9. TIME DOMAIN INDUCED POLARIZATION PROGRAM (TDIP)

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9.1 INTRODUCTION

PROGRAM DESCRIPTION
The Time Domain Induced Polarization (TDIP) program uses cross-correlation methods to lock on to the transmitted signal when operating in the asynchronous mode, and standard phase-lock stacking and averaging for the synchronous mode.

Refer to Section 6 – Receiver Setup for information concerning calibration, synchronization and generic screens and field parameters of all Survey Programs. Refer to the end of this section for suggestions for field measurement receiver connections.

FREQUENCY RANGE
The standard frequency ranges from 0.015625 (1/64 Hz) to 32 Hz.

FILTER
The TDIP Survey Program has a digital telluric filter, also referred to as a Moving Average (MAV) filter, for rejection of low frequency tellurics.

CALIBRATION CACHE
Calibration data for the TDIP Survey Program are stored in the Time Domain Calibration Cache.

NOTE: The TEM and NanoTEM Survey Programs also use the Time Domain Calibration Cache. Overwriting calibration data in this cache causes all Time Domain calibration data to be lost. However, the Time Domain IP and TEM calibration data should be identical.
9.2 PROGRAM OPERATION

Field Survey programs operate using several parameter entry screens. Press Enter to move to the next screen or Escape to return to the previous screen.

For a complete description of each screen and generic fields refer to Section 5 – Accessing Programs. Field parameters specific to this Survey Program are listed below.

SCREEN 1 - INITIAL PROGRAM SCREEN
Select or enter a parameter for each user programmable field. User programmable fields unique to TDIP are:

**Array Type**

Select one of the seven array types using the **SELECT UP** and **SELECT DN** keys:

- **Dipole-Dipole** D-D
- **Pole-Dipole** P-D
- **Schlumberger** Sch
- **Gradient** Grd
- **Pole-Pole** P-P
- **Downhole** D-H
- **Core Sample** LAB

If **Gradient** or **Schlumberger** arrays are chosen, then two additional lines, **Ax location** and **Bx location**, appear on the menu. These are the transmitter current electrode locations.

If the **Downhole** array type is chosen, resistivities will not be calculated or displayed.

The **Core Sample** selection provides for input of cross-section area (in square centimeters) and length of core samples (in centimeters) to get correct resistivity values in ohm meters. After continuing to the Data Acquisition Screen, press F5 to input the length and area and the current monitoring shunt resistor values. Refer to the CR Survey Program for more information.
Mode

The TDIP Survey Program has three different mode settings:

- **Synchronous** - Synchronous operation assumes that the receiver and transmitter have identical timing clocks and have been synchronized or phase-locked. (To use this option, the receiver and transmitter must have the high-accuracy clock that is standard with the GDP-32II.) This data acquisition method provides the best data quality under varied conditions.

- **Non-ZERO Tx** - This asynchronous mode is available for operators with a GDP-32II using a non-ZERO transmitter. This program first finds the frequency of the transmitter and locks on to the signal. Assuming the transmitter has a stability of one part in $10^{-3}$ or better, during the data acquisition time this option gathers accurate TDIP data under low to moderately noisy conditions.

- **Asynchronous** - Used for asynchronous or non-phase-locked mode operation with a ZERO built transmitter or a transmitter controlled with an XMT-series controller. The program uses a cross-correlation routine to synchronize with the transmitted waveform, then stacks and averages waveforms in a synchronous format. This option gathers accurate TDIP under low to moderately noisy conditions.

Gain Mode

The default mode is "Noisy". This limits the gains to obtain a maximum voltage of 1.0 Volts, leaving headroom for SP drift and random noise spikes. The other option is "Standard" which adjusts the gains for a maximum voltage of 2.25 Volts.

Environment Type

The TDIP Survey Program allows for two Environment Types:

- **Quiet** (default)

- **Noisy** - To be used in noisy environments. Uses low-pass filters with the same value as the RPIP program. The Noisy option strongly affects the first window on the decay curve due to the extra filtering.
SCREEN 2 - OPERATOR INFORMATION SCREEN

Select a parameter or fill in the appropriate information for each of the user programmable fields as described in Section 5 – Accessing Programs.

If Gradient array is selected, the Y-coordinate of the transmitter dipole (Ay) will be displayed in place of the line designator.

SCREEN 3 - CHANNEL PARAMETERS SCREEN

Set the channels displayed to ON, OFF or Ref as needed. For more information refer to Section 5 – Accessing Programs.

CH

Selections are ON, OFF, or Ref. Ref is used mainly for Lab Rock (core sample) measurements.
SCREEN 4 – DATA ACQUISITION SCREEN

Primary survey settings are displayed here once the initial parameters and channels have been set.

The following routines are accessed from this screen:

- Calibration or System Check
  - **CAL**
  - **F9**
- Gain Setting and Stack Count
  - **GAIN**
  - **F10**
- Bucking Out Self Potential
  - **SP**
  - **F11**
- Measuring Contact Resistance
  - **CRES**
  - **F12**
- Reviewing Data
  - **DATA**
  - **F7**

Refer to Section 5 – Accessing Programs for more information on Survey Program Screen. Refer to Section 6 – Receiver Setup for information on setting up the GDP-32™ receiver prior to gathering data.
9.3 DATA COLLECTION

After setting up the receiver for a TDIP Field Survey, press Enter from the Data Acquisition Screen to begin collecting data. For complete information on receiver setup see Section 6.

DATA COLLECTION EXAMPLE

The following example displays the screens and results of a TDIP Dipole - Dipole Field Survey. For this example the field parameters are set as follows:

**Initial Program Screen**

- **Survey type**: Dipole - Dipole
- **Mode**: Synchronous
- **Gain Mode**: Noisy (default)
- **Units**: Meters (default)
- **Environment Type**: Quiet (default)
- **Moving Average filter**: Enabled (default)

**Operator Information Screen**

- **OPER**: SMITH
- **TX ID**: 1
- **A-SP**: 100
- **JOB**: 94001
- **LINE**: 1 N (default)
- **SPREAD**: 1 (default)

**Channel Parameters Screen**

- **CH**: N
  - 1 ON 1
  - 2 ON 2
  - 3 OFF

**Data Acquisition Screen**

- **Frequency**: 0.125 Hz
- **Cycles**: 4
- **TX Curr**: 1
This Data Acquisition Screen is displayed when:

- Channels 1 and 2 are turned **ON**.
- The battery voltage has been measured and the A/D converter automatically calibrated before each measurement cycle
- Gains are set automatically (default)

### Screen Explanation

**G0, G1, G2**  
Gain stages 0, 1 and 2. All stages are set for unity gain.

**Atn**  
Set to OUT (bypassed)

**SP**  
Buckout values of SP are \(-7.14\) mv for Channel 1 and \(-3.98\) mv for Channel 2.

**GGG**  
Gain settings for stages G0, G1 and G2 (in powers of 2). For this example, gain stages G0, G1 and G2 = \(2^0 = 1\).

The program first sets up the gains, buck out the SP and then begins gathering data. Since we are operating in the default or "Noisy" gain mode, all of the necessary gain is put into G2 first. See Section 6.5 - Setting Gains.
Upon pressing \( \text{Enter} \), the program acquires four cycles of data for all enabled channels (unless the \( \text{Escape} \) key is pressed before completion) and the results will look similar to the following for the real-time displays (while data are being acquired).

**Screen Explanation**

- **SEM**: Standard Error of the Mean, (in milliseconds), calculated after each cycle.
- **M**: Average chargeability in millivolt-seconds per volt or milliseconds. Chargeability is determined by integrating from 0.45 to 1.1 seconds for both positive and negative polarities using an 8 second period (0.125 Hz). Data for other periods or frequencies are normalized to this standard.
After the selected number of cycles have been acquired (or *Escape* is pressed), the final display appears:

**Screen Explanation**

**Vp**  
Primary (ON) voltage, with magnitude calibration (located in the Time Domain calibration cache) removed.

**M**  
Average chargeability in millivolt-seconds per volt or milliseconds.

**ρ**  
Apparent resistivity in ohm-meters.
Upon pressing **Enter** to save the data (or **Escape** to discard the data), the screen appears as follows. The only difference in screens is the change in last block number (0095) and the bottom command line.

![GDP-32II](image)

<table>
<thead>
<tr>
<th>CH</th>
<th>N</th>
<th>Vp</th>
<th>M</th>
<th>rho</th>
<th>GGG</th>
<th>SEM</th>
<th>SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ON</td>
<td>1</td>
<td>0.0645</td>
<td>10.0</td>
<td>1629</td>
<td>0000</td>
<td>151.62</td>
</tr>
<tr>
<td>2</td>
<td>ON</td>
<td>2</td>
<td>0.0687</td>
<td>10.0</td>
<td>6550</td>
<td>0000</td>
<td>146.12</td>
</tr>
<tr>
<td>3</td>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*CONT-Take data, ESC-Prev Menu*
VIEWING DATA

Press \textbf{DATA F7} to display the last stack. The data display is in the following format:

![GDP-32II Multi-Function Receiver](image)

The contact resistance values have been saved, but are off the screen to the right. To view these values several times.

To move back to the left, press \textbf{NOTE: The Gains data column includes an Attenuator setting of O for OUT or I for IN.}

The windows data are integrated voltages (using 19 data points) and normalized by Vp and 19 (the number of data points) for each of 13 windows. See the following section for window specifications. When first entering data mode, only the first four windows appear. Press \textbf{NEXT FIELD} to view the rest of the windows.
Data Acquisition Options

**Plot Data** - Press [F5] to access the routines to plot decay curves.

**Skip Flag** - Pressing [F6] places an 'x' between the version number and the date in the header for the block being viewed. This flag is recognized by the plot routines and the flagged data is skipped when averaging multiple blocks for plotting. Pressing [F6] again removes the 'x'.
9.4 SAMPLE DATA BLOCKS

Data are exported to a computer in the following format:

**Program Data Header**

<table>
<thead>
<tr>
<th>Data</th>
<th>Dipole-Dipole array used</th>
<th>Card status: Passed or Failed QC test</th>
<th>Gain factors for each card</th>
<th>Analog card information</th>
<th>modification level indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>0003</td>
<td>TDIP0528</td>
<td>94-03-15 14:44:02 12.6v D-D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPER</td>
<td>1</td>
<td>TX ID 1 A-SP 100.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JOB</td>
<td>91001</td>
<td>LINE 1 SPREAD 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>DiffAmp</td>
<td>Notch+60,3-50,3 S/N 185 Passed 1.00192</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DiffAmp</td>
<td>Notch+60,3-50,3 S/N 177 Passed 0.99835</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DiffAmp</td>
<td>Notch+60,3-50,3 S/N 61 Passed 0.99921</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DiffAmp</td>
<td>Notch+60,3-50,3 S/N 57 Passed 1.00329</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DiffAmp</td>
<td>Notch+60,3-50,3 S/N 60 Passed 0.99876</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DiffAmp</td>
<td>Notch+60,3-50,3 S/N 66 Passed 0.99586</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Main Data Block**

<table>
<thead>
<tr>
<th>Data</th>
<th>SEM's in ms</th>
<th>SP in mv</th>
<th>Contact Resistance in ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0004</td>
<td>TDIP0528</td>
<td>94-03-15</td>
<td>14:55:48 12.6v D-D</td>
</tr>
<tr>
<td>OPER</td>
<td>1</td>
<td>TX ID</td>
<td>1 A-SP 100.0</td>
</tr>
<tr>
<td>JOB</td>
<td>91001</td>
<td>LINE</td>
<td>1 SPREAD 1</td>
</tr>
<tr>
<td>.125 Hz</td>
<td>4 Cyc</td>
<td>Tx Curr</td>
<td>1.00</td>
</tr>
<tr>
<td>1</td>
<td>ON</td>
<td>1</td>
<td>211.60m 2.6 398.9 0300 0.47 2.96 1.23K</td>
</tr>
<tr>
<td>2</td>
<td>ON</td>
<td>2</td>
<td>212.13m 2.6 1.599K 0300 0.47 0.12 690.1</td>
</tr>
<tr>
<td>3</td>
<td>ON</td>
<td>3</td>
<td>212.16m 2.6 3.999K 0300 0.47 -0.56 1.02K</td>
</tr>
<tr>
<td>4</td>
<td>ON</td>
<td>4</td>
<td>211.96m 2.6 7.991K 0300 0.46 -1.78 2.27K</td>
</tr>
<tr>
<td>5</td>
<td>ON</td>
<td>5</td>
<td>211.76m 2.6 13.97K 0300 0.48 -3.56 1.17K</td>
</tr>
<tr>
<td>6</td>
<td>ON</td>
<td>6</td>
<td>212.09m 2.6 22.39K 0300 0.47 -5.92 1.63K</td>
</tr>
</tbody>
</table>

**Windows**

<table>
<thead>
<tr>
<th>Windows</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2634</td>
<td>2651</td>
<td>2637</td>
<td>2628</td>
<td>2634</td>
<td>2626</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>617</td>
<td>623</td>
<td>624</td>
<td>616</td>
<td>618</td>
<td>615</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>152</td>
<td>151</td>
<td>151</td>
<td>152</td>
<td>152</td>
<td>151</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>44</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>14</td>
<td>12</td>
<td>14</td>
<td>13</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>03</td>
<td>03</td>
<td>04</td>
<td>03</td>
<td>03</td>
<td>04</td>
<td></td>
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<td>02</td>
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<td></td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows are in milliunits times 10 (10's of milliunits)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
These data were acquired using an RC network and a constant current laboratory transmitter. The RC network is as follows:

Block 0003 is the **Program Data Header**. A new Program Data Header is written to the data cache whenever the operator returns to the Operation Information Screen.

Block 0004 is the **Data Block** and is written to the data cache when Enter is pressed at the end of each data acquisition cycle.
9.5  ALGORITHMS

The equation used for calculating the time domain (see below) is the equation used in Swift (1973). By inverting the negative half-cycle, chargeabilities are averaged over each cycle until escape is pressed or until the specified number of cycles have been acquired. The output will be in milliseconds or millivolt-seconds per volt.

This equation was originally given to Zonge by Newmont as the "Newmont Standard" chargeability. Since that time it has been determined that this is not really the Newmont standard, but it can be obtained by multiplying this "Zonge Standard" by 1.53. In order to reduce confusion, we have retained the original chargeability definition, and convert to the Newmont Standard (if desired) in our data processing programs.

For the "Zonge" standard at 0.125 Hz (8 second period):

\[ M = \frac{T}{1024} \times \frac{1.87}{V_p} \times \int V_s \]

Where T is the cycle period of 8 seconds and the integral of the secondary (Vs) or off-time voltage is from 0.45 sec to 1.1 sec.

With 1024 points sampled per cycle, Vs is summed over 83 counts out of 256 per quarter-cycle. The 13 windows defining the off-time decay waveform are obtained on 150 ms intervals at 0.125 Hz. The closest combination of windows to get an approximation of the chargeability is a sum of windows 4, 5, 6, and 7. At 0.125 Hz this effectively integrates from 500 ms to 1100 ms, which is 50 ms shorter than the standard window, so this approximation will always be slightly lower than the Zonge Standard chargeability.

With \( W_i \) = Normalized decay point value in 10's of milliunits
\[ = \frac{(\text{Sum of } V_s \text{ over the 150 ms intervals})}{(V_p \times 19)} \]

the chargeability, \( M = \frac{T}{1024} \times 1.87 \times 19 \times \Sigma W_i/10 \)

where:  
1.87 is the Swift constant  
19 is the number of counts per 150 ms window  
\( T/1024 \) is \( \Delta \tau \), the digitization interval

The following formula for \( M \) is used for the approximation of the Zonge Standard at 0.125 Hz (8 second period):

\[ M = (1.87 \times 19 \times 8) \times (W_4 + W_5 + W_6 + W_7) / (1024 \times 10) \]

For frequencies up to and including 0.5 Hz (2 second period), 1024 points are sampled per cycle (256 during each on-time and 256 during each off-time). At 1 Hz the sample rate is 512. The windows measured are proportional to those taken at 0.125 Hz, and the results will be printed out in identical format.

Since the number of samples per cycle at 1 Hz is 512 rather than 1024, the equation for chargeability for 1 Hz is as follows:

\[ M = (1.87 \times 9 \times 1) \times (W_4 + W_5 + W_6 + W_7) / (512 \times 10) \]

9.6 TIME DOMAIN WINDOW TIMING INFORMATION

1024 points per waveform at all frequencies

64 points averaged for \( V_p \)
7 points skipped
Window 1 19 points averaged
Window 2 19 points averaged

58 points o thru 57
83 points 58 thru 140

Time values apply to 0.125Hz only.
7.8125ms between each point

Newmont Standard approximation

\( \frac{V}{V_p} \)

\( \text{Tx turns off} \)

451.38ms
1097.32ms
9.7 FIELD CONFIGURATIONS

Be very careful when running a multiple channel receiver to avoid common mode problems. Common mode effects are caused by lack of a reference voltage or level (floating ground), or a reference level that exceeds common mode limits of the input amplifiers.

The maximum permissible common mode levels for the standard configuration of the GDP-32II is ±10 volts. With isolation amplifiers, this level can extend to several thousand volts, but the tradeoff is higher noise and lower overall frequency response.

The best configuration that we have found is to install a standard copper/copper-sulfate Reference Electrode (or equivalent) connected to both analog ground (COM on the analog side-panel) and the case ground (CASE GND on the side panel). Place the electrode next to the receiver and at least two meters from the nearest receiving electrode. This also provides maximum protection from static discharge and nearby lightning strikes.

Additional protection in lightning-prone areas can be gained by using a galvanized iron plate (or equivalent) as a reference electrode. This plate should be buried close to the receiver in a hole that has been well watered and the soil mixed to make good mud contact with the plate. Typical size for the plate would be 30 cm by 30 cm.

The following figures provide examples of receiver connections using the Reference Electrode or Reference Pot connected to both analog ground (COM) and case ground (CASE GND).

To obtain the best noise rejection, Zonge Engineering recommends connecting the analog ground (COM) to the case ground (CASE GND) on the analog I/O side panel.

NOTE: The GDP-32II receiver has a captive jumper between COM and CASE GND for the standard configuration.
RECEIVER SETUP

Receiver Setup for Resistivity, Time Domain IP, Resistivity / Phase IP, and Non-Reference Complex Resistivity

Diagram showing connections:
- Porous Pot Electrodes PPE/1
- Geophysical Data Processor GDP-32II
- Signal Input through IO 32/8 meter/connection panel
- Wires from BR12W or BR12WR
- Reference Electrode
- Porous Pot Electrode PPE/1

Diagram illustrates the setup process for the mentioned types of resistivity measurements.
RECEIVER SETUP USING THE ROLL-ALONG CABLE

Receiver Setup for Resistivity, Time Domain IP, Resistivity / Phase IP, and Non-Reference Complex Resistivity Using the Roll-Along Cable

Geophysical Data Processor GDP-32II

IPC/GDP Cable using channels 1 through 6

IPC XX Cable Sections
IPC 50 = 50 m
IPC 100 = 100 m
etc.

Takeout Connectors

Porous Pot Electrode
PPE / 1

Reference Electrode

GDP-32II

Analytical I/O

CASE GND, COM

Porous Pot Electrode
PPE/1
TRANSMITTER SETUP

Tx Setup for Time Domain IP, Resistivity/Phase, and non-Reference CR