(s) = \frac{1}{s^2 + s + 100}$. First, we will define the Transfer Function and obtain the State Space Representation.
F1+ F2+ F3 F4 F5+ F6+ F7+ ⁵ ToolsZoom Trace Regraph (Math Draw Pen): Transfer Function to State Space H(s): 17(9+2355000) Enter=0K <u>ESC=CANCEL</u> GnuGPL 2005 Loreto Parisi TYPE+ LENTER]=0K AND LESC]=CANCEL	Now we'll get the characteristic polynomial, the natural frequency ω_n and the damping factor ξ .
<pre>St DEGRUTO FUNC PRUSE</pre>	Then we'll calculate the maximum Time Constant, Sample Time and other time constants, and the Discrete Time model relating to this Sample Time with Tustin method. We will save this transfer function $Wd(z)$ as the current discrete transfer function $W(z)$.
F1+ F2+ F3 F4 F5+ F6+ F7+ ³ Tools Zoom Trace Regraph Math Draw Pen :: Same ling Time and Time Constants W(s): 1/(s+2+s+100) Enter=0K ESC=CANCEL GnuGPL 2005 Loreto Parisi TYPE + LENTER]=0K AND LESC]=CANCEL	<pre>\$</pre>
F1* F2* F3 F4 F5* F6* F7* F1 Tanitizani Franciska Branch MathinzaulPeni: Continuous to Discrete Time Model W(s): 1/(s^2****100) Samplin3 time: .063 Method TU # Samplin3 time with tconst() ? No # Saue Wd(z) as W(z) ? ESC=CANCEL GnuGPL 2005 Longto Parisi USE € AND # TO OPEN CHOICES Contact of the second parisi	<pre>Sampling Time Tc= .063 Md(z)= 8.78ε-4⋅(z+1)² z² - 1.59⋅z + .944 CST DEGRUTO FUNC 20183</pre>

F1+ F2+ F3 F4 F5+ F6+ F7- F1+ Tools/2000 Trace/Regraph/Math/Draw/Pen:** Image: Construction of the constru	Now we will calculate Eigenvalues and eigenvectors, and the Spectral Decomposition of dynamics matrix A.
<pre>Eigenvalues λi (5 + 9.99 ⋅ i5 - 9.99 ⋅ i) T Eigenvectors ui [.995 .995 .005099 ⋅ i .005 +.099 ⋅ i </pre>	F1+ F2+ F3 ToolsZoomTraceRegraphMathDrawPen(*: Spectral Decomposition of matrix A A: [(05100)(151)) Enter=DK (ESC=CANCEL) GnuGPL 2005 Loreto Parisi TYPE + CENTERJ=DK AND CESCJ=CANCEL
Complex Eigenvalues •Complex Eigenvalues <u>.005·cos(9.99·t)</u> .995·c ↓et .005·c ↓et .005·c ↓et .005·c ↓et .005·c ↓et	Now let's calculate the Bandwidth, the Resonance Peak and the D.C. Gain.
\$1<0	Mp=.093 Mp>dB= -20.6 dB ▶ fr=1.48 Hz
Image: State	As we can see, <i>band()</i> and <i>peak()</i> sometimes differs in resulting values of Mp and fr because of numerical nature of <i>peak()</i> algorithm, instead of formulas in <i>band()</i> .

F1+ F2+ F3 F4 F5+ F6+ F7+ F3::: Tools/Zoom/Trace/Regraph/Math/Draw/Pen::: Step Response W(s): Step Response W(s): Step Response W(s): Step Response Enter:: Delay: Center:: Esc:: GnuGPL 2005 Loreto Parisi TYPE + CENTERD::: CESCI::	Let's now calculate and graph the Step Response. Finally we will get the Step Response parameters. This will take some minutes. Please be patient! If <i>pstep()</i> fails, the Error Management System prevents <i>cst</i> to abort, so don't break execution manually (you will loose all unsaved session's data). The EMS will do it for you, safing the current session.
$\frac{1}{100} - \frac{\sqrt{399} \cdot e^{\frac{-t}{2}} \cdot \sin\left(\frac{\sqrt{399} \cdot t}{2}\right)}{100} = \frac{1}{2} \cdot \sin\left(\frac{\sqrt{399} \cdot t}{2}\right)}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
Step Response parameters >Te= 1.39 sec >Tr= 3.91 sec >Ts= 6.8 sec >Tp= 11.2 sec >s= .12 % CST DEGAUTO FUNC PAUSE	Now we can analyse in the Time Domain the Step Response with <i>gstep()</i> . We can see the Step Response parameters (Data – F5), zoom and trace the graph, get a value (F6) such as the Settlement Time, Ts.
F1+ F2+ F3 F4 F5 F6+ F7 Tools200m Trace Re3raph Data Math Exit I	F1+ F2+ F3 F4 F5+ F6+ F7+ 510 ToolsZoom TraceRegraph MathDraw Pen Step Response parameters Te= 1.39 sec Tr= 3.91 sec Ts= 6.8 sec Ts= 5.8 sec Ts= 11.2 sec Enter=0K ESC=CANCEL
F1+ F2+ F3 F4 F5+ F6+ F7+ 511 Tools/200m/Trace/Regraph/Math/Draw/Pen Evaluation Evaluation Value: Evaluation Use parameter Ts=6.8 + Esc=cancel Value: Esc=cancel Use + and + to open choices Esc=cancel	F1+ F2+ F3 F4 F5+ F6+ F7+ 500 Tools/200m/Trace/Regraph/Math/Draw/Pen Image: Signature of S

Examples. 5 – Network Design I	
F1+ F2+ F3 F4 F5+ F6+ F7+ ³ Tools Zoom Trace Regraph Math Draw Pen :: Feedback Control System W(s): R0/((1+10s)(1+5s)(1+s) Delay: 0 <u>Enter=OK</u> <u>ESC=CANCEL</u> GnuGPL 2005 Loreto Parisi CST <u>DEGAUTO</u> FUNC	We want to design a closed-loop control system for transfer function $W(s) = \frac{10}{(1+10s)(1+5s)(1+s)}$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	This will be the current process transfer function, G(s), as we can see in Network menu (F2). Now we will design the controller. Choose <i>Design</i> from Controller menu (F1) and select the desidered structure. We will choose Custom.
Fiv F2v F3 F4 F5v F6v F7v Sii Tools Zoom Trace Regraph Math Draw Pen :: Controller Design L Controller R(1) MINOM + Enter=DK ESC=CANCEL SC=CANCEL USE + AND > TO OPEN CHOICES	F1+ F2+ F3 F4 F5+ F6+ F7+ ⁵ ToolsZoom Trace Regraph Math Draw Pen :: Custom Network R(s): 1/s Enter=OK Custom Cest Parisi CST DEG AUTO FUNC
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	From Network menu (F2) choose <i>Design</i> to design the network. As you can see, you can specify more than one controller. We will use the previously defined Custom controller as R(s) and, by now we don't specify R0(s). Then we will get the Closed Loop Transfer Function, L(s).
S: S: S: S: S: ►R(s)= 1 S CST DEGAUTO FUNC 20053	Calculating ►L(s)= .2 S·(s+.1)·(s+.2)·(s+1.) CST DEGRUTO FUNC FUNC

Controller Network Butput Data Tools Bther 1: Design 2: Final Usis 3: G(s) 4: R(s) 5: L(s) 6: F(s) 7: S(s) 8: Q(s) 6: F(s) 8: Q(s) 1: Desauto Func	Now we will analyse the network using <i>Analisys</i> from Network menu (F2), obtaining the Magnitude (from now Mag) and Phase margins. As we can see, they are both negative. We need a lead network to get a phase advancing and a lag network to get a good mag margin.
CST DEGAUTO FUNC 2005	State State F5 State N=1 State Promin State Phase Margin > φm= -88.1° > wc=.545 rad/s > φc= -268.° > τc= -2.82 State FUNC Promin
F1+ F2+ F3 F4 F5+ F6+ F7+5: Tools200m[TraceRegraph[Math]Draw[Pen]: Controller Design +Controller R(s) Lead-Lag+ Enter=DK ESC=CANCEL SC=CANCEL USE + AND + TO DPEN CHOICES	So we will define a Lead-Lag network from Controller menu (F1), and do the analysis again. To do so, we need to define again the network structure from Network menu(F2).
Lead-La3 Network µR:	State State Lead-Lag Network ▶R(s)= 2.5·(5·s + 1)·(10·s + 1) (s + 2.5)·(250·s + 1)
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	CST DEGAUTO FUNC 2008

St DEGAUTO FUNC 2005	State State Phase Margin >φm=92.6° >ωc=.04 rad/s >φc=*87.4° >τc=40.6 s	
F1+ F2+ F3 F4 F5+ F6+ F7+ F3+	We have obtained robust margins for $\omega c=0.04$ rad/sec. We can now define inputs from Output menu (F3) to analyse network time behaviour. Apply a Heavside step as input and a simply sin wave as noise. Suppose we have no measure noise. We now can see these inputs in Laplace domain.	
State State State 1 S CST RAD AUTO FUNC	State State <th< td=""></th<>	
Calculating ►F(s)= (s + .047)·(s + .931)·(s + 2.5) CST DEGRUTO FUNC PAUSE	Now we need to calculate the Network Transfer Function $F(s) = \frac{R(s)G(s)}{1 + R(s)G(s)}$ to obtain the Time Response against input from Network menu(F2). Then we will choose yr(t) from Output menu (F3).	
Image: State	F1+ F2+ F3 F4 F5 F6+ F7 ToolsZoomTraceRegraphDataMathExit	



Examples. 6 – Network Design II	

Examples. 7 – Network Tuning I	
$\frac{5}{3} + \frac{5}{3} + \frac{5}$	Consider a 3 rd order transfer function $G(s) = \frac{1}{(1+s)^3}$ We will tune the closed-loop control system using the closed-loop Ziegler- Nichols methodology. Choose <i>Tuning</i> from Controller menu (F1).
$\begin{array}{c c} F1+ F2+ F3 & F4 & F5+ F6+ F7+ 5:: \\ \hline ToolsZoomTraceRegraphMathDraw[Pen]:: \\ \hline Controller Tunin3 \\ \hline G(s): 1/(1+s)^3 \\ \hline Delay: 0 \\ \hline FTunin3 Method \\ \hline Tunin3 Method \\ \hline Tunin3 Method \\ \hline Scheren K \\ \hline \hline Center=0K \\ \hline Cent$	Select FB (FeedBack) Ziegler-Nichols as <i>Tuning Method</i> . Then choose PI (Proportional-Integral) as controller R(s).
F1+ F2+ F3 F4 F5+ F6+ F2+50 ToolsZoom Trace Regraph Math Draw Pen 20 Feedback Ziegler-Nichols PController R(s) 20 P10 Tuning Auto + P10 N: CEnter=0K CESC=CANCEL GnuGPL 2005 Loreto Parisi USE + AND + TO OPEN CHOICES	You will obtain the <i>Critical Mag</i> Kp' and relating frequency $\omega \pi$ and period T first. From Zieglier-Nichols tuning rules, then you will get PI parameters, Kp and Ti. Now select <i>Design</i> from Controller menu (F1) and choose PI. You will see those values filling relating input fields by a kind of magic.
State F5 State >Mangin Kp'=8. ωπ=1.73 T=3.63	State State <t< th=""></t<>
F1+ F2+ F3 F4 F5+ F6+ F24 F3 ToolsZoomTraceRegraphMathDrawPen PI Controller FI Controller F1 F2 F1	State State State PI Controller *R(s)= 3.6 · (s + .345) S

$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Now we can design the network. Select <i>Design</i> from Network menu(F2). Choose PI as controller R(s). Finally perform a network analysis choosing <i>Analysis</i> from the same menu. We'll see the closed-loop stability for G(s) by means of values of Mag and Phase margins.	
State State State Mag Margin * km=1.49 * (km)dB=3.49 * wm=1.46 rad/s	State State <t< td=""></t<>	
$\begin{array}{c c} F1+F2+F3\\ ToolsZoomTraceRegraph[Math]Draw[Pen]::\\ \hline Feedback Zie3ler-Nichols\\ \hline Feedback Zie3ler-Nichols\\$	In the same way, we can tune a PID controller to assign a custom Gain margin. Choose <i>PID</i> as R(s) and <i>Gain</i> <i>Margin</i> as <i>PID Tuning</i> . Specify a PID's N parameter for real PIDs (range 5÷20). When asked, insert the requested gain margin. Then procede with PID controller design in Controller menu(F1).	
State State <t< td=""><td>Similar Similar Simil</td></t<>	Similar Simil	
State State State > Tuning Kp=.889 Ti=1.15 Td=.289	Image: Second secon	

$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Now we will re-define the network with this PID controller and perform a network analysis from Network menu (F2). In this case, we have obtained a more robust control network as results from Mag and Phase margin values.	
Mag Margin ▶km=8.8 ▶(km)dB=18.9 ▶ωm=1.73 rad∕s	State State State Phase Margin ▶ ♠ m=37.6° ▶ ∞c=.563 nad/s ▶ ⊕ c=-142.° ▶ tc=1.17 s	
F1+ F2+ F3 F4 F5+ F6+ F7+ F8 Metwork Inputs Network Inputs Network Inputs Metwork Inputs Noise Noise Noise d(t): Sin(t) Network Inputs Noise Measure Noise Noise Noise Noise n(t): Sin(t) Escecancel GnuGPL 2005 Loreto Parisi CST DEGAUTO FUNC	We will analyse the output behaviour of network (with PI controller), defining inputs from Output menu (F3). First we will calculate F(s), S(s) and Q(s) needed by yr(t), yd(t) and ur(t), ud(t) respectly. Please refer to Section <i>Network Design</i> for further explanations about inputs.	
CST RAD AUTO FUNC	CST RAD AUTO FUNC	
CST RAD AUTO FUNC	CST RAD AUTO FUNC	

Examples. 8 – Network Tuning II	

Current Release

- Control System Toolbox for TI-89
 <u>Current release</u>: 1.3 October 2005

 <u>Supported Calculator</u>: TI-89 Hardware Version >2.00
 <u>Supported OS</u>: AMS >2.09
 New Features:
 - Symultaneous Continuous and Discrete Time Domain Analysis
 - Time Delay
 - Time Delay's Padè Approximation
 - Phase and Magnitude Margins
 - Routh Criterion and Conditions
 - Backward Eulero, Forward Eulero, Hold Equivalence Discretization
 - Nyquist Diagrams
 - Root Locus
 - Direct and Inverse Laplace Transformations
 - Direct and Inverse Zeta Transformations
 - Feedback Control Systems featuring
 - Design
 - P, PI, PD, PID Controllers
 - Lead, Lag, Lead-Lag Networks
 - Inputs and Noises
 - Analisys
 - Phase and Magnitude Margins
 - Network Transfer Functions
 - Time Domain Outputs

- Tuning

- Automatic Tuning featuring
 - Closed Loop Ziegler-Nichols
 - Open Loop Ziegler-Nichols
 - Optimal Control
- Adaptive Filtering
- Smith's Predictive Control
- The CST Start Guide

<u>Current version</u>: 1st edition, October 2005 <u>Distribuition</u>: Portable Document Format

- The CST Reference Guide <u>Current version</u>: 1st edition, October 2005 <u>Distribuition</u>: Portable Document Format
- The CST User Guide <u>Current version</u>: 5th edition, October 2005 <u>Distribuition</u>: Portable Document Format

Contents

Here are all functions, programs and other objects contained in *cst* folder.

Name	Description	Туре
azeros()		Func
band()		Func
Bandn()		Func
Bandsub()		Func
Bodex()		Prgm
c2d()		Func
Check()		Func
Cpoles()		Func
Cst()		Prgm
Cstpi_		Mat
Cstpid_		Mat
Cstver_		Expr
D2c()		Func
Damp()		Func
Db()		Func
Dcgain()		Func
Degroot()		Func
Degzero()		Func
Eigenv()		Func
Error()		Prgm
Feedback()		Prgm
Gain()		Func
Gettd()		Func
Gstep()		Prgm
Help()		Prgm
Install()		Prgm
Linmod()		Func
Linspace()		Func
Logspace()		Func
Mag()		Func
Mag1()		Func
Magz()		Func
Margin()		Func
Nyquist()		Prgm
Pade()		Func
Peak()		Func
Phase()		Func
Phase1()		Func
Phasez()		Func
Poly()		Func
Poly2cof()		Func
Polydeg()		Func
Polyz2s()		Func
Pstep()		Func
Name	Description	Туре
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Pzmap()		Func
Rlocdata()		Func
Rloceval()		Func
Rlocus()		Prgm
Roots()		Func
Routh()		Func
Routhc()		Func
Rts2poly()		Func
Sampler()		Func
Spectre()		Func
Splash		Pic
Splhlp		Pic
Ss2tf()		Func
Step()		Func
Tconst()		Func
Tf()		Func
Tf2nd()		Func
Tf2ss()		func
Tmmax()		Func
Trim()		Func
Zoomfit2()		Prgm
Zpk()		Func
Zpkdata()		Func

Removing or modifying one of the objects above could bring *cst* to don't work. Remember that *cst*, and all its contents are released under Gnu Public Licence.

Thanks to...

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The programmers

- 92BROTHERS Contribute: *bodex()* E-mail: 92brothers@infinito.it Home: http://www.92brothers.net/ - Francesco Orabona Contribute: logspace(), poly2cof(), zpk(), nyquist(), rlocus() E-mail: bremen79@infinito.it Homepage: http://web.genie.it/utenti/b/bremen79/ - Lars Frederiksen Contribute: *DiffEq()* E-mail: ltf@post8.tele.dk - Greg Dietsche Contribute: kerno() E-Mail: calc@gregd.org Home: http://calc.gregd.org/ - Kevin Kofler Contribute: hw3patch() Home: http://tigcc.ticalc.org. - Jiri Bazant Contribute: *lzt(*) E-mail: georger@razdva.cz

Home: http://www.razdva.cz/georger/

The Beta Testers

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