

UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

A TI-59 Calculator Program for  
Computation of Schlumberger Resistivity Sounding  
Curve for Models with as many as 25 Horizontal Layers

by

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Open-File Report No. 81-160

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Although this program has been extensively tested, the USGS cannot guarantee that it will give correct results in any or all particular applications.

TITLE Schlumberger Resistivity Sounding

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DATE 10/20/80

Partitioning (Op 17) 2,3,9,8,9

This program was developed to do rapid computation of theoretical Schlumberger resistivity sounding curves. It is based on the application of Ghosh's linear filter (Ghosh, 1971) to resistivity transforms calculated for a given earth model.

Haines and Campbell (1980) wrote a program for the computation of Schlumberger and Wenner sounding curves over structures with as many as 10 horizontal layers. Although it is generally not possible to visually recognize more than 8 layers on a field curve, the present program can be used to compute sounding curves from digitized electric logs provided the number of layers does not exceed 25.

The input data consists of the thicknesses, the resistivities, and the number of layers (up to 25). The program will compute the apparent resistivities at the rate of 6 points per logarithmic cycle starting at abscissa value of  $AB/2$  of 1 and ending at 10,000. The computed apparent resistivities will be stored successively in registers 37 to 61. This represents the output of the program, and the contents of these registers can be recalled by the user.

Note: The dimensions of the computed electrode spacings ( $AB/2$ ) and apparent resistivities will correspond to those of the entered thicknesses and resistivities, respectively.

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The following is the output of computed apparent resistivities for the above-mentioned illustrating example.

| Computed<br>apparent<br>resistivities | Stored<br>in<br>registers |                  |
|---------------------------------------|---------------------------|------------------|
| 241.1431472                           | 37                        | - for AB/2=1     |
| 217.0136337                           | 38                        |                  |
| 179.1268944                           | 39                        |                  |
| 139.846785                            | 40                        |                  |
| 113.1147091                           | 41                        |                  |
| 100.9726029                           | 42                        |                  |
| 96.86244975                           | 43                        | - for AB/2=10    |
| 95.1592856                            | 44                        |                  |
| 93.71288423                           | 45                        |                  |
| 91.59566606                           | 46                        |                  |
| 86.95311787                           | 47                        |                  |
| 76.90352711                           | 48                        |                  |
| 61.51721231                           | 49                        | - for AB/2=100   |
| 46.82094031                           | 50                        |                  |
| 40.00588464                           | 51                        |                  |
| 43.1819453                            | 52                        |                  |
| 53.71142519                           | 53                        |                  |
| 68.20108221                           | 54                        |                  |
| 84.45314038                           | 55                        | - for AB/2=1000  |
| 100.9135485                           | 56                        |                  |
| 116.0076031                           | 57                        |                  |
| 128.363842                            | 58                        |                  |
| 137.3269032                           | 59                        |                  |
| 143.100719                            | 60                        |                  |
| 146.4431868                           | 61                        | - for AB/2=10000 |

## References

- Ghosh, D. P., 1971, Inverse filter coefficients for computation of apparent resistivity standard curves for a horizontally stratified earth, *Geophys. Prospect.*, 19, p. 769-775.
- Haines, D. N. and Campbell, D. L., 1980, Texas Instruments Model 59 Hand Calculator Program to calculate theoretical Wenner and Schlumberger vertical electrode soundings of a structure of up to 10 horizontal layers, U.S. Geological Survey Open-File Report 80-190, 15 p.

**USER INSTRUCTIONS**

| STEP | PROCEDURE  | ENTER     | PRESS         | DISPLAY   |
|------|--|-----------|---------------|-----------|
| 1    | Clear memory   |           | 2nd CMs       |           |
| 2    | Repartition memory storage area  | 9         | 2nd Op 17     | 239.89    |
| 3    | Load Side 1 of Card<br>Load Side 2 of Card   |           | INV 2nd Write | 1.<br>2.  |
| 4    | Input layer parameters: starting with the first layer, enter and store thicknesses and resistivities as shown in the following example of a 4-layer model: |           |               |           |
|      | Thickness     Resistivity  |           |               |           |
|      | First Layer                    1                    259  | 1.00259   | STO 12        | 1.00259   |
|      | Second Layer                    46                    94   | 46.00094  | STO 13        | 46.00094  |
|      | Third Layer                    150                    27   | 150.00027 | STO 14        | 150.00027 |
|      | Fourth Layer                    ---                    150   | 0.00150   | STO 15        | 0.00150   |
|      | There are 25 available registers, from no. 12 to no. 36, for layer parameters entry.   |           |               |           |
|      | The last input resistivity value represents the resistivity of the infinitely thick last layer.  |           |               |           |

- 5 Enter number of layers (N=4 for above example) 4    4.
- 6 Press A to start program A
- 7 End of program is indicated by the display of 61

Press RCL followed by a register number from 37 to 61 to display successively the computed apparent resistivities for AB/2 of 1, 1.46, 2.15, 3.16, 4.64, 6.81, 10, 14.6, ....., 10000.

**Operating Restriction**

The values of layer resistivities should not be larger than 99999. A six digit number will be considered as a decimal fraction. Layer thicknesses can be entered up to a 4-digit number.

| USER DEFINED KEYS         | DATA REGISTERS ( INV    RCL ) | LABELS (Op 08)   |
|---------------------------|-------------------------------|--|
| A Starting of program     | 8 <sup>0</sup> 1.467799268    | INV   Inx   CE   CLR   x <sup>1</sup> x <sup>2</sup>       |
| B                         | 8 <sup>1</sup>                | √x   1/x   STO   RCL   SUM   Y <sup>a</sup>                |
| C 12-36 for input         | 8 <sup>2</sup>                | EE   C   I   →   GTO   X                                   |
| D layer parameter         | 8 <sup>3</sup> filter         | SBR   -   RST   +   R/S   .                                |
| E                         | 8 <sup>4</sup> coefficients   | ←/→   ≡   CLR   INV   M <sup>c</sup> C <sup>d</sup>        |
| A'                        | 8 <sup>5</sup>                | tan <sup>-1</sup> Perm   P→I   SSB   COS   CM <sup>s</sup> |
| B'                        | 8 <sup>6</sup>                | Luc   Prd   Int   Eng   Fr <sup>e</sup> Int <sup>o</sup>   |
| C' for recalling          | 8 <sup>7</sup>                | Deg   Phase   x <sup>r</sup> Map   D <sup>o</sup> Rad      |
| D' computed appar-        | 8 <sup>8</sup>                | Lbl   x=1   x <sup>o</sup> F   Grad   ST <sup>o</sup>      |
| E' current resistivity    | 8 <sup>9</sup>                | Int <sup>o</sup> RMS   Inv   List   Write   Bx             |
| D'' 7 <sup>0</sup> 100    |                               | AD <sup>o</sup> PL   |
| E'' 7 <sup>0</sup> 100000 |                               |  |
| FLAGS    - 0              | - 1                           | - 2  |
|                           | - 3                           | - 4  |
|                           | - 5                           | - 6  |
|                           | - 7                           | - 8  |
|                           | - 9                           |  |

PROGRAMMER \_\_\_\_\_ DATE \_\_\_\_\_

| LOC | CODE | KEY            | COMMENTS     | LOC | CODE | KEY | COMMENTS    | LOC | CODE | KEY | COMMENTS      |
|-----|------|----------------|--------------|-----|------|-----|-------------|-----|------|-----|---------------|
| 000 | 76   | LBL            |              | 055 | 10   | 10  | summation   | 110 | 95   | =   |               |
| 001 | 11   | R              | start,       | 056 | 08   | 8   | ↓           | 111 | 42   | STO |               |
| 002 | 42   | STO            | store no.    | 057 | 09   | 9   |             | 112 | 08   | 08  |               |
| 003 | 01   | 01             | of layers    | 058 | 32   | XIT |             | 113 | 73   | RC* |               |
| 004 | 43   | RCL            | max          | 059 | 43   | RCL |             | 114 | 08   | 08  |               |
| 005 | 79   | 79             | AB/2         | 060 | 04   | 04  |             | 115 | 22   | INV |               |
| 006 | 32   | XIT            |              | 061 | 42   | STO |             | 116 | 59   | INT |               |
| 007 | 43   | RCL            | min.         | 062 | 03   | 03  |             | 117 | 65   | X   |               |
| 008 | 80   | 80             | AB/2         | 063 | 73   | RC* |             | 118 | 43   | RCL |               |
| 009 | 33   | X <sup>2</sup> | and          | 064 | 05   | 05  |             | 119 | 79   | 79  |               |
| 010 | 55   | +              | store        | 065 | 65   | X   |             | 120 | 95   | =   |               |
| 011 | 43   | RCL            |              | 066 | 73   | RC* |             | 121 | 42   | STO |               |
| 012 | 78   | 78             |              | 067 | 03   | 03  |             | 122 | 10   | 10  |               |
| 013 | 95   | =              |              | 068 | 95   | =   |             | 123 | 69   | DP  |               |
| 014 | 42   | STO            |              | 069 | 44   | SUM |             | 124 | 38   | 38  |               |
| 015 | 02   | 02             |              | 070 | 10   | 10  |             | 125 | 43   | RCL |               |
| 016 | 03   | 3              |              | 071 | 69   | DP  |             | 126 | 01   | 01  |               |
| 017 | 07   | 7              |              | 072 | 23   | 23  |             | 127 | 42   | STO |               |
| 018 | 42   | STO            |              | 073 | 69   | DP  |             | 128 | 00   | 00  |               |
| 019 | 09   | 09             | clear        | 074 | 23   | 23  |             | 129 | 97   | DSZ |               |
| 020 | 25   | CLR            | register     | 075 | 43   | RCL |             | 130 | 00   | 00  |               |
| 021 | 42   | STO            |              | 076 | 05   | 05  |             | 131 | 01   | 01  |               |
| 022 | 10   | 10             |              | 077 | 67   | EQ  |             | 132 | 35   | 35  |               |
| 023 | 71   | SBR            | to recall    | 078 | 00   | 00  |             | 133 | 69   | DP  |               |
| 024 | 01   | 01             | and stor     | 079 | 85   | 85  |             | 134 | 38   | 38  |               |
| 025 | 05   | 05             | p and h      | 080 | 69   | DP  |             | 135 | 73   | RC* |               |
| 026 | 43   | RCL            |              | 081 | 25   | 25  |             | 136 | 08   | 08  |               |
| 027 | 02   | 02             | next         | 082 | 61   | GTO |             | 137 | 59   | INT |               |
| 028 | 65   | X              | AB/2         | 083 | 00   | 00  |             | 138 | 42   | STO |               |
| 029 | 43   | RCL            |              | 084 | 63   | 63  |             | 139 | 11   | 11  |               |
| 030 | 80   | 80             |              | 085 | 43   | RCL | ↑           | 140 | 73   | RC* |               |
| 031 | 95   | =              |              | 086 | 10   | 10  | store       | 141 | 08   | 08  |               |
| 032 | 42   | STO            |              | 087 | 72   | ST* | apparent    | 142 | 22   | INV |               |
| 033 | 02   | 02             |              | 088 | 04   | 04  | resistivity | 143 | 59   | INT |               |
| 034 | 77   | GE             | test for     | 089 | 06   | 6   | limit of    | 144 | 65   | X   |               |
| 035 | 00   | 00             | max. AB/2    | 090 | 01   | 1   | computation | 145 | 43   | RCL |               |
| 036 | 42   | 42             |              | 091 | 32   | XIT |             | 146 | 79   | 79  |               |
| 037 | 69   | DP             | if no, go    | 092 | 43   | RCL | test for    | 147 | 95   | =   |               |
| 038 | 29   | 29             | to next      | 093 | 04   | 04  | limit, if   | 148 | 42   | STO |               |
| 039 | 61   | GTO            | AB/2         | 094 | 67   | EQ  | yes stop.   | 149 | 07   | 07  |               |
| 040 | 00   | 00             |              | 095 | 01   | 01  | if no, go   | 150 | 71   | SBR | ↑             |
| 041 | 20   | 20             |              | 096 | 03   | 03  | back and    | 151 | 01   | 01  | to compute    |
| 042 | 03   | 3              |              | 097 | 69   | DP  | Continue    | 152 | 62   | 62  | transforms    |
| 043 | 07   | 7              |              | 098 | 24   | 24  |             | 153 | 97   | DSZ | decrement     |
| 044 | 42   | STO            |              | 099 | 61   | GTO |             | 154 | 00   | 00  | no. of layers |
| 045 | 03   | 03             |              | 100 | 00   | 00  |             | 155 | 01   | 01  | if zero       |
| 046 | 42   | STO            |              | 101 | 48   | 48  |             | 156 | 33   | 33  | store         |
| 047 | 04   | 04             |              | 102 | 68   | NOP |             | 157 | 43   | RCL | transform,    |
| 048 | 25   | CLR            |              | 103 | 91   | R/S |             | 158 | 10   | 10  | if no,        |
| 049 | 08   | 8              | store        | 104 | 00   | 0   |             | 159 | 72   | ST* | continue      |
| 050 | 01   | 1              | first filter | 105 | 01   | 1   |             |     |      |     |               |
| 051 | 42   | STO            | coefficient  | 106 | 01   | 1   |             |     |      |     |               |
| 052 | 05   | 05             |              | 107 | 85   | +   |             |     |      |     |               |
| 053 | 25   | CLR            | clear for    | 108 | 43   | RCL |             |     |      |     |               |
| 054 | 42   | STO            |              | 109 | 01   | 01  |             |     |      |     |               |

convolve resistivity transform with filter coefficients

test for conv. if no continue, if yes go 085

store apparent resistivity limit of computation test for limit, if yes stop. if no, go back and Continue

Store Pn, recall and store resistivity and thickness of (n-1) layer separately. Counter for no. of layers

MERGED CODES

|          |          |          |
|----------|----------|----------|
| 62 [GTO] | 72 [STO] | 83 [GTO] |
| 63 [RCL] | 73 [RCL] | 84 [XIT] |
| 64 [DP]  | 74 [SUM] | 92 [INV] |

PROGRAMMER \_\_\_\_\_ DATE \_\_\_\_\_

| LOC | CODE | KEY             | COMMENTS | LOC | CODE | KEY            | COMMENTS | LOC | CODE | KEY | COMMENTS |
|-----|------|-----------------|----------|-----|------|----------------|----------|-----|------|-----|----------|
| 160 | 09   | 09              |          | 215 | 07   | 07             |          |     |      |     |          |
| 161 | 92   | RTN             |          | 216 | 33   | X <sup>2</sup> |          |     |      |     |          |
| 162 | 02   | 2               |          | 217 | 54   | )              |          |     |      |     |          |
| 163 | 65   | X               |          | 218 | 22   | INV            |          |     |      |     |          |
| 164 | 43   | RCL             |          | 219 | 49   | PRD            |          |     |      |     |          |
| 165 | 11   | 11              |          | 220 | 05   | 05             |          |     |      |     |          |
| 166 | 65   | X               |          | 221 | 48   | EXC            |          |     |      |     |          |
| 167 | 43   | RCL             |          | 222 | 05   | 05             |          |     |      |     |          |
| 168 | 02   | 02              |          | 223 | 42   | STD            |          |     |      |     |          |
| 169 | 35   | 1/X             |          | 224 | 10   | 10             |          |     |      |     |          |
| 170 | 95   | =               |          | 225 | 92   | RTN            |          |     |      |     |          |
| 171 | 94   | +/-             |          |     |      |                |          |     |      |     |          |
| 172 | 22   | INV             |          |     |      |                |          |     |      |     |          |
| 173 | 23   | LN <sub>X</sub> |          |     |      |                |          |     |      |     |          |
| 174 | 42   | STD             |          |     |      |                |          |     |      |     |          |
| 175 | 06   | 06              |          |     |      |                |          |     |      |     |          |
| 176 | 53   | (               |          |     |      |                |          |     |      |     |          |
| 177 | 53   | (               |          |     |      |                |          |     |      |     |          |
| 178 | 01   | 1               |          |     |      |                |          |     |      |     |          |
| 179 | 75   | -               |          |     |      |                |          |     |      |     |          |
| 180 | 43   | RCL             |          |     |      |                |          |     |      |     |          |
| 181 | 06   | 06              |          |     |      |                |          |     |      |     |          |
| 182 | 54   | )               |          |     |      |                |          |     |      |     |          |
| 183 | 55   | ÷               |          |     |      |                |          |     |      |     |          |
| 184 | 53   | (               |          |     |      |                |          |     |      |     |          |
| 185 | 01   | 1               |          |     |      |                |          |     |      |     |          |
| 186 | 85   | +               |          |     |      |                |          |     |      |     |          |
| 187 | 43   | RCL             |          |     |      |                |          |     |      |     |          |
| 188 | 06   | 06              |          |     |      |                |          |     |      |     |          |
| 189 | 54   | )               |          |     |      |                |          |     |      |     |          |
| 190 | 54   | )               |          |     |      |                |          |     |      |     |          |
| 191 | 42   | STD             |          |     |      |                |          |     |      |     |          |
| 192 | 06   | 06              |          |     |      |                |          |     |      |     |          |
| 193 | 65   | X               |          |     |      |                |          |     |      |     |          |
| 194 | 43   | RCL             |          |     |      |                |          |     |      |     |          |
| 195 | 07   | 07              |          |     |      |                |          |     |      |     |          |
| 196 | 95   | =               |          |     |      |                |          |     |      |     |          |
| 197 | 42   | STD             |          |     |      |                |          |     |      |     |          |
| 198 | 06   | 06              |          |     |      |                |          |     |      |     |          |
| 199 | 85   | +               |          |     |      |                |          |     |      |     |          |
| 200 | 43   | RCL             |          |     |      |                |          |     |      |     |          |
| 201 | 10   | 10              |          |     |      |                |          |     |      |     |          |
| 202 | 95   | =               |          |     |      |                |          |     |      |     |          |
| 203 | 42   | STD             |          |     |      |                |          |     |      |     |          |
| 204 | 05   | 05              |          |     |      |                |          |     |      |     |          |
| 205 | 53   | (               |          |     |      |                |          |     |      |     |          |
| 206 | 01   | 1               |          |     |      |                |          |     |      |     |          |
| 207 | 85   | +               |          |     |      |                |          |     |      |     |          |
| 208 | 43   | RCL             |          |     |      |                |          |     |      |     |          |
| 209 | 06   | 06              |          |     |      |                |          |     |      |     |          |
| 210 | 65   | X               |          |     |      |                |          |     |      |     |          |
| 211 | 43   | RCL             |          |     |      |                |          |     |      |     |          |
| 212 | 10   | 10              |          |     |      |                |          |     |      |     |          |
| 213 | 55   | ÷               |          |     |      |                |          |     |      |     |          |
| 214 | 43   | RCL             |          |     |      |                |          |     |      |     |          |

Compute resistivity transforms from  $T_i = \frac{\rho_h + \rho_v}{1 + \rho_h \rho_v / \rho_i^2}$ ,  $V_i = \frac{1 - e^{-2d_i/u}}{1 + e^{-2d_i/u}}$



Store in Registers

|                     |             |    |
|---------------------|-------------|----|
|                     | 100.        | 78 |
|                     | 100000.     | 79 |
|                     | 1.467799268 | 80 |
| Filter coefficients | 0.0148      | 81 |
|                     | -0.0814     | 82 |
|                     | 0.4018      | 83 |
|                     | -1.5716     | 84 |
|                     | 1.972       | 85 |
|                     | 0.1854      | 86 |
|                     | 0.1064      | 87 |
|                     | -0.0499     | 88 |
|                     | 0.0225      | 89 |

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MERGED CODES

|            |          |               |
|------------|----------|---------------|
| 62 [P] [L] | 72 [STO] | 83 [GRO] [R]  |
| 63 [L] [M] | 73 [RCL] | 84 [L] [R]    |
| 64 [P] [M] | 74 [SUM] | 92 [INV] [SR] |