FOURIER SERIES ANALYSIS FOR THE TI-85 CALCULATOR

VERSION 1.00 -- Provisional

C O N T E N T S

I INTRODUCTION

1.1 Purpose of the Software

FOURIER is a program designed to assist in the formulation of Fourier series. It allows the user to specify an arbitrary time-domain periodic waveform. This waveform can be either described by a continuous function of x, or a "piecewise continuous" function of x; the number of sections is limited only by the TI-85 memory space.

In addition to computation of Fourier coefficients, FOURIER also computes peak phasor and RMS frequency component values for each harmonic in the series. Through the use of the built-in editors of the TI-85, the input and output data from the program can be easily accessed and modified.

1.2 Memory Requirements

FOURIER requires about 5K of free RAM for its data and code. When FOURIER executes, two lists are created and/or modified. These lists are named AN and BN. If another program in the calculator is using these list names, be aware that FOURIER will modify these list files.

The TI-85 calculator maintains data values even when it is turned off. Fourier series data is kept intact when exiting the program -- restarting FOURIER will result in the display of the previous problem's data.

1.3 Notation Conventions

Items appearing within brackets are TI-85 keystrokes. Some of these keys are menu keys, such as [MAIN], while others are fixed-function keys on the keyboard.

Quote marks " " surround references to fields on the LCD display. For example, the field marked "LL" refers to the lower limit of integration for a slice of time-domain data during the data entry process.

II HARDWARE REQUIREMENTS - LOADING THE SOFTWARE

2.1 TI-Link

FOURIER is supplied on a floppy diskette suitable for either an IBM personal computer or an Apple Macintosh. In order to load FOURIER into your calculator, you must have the TI-Link kit and software installed on your computer.

To load FOURIER into your calculator, follow the instructions that came with TI-LINK. The filename on the disk is FOURIER, and the name will be the same when it loads into the calculator.

2.2 Battery Life Warning

FOURIER should not be executed when batteries in the calculator are weak. Depending on the level of algorithm selected by the user, the computation process may take anywhere from a few seconds to a few hours. Since TI has not documented the outcome for failure of batteries during program execution, this should be assumed to be a danger to memory contents. Make frequent data backups.

III GETTING STARTED: WORKING A SAMPLE PROBLEM

3.1 Starting FOURIER

To start the program, you may do any of the following:

- Type "FOURIER" and press [ENTER] at the home screen.
- Press [PRGM] and select FOURIER from the menu of items; then press [ENTER].
- Call FOURIER from another TI-85 program.

The first time FOURIER executes, it will display the title and copyright message. Once a problem has been entered, the copyright message will be replaced with a graph of the user's input data.

FOURIER is menu-driven software. To move around inside the program, press the function key (F1 - F5) that corresponds to the selection desired.

When the program is started for the first time, the only valid command at the MAIN MENU is [NEW].

3.2 Time Domain Data Entry

Selecting [NEW] at the MAIN MENU will begin the process of entering time-domain data. A warning is issued before erasing the old data. Press [OK] to continue, or [STOP] to return to the MAIN MENU with no alterations of data.

FOURIER assumes that all functions have a period of 2ã radians, and that the time-domain form is expressible in piecewise-continuous fashion. The independent variable that will be used for the integrations is 'x', which is typed by pressing the [X-VAR] key on the keyboard. After selecting [NEW] and [OK] from the MAIN MENU, the following display appears:

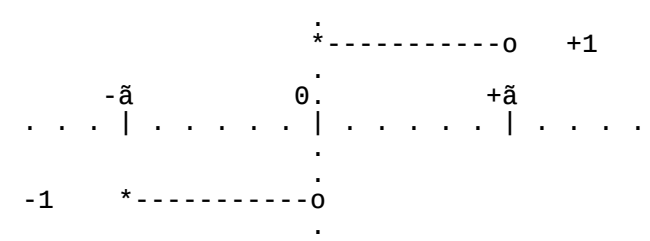
```
HIGHEST HARMONIC=10

LL: -ã
UL: ã
 F: (blank)


| L-LIM | H-LIM | FUNCT | NEXT | DONE |
 ------------------------------------
```

"LL" and "UL" represent the lower and upper integration limits for the "piece" of time-domain data being entered. "F" represents the algebraic value of the time-domain data over these limits. The limits are understood as (LL, UL] for all functions -- however, the user can modify the final function with the editor to change this assumption.

For example, to enter the time-domain form for a 50/50 duty squarewave with no DC level, 2 V p-p value, the following data would be entered:



[H-LIM] 0 [ENTER] (Sets integration been -ã and 0)
[FUNCT] -1 [ENTER] (f(x) = -1 in this segment.)
[NEXT] (Go to next piece. Note that FOURIER automatically makes the lower limit 0 in the next segment, based on the previous entry into UL.)

[FUNCT] 1 [ENTER] (Between 0 and ã, the function is +1 in value.)

[DONE] (Tells FOURIER that no more segments are forthcoming.)

Pressing [DONE] completes entry of the time-domain function. FOURIER compiles the data into equation y1, which is the same equation name used by the TI GRAPH command.

The time-domain graph now appears on the screen. FOURIER initially scales the Y-axis to a maximum of +2 and a minimum of -2; if a function exceeds these bounds, it will run off the screen. By accessing the TI equation editor (see section 4.1), it is possible to readjust the RANGE variables for the screen in any manner desired.

3.3 Harmonic Component Calculation and Display

From the MAIN MENU, the command [SPECT] is used for all spectral computations. Pressing this selection moves to the SPECTRUM menu:

| CALC | COEFF | HARM+ | HARM-| MAIN |

Selections [HARM+] and [HARM-] alter the GLOBAL HARMONIC COUNT for FOURIER. Pressing [HARM+] tells FOURIER to both COMPUTE and DISPLAY higher-numbered harmonics for the functions being investigated. For faster analysis, it is often wise to use [HARM-] to reduce the harmonic count to a smaller number. The default for HARMONIC COUNT is 10; the maximum is

25, and the minimum is 1. THESE KEYS PERFORM NO CALCULATION. THEY ONLY SET THE COUNT FOR LATER CALCULATION AND DISPLAY.

Selecting [CALC] initiates the computation process. The calculator announces each coefficient as it is being computed. Previously-calculated coefficients are merely displayed, but not evaluated, as FOURIER keeps track of the highest harmonic computed. Thus it is possible to do a calculation for 5 harmonics, render a result, then re-evaluate the same problem for 6 harmonics by merely pressing [HARM+] then [CALC].

NOTE: TO TERMINATE CALCULATIONS IN PROGRESS, PRESS [ENTER]. DO NOT PRESS [ON] TO STOP THE CALCULATOR.

Selecting [COEFF] displays the result menu, which looks like this:

```
A0 = 0


|  +    |   -   |       | SPECT| MAIN |
 ---------------------------------------
```

Pressing [+] and [-] moves through the result array, AN and BN. The first result displayed is the DC level (average), A0. Pressing [+] displays the first harmonic (fundamental):

```
A1 = 0
B1 = 1.27323954474

V1 = 1.273 < 0     pK
   = .90031631615 RMS
   = -.9120975839 dBV


|  +    |   -   |       | SPECT| MAIN |
 ---------------------------------------
```

Note that each harmonic is displayed three ways:

- As AN and BN (COSINE and SINE coefficients)
- As a PEAK (pK) Phasor quantity
- As an RMS spectral magnitude, in both VRMS and decibel-Volts (dBV).

NOTE: Zero spectral components can not be represented in dBV. For these, the dBV line will be blank.

Pressing [SPECT] returns to the SPECTRUM menu. Pressing [MAIN] returns to the MAIN MENU.

3.4 Wave Reconstruction using the Series Representation

FOURIER has the capability of reconstructing time-domain data using the computed coefficient arrays. Pressing [VIEW] at the MAIN MENU selects which functions will be drawn on the screen:

ORIG	RECON	BOTH	SPEC	MAIN

- [ORIG] selects the original user time-domain data. This is the default setting each time a new problem is entered.

- [RECON] selects the Fourier-series reconstructed data. The data is calculated using the highest harmonic number selected from the SPECTRUM menu. [RECON] can be used to demonstrate the effect of harmonic attenuation by using the [HARM-] key at the SPECTRUM menu to reduce the harmonic count. It will also demonstrate the effect of harmonic count on reproduction accuracy.

- [BOTH] superimposes graphs of the original and reconstructed data for easy comparison.

- [SPECT] provides a jump to the SPECTRUM MENU for recalculation or harmonic count adjustment.

- [MAIN] returns to the main menu.

FOURIER programs the equation y2 (the same equation used by the TI GRAPH command) with the time-domain form of the reconstructed Fourier Series. This equation can be used in other programs.

IV Accessing and Editing Machine Data

4.1 Original Time-Domain Information

The [EDIT] key at the MAIN MENU accesses the TI GRAPH and equation editor. The equations y1 and y2 are used by FOURIER for computation and graphing.

Equation y1 is the piecewise time-domain data. For example, equation y1 contains the following information for the sample data of section 3.2:

```
y1 = (x>=-ã)*(x<0)*(-1) + (x>=0)*(x<ã)*1
```

The relational expressions define the limits for each expression. From the above expression, it can be seen that y1 = -1 (-ã, 0]. By modifying the relational expressions, the limits can be altered as desired.

Pressing [EXIT], then [ENTER] at the editor screen returns control to FOURIER.

NOTE: USING THE [EDIT] COMMAND AT ANY TIME WILL FORCE FOURIER TO ASSUME THAT CHANGES HAVE BEEN MADE TO THE TIME-DOMAIN FUNCTION y1. FOURIER WILL ASSUME THAT ALL HARMONICS NEED TO BE RECOMPUTED WHENEVER [EDIT] IS PRESSED, EVEN IF NO CHANGE HAS BEEN MADE TO y1 IN THE EDITOR.

4.2 Reconstruction Equation

Equation y2 is the reconstructed form of the series. To properly use this equation, the coefficients AN, BN and A0 must have been previously defined by executing a [CALC] command in FOURIER. The variable N in equation y2 should NOT be modified. It represents the highest harmonic being computed. Variable J is an index counter and can be used by other programs.

4.3 Fourier Series Coefficients

There are three components to the series cofficients: The average A0, the series of cosine coefficients AN, and the sine coefficients BN.

The average is contained in the variable A0.

The sine and cosine coefficients are contained in LIST variables BN and AN, respectively. They can be inspected outside of FOURIER by using [2nd] [List] (see the TI-85 user's guide). Since these coefficients are global, other programs can access the calculated data.

Note that AN and BN are the peak coefficients. FOURIER does not maintain a list of RMS coefficients; the RMS values are computed during the spectral display routine.

FOURIER can be used to reconstruct time-domain data from AN and BN coefficients obtained from "outside sources." To do this, enter a problem into FOURIER. The problem itself is immaterial; it merely enables all the menus in the program. Then, exit FOURIER and use the LIST EDITOR (see the TI-85 user's guide) to modify the lists AN and BN. Upon returning to FOURIER, these list values will be intact, and FOURIER will use them until a [CALC] command is issued (or a new problem is started).

V. Program Limitations

5.1 Error Trapping

There is NO error trapping in FOURIER except that provided at the user menus. The TI-85 does not provide a mechanism for interception of errors, and any error will halt the execution of the program.

Errors generally result from poorly-formed function segments during the entry process. To recover, either restart FOURIER, or use the GRAPH key to access the equation editors, which can be used to fix the mistake. Worst case, if FOURIER refuses to run due to the error, delete equations y1 and y2 from the calculator ([2nd] [MEM]) and start over.

5.2 Accuracy

Because of the large number of chain calculations in this program, and the variability of user-defined functions, accuracy will be widely variable. For time-domain functions of 10th degree or less, FOURIER will generally provide accuracy to 7 digits or better. FOURIER truncates any coefficient result which has a magnitude of < 1E-9 to zero.

5.3 Variable Usage

The following variables are important to the internal operation of FOURIER, and shouldn't be modified unless a [NEW] problem is going to be started:

LISTS AN , BN

REALS A0, I, N, CF, HCF

```
EQUATIONS  y1, y2
```

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