9. TIME DOMAIN INDUCED POLARIZATION PROGRAM (TDIP)

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 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.

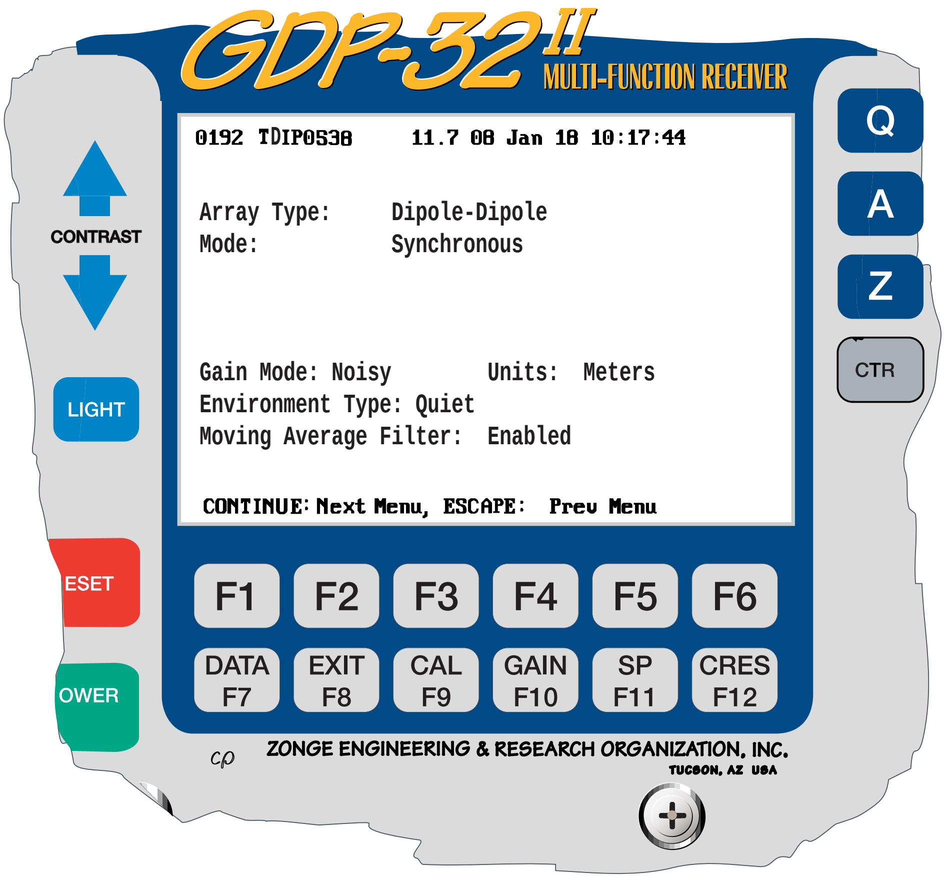
9.2 PROGRAM OPERATION

Field Survey programs operate using several parameter entry screens. Press CONTINUE Enter to move to the next screen or STOP AVG 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 program-



mable fields unique to TDIP are:

Array Type

Select one of the seven array types using the 

and 

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 that 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-32 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, and then stacks and averages waveforms in a synchronous format. This option gathers accurate TDIP under low to moderately noisy conditions.

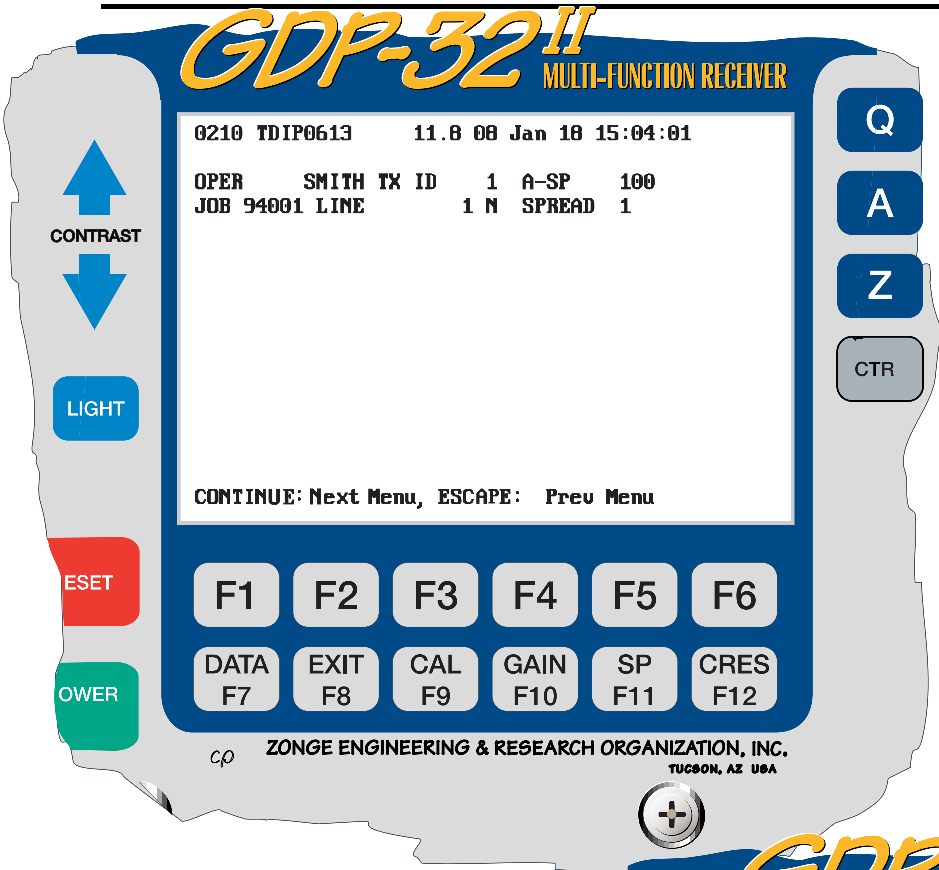
Gain Mode

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.



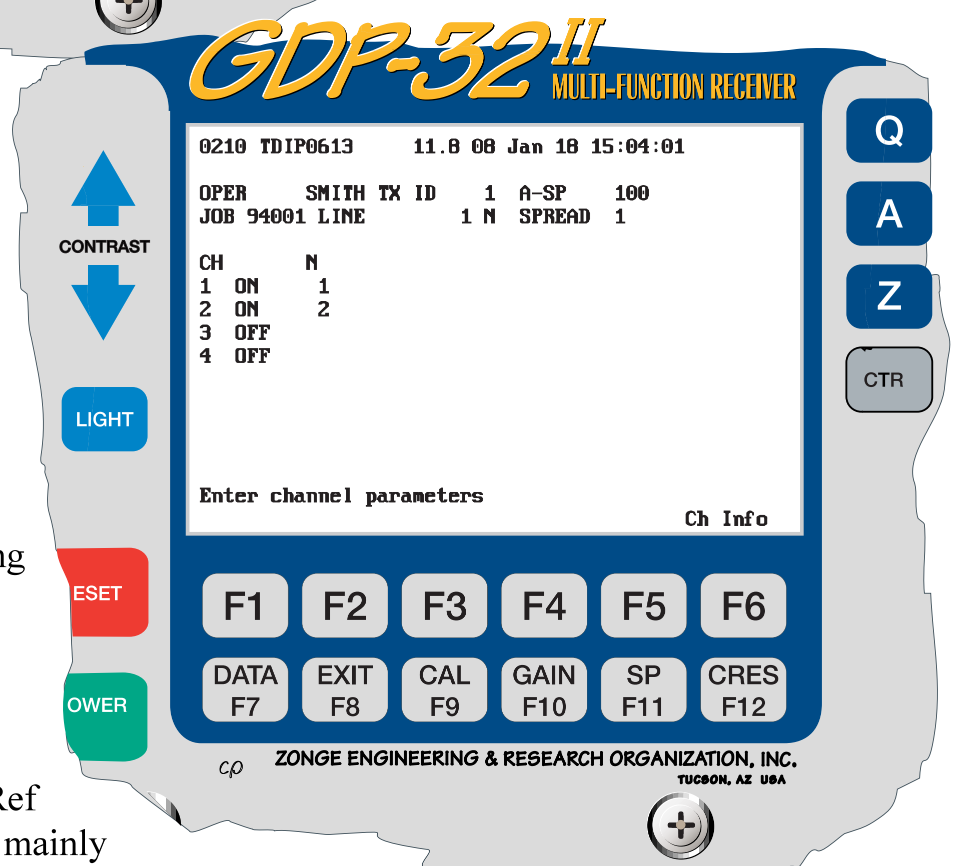
SCREEN 2 - OPERATOR INFORMATION SCREEN

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 chosen, the Y-coordinate of the transmitter dipole (Ay) will be displayed in place of the line designator.

SCREEN 3 - CHANNEL PARAMETERS SCREEN

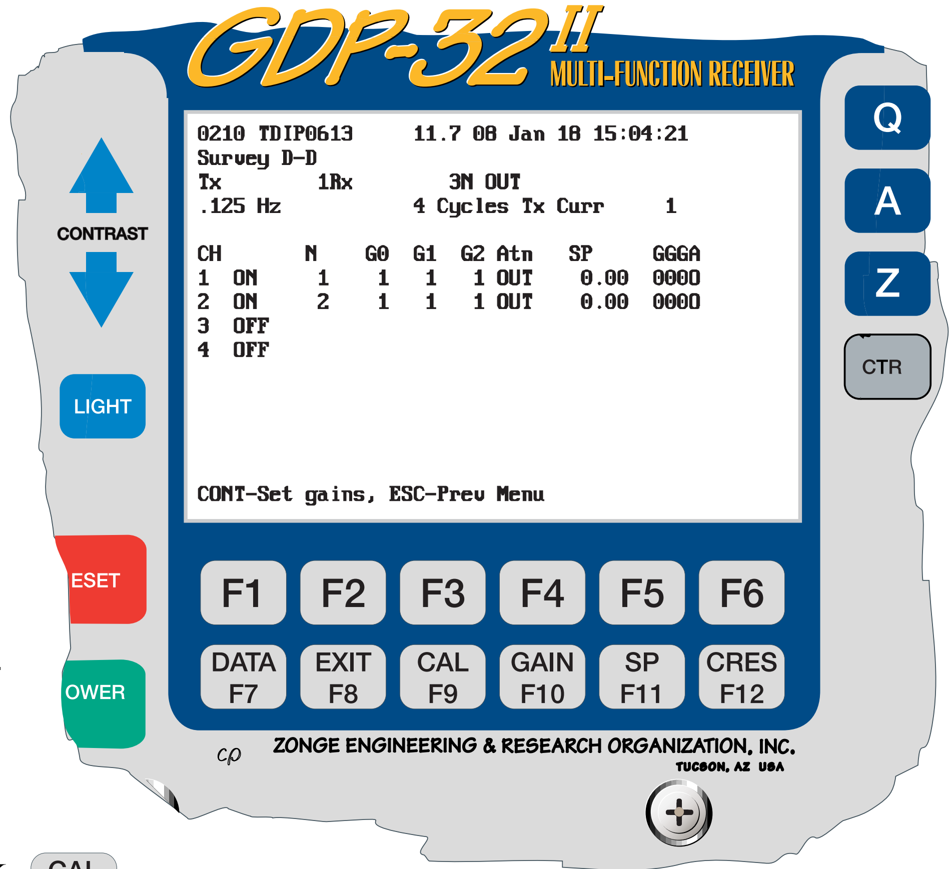
Set the channels displayed to ON, OFF or Ref as needed. For more information refer to Section 5 – Accessing Programs.



CH

Selections are ON, Ref or OFF. 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 CONTINUE 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 an 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

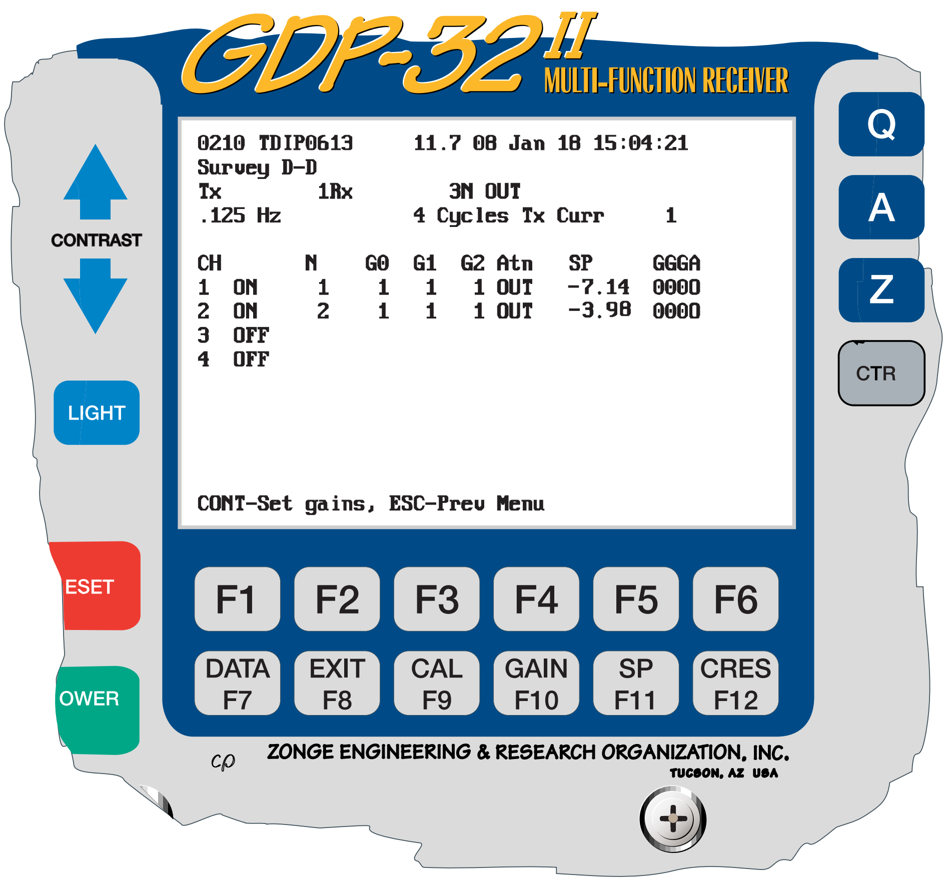
OPER	SMITH
TX ID	1
A-SP	100
JOB	94001
LINE	1 N (default)
SPREAD	1 (default)

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` The buckout values of SP are -7.14 mv for Channel 1 and -3.98 mv for Channel 2.

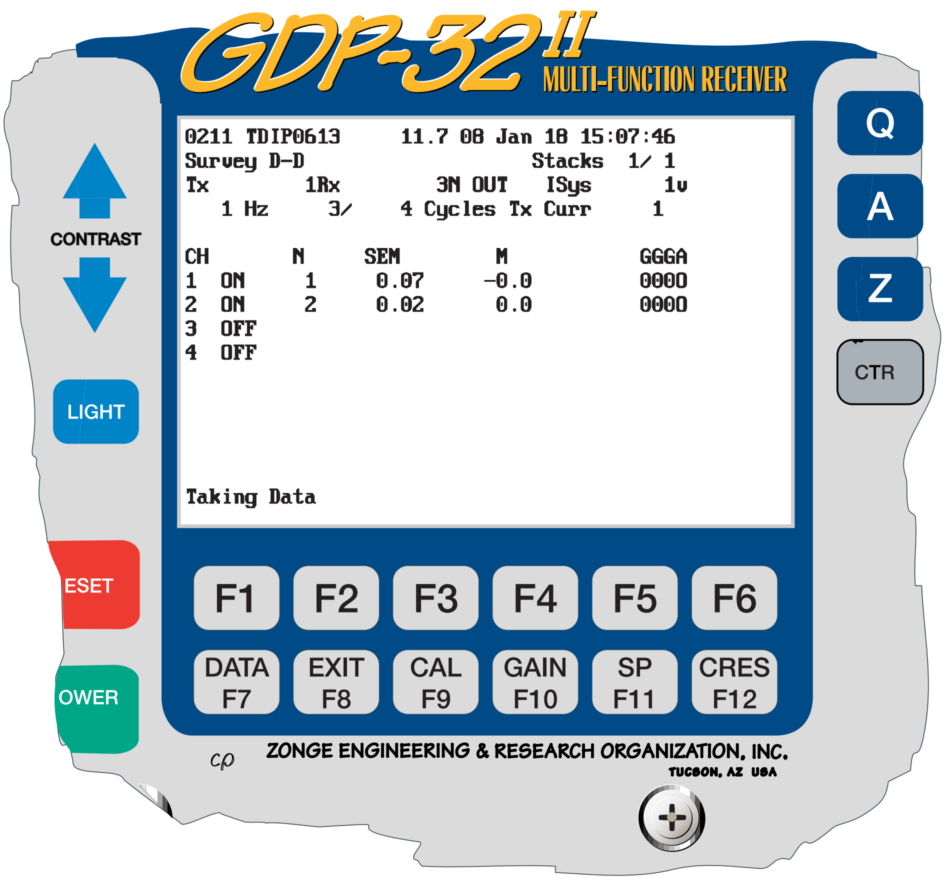
`GGG` Gain settings for stages G0, G1 and G2 (in powers of 2). For this example, gain stages G0, G1 and G2 = $2^0 = 1$.

The program first sets up the gains, bucks 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 

, the program acquires four cycles of data for all enabled channels (unless the 

key is pressed before completion) and the results will look similar to the following for the real-time displays (while data are being acquired).

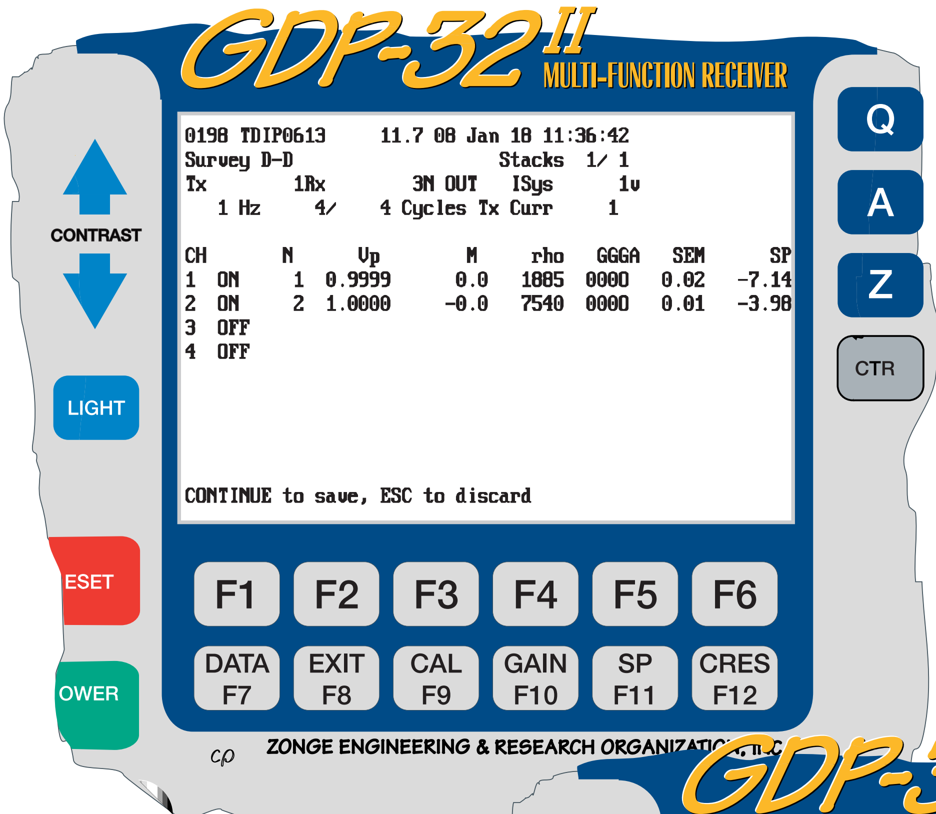


Screen Explanation

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 STOP AVG Escape is pressed), the final display appears:



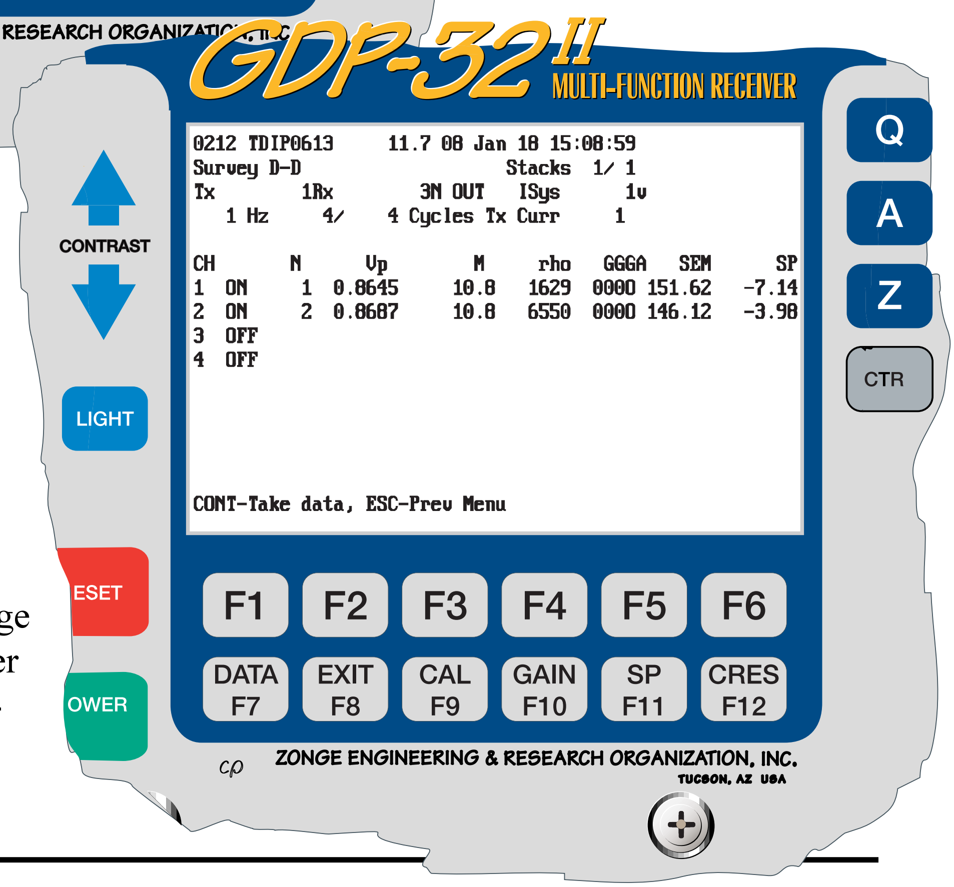
Screen Explanation

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.

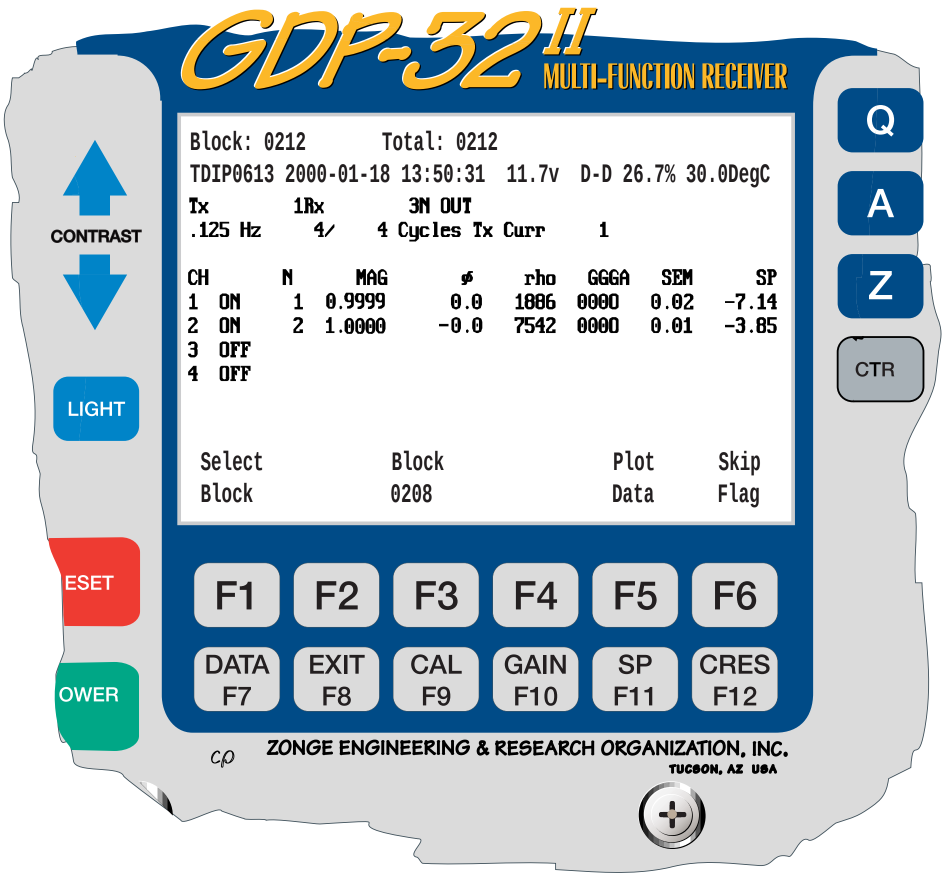
rho Apparent resistivity in ohm-meters.

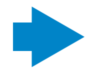
Upon pressing CONTINUE Enter to save the data (or STOP AVG Escape to discard the data), the screen appears as follows. The only difference in screens is the change in last block number (0095) and the bottom command line.

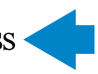


VIEWING DATA

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



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

To move back to the left, press 

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  or NEXT FIELD Pg Dn 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 and data processing routines and the flagged are 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

Dipole-Dipole array used

Card status: Passed or Failed QC test

Gain factors for each card

Analog card information

Modification level indicator

```
0003
TDIP0528   94-03-15 14:44:02 12.6v D-D
OPER     1  TX ID     1 A-SP  100.0
JOB 91001  LINE          1 N  SPREAD  1
1 DiffAmp  Notch+60,3,5,9  S/N  185 Passed 1.00192
2 DiffAmp  Notch+60,3,5,9  S/N  177 Passed 0.99835
3 DiffAmp  Notch+60,3,5,9  S/N   61 Passed 0.99921
4 DiffAmp  Notch+60,3,5,9  S/N   57 Passed 1.00329
5 DiffAmp  Notch+60,3,5,9  S/N   60 Passed 0.99876
6 DiffAmp  Notch+60,3,5,9  S/N   66 Passed 0.99586
```

Main Data Block

SEM's in mr

SP in mv

```
0004
TDIP0528   99-03-12  14:15:03  12.7v D-D
Tx             1 Rx          3 N OUT
.125 Hz          4 Cyc Tx Curr  1.00
1 ON           1   211.60m   2.6  398.9   0300          .47     2.96    1.23K
2 ON           2   212.13m   2.6  1.599K  0300          .47     0.12    690.1
3 ON           3   212.16m   2.6  3.999K  0300          .47    -0.56    1.03K
4 ON           4   211.96m   2.6  7.991K  0300          .46    -1.78    2.27K
5 ON           5   211.76m   2.6  13.97K  0300          .48    -3.56    1.17K
6 ON           6   212.09m   2.6  22.39K  0300          .47    -5.92    1.63K
```

Contact Resistance in ohms

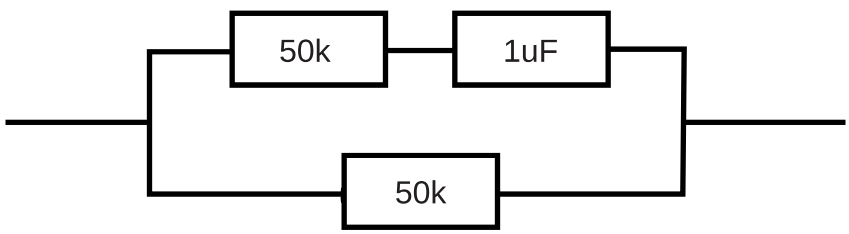
Windows

Windows

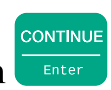
1	2	3	4	5	6	7	8
2634	2651	2637	2628	2634	2626		
617	623	624	616	618	615		
152	151	151	152	152	151		
43	44	43	43	43	43		
14	14	13	14	13	14		
03	03	04	03	03	04		
02	02	03	02	02	03		
02	02	02	02	02	02		
01	01	01	01	01	01		
01	01	01	01	01	01		
0	0	0	0	0	0		
0	0	0	0	0	0		
0	0	0	0	0	0		

Windows are in milliunits times 10 (10's of milliunits)

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 

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 

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):

$$M = \frac{T}{1024} \times \frac{1.87}{Vp} \times \int Vs$$

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

= (Sum of Vs over the 150 ms intervals)/(Vp x 19)

the chargeability, $M = T/1024 \times 1.87 \times 19 \times \Sigma W_i/10$

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):

$$M = (1.87 \times 19 \times 8) \times (W4 + W5 + W6 + W7) / (1024 \times 10)$$

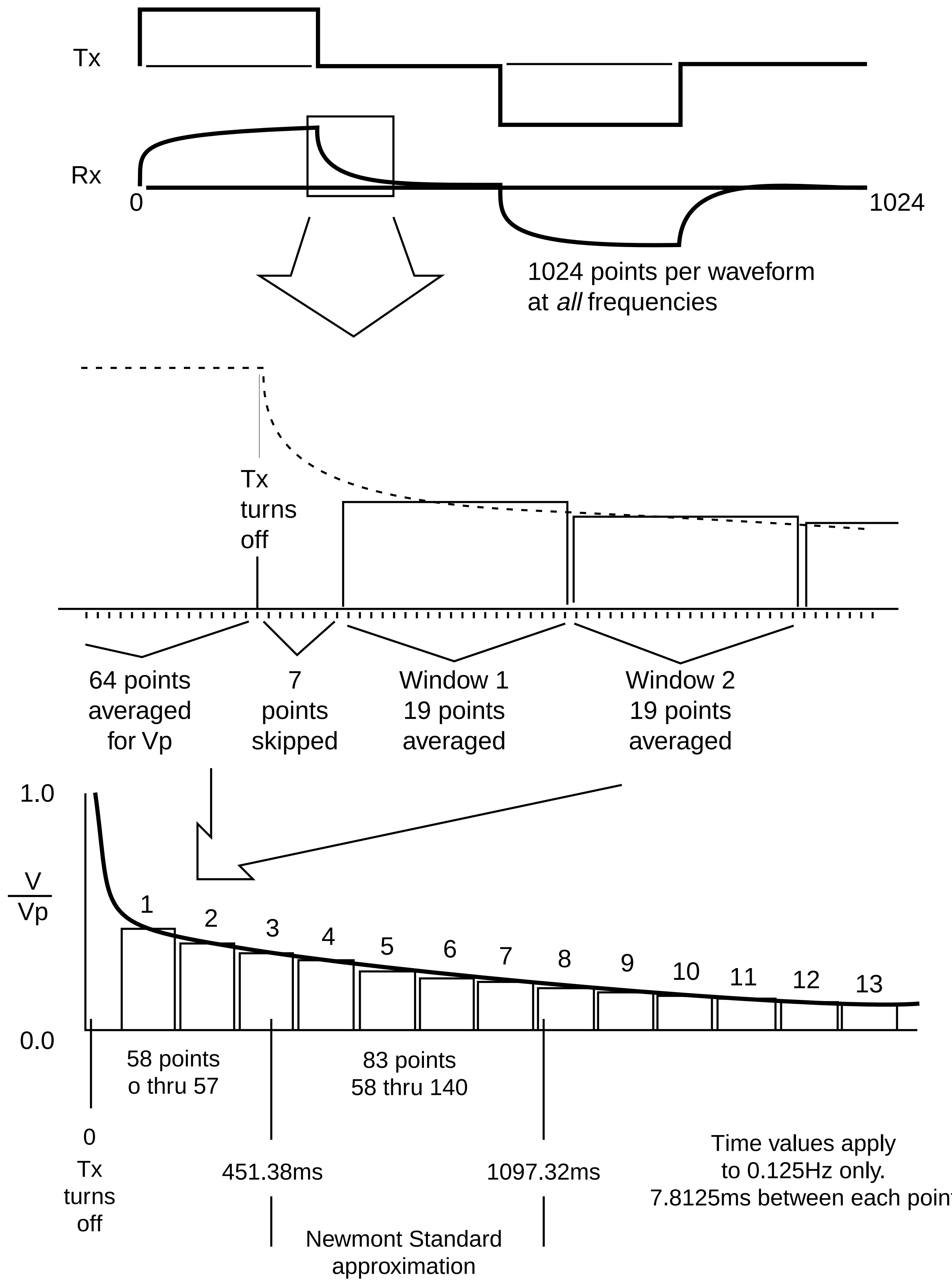
For frequencies up to and including 0.5 Hz (2 second period), 1024 points are sampled per cycle (256 during each on-time and 256 during each off-time). At 1 Hz the sample rate is 512. The windows measured are proportional to those taken at 0.125 Hz, and the results will be printed out in identical format.

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:

$$M = (1.87 \times 9 \times 1) \times (W4 + W5 + W6 + W7) / (512 \times 10)$$

Reference: Swift, C.M., Jr, 1973, The L/M parameter of time domain IP measurements — a computational analysis, Geophysics, v 38, p 61-67.

9.6 TIME DOMAIN WINDOW TIMING INFORMATION



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-32 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-32 receiver has a captive jumper between COM and CASE GND for the standard configuration.

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

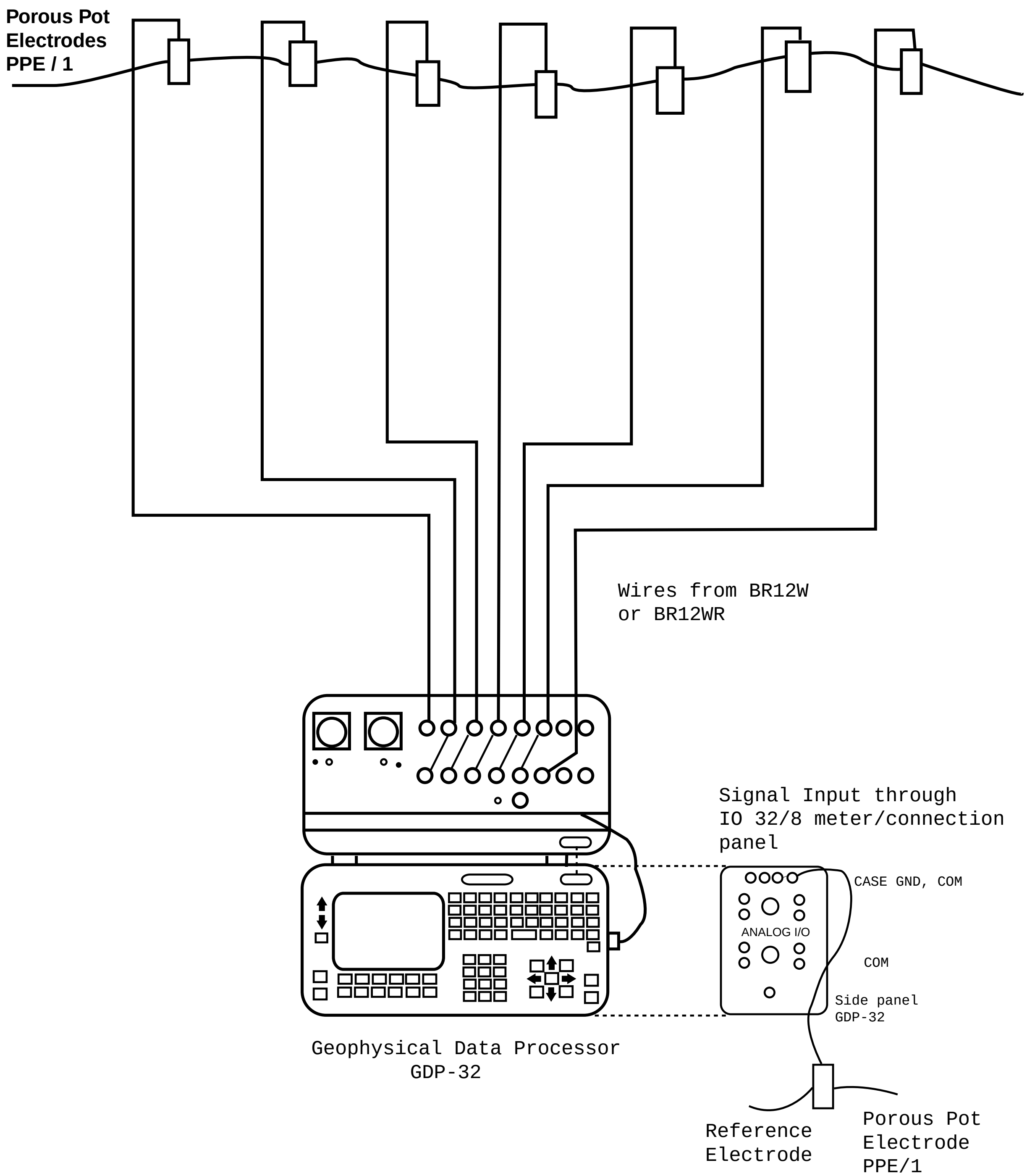


Figure 9.1 Receiver Setup

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

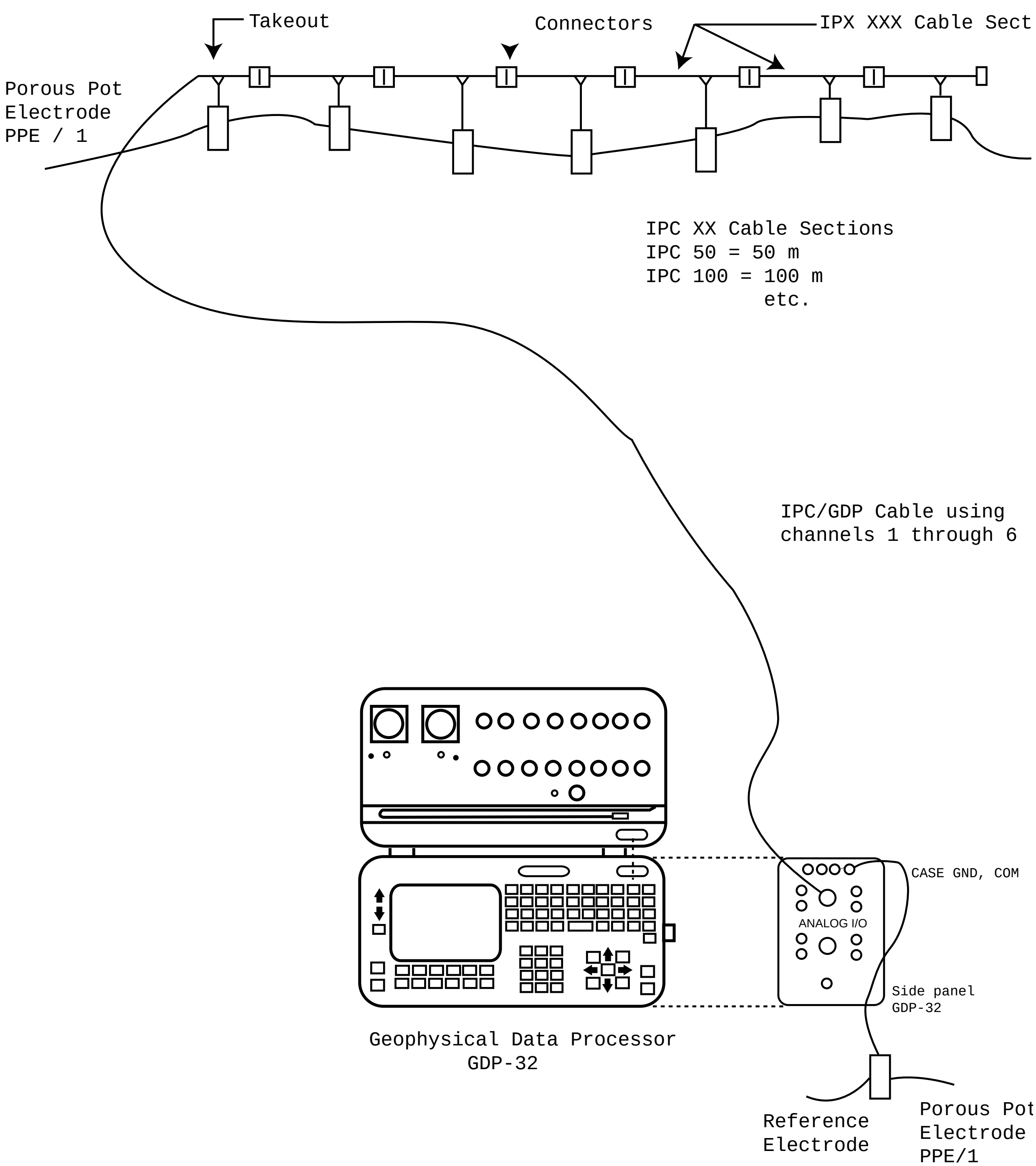


Figure 9.2 Receiver Setup using the Roll-Along Cable

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

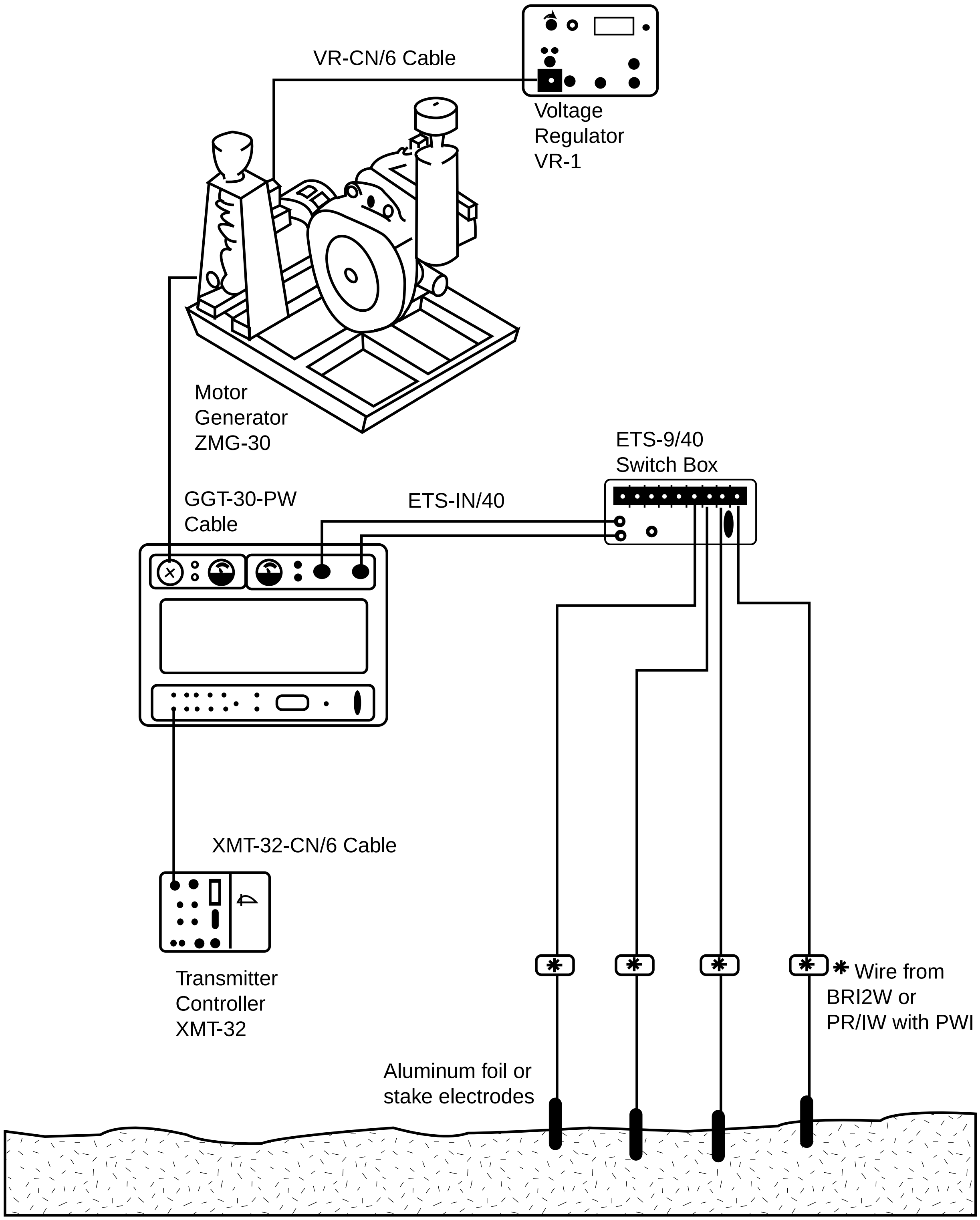


Figure 9.3 Transmitter Setup