SGS-THOMSON MICROELECTRONICS

APPLICATION NOTE

COMPUTATION OF TONE DETECTOR COEFFICIENTS USING TD SOFTWARE FOR ST75C502

I - Tone Detector Description

Refer to the ST75C502 Data Sheet for detailed description of the tone detectors, Figure 2 (ST75C502 Data Sheet) for the biquadratic IIR filter, Figure 3 for the power estimator, Figure 4 for the tone detector wiring address (first half) and Figure 5 for the tone detector wiring address (second half).

There are 16 programmable tone detector cells available. Each cell contains a 4th order IIR (biquadratic) filter, energy estimator consisting of an absolute value measurement and a 1st order low pass filter, 2 input comparator, and a static level.

Detect information is sent to status word ***TONEDET***. The user has the possibility of sending commands to the data pump to program the tone detectors for almost any desired transfer function. For each cell, the command ***TDWC*** can be used to program the 12 coefficients of the 4th order IIR filter (C0 to CB), the 1st order low pass filter coefficient, and the static level. The command ***TDWW*** can be used to program the wiring between cells for cascading and signal routing. One is free to program the IIR input, energy estimator input, and comparator + and - inputs.

II - Program TD Description

The user has the possibility of calculating his proper coefficients and determining the corresponding ***TDWC*** and ***TDWW*** commands manually but, the program TD was written to facilitate this task.

The purpose of this chapter is to give the operating instructions for using program TD for quick development of the code needed to program the detectors.

III - Compatability and Input/output

Program TD is written in FORTRAN and is executable on almost any PC with hard disk using MS-DOS.

Input is from the keyboard and output is on the screen.

Also, several useful files are generated by the program :

a) TD.SPC - contains trace of filter specifications given by user
b) TD.RES - shows floating-point frequency response of specified filter
c) TD.CCI - CCI commands needed for the data pump for specified filter

IV - Starting the Program

To start the program, the user should first create a directory and load program TD.EXE into the directory. The command TD is now sent while in the created directory to start program execution. The program will then display ENTER TYPE. The following paragraph will describe the filter types.

V - Choosing a Filter Type

Four possible filter types are available to the user with the following characteristics :

- BUTTERWORTH : This type of filter has a maximally flat pass-band with no ripple. It has multiple zeroes at half the sampling frequency (3600Hz) or D.C. or at the center of the band for band-stop configurations.
- CHEBYCHEV : Equiripple in the pass band and flat response in the stop band which is particularly useful for band rejection filtering.
- INVERSE CHEBYCHEV : Ripple-free pass band and more efficient than the Butterworth. For the same target design template, a lower order filter is necessary. Equiripple stop-band characteristics render this type useful for band-pass, low-pass or high-pass filtering.
- ELLIPTIC : This type of filter is the most efficient and can have narrow transition bands. However, it is characterized by ripple in the pass and stop bands. Once the type is chosen, the program will ask for LOPASS, HIPASS, BANDPASS, or BAND REJECT filters.

VI - Choosing a Filter Order

For all but Elliptic types, the program TD will ask the desired order. The user must specify the number of cascaded biquads (2nd order sections) desired.

VII - Defining and Optimizing a Target Template

The corner frequencies for pass band and/or stop band are required by the program, and attenuation in the pass band and/or stop band for all types except Butterworth. These attenuations are in dB referenced from the input to the output. The program now calculates the transfer function in the Z domain displaying locations of poles and zeroes, and the required number of 4th order tone detector cells needed. This information is displayed on the screen and output to file TD.SPC. For the case of an Elliptic type, the order required is calculated from the transition band specified by the user, rather than specified directly by the user as for the other types. The order may be too high for the number of cells available or desired. The user may re-specify the filter. In general, one or more of the following steps may be performed, if the application enables it, to decrease the required order of an Elliptic type filter :

- change from band pass or band reject to low pass or high pass,
- increase difference between pass band and stop band frequencies,
- increase the pass band ripple and/or decrease the stop band atten.

Using an iterative process, one can optimize the target specification of the filter before continuing to the next step.

VIII - Displaying the Ideal Frequency Response

The program TD will now calculate the frequency response of the specified filter and normalize coefficients to avoid overflow in the DSP ALU. The program now proceeds with the display of the frequency response on the screen. The user is asked by the program TD to specify start, stop, and step frequencies to facilitate interest in a particular portion of the frequency response. Once displayed, the program asks if the response is to be re-displayed allowing the user to change the frequency ranges. The desired frequency response is calculated in floating-point while the actual program implemented in the data pump uses a fixed-point DSP. In most cases, there should not be too much difference between the two calculation methods if the transition bands are not too narrow in the case of Elliptic types or the order is not too high for all types. At this point, the user has a better idea of the transition bands for Butterworth and Chebychev designs and also the unity gain loss. The normalization process may, in some cases to avoid overflow, result in an attenuation in the pass band or unity gain loss. Increasing the order of the Butterworth or Chebychev filters may be necessary for a narrower transition band. Widening of the transition band may be necessary for diminuing the unity gain lossof an Elliptic filter. In any case, the frequency response is written to file CP.RES for reference after the end of program execution. This can be especially useful for reference if several optimization attempts are desired.

IX - Choosing the Used Cells

The program TD will now ask for the starting cell number (a number from 0 to F). The program will write CCI instructions for programming n (n = order/4) cells starting from the given address. The program cascades the biquadratic filters. However, only the last comparator and static level are used for the detection decision. This means that, eventually, the comparators or static levels for intermediate cells could be programmed for other functions. If the user, for example chooses 1 for the starting address, and there are 3 cells used, then the detection bit for this configuration will be available in ***TONEDET(0)*** position 3 (refer to ST75C5x Data Sheet). The user should choose a relatively low starting address beginning with the first unused position, if possible. This is because the execution time of the detectors in the non-idle mode may necessitate the utilizaton of less than 16 cells (NTDCELL .lt. 16 refer to ram mapping application note). In this case the higher cell numbers are not executed.

X - Selecting the Detection Thresholds

The detection threshold is now asked for by the program to define the minimum detectable input signal level at a pass band frequency with 0dB unity gain loss. The program will remind the user of the actual unity gain loss due to normalization and, in general, the desired threshold must be lowered by the number of dB in the unity gain loss. However, threshold levels lower than -50dBm are not reliable as the minimum dynamic range of the detectors will be surpassed.

XI - Selecting the Energy Estimator Time Constant

The energy estimator time constant is now asked for by the program and the user will specify the value in milliseconds. A typical value of 8 is used for the default tone detectors but, if the user designs a filter with a particularly large group delay, he should also increase this value to avoid undesirable transients in the detection decision. Please note that group delay calculation is beyond the scope of this program and must be calculated by other techniques from the coefficients in TD.SPC.

XII - Example Listings

The following listings give an example printout of the files TD.SPC, TD.RES, TD.CCI for a Butterworth 8th order low pass filter with cut-off frequency of 1000Hz.

```
EXAMPLE FOR 8th ORDER BUTTERWORTH
LPF FC=1000HZ, TH=-40dBM

           TD.SPC
           ------

  ENTER TYPE: 1 BUTTERW, 2 CHEBY, 3 ICHEBY, 4 ELLIP
     1
  ENTER 1 LOPASS, 2 HIPASS, 3 BPASS, 4 BREJ
     1
  ENTER NUMBER OF CASCADED BIQUADS DESIRED
     4
  ENTER BAND EDGE IN UN-NORMALIZED HZ
   1000.000
  Z PLANE
  #,   ZEROS  (REAL,  IMAG),      POLES (REAL, IMAG)
  1     -1.000000      0.000000      0.367029      0.085334
  2     -1.000000      0.000000      0.392676      0.259992
  3     -1.000000      0.000000      0.450892      0.446792
  4     -1.000000      0.000000      0.559214      0.653640
  5      1.000000      0.000000      1.000000      0.000000

           2 4TH ORDER TONE DETECTOR CELLS NEEDED !

  F(Z) = (Z*Z + B1Z + B2)/(Z*Z + A1Z + A2)
       1    2.000000    1.000000      -0.734059    0.141992
       2    2.000000    1.000000      -0.785351    0.221790
       3    2.000000    1.000000      -0.901784    0.402926
       4    2.000000    1.000000      -1.118428    0.739966

                TD.RES
                ------

 Freq(Hz):                                              Gain(dB):
 ---------                                              ---------
    0.**************************************************    0.0
  100.**************************************************    0.0
  200.**************************************************    0.0
  300.**************************************************    0.0
  400.**************************************************    0.0
  500.**************************************************    0.0
  600.**************************************************    0.0
  700.**************************************************    0.0
  800.**************************************************   -0.1
  900.*************************************************    -0.6
 1000.**********************************************       -3.0
 1100.*****************************************            -8.3
 1200.**********************************                  -15.0
 1300.****************************                        -21.7
 1400.**********************                              -28.3
 1500.***************                                     -34.6
 1600.*********                                           -40.8
 1700.***                                                 -46.9
 1800.                                                    -53.0
 1900.                                                    -59.1
 2000.                                                    -65.2
 2100.                                                    -71.4
 2200.                                                    -77.8
 2300.                                                    -84.3
 2400.                                                    -91.2
 2500.                                                    -98.4
 2600.                                                   -100.0
 2700.                                                   -100.0
 2800.                                                   -100.0
 2900.                                                   -100.0
 3000.                                                   -100.0
 3100.                                                   -100.0
```

XII - Example Listings (continued)

```
                      TD.CCI
                      ------

; 4TH ORDER BIQUAD CELL 9 COEFS
CCI TDWC 9 0 1B 1A
CCI TDWC 9 1 FA 2E
CCI TDWC 9 2 EA F6
CCI TDWC 9 3 00 40
CCI TDWC 9 4 00 20
CCI TDWC 9 5 00 40
CCI TDWC 9 6 EE 1B
CCI TDWC 9 7 43 32
CCI TDWC 9 8 CF F1
CCI TDWC 9 9 00 40
CCI TDWC 9 A 00 20
CCI TDWC 9 B 00 40
; 4TH ORDER BIQUAD CELL A COEFS
CCI TDWC A 0 12 20
CCI TDWC A 1 B6 39
CCI TDWC A 2 37 E6
CCI TDWC A 3 00 40
CCI TDWC A 4 00 20
CCI TDWC A 5 00 40
CCI TDWC A 6 9E 23
CCI TDWC A 7 94 47
CCI TDWC A 8 A5 D0
CCI TDWC A 9 78 47
CCI TDWC A A BC 23
CCI TDWC A B 78 47
; POWER ESTIMATOR AND BIQUAD INPUTS
CCI TDWW 9 0 19 02
CCI TDWW A 0 1A 19
; COMPARATOR - AND + INPUTS
CCI TDWW A 1 3A 2A
; DETECTION THRESHOLD AT   -40.00 DB
CCI TDWC A 20 70 00
; ENERGY TIME CONSTANT IS     8.00 MS
CCI TDWC A 10 E3 08
; CLEAR INTERNAL VARIABLES OF ALL USED CELLS
CCI TDZ 9
CCI TDZ A
```