Texas Instruments
TI-99/4 Home Computer

Cassette Software

Model PHT 6008

Electrical Engineering Library

Four powerful programs which assist you in designing components for electrical systems.

- **FILTER DESIGN—Computes component values for three active filters and two passsive filters.**
- **PHASE LOCK LOOP DESIGN—Calculates design parameters for a basic phase lock loop.**
- **ROOT LOCUS CALCULATIONS—Computes asymptote intersection point, asymptote angles, and arrival and departure angles from zeroes and poles.**
- **SMITH CHART CALCULATIONS—Performs various transmission line calculations equivalent to the Smith Chart graphical constructions on the Smith Chart.**

Requires the use of cassette tape recorder (not included) for loading the program contents into the TI 99/4 Home Computer memory.

As this manual was designed for the U.S. market, the warranty conditions described herein are not applicable in the U.K. The only valid Guarantee Conditions are those set forth in the "Users Reference Guide" accompanying the Home Computer.

Table of Contents

Author: Texas Instruments

Language: TI-99/4 BASIC

Hardware: TI-99/4 Home Computer
Disk Controller and Drive or cassette recorder

Media: Diskette and Cassette

The Electrical Engineering Library is a collection of programs which can assist you in designing components for electrical systems. Each program performs time-saving electrical engineering calculations and thus helps to simplify your design task.

- FILTER DESIGN - Computes component values for the design of active filters (lowpass, highpass, and bandpass) and passive filters (Butterworth and Tchebycheff).

- PHASE-LOCKED LOOP DESIGN - Calculates design parameters for a basic phase-locked loop with either an active or passive loop filter.

- ROOT-LOCUS CALCULATIONS - Computes asymptote intersection point and asymptote angles, and appropriate arrival and departure angles from zeros and poles.

- SMITH CHART CALCULATIONS - Performs various transmission-line calculations equivalent to the graphical constructions on the Smith Chart.

The Filter Design program computes the necessary component values that yield the required performance parameters for various filters. Component values can be computed for both active filters (lowpass, highpass, and handpass) and passive lowpass filters (Butterworth and Tchebycheff). You specify the performance parameters, such as peak, gain, cutoff frequency, and quality. The computer displays the required capacitances, inductances, and resistances.

The corresponding bandpass network function is:

$$H(s) = \frac{-H_0 \alpha \omega_0 s}{s^2 + \alpha \omega_0 s + \omega_0^2}$$

where α = 1/Q
Q = F/B, quality factor measure of selectivity of filter
F = Center frequency of passband in hertz
B = 3-dB bandwidth in hertz

Given B, A, F, C_1, and C_2 in microfarads, the program calculates R_1, R_2, and R_3 as follows:

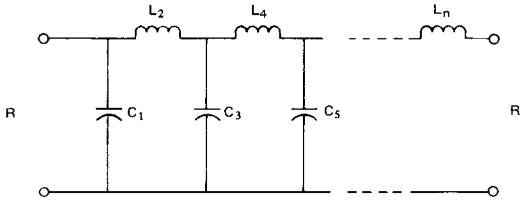
$$R_1 = \frac{Q}{2\pi F H_0 C_1}$$

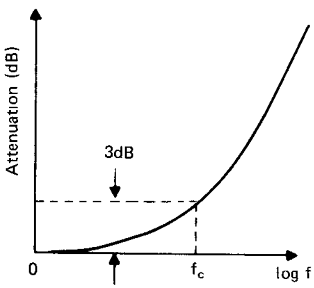
$$R_2 = [Q(C_1 + C_2)2\pi F - (1/R_1)]^{-1}$$

$$R_3 = \frac{Q}{2\pi F}\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

Butterworth Filter

The form of the Butterworth filter, along with its characteristic response, is shown below.





BUTTERWORTH LOWPASS CHARACTERISTIC

For Butterworth filters with response of the form shown, the component values are computed as follows:

$$C_i = \frac{1}{\pi f_c R} \sin\left[\frac{(2i - 1)\pi}{2n}\right] \qquad i = 1, 3, 5, \cdots$$

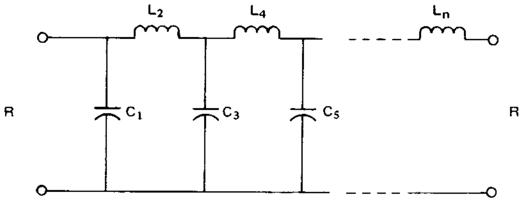
$$L_i = \frac{R}{\pi f_c} \sin\left[\frac{(2i - 1)\pi}{2n}\right] \qquad i = 2, 4, 6, \cdots$$

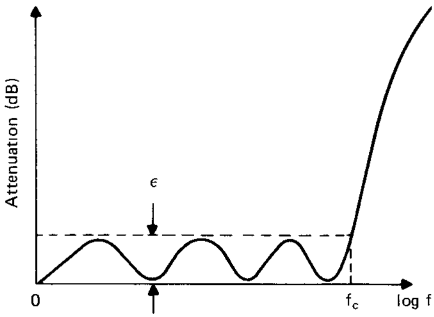
where f_c = cutoff frequency in hertz
n = filter order
R = terminal resistance in ohms

Note: This program assumes that the generator resistance Rg is equal to the load resistance R_L; therefore, $R = R_g = R_L$.

Tchebycheff Filter

The form of the Tchebycheff filter, along with its characteristic response, is shown below.





TCHEBYCHEFF LOWPASS CHARACTERISTIC

For Tchebycheff filters with response of the form shown, the component values are computed as follows:

$$\beta = \ln\left[\coth\left(\frac{\epsilon}{40 \log e}\right)\right]$$

$$\gamma = \sinh\left(\frac{\beta}{2n}\right)$$

$$a_i = \sin\left[\frac{(2i-1)\pi}{2n}\right] \qquad i = 1, 2, 3, \quad , n$$

$$b_i = \gamma^2 + \sin^2\left(\frac{i\pi}{n}\right) \qquad i = 1, 2, 3, \cdots, n$$

$$g_1 = \frac{2a_1}{\gamma}$$

$$g_i = \frac{4a_{i-1}\, a_i}{b_{i-1}\, g_{i-1}} \qquad i = 2, 3, 4, \cdot \quad \cdot, n$$

$$C_i = \frac{g_i}{2\pi f_c R} \qquad i = 1, 3, 5, \cdot \quad \cdot$$

$$L_i = \frac{R g_i}{2\pi f_c} \qquad i = 2, 4, 6, \cdot \cdot$$

Note: For odd-order Tchebycheff filters, the generator resistance R_g is equal to the load resistance; therefore, the termination resistance $R = R_g = R_L$. In the case of even-order Tchebycheff filters, $R_L = R_g/\coth^2(\beta/4)$ which, for small ripple, results in the generator resistance R_g being approximately equal to the load resistance R_L. Thus, the termination resistance $R = R_g \approx R_L$.

STEP 1: Be sure that the disk drive or cassette recorder is attached to the computer and turned on. (See the owner's manuals or the Users Reference Guide for product details.)

STEP 2: Press any key to pass the title screen. Then press 1 to select TI BASIC. To load the program from diskette, insert the diskette into Disk Drive 1, type

OLD DSK1.FILTERS

and press ENTER.

To load the program from a cassette tape, insert the tape into the recorder. Next, refer to the "Loading Cassettes" section in this manual for instructions on determining the program's position on the cassette tape. When you have inserted the cassette tape and properly positioned the tape counter, type

OLD CS1

and press ENTER. The computer then displays directions for loading the program. Refer to "Loading Cassettes" if you have difficulty in loading the program from the cassette.

STEP 3: When the cursor reappears, type RUN, and press ENTER. The FILTER DESIGN title screen appears. Press ENTER to display the list of options.

ACTIVE FILTERS:

1. Lowpass
2. Highpass
3. Bandpass

PASSIVE FILTERS:

4. Butterworth
5. Tchebycheff

OR:

6. EXIT PROGRAM

STEP 4: Select the type of filter you wish to design.

OPTION 1: LOWPASS FILTER
If you choose option 1, the program displays a diagram showing the components for a lowpass filter circuit. Next, enter the peaking factor, the passband voltage gain in decibels, the cutoff frequency in hertz, and the value of C2 in microfarads. The program then calculates and displays the values for C1, R1, R2, and R3. To continue, press ENTER, and the program displays the list of options again. You may then calculate values for another filter or choose option 6 to exit the program.

OPTION 2: HIGHPASS FILTER
If you choose option 2, the program displays a diagram showing the components of a highpass filter circuit. Next, enter the peaking factor, the passband voltage gain in decibels, the cutoff frequency in hertz, and the value of C in microfarads. The program then calculates and displays the values for C1, R1, and R2. To return to the list of options, press ENTER. You may then calculate values for another filter or choose option 6 to exit the program.

OPTION 3: BANDPASS FILTER
If you choose option 3, the program displays a diagram showing the components of a bandpass filter circuit. Next, enter the frequency of the passband in hertz, the values of C1 and C2 in microfarads, the quality factor, and the voltage ratio or midband voltage gain in decibels. The program then calculates and displays the values for R1, R2, and R3. To return to the list of options, press ENTER. You may then calculate values for another filter or choose option 6 to exit the program.

OPTION 4: BUTTERWORTH FILTER

If you choose option 4, the program displays a diagram showing the components of a Butterworth filter circuit. Next, enter the filter order ($n \leq 10$) which defines the number of reactive components, the terminal resistance in ohms, and the cutoff frequency in hertz. If you enter a value that is outside the normal range for a variable, the screen displays "INVALID INPUT -- PRESS ENTER" or a warning message, followed by "PRESS ENTER." To return to the list of options, press ENTER. Enter 4 and reenter your parameters for the Butterworth filter. The program then calculates and displays the values for C1, C3, C5, . . ., and L2, L4, L6 . . . . Press ENTER to return to the list of options. You may then calculate values for another filter or choose option 6 to exit the program.

OPTION 5: TCHEBYCHEFF FILTER

If you choose option 5, the program displays a diagram showing the components of a Tchebycheff filter circuit. Next, enter the filter order ($n \leq 10$) which defines the number of reactive components, the terminal resistance in ohms, the cutoff frequency in hertz, and the allowable ripple in decibels. If you enter a value that is outside the normal range for a variable, the screen displays "INVALID INPUT -- PRESS ENTER" or a warning message followed by "PRESS ENTER." The list of options is displayed when you press ENTER. Enter 5 and reenter your parameters for the Tchebycheff filter. The program then calculates and displays the values for C1, C3, C5, . . . , and L2, L4, L6 . . . . To return to the list of options, press ENTER. You may then calculate values for another filter or choose option 6 to exit the program.

OPTION 6: EXIT PROGRAM

If you select option 6, the message **DONE** is displayed, and the program stops.

To help you understand how the program functions, work the following example.

Find the component values for an active bandpass filter with a center frequency of 150 hertz, a midband voltage gain of 30dB, a quality factor of 9.375, and C1 = C2 = 0.1 μF.

First, load and run the program as described in Steps 1 and 2 of the "User Instructions." Next, enter 3 to select Bandpass Filter design. You are now ready to input the performance parameters of the desired filter.

PROMPT	ENTER	COMMENTS
CTR FREQ?	150	Center frequency in hertz
C1 μF?	.1	Capacitance in microfarads
C2 μF?	.1	Capacitance in microfarads
3-DB BW?	9.375	Quality factor (CTR FREQ/BANDWITH)
GAINμ	30	Midband voltage gain in dB

The following answers are displayed.

R1 = 5.37 KΩ
R2 = 353.4Ω
R3 = 339.53 KΩ

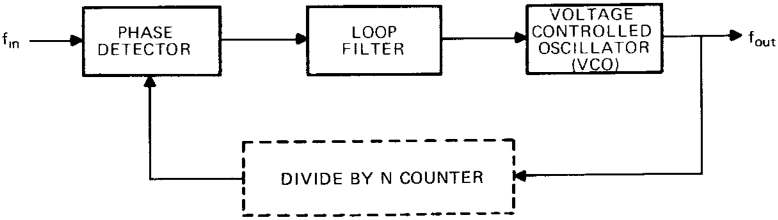
To return to the list of options, press ENTER.

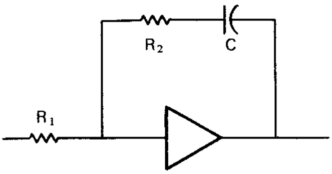
The Phase-Locked Loop Design program computes the design parameters for basic phase-locked loops. You are given the option of designing a type-2, second-order loop with an active filter or a type-1, second-order loop with a passive filter. You provide the following information.

N = integer divisor (active filter only)
Gain = the loop gain, sec^{-1}
C = filter capacitance, μF

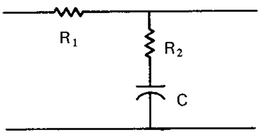
At this point you have the option of either entering ω, the natural angular frequency in radians/second, and ζ, the damping factor, to solve for the resistances R_1 and R_2 in ohms, or entering the resistances R_1 and R_2 to calculate ζ and ω. In either case, the loop-noise bandwidth is calculated and displayed.

After you choose an appropriate loop filter (active or passive), this program computes the resulting design parameters for a basic phase-locked loop (PLL) as illustrated below.





ACTIVE FILTER



PASSIVE FILTER

The basic PLL transfer function is:

$$\frac{\theta_o}{\theta_i}(S) = \frac{G\,F(S)}{S + G\,F(S)}$$

where θ_o = the output phase
θ_i = the input phase
G = the loop gain
F(s) = the transfer function of the loop filter

G = K_pK_v

where K_p = the gain of the phase detector in volt/radian
K_v = the gain of the VCO in radians/second-volt

If the loop filter is active, an N counter can be added to the loop, making the output frequency, f_{out}, an integral multiple of the input or reference frequency, f_{in}. Thus, $f_{out} = Nf_{in}$, where $N \geq 1$.

For both active and passive filters, the time constants are $\tau_1 = R_1C$ and $\tau_2 = R_2C$.

Active Filter Calculations

For an active filter with a very large amplifier gain,

$$F(S) = \frac{S\tau_2 + 1}{S\tau_1}$$

The (÷N) counter changes the form of the PLL transfer function,

$$\frac{\theta_o}{\theta_i}(S) = \frac{G\,F(S)/N}{S + G\,F(S)/N}$$

Using the transfer function representative F(S), the PLL transfer function becomes

$$\frac{\theta_o}{\theta_i}(S) = \frac{G(S\tau_2 + 1)/N\tau_1}{S^2 + S(G\tau_2/N\tau_1) + G/N\tau_1}$$

By inserting the natural angular frequency ω_n and the damping factor ζ for the time constants τ_1 and τ_2, the PLL transfer function becomes

$$\frac{\theta_o}{\theta_i}(S) = \frac{2\zeta\omega_n S + \omega_n^2}{S^2 + 2\zeta\omega_n S + \omega_n^2}$$

To calculate ω_n and ζ, given R_1 and R_2,

$$\omega_n = \sqrt{\frac{G}{N\tau_1}} \quad \text{and} \quad \zeta = \frac{\omega_n\tau_2}{2}$$

To calculate R_1 and R_2, given ω_n and ζ,

$$R_1 = \frac{G}{N\omega_n^2 C}$$

$$R_2 = \frac{2\zeta}{\omega_n C}$$

Passive Filter Calculations

For a passive filter,

$$F(S) = \frac{S\tau_2 + 1}{S(\tau_1 + \tau_2) + 1}$$

Using the transfer function representative F(S), the basic PLL transfer function becomes

$$\frac{\theta_o}{\theta_i}(S) = \frac{G(S\tau_2 + 1)/(\tau_1 + \tau_2)}{S^2 + S(1 + G\tau_2)/(\tau_1 + \tau_2) + G/(\tau_1 + \tau_2)}$$

By inserting the natural angular frequency ω_n and the damping factor ζ for the time constants τ_1 and τ_2, the PLL transfer function becomes

$$\frac{\theta_o}{\theta_i}(S) = \frac{S\omega_n(2\zeta - \omega_n/G) + \omega_n^2}{S^2 + 2\zeta\omega_n S + \omega_n^2}$$

To calculate ω_n and ζ, given R_1 and R_2,

$$\omega_n = \sqrt{\frac{G}{\tau_1 + \tau_2}} \quad \text{and} \quad \zeta = \frac{\omega_n}{2}(\tau_2 + \frac{1}{G})$$

To calculate R_1 and R_2, given ω_n and ζ ,

$$R_1 = \frac{G}{\omega_n^2 C} - R_2 \quad \text{and} \quad R_2 = \frac{2\zeta}{\omega_n C} - \frac{1}{GC}$$

For both active and passive loops, the one-sided loop-noise bandwidth BW in hertz is calculated using the formula:

$$BW = \frac{\omega_n}{2}(\zeta + \frac{1}{4\zeta})$$

STEP 1: Be sure that the disk drive or cassette recorder is attached to the computer and turned on. (See the owner's manuals or the Users Reference Guide for product details.)

STEP 2: Press any key to pass the title screen. Then press 1 to select TI BASIC. To load the program from diskette, insert the diskette into Disk Drive 1, type

OLD DSK1.PHASELL

and press ENTER.

To load the program from a cassette tape, insert the tape into the recorder. Next, refer to the "Loading Cassettes" section in this manual for instructions on determining the program's position on the cassette tape. When you have inserted the cassette tape and properly positioned the tape counter, type

OLD CS1

and press ENTER. The computer then displays directions for loading the program. Refer to "Loading Cassettes" if you have difficulty in loading the program from the cassette.

STEP 3: When the cursor reappears, type RUN, and press ENTER. The PHASE LOCKED LOOP DESIGN title screen appears. Press ENTER to display the following list of options:

1. ACTIVE FILTER
2. PASSIVE FILTER
3. EXIT PROGRAM

STEP 4: Next, choose the type of phase-locked loop (PLL) you wish to design. If you select an active loop filter, you are asked to enter the integer divisor (N), where $N \geq 1$. The remaining data entries for active and passive filters are identical. Enter the loop gain ($G = K_pK_v$) in sec^{-1}. Next, enter the filter capacitance in microfarads. At this point you are asked to enter either R (calculate resistances R_1 and R_2) or F (calculate natural angular frequency ω and damping factor ζ).

To calculate values for R_1 and R_2, enter R. Next, enter the natural angular frequency ω in radians/second, and the damping factor ζ . If you enter a value that is outside the normal range for a variable, the message "INVALID INPUT -- PRESS ENTER" is displayed. Press ENTER to display the list of options. You may then begin your calculations again. After you enter all the necessary values, the program then calculates and displays the values for the resistances R_1 and R_2, and the bandwidth, BW, in hertz. Press ENTER to display the list of options. You may then choose another PLL design or enter 3 to exit the program.

On the other hand, to calculate values for ω and ζ, enter F. You are now asked to enter the values for resistances R_1 and R_2 in ohms. The program then calculates and displays the values for the natural angular frequency ω in radians/second, the damping factor ζ , and the bandwidth, BW, in hertz. Press ENTER to display the list of options. You may then choose another PLL design or enter 3 to exit the program.

STEP 5: When you have completed all calculations, select option 3. The message **DONE** is displayed, and the program stops.

To help you understand how the program works, the following example is provided.

A phase-locked loop has an overall loop gain of 20000. If the passive filter component values are R_1=5kΩ, R_2=500Ω, and C=50µF, what is the natural frequency, damping factor, and noise bandwidth for the loop?

First, load and run the program as described in Steps 1 and 2 of the "User Instructions." Then select option 2 to calculate values for a passive loop filter. Now enter the required data in response to the prompts shown below.

PROMPT	ENTER	COMMENTS
GAIN?	20000	Enter loop gain
C µF?	50	Enter capacitance in microfarads
FIND R or F:	F	Calculate ω and ζ, given R_1 and R_2
R_1Ω ?	5000	Enter resistance in ohms
R_2Ω?	500	Enter resistance in ohms

The results are displayed as follows.

ω = 269.68 R/S
ζ = 3.378
BW = 465.43 HZ

To return to the list of options, press ENTER.

The Root Locus Program performs the calculations required to describe a linear system using the root-locus method. You specify the open-loop poles and zeros of the system. The program then calculates the asymptote intersection point, asymptote angles, departure angles from poles, and arrival angles at zeros.

Given an equation of the following form

$$F(s) = \frac{\prod_{i=1}^{m}(s-z_i)}{\prod_{k=1}^{n}(s-p_k)}$$

where z_i is a zero and p_k is a pole of F(s), the following equations are used to determine the necessary parameters.

The root-locus has n-m asymptotes. They intersect at the point σ_0 where

$$\sigma_0 = \frac{1}{n-m}\left(\sum_{k=1}^{n} p_k - \sum_{i=1}^{m} z_i\right)$$

The angles of the asymptotes, ψ_ν, are calculated using the equation:

$$\psi_\nu = \frac{1}{n-m}\left(180° + (\nu - 1)\,360°\right) \qquad \nu = 1, 2, \cdots, n-m$$

The departure angle at any complex pole p_j is

$$\phi_J = \sum_{i=1}^{m} \angle(p_J - z_i) - \sum_{\substack{k=1 \\ k \neq J}}^{n} \angle(p_J - p_k) + 180° \qquad J = 1, 2, \cdots, n$$

The arrival angle at any complex zero z_k is

$$\theta_K = -\sum_{\substack{i=1 \\ i \neq K}}^{m} \angle(z_K - z_i) + \sum_{k=1}^{n} \angle(z_K - p_k) - 180° \qquad K = 1, 2, \cdots, m$$

The program calculates σ_0, ψ_ν, ϕ_j, θ_k for up to 30th order systems ($n \leq 30$, $m \leq 29$).

STEP 1: Be sure that the disk drive or cassette recorder is attached to the computer and turned on. (See the owner's manuals or the Users Reference Guide for product details.)

STEP 2: Press any key to pass the title screen. Then press 1 to select TI BASIC. To load the program from diskette, insert the diskette into Disk Drive 1, type

OLD DSK1.ROOTLOCUS

and press ENTER.

To load the program from a cassette tape, insert the tape into the recorder. Next, refer to the "Loading Cassettes" section in this manual for instructions on determining the program's position on the cassette tape. When you have inserted the cassette tape and properly positioned the tape counter, type

OLD CS1

and press ENTER. The computer then displays directions for loading the program. Refer to "Loading Cassettes" if you have difficulty in loading the program from the cassette.

STEP 3: When the cursor reappears, type RUN, and press ENTER. The ROOT LOCUS title screen appears. Press ENTER to continue.

STEP 4: Now enter the open-loop poles, separating each pole with a single space. If you do not separate the poles properly, the program asks you to reenter the poles. Complex poles are entered in the form: A±JB, where A and B are numeric values. When the plus sign is typed, the program automatically displays a ± sign to account for the conjugate complex pole. Press ENTER after typing all poles. Then follow the same procedure to enter the open-loop zeros. The number of poles entered must be greater than the number of zeros entered. If not, the program asks you to reenter the poles and zeros.

STEP 5: The program now calculates and displays the number of asymptotes, the asymptote intersection point, the asymptote angles, the departure angles from poles, and the arrival angles at zeros. To repeat the program, press R and the program asks you for new values. When you finish your calculations press E to exit the program. The message **DONE** is displayed, and the program stops.

To help you understand how the program works, the following example is provided.

Find the root-locus parameters for the following function.

$$F(s) = \frac{[s - (-.5 + j)][s - (-.5 - j)]}{(s-0)\,[s - (-2 + 3j)][s - (-2 - 3j)][s - (-4)]}$$

First, load and run the program as described in Steps 1 and 2 of the "User Instructions." Then enter the data in response to the prompts shown below.

PROMPT	ENTER	COMMENT
ENTER N POLES: ?	0 -2±J3 -4	Enter poles by inspecting denominator.
ENTER M ZEROS: ?	-.5±J	Enter zeros by inspecting numerator.

The program displays the following results:

THERE ARE 2 ASYMPTOTES
INTERSECTING AT σ = -3.5
AT THE ANGLES:
90° - 90°

DEPARTURE ANGLES AT POLES:

0	180°
-2±J3	±147°
-4	0°

ARRIVING ANGLES AT ZEROS:

-.5±J	∓122°

PRESS (R)EDO, (E)XIT

Press E. The message **DONE** is displayed, and the program stops.

The Smith Chart Calculations program allows you to perform various transmission-line calculations equivalent to the graphical constructions on the Smith Chart. The program makes provisions for lines with attenuation and complex characteristic impedance. You enter the following information:

ZO = Complex characteristic impedance in ohms

ZL or YL = Termination impedance, ohms or termination admittance in mhos

AC = Attenuation constant in decibels/wavelength

DW = Distance from termination in wavelengths

The program then calculates the following:

Input values:

ZI = Impedance in ohms

YI = Admittance in mhos

VSWR = Voltage standing wave ratio

PCR = Power reflection coefficient

Termination Values:

VSWR = Voltage standing wave ratio

PCR = Power reflection coefficient

The following terms are used in many equations and are defined here for convenience.

AC = attenuation constant
DW = distance from termination
Z_0 = characteristic impedance
Z = impedance*
z = normalized impedance*
Y = admittance*
P = reflection factor* (rectangular coordinates)
$|P| \angle P$ = reflection factor* (polar coordinates)
VSWR = voltage standing wave ratio
PCR = Power Reflection Coefficient

* Note that a subscript "L" indicates values at termination, and a subscript "i" indicates values at input.

Given Z_0, Z_L or Y_L, AC, and DW, the following equations are used to calculate input and termination terms. A low-loss line is assumed.

Termination Terms

If Y_L is entered

$$Z_L = \frac{1}{Y_L} \quad \text{and} \quad z_L = \frac{Z_L}{Z_0}$$

then the complex reflection factor is

$$P_L = \frac{z_L - 1}{z_L + 1}$$

and

$$VSWR = \frac{1 + |P_L|}{1 - |P_L|}, \quad PCR = |P_L|^2$$

Input Terms

The input impedance, $Z_i = Re(Z_i) + jIM(Z_i)$, at a distance DW from termination is computed by the following sequence.

$$|P_i| = |P_L| \, (10^{-0.1AC})^{DW}, \quad \angle P_i = \angle P_L - 4\pi(DW)$$

$$z_i = \frac{1 + P_i}{1 - P_i}, \quad Z_i = Z_0 z_i$$

Note that this sequence applies in the reverse direction (from Z_i to Z_L) if DW is entered as a negative quantity.

Then the admittance, voltage standing wave ratio, and power reflection coefficient are

$$Y_i = \frac{1}{Z_i} \quad , \quad VSWR = \frac{1 + |P_i|}{1 - |P_i|} \, , \, PCR = |P_i|^2$$

STEP 1: Be sure that the disk drive or cassette/recorder is attached to the computer and turned on. (See the owner's manuals or the Users Reference Guide for product details.)

STEP 2: Press any key to pass the title screen. Then press 1 to select TI BASIC. To load the program from diskette, insert the diskette into Disk Drive 1, type

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OLD DSK1.SMITHCRT
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and press ENTER.

To load the program from a cassette tape, insert the tape into the recorder. Next, refer to the "Loading Cassettes" section in this manual for instructions on determining the program's position on the cassette tape. When you have inserted the cassette tape and properly positioned the tape counter, type

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OLD CS1
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and press ENTER. The computer then displays directions for loading the program. Refer to "Loading Cassettes" if you have difficulty in loading the program from the cassette.

STEP 3: When the cursor reappears, type RUN, and press ENTER. The SMITH CHART CALCULATIONS title screen appears. Press ENTER to continue.

STEP 4: Now enter the value of Z0 in ohms (enter as A+JB if complex, where A and B are numeric values). Next, choose between entering the termination impedance or admittance. To enter impedance, type "ZL=" followed by its value in ohms. To enter admittance, type "YL=" followed by its value in mhos. To complete the required information, enter the value of the attenuation constant in decibels/wavelength and the distance from termination in wavelengths.

STEP 5: The computer automatically displays the values you entered, along with the results of the calculations. The input values--ZI, YI, VSWR, and PCR--and the termination values--VSWR and PCR--are displayed. You then have the option of changing your entries, repeating the program, or exiting the program. To change your input, simply press C. Type the variable and its new value (i.e., DW=2) and press ENTER. To change more than one input, type both changes and separate them with a semicolon. When you press ENTER, the program recalculates the results and displays them along with the values you entered . To repeat the program, press R, and the program asks you for new data entries. When you finish your calculations, press E to exit the program. The message **DONE** is displayed, and the program stops.

To help you understand how the program works, the following example is provided.

Given a transmission line with a characteristic impedance (Z_0) of 50 + j0 ohms, an attenuation constant of 0.4 dB, and a termination impedance of 10 + j40 ohms, find the input impedance (Zi) and the input VSWR at 1 and 2 wavelengths (DW) from the termination.

First, load and run the program as described in Steps 1 and 2 of the "User Instructions." Now enter the required inputs in response to the prompts shown below.

PROMPT	ENTER	COMMENTS
CHARACTERISTIC IMPEDANCE? ZO=	50	Z_0 in ohms
TERM LOAD (ZL= or YL=)?	ZL=10+J40	Z_L in ohms
ATTENUATION CONSTANT IN DB/WAVELENGTH? AC =	.4	AC in dB/wavelength
DISTANCE FROM TERMINATION IN WAVELENGTH? DW =	1	DW in wavelengths

The values you entered and the computed results are displayed as follows.

```
                              INPUT SUMMARY:
ZO = 50
ZL = 10 + J40
AC = .4
DW = 1

                              INPUT VALUES:
ZI = 13.6 + J39.1
YI = .007 + J.022
VSWR = 6.02839
PCR = .511854

                           TERMINATION VALUES:
VSWR = 8.27921
PCR = .615384

PRESS (C)HANGE, (R)EDO, (E)XIT
```

Now press C to change the distance from termination to 2 wavelengths. Type DW = 2, and press ENTER. Your entry values and answers are displayed as follows.

```
                          INPUT SUMMARY:
ZO = 50
ZL = 10 + J40
AC = .4
DW = 2

                          INPUT VALUES:
ZI = 17 + J38
YI = .009 + J.021
VSWR = 4.75521
PCR = .425742

                        TERMINATION VALUES:
VSWR = 8.27921
PCR = .615384


PRESS (C)HANGE, (R)EDO, (E)XIT
```

Press E. The message **DONE** is displayed, and the program stops.