PI 4100

Medium-Wave Field Strength Meter

User's Guide

PI

Potomac Instruments, inc.

7309 Grove Rd Unit D Frederick, MD 21704 Phone 301-696-5550 Fax 301-696-5553

The following items are included with the original packing:

The PI 4100

PI 4100 User's Guide

CD including *PI 4100 Data Downloader* software, *4100 Data Report Template1*software, and the *PI4100 Field Calibration Data Sheet*

Operator's Quick Reference Guide

Charging power supply and power cord

Charging cable for vehicle use

USB A to B Cable

Battery holder for six AA cells

About the packing material:

Save the box and foam insert for use when returning the PI 4100 for calibration or repair. See the User's Guide or www.pi-usa.com for return procedures.

Note that the foam inserts will fit exactly into the *PELICAN® 1610 CASE* for transport and storage. This case is available from a number of suppliers that can be reached via the internet.

PI 4100 Medium Wave Field Strength Meter

User's Guide

Operating and Service Instructions

Version E, Universal
15 January 2014

Potomac Instruments inc,
7309 Grove Road, Unit D, Frederick, MD 21704, USA

Table of Contents

1. General Description

1.1 Overview

The PI-4100 is Potomac Instruments' third generation of precision survey instrumentation designed specifically for the direct measurement of electromagnetic field strength in the 200 kHz to 5.1 MHz frequency spectrum. This microcontroller driven instrument combines a laboratory quality measuring receiver, a balanced loop antenna, an internal GPS receiver, an internal calibration source, data acquisition hardware and software, and a graphical LCD display in a single rugged package weighing less than 3 kg. The device measures, displays, and at the option of the operator, records the following:

Field Strength. This instrument measures and indicates electromagnetic field strength in the 200 kHz to 5.1 MHz spectrum at levels ranging from 30 μV/m (29.5 dBuV/M) to above 50 V/m (154 dBuv/M).

Date & Time of measurement. For logging the PI 4100 indicates date and coordinated universal time (UTC) derived from the Global Positioning Satellite (GPS) constellation. For users preferring to record data in local time, the operator has the option of offsetting UTC time via menu selection.

Distance from the transmitting antenna or array. Line-of-sight distance from the point of measurement to the transmitting source is displayed both for operator feedback and for logging. This feature is enabled when the latitude and longitude coordinates of the source are entered into PI 4100 memory by the operator.

Magnetic bearing from the measuring point to the transmitting antenna or array. The PI 4100 indicates Magnetic Bearing (True Bearing ± Declination) to the source if the latitude and longitude and magnetic declination for the source has been entered into memory.

True azimuth (radial) from the source to the measuring point. Conventional use of Field Strength data often requires the data to be presented as a plot, on polar graph (or map), referenced to True North. The PI 4100 employs its internal GPS receiver to calculate and display the True azimuth, in degrees, from the source to the measuring point both for operator reference and logging purposes.

Geographical coordinates of the measuring point. The PI 4100 internal GPS captures and displays the Latitude and Longitude of the physical location from which a given measurement is conducted (degrees, minutes, and seconds). This information can be stored with other pertinent data for future retrieval.

Spectrum occupancy (visual display) for the RF spectrum immediately adjacent to the measured frequency. The spectrum display screen provides 1.0 kHz resolution bandwidth and a sweep width of either ±22 kHz or ±64 kHz from center. Amplitude resolution on-screen is 1.0 dB. Carrier frequency is displayed (center screen) and an internal Marker can be moved in increments of 1.0 kHz either side of the carrier to precisely measure frequency response or interference level (in dB below carrier with 0.1 dB resolution) at the Marker frequency.

Functional elements: The PI 4100 Functional Block Diagram, Fig. 1, p. 10, shows the PI 4100's functional elements.

1.2 PI 4100 KEY FEATURES

- 126 dB dynamic range measuring receiver
- Digitally synthesized tuning in 1.0 kHz increments
- Spectrum display to facilitate various measurements (Field Strength and Spectrum occupancy) in a single instrument
- Provisions for a third party calibration check, using their laboratory standards, when it is impractical to return the instrument to the manufacturer for calibration
- Data acquisition software and PC interface to enable the collection, analysis, and e-distribution of field measurements. (This feature anticipates the future acceptance of data e-filing by federal regulatory agencies.)
- Magnetic compass to aid in the initial orientation of the integral loop antenna
- External RF input port (BNC) so that the instrument can be used as a stand-alone calibrated tuned RF Voltmeter
- External RF output port (BNC) so that the buffered output from the loop antenna can be used to drive external detectors and spectrum display devices
- USB port for downloading data from the PI 4100 internal memory to a compatible computer
- Comma separated data format for ease of importation to third party commercial software
- DC Field strength output for external recording
- DRM and HD Radio™ measurement capability with automatic correction

1.3 SPECIFICATIONS

Field Strength Measurement

Frequency Range	520 kHz to 5.1 MHz or 200 kHz to 5.1 MHz, calibrated
Minimum frequency step	1.0 kHz
Measuring accuracy:	
AM & Simulcast DRM	± 3 %
Pure DRM	± 6 %
Field strength measuring range:	
AM & Simulcast DRM	28 dBuV/m to 154 dBuV/m (25 µV/m to 50 V/m)
Pure DRM, 4.5/5 kHz BW	33 dBuV/m to 146 dBuV/m
Pure DRM, 9.0/10 kHz BW	36 dBuV/m to 146 dBuV/m
Pure DRM, 19/20 kHz BW	39 dBuV/m to 146 dBuV/m
Measurement units	µV/m-mV/m-V/m; mV/m only; dBuV/m (dB above 1 µV/m)
Measurement bandwidth	1.0 kHz @-3 dB
Image rejection ratio	>60 dB
Spurious rejection	>75 dB

Harmonic measurement

Harmonics, menu-selected	2nd, 3rd, 4th, 5th
Measurement range	to -80 dBc or lower, for carrier FS of (0.3 – 3) V/m

Spectrum Display

Modes	Norm (referenced to center freq FS)
	Peak (Norm with peak hold)
	Abs (displays 20 - 140 dBuV/m FS)
Center frequency range	Same as FS frequency range
Span (Sweep width)	128 kHz, 45 kHz
Resolution bandwidth	1 kHz

I/O Ports:

Data output jack	USB B jack
Cal In jack	BNC, nominal calibration input 700 mV rms
RF In jack	BNC, RF input and dc FS output
RF Out jack	BNC, RF output and dc cal detector output
Headphone jack	Audio jack, 3.5 mm
Battery charging jack	Power jack, 2.1 mm

RF Voltmeter (RF In jack)

Input impedance	2500 Ω
Voltage range	30 μV to 40 V rms
Measurement units	μV-mV-V; mV only; dBuV

RF Out 28 ±2 mV rms in 50Ω for 1 V/m FS, 200 kHz – 5.1 MHz

DC Field Strength output Proportional to dBuV/m, 1.0 Vdc @ 100 dBuV/m with a 1 MΩ load (10 mV/dB)

Audio outputs For AM and Simulcast DRM only:
Front panel speaker
Headphone jack, 3.5 mm, mono or stereo (use disconnects speaker), up to 4.0 V p-p max output

Data items stored 28 items, listed in Users Guide Sec. 4.5.6

Battery power supply

Battery type	Rechargeable NiMH, 7.2 V, PI supplied
Battery operating time	5 hours min., new battery
Battery recharge time	3 hours typical for full charge
Charging supply	11 - 15 Vdc, 1.2 Amperes min., 2.1 mm plug
Alternative battery	Six AA cells in a PI-supplied battery holder

Environmental characteristics:

Operating temperature range	0ºC to 50ºC dry, RH 95% (non-condensing)
Operating altitude	Up to 13000 ft. (4700 m)

Dimensions and weight:

Length, Width, Height	L: 15 in, 38 cm W: 7 in, 18 cm H: 11 in, 28 cm
Weight	5.5 lb, 2.5 kg

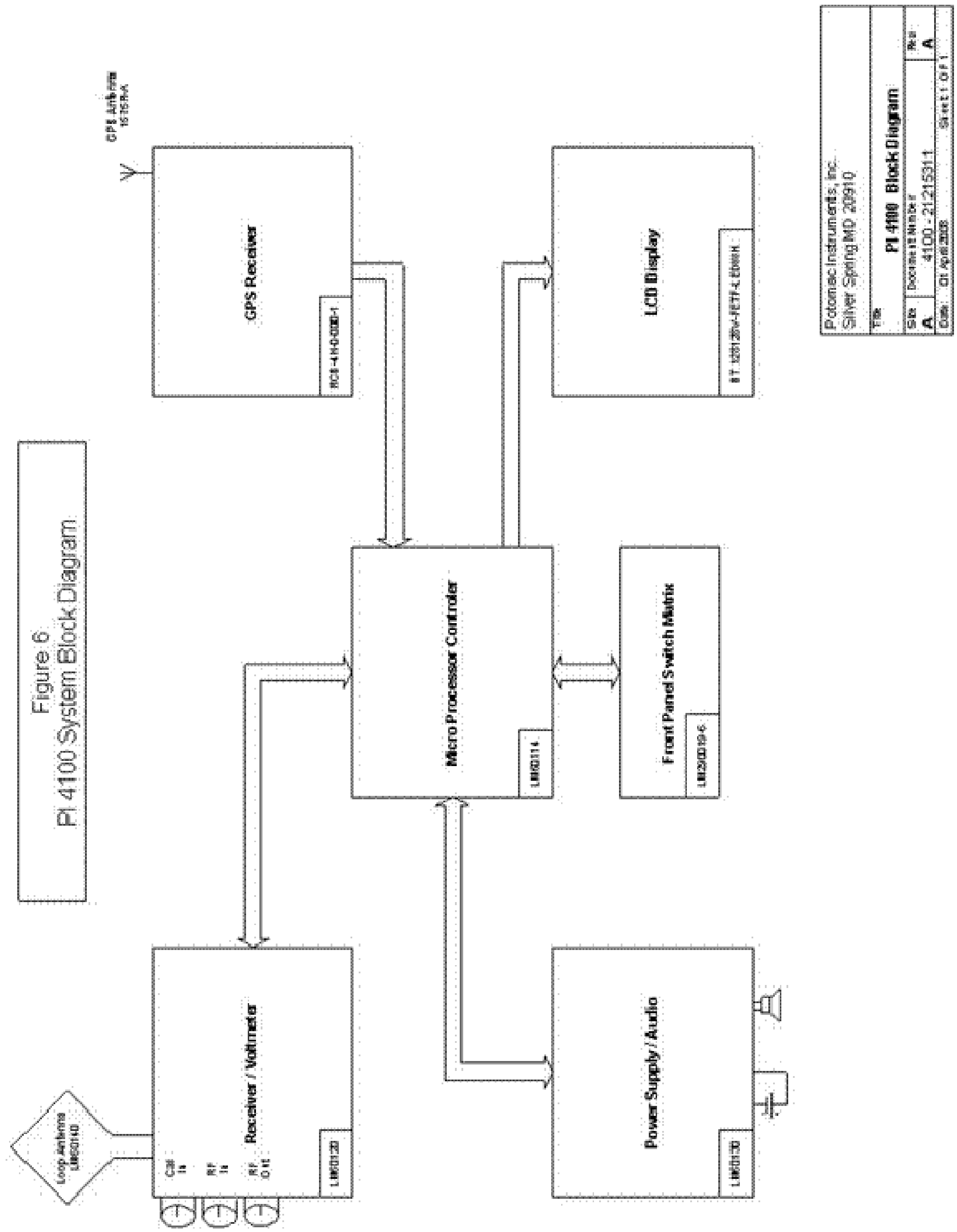

Figure 1. PI 4100 Functional Block Diagram

2. Receipt, Inspection, and Reshipment

2.1 Unpacking

The PI 4100 is packed in a custom shipping carton. Inspect the carton for any signs of serious damage. Report any damage to the shipping company.

Carefully remove the PI 4100 from the shipping carton. A User's Guide, a charger power supply with power cord, an in-vehicle charging cable, a battery holder, a USB cable, and a CDROM are included in the carton. Please retain the carton, the plastic foam insert holding the PI 4100, and other packing materials in case the unit and accessories must be shipped. The foam insert can be used in the Pelican 1610 hard case, see Appendix 4 for details.

The PI 4100 is ready for operation as delivered. See Section 4 of this Manual for operating instructions.

WARNING

In all locations where power receptacles have a ground pin socket, the PI 4100 recharging power supply's power input ground terminal must be connected to the receptacle ground pin socket. Failure to use a grounded outlet may result in improper operation or a safety hazard.

2.2 Reshipment to factory

If a PI 4100 must be returned to the factory it is best shipped in its original carton and packing materials or in a Pelican 1610 case. Shipping cartons can be ordered from the factory if suitable packaging is not available. Contact information can be found below and in Section 5 of this Guide.

2.3 Service and Warranty for Equipment and Accessories

Warranty: Potomac Instruments, Inc., warrants each new equipment to be free of defects in material and workmanship, for a period of one (1) year after the date of receipt of the equipment in satisfactory working condition. Any instrument which is found within one year not to meet the foregoing standards after examination by our factory or representative, will be repaired, or at the option of Potomac Instruments, replaced without charge. This warranty does not apply to equipment which has been altered, improperly handled, or damaged after receipt.

If the PI 4100 fails to perform properly, initially or after a period of use, or if it requires factory recalibration: if there is a local factory-authorized dealer or service facility, first contact the dealer or facility. A technician there will determine the best procedure to deal with the problem, in consultation with the factory if necessary. Otherwise, contact the factory directly. In either case it is recommended to use the use the factory online RMA (Returned Material Authorization) system by going to the Potomac web site at http://www.pi-usa.com, and clicking Request Service - On-line RMA Request. For units that are not under warranty, repair cost estimates will be provided, and authorization to proceed will be obtained from the customer before repairs are carried out. If return to the factory is not possible, Potomac Instruments will work with the authorized service facility or user to complete the repair, and will supply technical data and parts as necessary.

2.4 Contact information

Factory:

Potomac Instruments inc.
Attn: Service Dept.
7309 Grove Road, Unit D
Frederick, MD (Maryland) 21704
Phone: +1-301-696-5550
Fax: +1-301-696-5553
email: service@pi-usa.com
http://www.pi-usa.com

3. Controls, Indicators, and External Ports

3.1 Front Panel

Refer to Figure 1 or to the PI4100 itself for the following discussion. Each control is described below, starting with the **Power/Bklt** key, and moving counterclockwise aound the panel to the other keys..

Figure 1. PI 4100 Front Panel Controls and Indicators

POWER/BKLT: Turns the 4100 on (press until screen text appears) and off (press until screen text disappears). Turns the display backlight on and off, a short press for both.

UP and DOWN arrowhead keys: These keys (1) move a reverse video cursor to step through the choices available in the menu and submenus, and (2) step through the available values of a digit or character, 0-9 and/or A-Z.

LEFT and RIGHT arrowhead keys: These keys (1) for some menu items, move an underline cursor to select options; (2) for some menu items, move a reverse video cursor to select a number or character to change; and (3) for FREQ SET, move an underline cursor to select digits to change.

MENU: When in the field strength screen or a spectrum screen, press to display the menu of operational and setup options; press again to go back to the previous screen. For details see Sec. 4.3, p. 24.

SELECT: Used in menu operations to confirm a selection from a list, to confirm the choice of an item to modify, and to confirm that the modification is complete, all in accordance with on-screen instructions.

DELETE: Used to review the data records stored in the PI 4100, and (using **SELECT)** to delete selected data records. For details see Sec. 4.5.2, p. 27.

AUDIO/F4: Turns audio in the speaker or headphones on and off, a short press for on and a long press for off. For audio on, short presses step the sound level through four steps. For **F4** see **FREQ PRESET.**

SAVE/F3: Used to save a measurement and associated data in internal memory. Press once to review and change the associated data on the Save screen, and press again to complete the Save operation and go back to the Field Strength screen. For details see Sec. 4.2.4, p. 19. For **F3** see **FREQ PRESET**.

HOLD/F2: When pressed, the field strength value at that time is held on the display and in temporary memory. For details see Sec. 4.2.4, p. 19. For **F2** see **FREQ PRESET.**

LPF/F1: Controls stepping through three low-pass filter choices for three degrees of field strength value smoothing. For details see Sec. 4.2.5.3, p.20. For **F1** see **FREQ PRESET**.

FREQ PRESET: Allows quick selection of any of four previously stored frequencies which are shown on the display as F1, F2, F3, and F4 after FREQ PRESET is pressed. Selection is made by pressing one of the keys marked F1, F2, F3, or F4 as indicated above. For details see Sec. 4.2.1.3, p. 17.

FREQ SET: Allows setting the receive frequency to any available value by setting each digit of the kHz number on the display to the desired value. For details see Sec. 4.2.1.3, p. 17.

MODE: From the Field Strength screen, steps the display through three spectrum display modes and back to the Field Strength screen. For details see Sec. 4.2.7, p.22.

BATT LED**:** Signals by flashing that the 4100 will soon turn itself off because of low battery voltage and. the battery pack needs to be recharged. For details see Sec. 4.4.1, p. 26.

3.2 Primary Display Screen Elements

Refer to Figure 2 or to the PI4100 itself for the following discussion. Screen element descriptions are given below with reference to horizontal lines of text, starting at the top with Line 1 and reading from left to right in each line. For more detail on an item refer to Sec. 4, Operation.

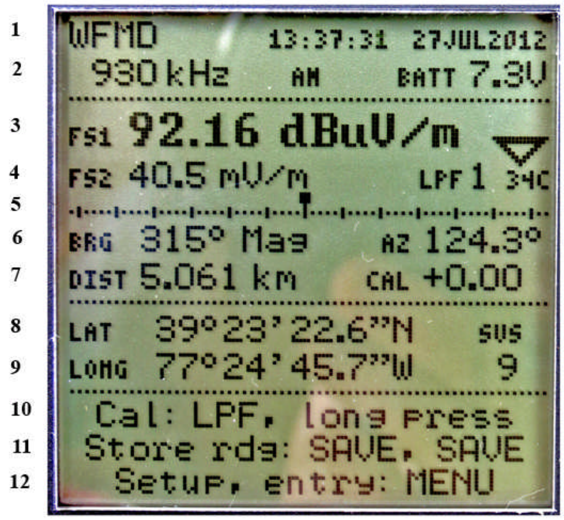

Figure 2. PI 4100 Field Strength display

Line 1: Call sign of the selected station; **Time and date** from GPS (UTC + Offset).

Line 2: Frequency of the selected station; **Modulation type; Battery voltage.**

Line 3: Field strength value and units; Field strength **trend indicator,** points up for increasing, down for decreasing field strength.

Line 4: Field strength value and units; **LPF setting,** degree of field strength smoothing, 1, 2, or 3; internal temperature, ºC..

Line 5: Analog field strength indicator, each major division indicates 1 dB (12%) change.

Line 6: Bearing (magnetic) of the station from the PI4100; **Azimuth** of the PI4100 from the station.

Line 7: Distance of the PI4100 from the station; Internal correction value (for reference only)

Line 8: Latitude of the PI4100, degrees/minutes/seconds, from GPS.

Line 9: Longitude of the PI4100, degrees/minutes/seconds, from GPS; Number of GPS satellites in view.

Lines 10, 11,12: Prompts for the operator, on manual self-calibration, storing a reading, and menu use. Prompts vary with screen function.

3.3 Rear Panel Signal and Power Ports

Figure 3. PI 4100 Rear Panel Signal and Power Ports

Figure 4. Charger Cable installed for charging

Figure 5. Battery charger and Interface Cables supplied

4. Operation

4.1 FIRST- TIME OPERATION

After unpacking the 4100, a trial run will help a new user to become familiar with its operation. The following is suggested:

- Connect and charge the supplied battery pack, if either is necessary.
- Adjust the compass index
- Go outdoors and try some field strength measurements.
- Review the menu options and enter the time offset between UTC and local time.
- Enter data for a station to be measured.
- Use GPS-derived data and the compass to orient the 4100.
- Make and save some field strength measurements.
- Download the measurement results to a computer.

Details on operating the 4100 can be found throughout this Guide, therefore browsing through the Manual may reveal information of special interest.

• Connect the battery:

The 4100 is shipped with its battery pack connected except in unusual circumstances. If it is shipped with the pack disconnected (there is no response on pressing the POWER key), connect the battery as follows:

Open the battery access door at the bottom of the front panel by pulling the upper left-hand corner of the door away from the panel.

Locate the cable on the battery as well as the cable to the unit above. Both cable ends are usually found under the battery, after the battery is removed.

Plug the connectors on these two cables together and reinstall the battery with the mated connectors under the battery.

Close the battery door, pressing in on first the sides and then the top of the door so the flange on the inside of the door is caught behind the panel edges.

• Adjust the compass index:

The 4100's compass has a red vertical index line facing the operator, which should be on center, aligned with the joint line of the two halves of the compass mount. If it is not so aligned, rotate the compass in its mount to bring the index line into alignment.

• Adjust the hand strap:

To adjust the length of the strap, separate the two halves of the wide padded part of the strap, which are held together by hook-and-loop material. Pull the lower strap end loose from the pad, reposition it in the bottom metal loop as desired, press the strap back onto the pad it was removed from, and press the two padded halves together. The strap can be moved to the right-hand side of the 4100 by removing and reinstalling the screws that fasten the strap mounting rings to the case.

• Turn on the 4100 and make a measurement:

Turn the 4100 on: Press POWER/BKLT until text appears on the display. If the battery has enough charge the main screen appears after a few seconds. If nothing appears on the display the pack must be charged, see **Battery information, Sec. 4.2.5.**. When text appears look for the battery voltage readout BATT 7.2V (7.2V is a typical value) at the right side of the screen near the top. If the voltage is 7.0 or more, go ahead with measurements. Sec. 3.2, p. 14, describes other screen elements.

Set the frequency: Change from the factory set 500 kHz to the frequency of the desired station. A stronger one is better for the first try: Press FREQ SET; a cursor line appears under the 10 kHz digit (for 9 kHz channel spacing, the 1 kHz digit). Set that digit to the desired value using the up & down arrow keys (UD). Use the left arrow key to move the underline to the next digit to be changed, and change it in the same way. Repeat until the display shows the desired frequency.

Press AUDIO to hear the station's audio: The level does not change with field strength. Short presses of AUDIO will change the sound level through four steps and a long press turns it off. Audio quality is limited by the receiver's narrow bandwidth and the speaker's small size.

Start Self-Calibration: Press and hold the LPF/F1 key until **CAL** appears in a box. Self calibration at the selected frequency proceeds and ends with **CAL OK** in a box if all is normal.

Measure Field Strength: orient the loop antenna for maximum reading (while keeping it vertical) by using the analog indicator, a small block which moves right or left as the level increases or decreases. There is also a trend indicator with an arrow that points up when level is increasing and down when it is decreasing. To reduce rapid variations in the reading, usually due to modulation, press LPF; on the display LPF1 changes to LPF2. This reduces variation and slows response time by applying a lowpass filter. Press LPF again to obtain more filtering; LPF2 changes to LPF3. A third press of LPF returns to LPF1 for the least filtering.

When the reading is maximum press SAVE to save the reading. The value is held internally while the screen changes to the Save Screen, in which additional data can be entered and saved with the measurement. On this screen the operator has the option to enter the pattern being measured, a letter/number code for the measurement location, operator's ID, and a 14-character note. After the desired entries are made, press SAVE again to complete the operation and return to the field strength screen.

GPS use: In an outdoor location where GPS reception is possible, latitude and longitude will appear on the display (the first fix after the 4100 has been shipped a long distance may take several minutes). Distance, azimuth, and bearing can be displayed if the latitude, longitude, and magnetic variation are entered in the 4100 for the transmitting antenna location. To do this, press MENU, go to Tx add, and enter the data. For more detail see Sec. 4.2.2, p.18. The 4100 can now be oriented for measurements by making the compass reading equal to the bearing value on the display.

Downloading data to a computer: To download data, first, install the 4100 Data Downloader program supplied with the 4100 and start the program (see Sec. 4.5, p.28). A program window appears with four buttons indicating the tasks the program can perform. When a USB cable, Type A to Type B, is connected between the computer and the 4100, "PI 4100 connected" appears at the top of the program window and the 4100 display blanks. On the computer click the top "Download..." button; specify the file name of the .csv file that will contain the data and where that file is to be stored. The download then proceeds. Downloaded data may be viewed in the program or by opening the .csv file in a spreadsheet program.

To turn the 4100 off, press and hold down POWER/BKLT until the screen text disappears after about two seconds.

4.2 PI4100 Operating procedure details

4.2.1 Setting the operating frequency:

Frequency can be set in these ways:

Accept the turn-on setting
MENU - Tx select
FREQ PRESET key
FREQ SET key
MENU - Harmonic select

4.2.1.1 Turn-on: A new 4100 turned on for the first time shows the factory setting, 500 kHz. If the unit has been used: if it was on a frequency chosen using Tx select (see below) at turn-off, it will be on that frequency when next turned on. If it was on a frequency set using FREQ SET at turn-off, when turned on it will be on the frequency most recently selected using Tx select, or on 500 kHz.

4.2.1.2 Use MENU-Tx select to make a radio station for which data has been stored the active station. The station's frequency and call sign appear on the display, and its antenna location and declination is used to calculate distance, azimuth, and bearing. For DRM and all-digital HD stations a correction is added to the field strength reading. A new unit will have no station data stored.

To use Tx select: Press MENU; with the cursor on Tx select press SELECT; use the up-down keys to select a station: press SELECT; press MENU. If the desired station is not shown, use Tx add in the menu to enter it, see Sec.4.2.2. Self-calibration will take place automatically.

4.2.1.3 Use FREQ PRESET to change to a new frequency. To store a frequency as a preset to use later, first use MENU-Tx select to go to that frequency (only frequencies stored in Tx select can be made presets). Then press FREQ PRESET; press one of the F1 - F4 keys and hold it down until you hear a beep and the display shows the new frequency. Repeat this for other frequencies desired as presets.

To go to a preset frequency, press FREQ PRESET; the display shows the available presets. Briefly press the F1 … F4 key for the desired frequency, do not hold the key down. If station location data has been entered for that frequency, and GPS reception is possible, location-related data, date, and time appear on the display. Self-calibration will take place automatically.

4.2.1.4 Use FREQ SET to change to a new frequency. To set a frequency**:** Press FREQ SET; use up-down keys to change the frequency digit over the underline cursor; press the left key to move the cursor to the next digit, changing its value the same way; repeat as needed. The 4100 will then receive a signal on the new frequency but no location-related or time data will appear. For accurate measurements press LPF to initiate self-calibration, holding the key down until **CAL** appears in a box.

4.2.1.5 Use MENU-Harmonic to go to a harmonic of the current frequency. To select a harmonic, press MENU and use the down arrow to go to Harmonic: 1 2 3 4 5. Use the right arrow key to move the underline cursor to, for example, 3 for the third harmonic, and press MENU. The receive frequency then changes to three times the displayed frequency, and on the display, 3x appears to the left of the frequency. If a new frequency is selected by using Tx select or FREQ PRESET, the harmonic selection changes to the fundamental. For more detail see Sec. 4.2.6, p.23, Measuring Harmonics.

4.2.2 Entering and changing station data for GPS use

To use the internal GPS receiver to obtain distance and azimuth of the measuring point from the transmitting antenna, and to use the compass for loop antenna aiming, data must be stored in the 4100 for the station to be measured. Data is stored, modified, and retrieved by using the menu items Tx add, Tx edit, and Tx select. As many as 50 stations may be entered. Station data can be entered by using the front-panel keys or by using the Data Downloader program, see Sec. 4.5.4, p. 28. If the GPS derived data is not needed, measurements can be made without this data-entry step by using FREQ SET to set the frequency.

4.2.2.1 To enter station data using MENU – Tx add:

Press POWER/BKLT to turn on the 4100.

Press MENU after the field strength screen appears; the menu screen appears.

Press the Down arrow key to go to Tx add; press SELECT. The Tx data entry screen appears, listing six data items to be entered, and with the reverse video cursor on the first item, Call - Site. Call is the station identifier; if there is more than one antenna site for the call, each one can have a separate Tx entry with the same call but a different dash number. As many as eight characters can be entered. Press SELECT; reverse video appears on the first character. Press the **Up** key to scroll through the numbers and the alphabet, or press the **Down** key to scroll backwards, to change this character to the desired one. Press the **Right** arrow key to go to the next character and change it the same way. Continue this procedure until all characters are as desired, then press SELECT to exit Call-Site.

Press **Down** to go to Freq, and press SELECT. Proceed as for Call-Site, using the arrow keys to change each frequency digit to the desired value. When done press SELECT, as before, to exit Freq..

At this point it is possible to exit Tx add, if the location data is not available or not of interest, and the new entry will appear in the Tx select list.

To enter location data, move to each of the remaining data items and enter the required data.

Latitude and Longitude are the transmitting antenna location coordinates in degrees, minutes, and seconds.

Var is the magnetic declination, also known as variation, the angular difference in degrees and minutes between the bearing of true north and magnetic north. It can be calculated from the latitude and longitude at this NOAA web site: http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp.

Modulation is the modulation system used by the station. Going to Modulation and pressing SELECT gives the available choices. AM refers to normal double-sideband amplitude modulation. DRM with a number refers to Digital Radio Mondiale; the number is the occupied bandwidth in kHz. HD-ad refers to the all-digital mode of HD Radio™. When a DRM or HD station is selected in the 4100, a correction is automatically added to the field strength reading to account for the difference between the measuring bandwidth, 1.0 kHz, and the occupied bandwidth. The DRM correction would be valid for any digital modulation system of the same bandwidth in which the power per unit bandwidth is uniform across the band.

When the required data has been entered, press MENU to go back to the main menu, and press MENU again to return to the field strength screen. The station just entered becomes the active station, meaning that the receiver is tuned to its frequency. Its antenna coordinates are used to calculate distance, the azimuth of the 4100 from the station, and the magnetic bearing of the station from the 4100.

4.2.2.2 To enter station data using the Data Downloader Program: With this program, data can be entered from the keyboard of a connected computer. To do this see the Downloader program instructions, Sec. 4.5.4, p. 28.

4.2.2.3 To change existing station data: MENU – Tx edit: Press MENU, go to Tx select, and select the station needing a change. Press SELECT to return to the menu, go to Tx edit, and press SELECT again. All data items for the selected station can then be entered or edited as described above for TX add.

4.2.3 Self-calibration, automatic and manual

Automatic calibration: The 4100 calibrates itself using an internal calibrating source. This takes place automatically when the unit is turned on, and also when the selected station is changed by using Tx select or FREQ PRESET.

Manual calibration: To initiate calibration at any time press LPF, holding the key down until a blinking CAL message appears on the display, followed by CAL OK. Do this when the frequency is changed using FREQ SET since it will not be done automatically. Do it immediately before critical measurements, especially when the 4100 has been subjected to a large temperature change. Manual calibration is intended to be used only for field strength measurements, not for the RF Input mode.

CAUTION: For accurate measurements, all parts of the 4100 must be at least 12 inches (30 cm) from any large metal surface during self-calibration. If the unit is turned on while resting on a metal surface, and self-calibration takes place, its readings when handheld will be about three percent too high. It is best to turn the 4100 on and change its frequency selection after the unit is positioned for measurements.

How self-calibration works: When LPF is held down, CAL appears blinking in a box on the display, and the 4100 checks to see if the received signal is large enough to affect the calibration. If so, the receiver frequency is shifted a few kHz and the check repeated; when this test is passed, the internal calibrating source is turned on and injected into the loop antenna; the resulting field strength value is compared to a factory-set reference. The dB difference between the two, which is the CAL number seen on the display, is saved and added as a correction to all field strength dBuV/m readings until the next self-calibration. Voltage unit readings are calculated from the corrected dBuV/m values. CAL OK appears in a box on the display to show that the process is complete, and the new CAL value is displayed. If there is a problem with the calibration, NO CAL 1 (received signal on the cal frequency too high) or NO CAL 2 (change from the previous CAL value too great) may appear instead of CAL OK, and the previous CAL value will be retained. The CAL value indicates the receiver internal gain correction; the operator does not need to make use of it.

4.2.4 Saving measurements: SAVE and HOLD

4.2.4.1 To save a measurement, press SAVE. All screen data is held at the values existing when SAVE was pressed. The Save screen appears, which allows operator- entered data to be stored with the measurement. Pressing SAVE a second time stores the measurements together with the following optional operator notations:

Pat (pattern): Gives the antenna pattern in effect for the measurement, following standard US practice. The choices are Dy (day), Nda (non-directional), Nt (night), Cr (critical hours), and -- (no pattern designation). Choose one by using the left and right arrows to move the underline cursor to the desired pattern. Then press the down arrow to go to the next screen item.

Meas. Point: Enter a predetermined code to identify the measurement point. Enter up to four characters following the same method given above for entering a call sign for Tx add (see p. 19).

Radial: Enter the radial angle associated with the measurement, if applicable (the azimuth shown on the field strength screen should be close to this value).

Initials: Enter the initials or other ID of the person making the measurement.

Data point: This is a number that steps up one unit each time a measurement is saved to provide an identifying number for the measurement. To reset the number to a desired value at the start of a series of measurements use the methods described for Tx add above. To see the number of the last measurement saved, to prevent duplication of numbers, press DELETE.

Note: A note of up to 14 characters may be entered, using the Tx add call sign methods. This could be the call sign of a station measured using FREQ SET, not otherwise saved.

4.2.4.2 Completing the Save: Press SAVE a second time to complete the Save process and return to the field strength screen for the next measurement. The 4100 allows up to 250 measurement records to be saved before some records must be downloaded to make space for more. At the top of the Save screen the number of measurements that can be saved at any time is given as NNN Free. To reduce the possibility of data loss it is advisable to download saved data as soon as possible, using the PI 4100 Data Downloader program supplied (see Sec. 4.5).

4.2.4.3 Entering Save screen data before measuring: Data can be entered on the Save screen before starting measurements, which saves time during measurements. To do this press SAVE once, enter the data, and press MENU to go back to the field strength screen. All Save screen data is held for all measurements until the operator changes the data, except Data point, which automatically increases by one as each measurement is saved. When measuring, press SAVE to hold the measurement data and view the Save screen, which will show the previously entered data. Edit as necessary as described above and press SAVE a second time to save the data.

4.2.4.4 The HOLD key: Press HOLD to 'freeze' everything on the field strength screen at the instant the key is pressed; all values on the screen remain fixed until further action is taken. Press HOLD again to return to normal operation without saving the data, or press SAVE to save the data and return to normal operation. The operator may make a measurement and press HOLD when satisfied that the measurement is accurate, and then decide whether to save it.

4.2.4.5 Viewing and deleting saved data: To view measurement data records saved in the 4100, press DELETE. The screen now shows the most recent record and gives on-screen instructions for going to other records. Press the up arrow key to go to an earlier record or hold the key down to step through the saved records. Press the left arrow key to go to the earliest record. To delete a record, make it the one shown on the screen and press SELECT. To go back to the field strength screen press MENU.

4.2.5 Measuring Field Strength

4.2.5.1 Field strength units: FS1 and FS2 on the display express the same measurement in different units, which are selected for each as follows: press MENU; press Fld Str 1 or Fld Str 2; press SELECT; move the cursor to the desired units; press SELECT. The choices are voltage units, uV-mV-V/m or mV/m only, or dB units, dBuV/m (dB above 1 uV/m). Although voltage units are standard in US practice, dB units can be easier to interpret when the value is fluctuating because a one unit change in the last digit always represents approximately a one percent change in value. When it is desired to find the dB difference between two values, having dB units simplifies the calculation. FS1 and FS2 values are both saved when a measurement is saved.

4.2.5.2 Loop antenna orientation: When measuring, the loop antenna can be oriented for the highest reading, or it can be pointed at the transmitting antenna by making the compass reading equal the displayed bearing value. When using the compass, be sure that no nearby iron or steel objects are affecting the compass, and that declination (variation) is entered correctly. Pointing at the antenna may give a lower value if there is significant reflection from conducting objects in the area. If this is the case, both values can be saved for analysis after downloading. Standard practice is to keep the loop antenna plane vertical; this also can be varied and the results saved.

4.2.5.3 LPF use: Low-pass filtering to reduce fluctuation in the displayed value is available by using LPF to step through three choices. Approximate values of the time it takes for the reading to reach its final value are for LPF1, 0.5 sec; for LPF2, 1.5 sec; and for LPF3, 5 sec. When the FS reading goes below 35 dBuV/m the 4100 switches from LPF1 to LPF2. When cochannel interference is present, and the frequency difference is 2 Hz or greater, use of LPF3 allows measurements when the desired signal exceeds the undesired signal by 4 dB or more.

Another way to deal with varying readings is to save several readings and average them after downloading.

4.2.5.4 DC field strength output: A dc voltage output proportional to dBuV/m is available at the center pin of the RF In BNC jack. With a high-resistance load the voltage is approximately 10 mV/dBu, or 1V for 100 dBuV/m, with a maximum range of 0.2 to 2.0 V. The source resistance is 10,000 Ohms. A 100ua full scale analog meter could be connected between this point and ground for remote reading. This output can be used while an external RF input signal is connected by feeding the signal to a T junction through a coupling capacitor.

4.2.5.5 Temperature effects: The low-temperature limit for display operation is -20C/-4F, but measurements become difficult as the temperature approaches these values because the display response time becomes very slow. Battery performance is reduced as well. A good cold-weather strategy is to keep the 4100 in a warm environment as long as possible and to transport it an insulated carrier so its exposure to cold is minimized. The high-temperature limit is +50C/122F, also set by the display. In warm weather it is advisable to minimize the time the unit spends in a closed vehicle in the sun, or the time spent in direct sunlight. The temperature shown on the display is the processor temperature, which increases to several degrees above ambient with operation.

4.2.5.6 Measuring pure DRM transmissions: In pure DRM transmissions the transmitted power is uniformly distributed throughout the assigned signal bandwidth, which may be 4.5, 5, 9, 10, 19 or 20 kHz. Since the 4100 measures the power in a 1.0 kHz bandwidth, the total power received is greater than the measured power in a 1.0 kHz bandwidth by a factor equal to the signal bandwidth in kHz. Thus the observed field strength in dBuV/m in the 4100 must have added to it a correction quantity 10logB (where B is the DRM signal bandwidth in kHz) to obtain the total received field strength value to be displayed. Voltage unit values for display are calculated from the dBuV/m values. This correction is done automatically in the 4100 (for operating software versions 2.3.06 and higher) when a station is selected from the Tx select list which has the appropriate modulation entry (see Sec. 4.2.2.1, p.19). The correction values are: 4.5&5, 6.8dB/2.19; 9&10, 9.8 dB/3.1; 19&20, 13.0 dB/4.4. Simulcast DRM transmissions with full carrier do not require this correction and are treated the same as AM signals.

4.2.5.7 Measuring HD Radio™ All-Digital transmissions: For this signal the carrier but only part of the sideband power are within the 4100's 1 kHz bandwidth. A correction must therefore be added to the measured value to obtain the total field strength. This correction has been calculated to be 3.9 dB for dBuV/m units or a factor of 1.57 for voltage units. In PI 4100s with software version 2.3.07 or higher this correction is added automatically if the station data has been entered using Tx add (see Sec. 4.2.2.1, p. 19) with modulation type HD-ad.

4.2.5.8 Low measuring limit: In the absence of significant ambient RF noise the 4100's field strength noise floor is typically 10 - 14 µV/m (20 - 23 dBuV/m) and the field strength of AM and Simulcast DRM signals as low as 25 µV/m (28 dBuV/m) can be measured with approximately ±5 per cent error. If the noise indication exceeds 14 µV/m at a no-signal frequency near the signal to be measured, because of ambient RF noise, the low limit for field strength accuracy is correspondingly higher. For pure DRM signals the low limit for measurements is higher because only the signal within a 1.0 kHz band is measured; the full signal is greater as explained in Sec.4.2.5.6 above. Based on measurements of a simulated pure DRM signal with a typical PI4100, the low limit for accuracy is, for bandwidths of 4.5 and 5 kHz, 45 µV/m (33 dBµV/m); for 9 and 10 kHz, 63 µV/m (36 dBµV/m), and for 19 and 20 kHz, 89 µV/m (39 dBµV/m).

4.2.5.9 High measuring limit: The 4100's autoranging input attenuator allows measurement of very high AM field strengths, up to and beyond the recommended limits for worker exposure, 600 V/m at or below 1 MHz and (600/f in MHz) above 1 MHz. Potomac Instruments strongly recommends that 4100 users stay within these limits. In high field work, near an antenna tower, electric field strength readings may not be accurate because the 4100's loop antenna responds to the magnetic field and is calibrated to read electric field on the assumption that the ratio of electric to magnetic fields is 377, as it is in free space or the antenna far field. This ratio may or may not hold in the near field.

4.2.5.10 Frequency range for measurements: While the 4100's specified frequency range for accurate measurements is 200 kHz - 5.1 MHz, it can be used outside this range. The frequency range for which the unit is calibrated is shown on the nameplate on the bottom of the case and on the screen that appears for three seconds when the unit is first turned on. At the low end it can be used as long as manual self-calibration gives a CAL OK message, typically below 200 kHz, and calibration down to 200 kHz is available. At the high end the 4100 can be used with reduced accuracy at least to 8.5 MHz, so 5th harmonic measurements of 1.7 MHz are possible.

4.2.6 Measuring Harmonics

4.2.6.1 Measurement conditions: The PI 4100 can measure broadcast harmonics with full accuracy for harmonic frequencies up to 5.1 MHz and with reduced accuracy to 8.5 MHz. For accurate measurements the received signal must be large enough that the harmonic to be measured will be above the 4100's noise floor, but not large enough to cause significant harmonic generation within the 4100. The range of fundamental frequency field strength values that satisfy these conditions, depending on the target harmonic ratio it is required to equal or exceed, is as follows:

Target harmonic ratio:	60 dB:	Fundamental field strength must be:	30 mV/m to 12 V/m
	70 dB		100 mV/m to 6 V/m
	80 dB		300 mV/m to 3V/m

If local RF noise picked up is greater than the 4100's noise floor, the lower field strength limit needs to be greater than stated above. Generally, greater fundamental field strength is better; the best value for accurate harmonic ratio measurements is approximately 2 V/m.

4.2.6.2 Measurement procedure:

- Use Tx select to select the desired station.
- Position the 4100 and orient it for maximum field strength, near 2 V/m if possible.
- Press MENU and move the cursor to Harmonic.
- Move the underline cursor to the desired harmonic multiple, for example 3.
- Press MENU to return to the field strength screen.

3x now appears on the display to the left of the frequency, and the 4100 is set to receive at three times the displayed frequency. The received field strength is displayed in dB relative to the fundamental field strength, or dBc, so a harmonic 72 dB below the fundamental will display as -72 dBc.

4.2.7 Spectrum mode operation

The 4100 can display the spectrum of a signal as a plot of received amplitude vs. frequency over a span of 128 kHz, which is centered on the frequency shown on the field strength screen at the time MODE is pressed (see below). It does this by stepping its operating frequency in 1 kHz steps across the span, producing a plot on the display in 1 dB amplitude steps. Amplitude values are held internally with 0.1 dB resolution. The measurement bandwidth, or resolution bandwidth, at each frequency is fixed at 1.0 kHz. Each amplitude value is the average of the signal received over a period of approximately 20 milliseconds. The total amplitude range available is approximately 128 dB. These parameters are at variance with NRSC requirements for spectral occupancy measurements, which call for a 300 Hz resolution bandwidth and peak hold without averaging.

Spectrum modes: There are three spectrum modes, designated Normal, Peak, and Abs (meaning Absolute). From the field strength screen press MODE to go to Normal, press it again to go to Peak, press it again to go to Abs, and press it again to return to the field strength screen.

Normal mode: This is a plot of amplitude in dBc (dB below the center frequency carrier amplitude) with the center frequency point at the top center of the plot.

Peak mode: This is a dBc plot like the normal mode but with peak hold added. Each point remains at the highest value it reaches during any sweep since the start of the plot, and a timer shows the time elapsed since the plot was started.

Absolute mode: This is a plot of field strength value in dBuV/m vs. frequency, with 20 dBuV/m (10 uV/m) at the bottom of the screen and 148 dBuV/m (25 V/m) at the top, without peak hold. This mode is the most useful for showing what signals are present whether or not there is a signal at the center frequency.

Marker: All modes have a marker to give precise amplitude and frequency values. The marker is a short vertical line which extends above the plot and is moved across the plot by the right and left arrow keys. As it is moved, the frequency difference from center and the amplitude value is displayed. There is also a very short cursor that moves across the plot as the frequency is stepped.

S**pan (sweep width):** In the menu the span can be shortened from 128 kHz to 45 kHz, which gives 2.8 times as many sweeps per minute of the central part of the plot. The central part occupies the same width on the display space as it does for the 128 kHz span. To change the span to 45 kHz, press MENU, go to Spectrum kHz: 128 45, and use the right arrow key to move the underline cursor to 45, or the left arrow key to change back to128. Press MENU a second time to return to the spectrum screen.

4.2.8 Measuring RF voltage: the RF In BNC jack

General: The PI 4100 can serve as a tuned RF voltmeter to measure the level of a signal connected to its RF In BNC jack, with approximately ±5 per cent accuracy over a range of 30 microvolts (32 dBuV) to 40 Volts (151 dBuV). Voltages greater than 40 V can damage the input circuits. The input resistance is 2500 Ohms, therefore an external termination must be used when measuring a transmission line that requires correct termination. This is essential when measuring the output voltage of an antenna current sampling line, especially one driven by a sampling loop; the line must be terminated before the RF In jack is connected to it to prevent 4100 damage caused by high voltage. The bandwidth for measurements is 1.0 kHz. Measurement units are both voltage units and dBuV, according to the units selected for field strength.

Bridge detector use: The 4100 can serve very well as a detector for an RF bridge, with the bridge output connected to the RF In jack. The measuring range is very large with no range switching and the analog level indicator serves as the null indicator. In the voltage measuring mode the output of the loop antenna due to external fields is well isolated from the measuring circuits and is not likely to cause errors.

Voltage measurement procedure: To measure voltage press MENU and move the cursor to Input. Move the underline cursor from LoopAnt to RF in and press MENU again to cause switching to take place. On the display the two legends FS1 and FS2 change to RF1 and RF2 with voltage units related to the units selected for field strength. Manual calibration is not needed and does not function.

4.2.9 RF Out BNC jack use

General: The RF Out BNC connector provides a broadband output from an amplifier driven by the loop antenna. The source impedance at RF Out is 50 Ω. The output voltage for a given field strength is nearly constant over the frequency range 200 kHz – 5 MHz, which makes the output useful as an input to a spectrum analyzer. For a field strength of 1 V/m the output level is approximately 28 mV rms (89 dBμV) with a 50 Ω load. If the spectrum analyzer displays amplitude in dBuV, add 31 dB to the displayed value to get field strength in dBuV/m. If it displays amplitude in dBm, add 138 dB to get dBuV/m. At field strengths above approximately 21 V/m (146 dBuV/m) an attenuator is switched in, reducing the output level by 31 dB. The noise floor of the spectrum display will be determined by the analyzer rather than by the 4100 unless analyzer has a low-noise input amplifier, or a separate low-noise amplifier is used at the RF Out jack.

4.3 MENU Operation reference

4.3.1 Menu Navigation:

Use the menu to choose options and enter data as indicated below for each item. Press MENU and follow the directions at the bottom of each screen or the instructions below.

For all items, use the up and down arrow keys to move the reverse video cursor to the desired item, and then do the following:

For items showing two or more options with one option underlined, use the right and left arrow keys to move the underline to the desired option. Then press MENU to put the option into effect and return to the field strength screen.

For all other items, press SELECT and follow on-screen instructions. To return to the field strength screen when finished, press MENU.

4.3.2 Menu item descriptions:

Tx select: ABCD

Gives a list of frequencies and call signs of stations for which data has been stored in the 4100. To choose a station for reception move the cursor to the station's call sign, press SELECT, and follow on-screen instructions. ABCD is the call sign of the station currently selected. See Sec. 4.2.2.1, p.19.

Tx edit…

Use to change previously-entered data for a station. To choose a station for editing, use Tx select. Then press MENU, move the cursor to Tx edit, press SELECT, and make changes in the entered items as desired. See Sec. 4.2.2.3, p.19.

Tx add (NN Free)…

Use to enter station data to be stored in the 4100. NN is the number of stations that can be added; the maximum is 50. Follow on-screen instructions or see Sec. 4.2.2, p.18 for detailed instructions.

Input: LoopAnt RF in

Use to choose the signal source for measurements, the loop antenna for off-air signals or the RF In BNC jack for voltage sources. Move the cursor to Input, move the underline cursor to the desired source, and press MENU. See Sec. 4.2.8, p.24.

Harmonic: 1 2 3 4 5

Use to choose a harmonic of the currently-selected station for measurement. The underline cursor indicates the current harmonic (1 = the fundamental). For details on choosing a harmonic see Sec. 4.2.1.5. For further important information on measuring harmonics see Sec. 4.2.6.

Spectrum kHz: 128 45

Use to choose spectrum mode spans of 128 kHz (the default) or 45 kHz. For spectrum mode details see Sec. 4.2.8.

Auto off: NN min

Use to set the number of minutes of no 4100 keypresses after which the 4100 turns itself off to save its battery. NN is the current number of minutes and is factory set to 15. To enter a new value, move the cursor to Auto off and follow the on-screen instructions. To disable automatic turn-off set NN to 00.

UTC offset: +NNhNNm

Use to enter the time interval (offset) in hours and minutes which must be added to UTC time to enable the display to show local time correctly when a GPS fix is obtained. To set the interval, move the cursor to UTC offset and follow on-screen instructions. +NNhNNm is the current offset. The offset interval must be reset manually when there is a standard/daylight time change.

Fld Str 1: mV/m

Use to choose measurement units for the FS1 field strength number on the display. For detailed instructions see Sec. 4.2.5.1, p.21.

Fld Str 2: dBuV/m

Use to select measurement units for the FS2 field strength number on the display. For detailed instructions see Sec. 4.2.5.1, p.21.

Datum: LLLNN

Use to choose the geodetic datum for GPS location calculations. LLLNN is the current datum. Move the cursor to Datum and press SELECT; move the cursor to the desired datum and press SELECT.

Spacing kHz: <u>10</u> 9

Use to input the local station frequency separation (affects the FREQ SET cursor initial position). Move the cursor to Spacing, move the underline to the appropriate number, and press MENU.

4.4 Battery information

General: The PI4100 is supplied with a rechargeable battery pack made up of six matched nickel-metal hydride (NiMH) AA size cells. Included in the pack is a temperature sensor which connects to the charging circuit to prevent charging when the temperature is too high or too low. When the pack reaches the end of its useful life, as indicated by a decreasing number of measurements possible per charge, it is recommended to replace it with an identical pack from the factory.

4.4.1 Charging the battery:

To charge from the AC line (mains): Locate the supplied charging power supply (Input, 100 - 240 VAC; output 12 VDC regulated, 2 A), Connect its output to the 4100 charge input (see figure 4) and connect its input to the AC line using the supplied power cord. Charging now begins and will be completed in three hours or less. If the 4100 is turned on during this time, charging still proceeds at the same rate and a blinking word CHARGE appears on the display. When charging is completed the display shows BATT and a voltage near 9.0 V while the charger is connected. When the charger is disconnected the voltage drops to a value near 8.3 V.

To charge from vehicle power (12V nominal only), for example while traveling between monitor points: Connect the 4100 charge input directly to vehicle power using the supplied cable with lighter plug (the plug has a fuse, 3A, 8AG). The current drain is approximately 1.0 A with the 4100 off and 1.3 A with the 4100 on. A complete charge reduces the vehicle battery's available capacity by about three ampere-hours if the vehicle engine isn't running, not a large loss. Note: During charging the charging circuit generates significant interference at multiples of approximately 400 kHz..

When to charge the 4100 battery: The battery voltage appears on the display at the upper right when the unit is on. Although voltage is known to be generally not a good indicator of remaining operating time, it can indicate when the battery is nearing depletion. When a battery is first used after a charge the voltage may be near 8V; it drops steadily with use to about 7.2V, where is changes little until the battery is nearly depleted. Voltage then begins to drop at an increasing rate, and at 7.0V about one hour of operation remains. This is a good time to plan to recharge. The front-panel BATT LED blinks as a warning when the voltage falls below 6.6 V, at which point only a little operating time remains. During charging the voltage reading is replaced by the word CHARGE blinking.

Non-operating charging: When the 4100 is not in use the battery self-discharges and its voltage drops; if the voltage goes below 6.0V charging becomes difficult. Therefore, if the 4100 is not to be used for a long period, charge it fully before putting it on the shelf, and recharge after not more than three months of non-use. The battery manufacturer recommends storage at normal room temperature, avoiding heat or cold.

Charging temperature: The charging circuit allows charging only at ambient temperatures between approximately 5C/41F and 40C/104F.

Charge maintenance: If the charging supply is left connected for much longer than the normal charge time, charging will automatically restart when the voltage drops to 7.6V and restore a full charge. Continued operation with the charger connected for a long period may shorten the life of the battery.

Battery life: The manufacturer states that the expected life is 500 charge-discharge cycles or two years. End of life is indicated by shortening of the operating time between charges.

4.4.2 Loose-cell battery:

A battery holder for six individual AA cells is supplied with the 4100. It can use rechargeable nickel-metal hydride cells, which can be recharged in the 4100. It can also use primary (non-rechargeable) cells. Non-rechargeable 1.5V Lithium AA cells will give a reasonable number of measurements. A strip of tape may be needed around the holder to keep loose cells from popping out of the holder.

Warning: <u>Do not connect a charger while using non-rechargeable cells</u>.

4.5 Data storage and retrieval: The PI 4100 Data Downloader Program

4.5.1 General: For every saved measurement in the 4100 a data record containing 31 data fields is stored in memory, using the .csv (comma-separated value) format. The fields are listed in Sec. 4.5.6 below. For each station data set entered using Tx add, a record is stored containing the entered Tx data. Up to 250 measurement records and 50 station records can be stored. The user can view each stored data and Tx record and delete unwanted records using the front panel controls and display. The user can also download records to a Windows™-based computer by using the **PI4100 Data Downloader** program supplied with the 4100. Data is downloaded as a .csv file which can be opened in a spreadsheet or database program, and the desired data items extracted to a user-designed report. Appendix 4 describes a sample Microsoft Excel® Workbook report which presents selected data items. The CD supplied with the 4100 includes a template file and instructions for using it.

4.5.2 Viewing and deleting data using the PI 4100 controls and display: To view data records on the PI 4100 display, press the DELETE key; data items from the last record stored appear. The data items shown are Data point, Date, Time, Frequency, Azimuth, Pattern, Distance, and Field Strength (FS1). To go to an earlier record press the UP arrow key and hold it down until the desired record appears. A beep is heard when the earliest record appears. Press the Left arrow key to go to directly to the earliest (oldest) record. Press the Right arrow key to go to the latest record. To delete the record currently on the display from memory, press SELECT. NOTE THAT THERE IS NO UNDELETE FUNCTION. A deleted record cannot be recovered.

To return to the Field Strength screen after viewing records, press MENU.

4.5.3 The PI 4100 Data Downloader Program: The CDROM supplied, **PI4100 Supplemental Information,** contains the Downloader program for Windows™ computers in a compressed (zipped) file, **Installxx.zip,** where xx = 53 or greater, as well as the Excel® template file, **4100 Data Report Template1.xlt,** and template instructions, **Using the 4100 Data Report Template.pdf.**

4.5.4 Data Downloader program installation: First, copy the file **Installxx.zip** to the desired location in the target computer and uncompress (unzip) the file. The result is three files: **PI4100 Data Downloader.CAB; SETUP.LST**; and **setup.exe**. To start the installation proceed as follows:

● Click **setup.exe**. If an "Unidentified Program" box appears click **Allow** to continue. The setup box appears.

● In the **PI4100 Data Downloader Setup** box click **OK** to continue. A new box appears.

● To accept the proposed program file location click the large square box, or click **Change Directory** to specify a different location. A new box appears.

● Choose the desired Program Group; click **Continue**, a new box appears. If a file version conflict box appears, it is usually best to keep the newer version.

● Installation proceeds and a "successfully completed" box should appear. Click **OK** to finish.

To install icons to open the program: First, make the computer's Desktop visible. Then click **Start**, click **Programs**, and click **Potomac Instruments;** the program with icon **[PI] PI4100 Data Downloader** should appear. **[PI]** is the program icon, a white PI in a blue box. Copy the icon to the Desktop or to the quick launch area, or both, where it can be used to open the program.

4.5.5 Data Downloader program operation:

●**To open the program** click the PI icon, or click Start - Programs - Potomac Instruments - PI4100 Data Downloader. The PI4100 Data Downloader window should appear (Fig. 6, appearance may differ for different Windows™ versions). If the 4100's USB cable is not yet connected, the title bar of the box shows **PI 4100 Not Connected** and the selection buttons do not function.

●Connect a USB Type-A-to-Type-B cable between the computer and the 4100; if all is normal the box title bar now shows **PI 4100 Connected**.

Figure 6. PI 4100 Data Downloader Program – Opening Screen

●**To view stored data records in the 4100** and to delete selected records, click the **View/Delete Saved Data** button. For each record, 13 of the 31 saved data items are downloaded and shown in the Saved Data box. To delete a record without saving it to a .csv file, click in that record's row and click the **Delete** button on the left. To select all records for deletion use the **Select All** button

●**To download all data records to a .csv file:** click the **Download Saved Data** button. Enter a file name for the .csv file to receive the data, and specify where the file is to be saved. To work with the data, open the file in a spreadsheet or database program.

●**To view, edit, delete, or add new Tx data:** click the **View/Delete/Edit/Add Tx Data** button. The data for stations previously entered in the 4100 using MENU -Tx add is shown in the Tx Data box. To edit a Tx data set, click its row and click **Tx Edit**. To delete a Tx, click its row and click **Delete**. To add a new Tx, click **Tx add**, enter data in the form provided, and click **Save**. Note that for older PI 4100s having software versions below 2.2.01, the Tx Edit and Tx add functions are not available and the software will not offer them. The version number appears at the top of the MENU screen.

●**To download all Tx data records to a .csv file:** click the **Download Tx Data** button, enter a file name, and specify where the file is to be saved. Open the file in a spreadsheet or database program.

●**To generate a Data Report:** From the CDROM copy the files **4100 Data Report Template1.xlt** and **Using the 4100 Data Report Template.pdf** to the desired computer location. Refer to Appendix 3 for more detail. Use the template as is, modify it to suit, or generate a new one to suit local requirements and the spreadsheet or database program in use.

4.5.6 Data record fields: The data record for each measurement contains 31 fields, listed below in the order in which they appear in the .csv file. For details on any item , go to the applicable section of this User's Guide.

Dir ID	Internal use only
Rec ID	Internal use only
Point Number	Data point: number from the Save screen (incremented with each save)
Tx ID	Internal use only
Call Sign	The call sign of the station chosen in Tx select
Tx Frequency	Frequency in kHz of the station chosen in Tx select
Meas. Freq.	Operating frequency in kHz (may differ from Tx Frequency if FREQ SET has been used)
Radial	Radial from the Save screen
Pattern	Pat: setting from the Save screen
Initials	Initials from the Save screen
Note	Note from the Save screen
Meas. Point	Meas. point from the Save screen
UTC Time	UTC Date (m/d/y) and Time (h:m) from GPS
Local Time	UTC Date and Time from GPS plus UTC offset value from MENU
Harmonic	Harmonic: setting from MENU
RF Source	Input: setting from MENU
GPS Valid	TRUE = a good fix, GPS data is valid; FALSE = no fix, data invalid
Latitude	PI4100's latitude in decimal degrees from GPS
Longitude	PI4100's longitude in decimal degrees from GPS
Elevation	PI4100's elevation above sea level in meters from GPS
Fld Str 1	FS1 (upper) field strength value as displayed
Units 1	Units for FS1 or RF1 value
Fld Str 2	FS2 (lower) field strength value as displayed
Units 2	Units for FS2 or RF2 value
mV/m	Field strength in mV/m or RF Input in mV, without rounding
dBuV	Field strength in dBuV/m or RF Input in dBuV, without rounding
Tx distance	Distance in km of the PI4100 from the Tx antenna location
Azimuth	Azimuth (true) of the PI4100 from the Tx antenna location
Temperature	The PI4100's internal temperature in degrees Celsius
Tx Lat/Long	TRUE = Lat/Long data for the station chosen in Tx select is present; FALSE = the data is absent
Modulation	Modulation format of the station chosen in Tx select

5. Service Information

5.1 Maintenance

Two regular maintenance operations are recommended for the PI4100.

●**Cleaning:** Clean the unit's outside surface with a cloth dampened with water only, not a solvent, as needed. A mild solvent such as a citrus product may be used for spot cleaning, but do not use a solvent of any kind on the display window, which is polycarbonate. A brush or vacuum may be used to remove dust from crevices.

●**Battery charging:** When not in use the battery slowly discharges itself and its voltage drops. The voltage must not go below 6.0 V before recharging. Therefore if the 4100 is not used for three months or more, charge its battery three to four months after the unit was last used, and at three to four month intervals thereafter until the next use. Experience may show that the maximum time between charges needs to be reduced as the battery ages. If the battery voltage is allowed to go below 6.0 V before charging, the charge time may become very long because the charge rate is low until the voltage exceeds approximately 6 V. For long battery life, store the unit at or somewhat below normal room temperature and avoid excessive heat (see Sec. 4.4, Battery Information).

5.2 Troubleshooting and repair

●**Unit does not operate:** If a PI4100 does not respond when its POWER Key is pressed, the most likely cause is low battery voltage. To check this, open the battery door at the bottom of the panel, pull the battery out, and measure the battery voltage at its connector using sharp probes. If the voltage is less than 6.0 the unit will not turn on and the battery must be charged or replaced.

●**Operating problems:** If a PI4100 or its Data Downloader software appears not to function properly in any respect, the following course of action is recommended: (1) prepare a written description of the problem, including all factors and conditions that might be related to the problem; (2) contact the nearest designated service facility (see Contact information below) with the problem description, in order to discuss the problem. It will then be decided how to deal with the problem, in consultation with the factory. It is also possible to contact the factory directly (see Contact information below) with the problem description in as much detail as possible.

●**Repair:** The PI 4100 is not considered field repairable, except that some minor repairs and possibly module replacement can be done at an authorized service facility. Future problems are less likely when all but the simplest repairs are done at the factory, especially if they involve opening the unit.. See Figure 1, PI 4100 Functional Block Diagram, which depicts the functionality and interrelationship of the replaceable modules. The Front Panel Switch Matrix, LCD Display, GPS Receiver, and GPS antenna are purchased third party components. The remaining modules are manufactured by Potomac Instruments, inc. and their respective schematic diagrams are provided as reduced images in this book but are also provided as PDF files (for greater viewing detail) on the CD that is supplied with the instrument.

●**Repair under warranty:** Units that are under warranty should be returned to the factory for any needed repairs. Potomac Instruments warrants each new equipment to be free of defects in material and workmanship, for a period of one (1) year after the date of receipt in good operating condition by the initial customer. Any instrument which is found within one year not to meet the foregoing standards after examination by our factory, will be repaired or at the option of Potomac Instruments replaced without charge. This warranty does not apply to equipment which has been altered, improperly handled, or damaged in any way.

5.3 Calibration

The PI4100 normally holds its calibration for a very long period with minimal change. Nevertheless, it is prudent to recheck the calibration periodically, especially in situations where repeatability of measurements is critically important. It is therefore recommended that a calibration check be done at two-year intervals. For the greatest certainty a factory recalibration is preferable. When return of a unit to the factory is not practical, a field test to verify the calibration can be done; a detailed procedure for such a verification test appears below. If it is planned to use this test at regular intervals without returning the PI4100 to the factory for calibration, it is recommended to perform the test according to this procedure on the unit when it is first received, using the same test equipment and test setup which will be used for all future tests. This will establish a local basis for judging whether the calibration has changed. For every verification test done it is recommended to keep a copy of the test data sheet together with the factory certificate of calibration in order to maintain a record of calibration test results.

5.4 PI 4100 Calibration Verification Test

General: The purpose of this procedure is to verify that a particular PI 4100 Field Strength Meter continues to perform in accordance with its published specifications and its factory calibration. The test makes use of the 4100's external connectors and loop antenna and requires an external signal generator and a precision voltmeter. It is a detailed version of the test described on the certificate of calibration.

Test Method: The CAL In BNC jack provides a way to check the 4100's calibration using an external signal generator. An RF voltage source at this jack produces an RF current in a conductor at the outside edge of the loop antenna pc board. This current generates an RF magnetic field around the loop antenna which simulates a received radio station field. It induces a voltage in the loop antenna just as a radio station transmission does, and the 4100 measures its value and displays the result as an equivalent received field strength value. The calibration circuit is so designed that the displayed value in dBuV/m (or mV/m) is within ±10 per cent of the RF voltage in dBuV (or mV) at the CAL In jack. This test using an external signal generator is done at the factory after all adjustments and calibration of the 4100 are completed. The test results are recorded on the certificate of calibration supplied with the 4100 and are kept on file at the factory. At any future time, therefore, the overall performance of the 4100 from antenna to display can be checked by connecting a signal generator to the CAL In jack and repeating this factory test. A change in the displayed field strength for the same generator voltage as indicated by the dc output at RF Out would be cause for concern.

Accuracy - the calibration detector: The accuracy of this verification test depends on knowing precisely the calibrating signal generator voltage at the CAL In jack. If the generator output accuracy is specified at +/- 0.5 dB, for example, the resulting 4100 reading could deviate as much as +/- 0.5 dB from the expected value when its calibration has not changed from the factory setting. To prevent generator inaccuracy from affecting calibration, the 4100 includes a precision detector circuit at the CAL In jack which produces a dc voltage equal to the RF rms voltage over the range of 114 – 117 dBuV (500 – 750 mV). This dc voltage can be measured at the RF Out jack center pin using an acccurate, high-impedance voltmeter and is used to adjust the generator output level to the required value in both factory and verification tests. A small uncertainty remains when a different generator is used for verification because the detector dc output for a given generator voltage depends slightly on the generator's output harmonic content.

Low signal level tests: Checking the 4100's accuracy at low signal levels requires a precision 50 Ohm attenuator between the generator output and the Cal In jack. This can be the generator's internal attenuator. Again, test accuracy is limited by the attenuator accuracy. An uncertainty of ± 1 dB in the attenuation value results in ±1 dB uncertainty in the expected 4100 reading, which must be added to the generator output uncertainty.

Verification test, equipment required:

Signal Generator:

Frequency: 520 kHz or lower to 5100 kHz or higher, settable in steps of 1 kHz or less (steps of 10 Hz or less required for bandwidth measurement), accuracy ± [5 x 10e-6].

Output level: maximum, at least 700 mV rms with a 50Ω load, settable in steps of 0.1 dB or less; harmonic level, less than -40 dBc desirable.

Digital DC Voltmeter:

Range: 3-1/2 digits minimum, accuracy ±0.1% or better and resolution 1 mV or better at 500 – 750 mV input.

Input resistance: 10 Megohms minimum.

Verification test procedure:

1. Setup:

Perform this test in a location as free as possible from high RF fields from nearby transmitters. Place the 4100 on a non-metal bench top with no metal objects of similar or larger size less than 12 inches from the 4100 (to avoid affecting the loop antenna). On a metal bench the 4100 can be placed on a non-metal support such as a cardboard box at least 12 inches above the bench.

2. Connections:

Connect the Signal Generator output to the 4100 **CAL in** jack using a 50 Ohm coaxial cable with BNC connectors. No external terminating resistor is required, the jack input resistance is 50 Ohms.

Connect the 4100 **RF out** jack to the digital voltmeter test probes using a BNC-to-clip cable, with the ground clip to the voltmeter low probe and the center-conductor clip to the high probe.

3. Test data sheet:

Prepare a test data sheet showing the following: full identification of the PI4100 under test; the location, date, and time of the test, the test equipment used, and the person performing the test; columns for recording frequency, final generator level setting, 4100 dc detector (RF Out) voltmeter mV reading, 4100 field strength mV/m reading, a corrected value of this reading (if needed, see 5a below), previous field strength reading from the calibration certificate, the calculated ratio of these two field strength values, and any other appropriate data and notes.

Supplied Data Sheet: A Calibration Data Sheet is included on the CD-ROM supplied with the PI 4100. It is a Microsoft Excel™ file, PI4100FieldCalCheckDataSheet2.xls, for downloading to a user's Windows™ computer. To use it, for each frequency enter the following: in Column B, the factory indicated field strength for the unit from the supplied calibration certificate; in Column C, the measured detector dc millivolts; and in Column D, the indicated field strength. Columns E and F will then be automatically calculated. Or, the sheet may be printed and filled in by hand.

4. Tests:

Perform the following procedure at each desired test frequency. For an overall performance test use the applicable test frequencies shown on the calibration certificate: 200, 250, 320, 410, 520, 670, 860, 1100, 1400, 1800, 2400, 3100, 4000, & 5100 kHz.

4a. Turn on the signal generator and set it to the first desired frequency, 520 kHz for a 520 – 5100 kHz unit, and an output level of 117 dBuV or 700 mV, with no modulation. Then, wait for whatever warmup time the generator requires for its output to stabilize. Its frequency must be within 50 Hz of the desired value.

4b. Turn on the 4100 and set it to the same frequency, 520 kHz, using the FREQ SET key as described in the PI 4100 Users Manual. The field strength reading should be in the neighborhood of 700 mV/m and the dc voltmeter reading should be in the neighborhood of 700 mV.

4c. Switch the generator RF output off or to its lowest level, or disconnect it, and check that the 4100 reading is below 1.0 mV/m. If the reading is greater because of an interfering signal, change the 4100 frequency just enough to reduce the interference well below 1.0 mV/m, and change the generator frequency to match.

4d. Perform manual calibration of the 4100 (press and hold LPF until the word CAL in a box appears, and wait until CAL OK appears).

4e. Switch the generator RF output on, returning its level to 700 mV. Check that the generator and the 4100 are set to the same frequency. Readjust the generator output level for a dc voltmeter reading of exactly 700 mV , or as close to 700 mV as possible. Record the 4100's field strength reading in mV/m and the dc voltmeter reading in mV.

4f. Repeat steps 4a thru 4e above for each test frequency.

5. Calculations and Report:

5a. If in **4e** it was not possible to adjust the generator output for a dc voltage of exactly 700 mV, calculate a corrected field strength value by multiplying the measured field strength by the quantity [700/dcmV] where dcmV is the measured dc voltage. Use this corrected field strength value in the next calculation.

5b. Calculate the per cent change in the measured (and corrected, if required) field strength value from the value shown on the calibration certificate, as follows: (per cent FS change) = 100x[(FSmeas – FScal)/FScal] where FSmeas is the value recorded in **4e** or **5a**, and FScal is the calibration certificate value. If a measurement frequency is between two calibration certificate frequencies, estimate the FScal value by interpolation.

Keep a copy of the completed data sheet with the calibration certificate for future reference.

6. Low-level tests:

For checks at lower signal levels a precision attenuator is needed such as are found in the better modern signal generators. A convenient test is to increase signal attenuation in precise 10 dB steps while observing the 4100 dBuV/m reading, which should also change in 10 dB steps. At each 10 dB step the deviation from the ideal field strength value (a multiple of 10.00 dB below he starting value) should be no more than 0.2 dB plus the attenuator error. The lowest level for which measurements are valid is approximately 10 dB above the no-signal noise reading found in the measurement location. The ideal location is a screened enclosure that reduces ambient radiated signals and noise to a low level.

7. RF In jack voltage measurement tests:

RF voltage measurements done by connecting a precision generator to the 4100's RF In jack is another way to evaluate measurement accuracy. This port has its own path into the receiver which bypasses the antenna and most of the RF circuitry ahead of the mixer stage. The procedure is simply to connect the generator directly or through a precision attenuator to the RF In jack, but a T-connector must be used at the jack with an external 50 Ohm terminating resistor. The input resistance at the jack is 2500 Ohms. The RF voltage read on the display is typically within ±5 per cent of the input voltage, ± the generator voltage accuracy.

This check can be done at an input level of 700 mV using the calibrate input detector to eliminate generator level inaccuracy, as follows:

●Connect a BNC Tee connector to the Cal In jack; connect one side of the Tee to the generator and the other side to the RF In jack.

●Connect a DVM to read the dc voltage at the RF Out jack. Adjust the generator output level for a DVM reading as close as possible to 700 mVdc.

●Press MENU, go to Input and select RF In. The 4100 voltage reading should be 700 ± 35 mV.

5.5 Contact information

Factory:

Potomac Instruments inc.
Attn: Service Dept.
7309 Grove Road, Unit D
Frederick, MD (Maryland) 21704
USA

Phone: +1 - 301 - 696 - 5550
Fax: +1 - 301 - 696 - 5553
email: service@pi-usa.com
Time zone: North American Eastern, UMT-5
Web site: www.pi-usa.com

Authorized service facility, India:

Harriban Broadcasting and Communication (P) Ltd
C-2, FIE, DSIDC, Patparganj
New Delhi - 110 092
Phone: 91-11-22162605/22484557
Fax: 91-11-22157281
Cell: +91-9811077882
Web site: www.harriban.com

6. Technical Information

6.1 Introduction

This section contains a description of the PI 4100's circuits with reference to its printed circuit boards as shown on the System Block Diagram, Fig. 1, p. 10. This is followed by schematic diagrams and component layout drawings for the printed circuit boards manufactured by Potomac Instruments.

6.2 PI 4100 Technical Description:

The PI 4100's circuitry is contained on six printed circuit boards (pcbs), which are designated the Antenna, Receiver, Power/Audio, CPU, Display, and GPS pcbs. The pcbs are all interconnected by short ribbon cables. The following paragraphs describe the circuits found on each pcb.

Antenna: The PI 4100 uses a multiturn loop antenna, balanced to ground, formed on a printed-circuit board which is encapsulated in molded plastic. It works into a balanced low-impedance receiver input circuit (on the receiver pcb) for which the signal level to the receiver for a given field strength is nearly constant in the working frequency range. Around the receiving loop antenna on the pcb is a separate single-turn loop to which a calibrating current is fed to generate a calibrating field for self-calibration. Both loops are connected to the receiver pcb by a short ribbon cable.

Receiver: On the receiver pcb the balanced-to-unbalanced receiver input circuit feeds a low-noise, low-distortion broadband RF amplifier which drives the receiver mixer and supplies an external RF output. A frequency synthesizer generates the local oscillator signal for the mixer in 1 kHz steps under the control of the central microcontroller (cpu) and the front-panel keys. The balanced mixer up-converts the selected RF signal to an IF frequency of 10.703 MHz. At this frequency the signal passes through a 4 kHz bandpass crystal filter which gives high adjacent-channel rejection. The filter output drives a three-stage variable-gain IF amplifier for which the gain in dB varies linearly with control voltage. A second crystal filter between two amplifier stages narrows the measuring bandwidth to 1.0 kHz. A detector at the amplifier output is forced to have a constant output by having its output control the amplifier gain, so that the amplifier gain control voltage is proportional to the received field strength (in dBuV/m) and is the output to the measuring circuits on the cpu pcb.

Calibration signal source: Also on the receiver pcb, a calibration signal at the RF frequency is generated in a second balanced mixer for which the inputs are (1) the local oscillator synthesizer which also drives the receive mixer, and (2) a 10.703 MHz crystal oscillator. The frequency difference between these inputs is the RF frequency to which the receiver is set. The mixer provides balanced current-source outputs directly to the two terminals of the calibrating loop on the antenna pcb. The source is switched on only for 700 milliseconds during the calibration cycle under the control of the cpu, as described in Sec. 4.2.3, p. 20.

Power/Audio: This pcb contains the battery charge control IC, with protection circuits and a linear regulator at its input. The battery feeds a second linear regulator to provide the main +5 Volt supply. This in turn drives a dc-dc converter, operating at 5.4 MHz to avoid signal interference, which has outputs at -5 Volts and -17 Volts. There is also a "class D" audio power amplifier to drive the speaker with high efficiency.

CPU: This pcb receives outputs from, and sends inputs to, all other boards. It contains the main microcontroller for the unit; the main memory IC; the USB interface IC; audio response shaping circuits; a 3.3 Volt linear voltage regulator; a signaling buzzer; and various switching transistors. The microcontroller controls the frequency synthesizer, the memory IC, and the USB IC by means of an SPI bus. It directly controls the display, the buzzer, and supply voltage switching. From the front panel key switch matrix it receives row and column inputs, responding when keys are pressed. It receives data messages from the GPS receiver, and calculates and sends to the display GPS derived information. The cpu pcb receives the outputs of the power supply and distributes power to the other boards. The analog voltage proportional to received field strength from the receiver pcb drives lowpass active filters on the cpu pcb, which are selected by the front panel LPF key to smooth the data. The selected filter output feeds an analog-to-digital converter on the cpu IC from which the cpu generates the field strength value directly in dBuV/m units, and from which it calculates field strength in voltage units. For reprogramming the microcontroller in the field the pcb has a connector with cable attached which is accessed through the PI 4100's battery compartment.

Display: The display pcb contains the liquid crystal display and its controller ICs. The display itself has 128x128 pixels and is backlighted by an array of LEDs.

GPS: The GPS pcb and its receiver module are products of the u-blox AG company, which is known for its advanced GPS receiver ICs. The pcb is fed by a ceramic antenna located at the top of the PI 4100's case.

6.3 Printed circuit board drawings

Circuit schematic and component layout diagrams are shown on following pages for the CPU Board, the Receiver Board, and the Power/Audio Board.

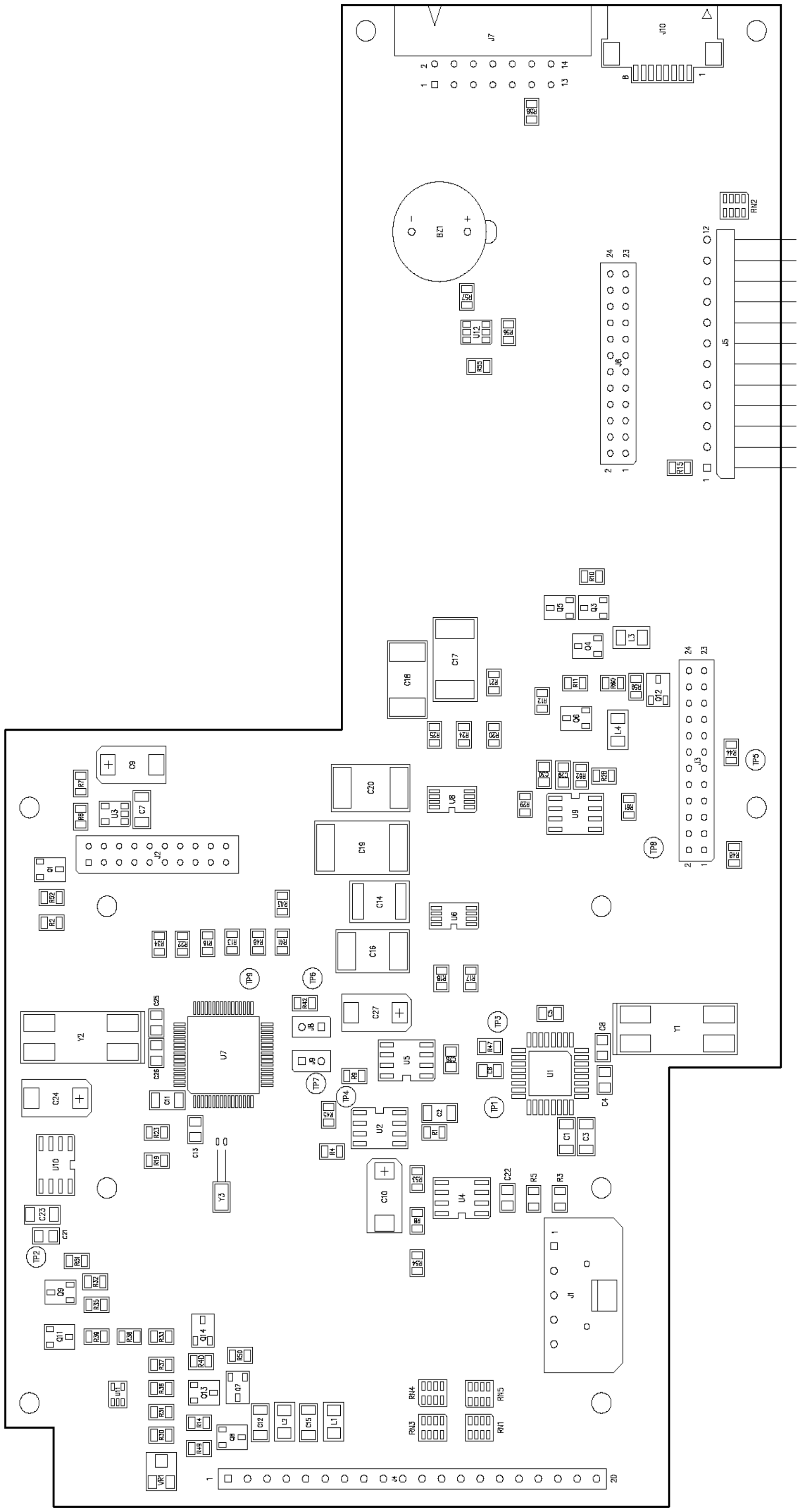

Figure 8   CPU Board layout

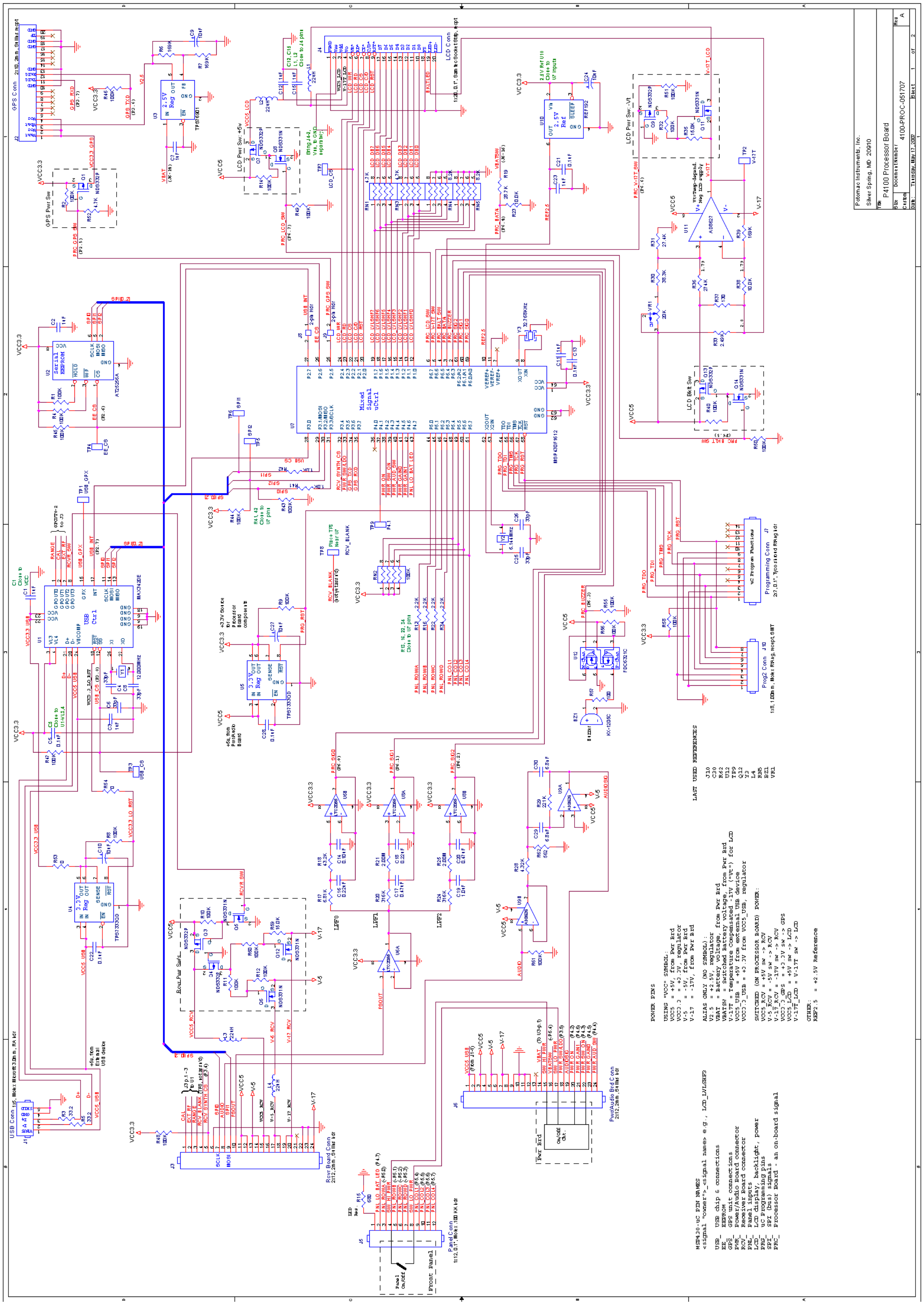

Figure 9 CPU Board schematic

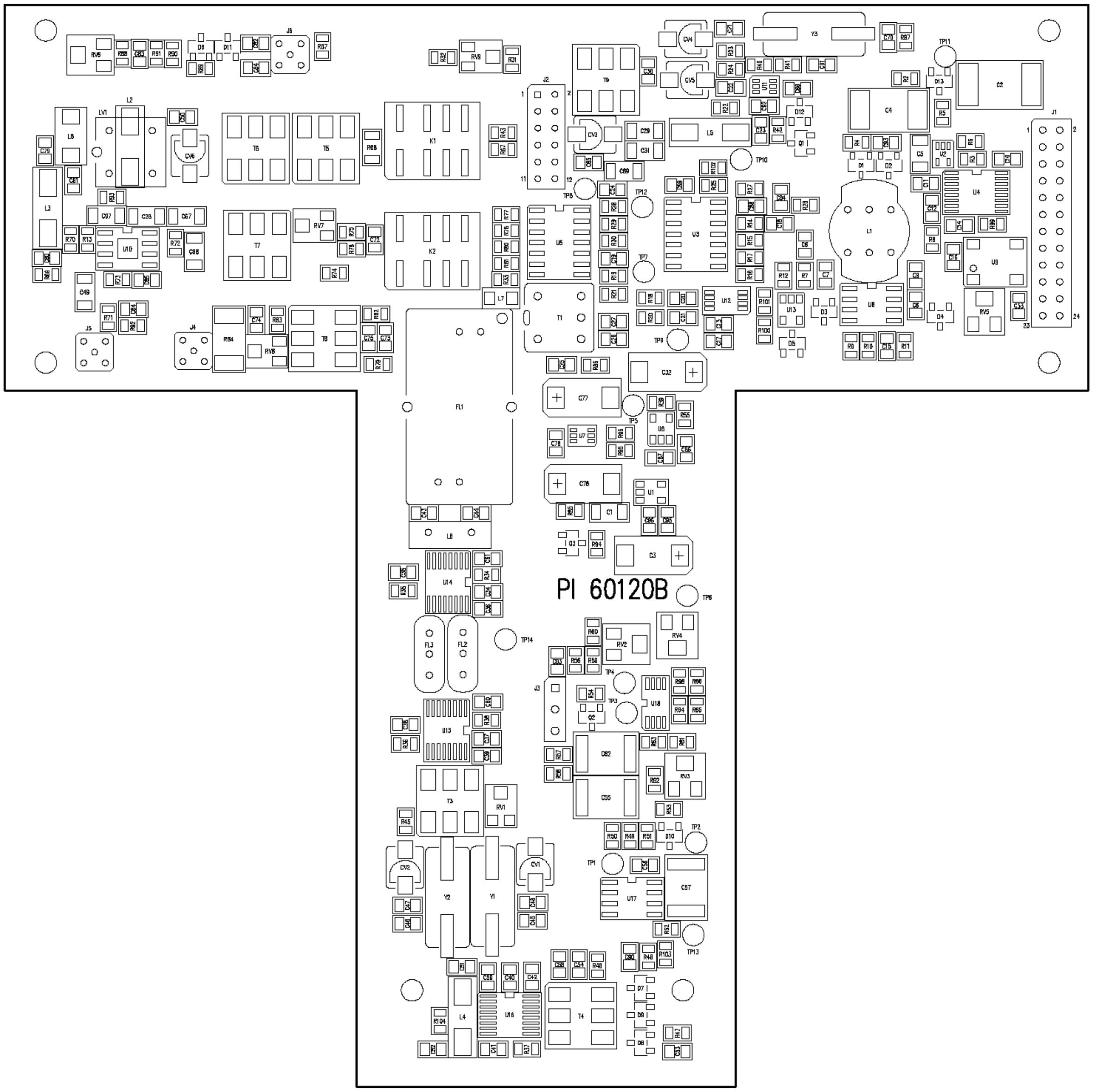

Figure 10 Receiver Board layout

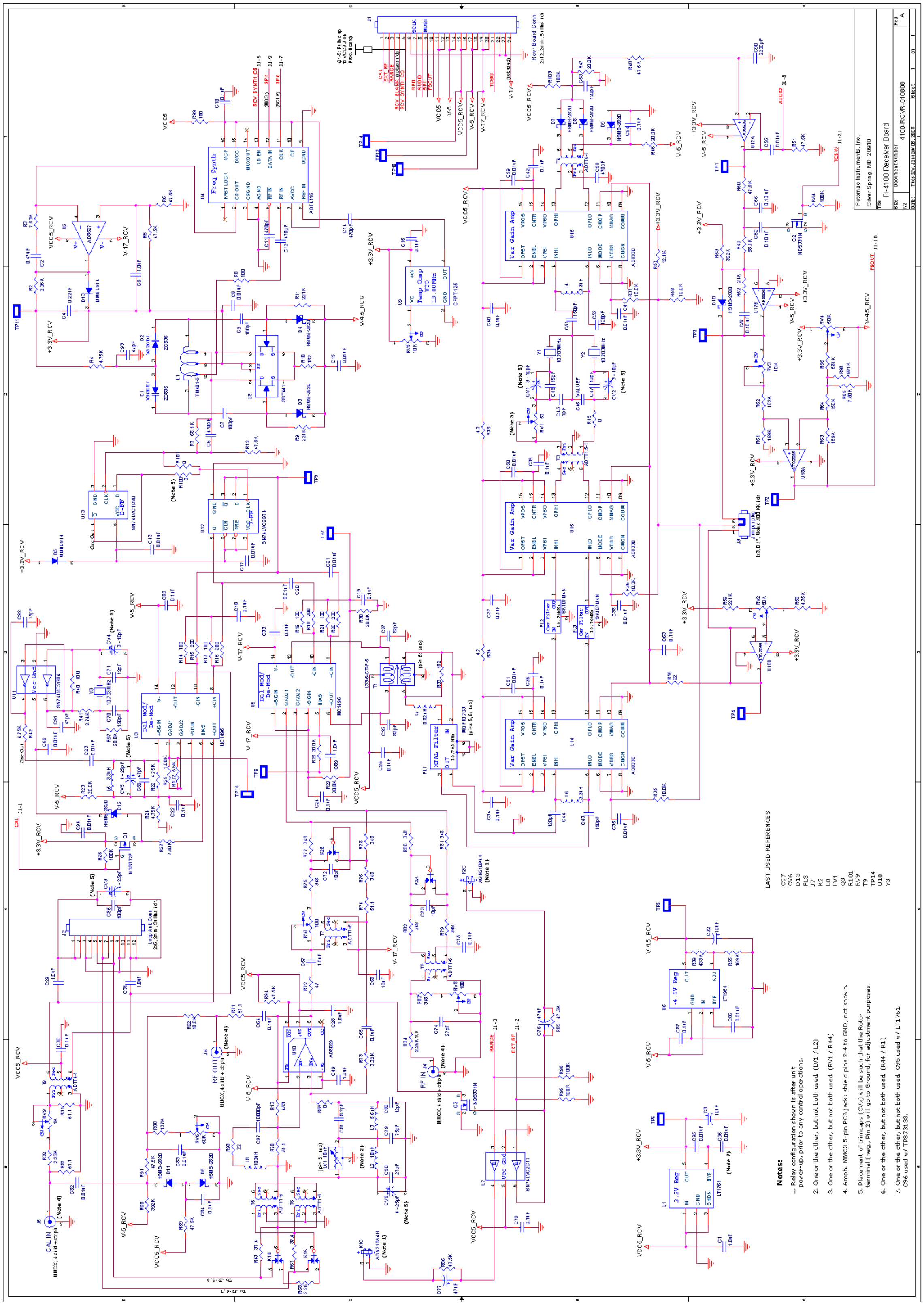

Figure 11 Receiver Board schematic

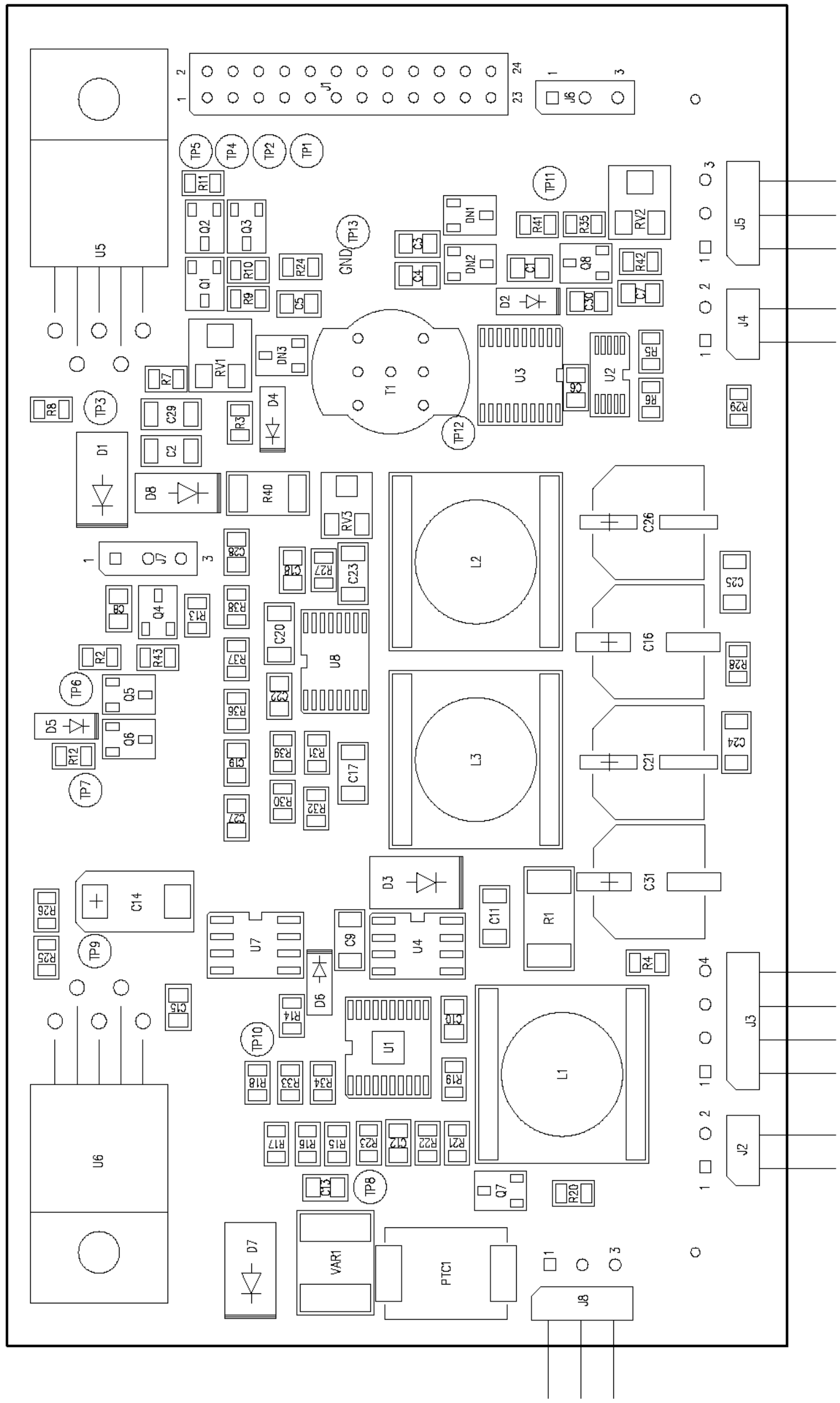

Figure 12   Power/Audio Board layout

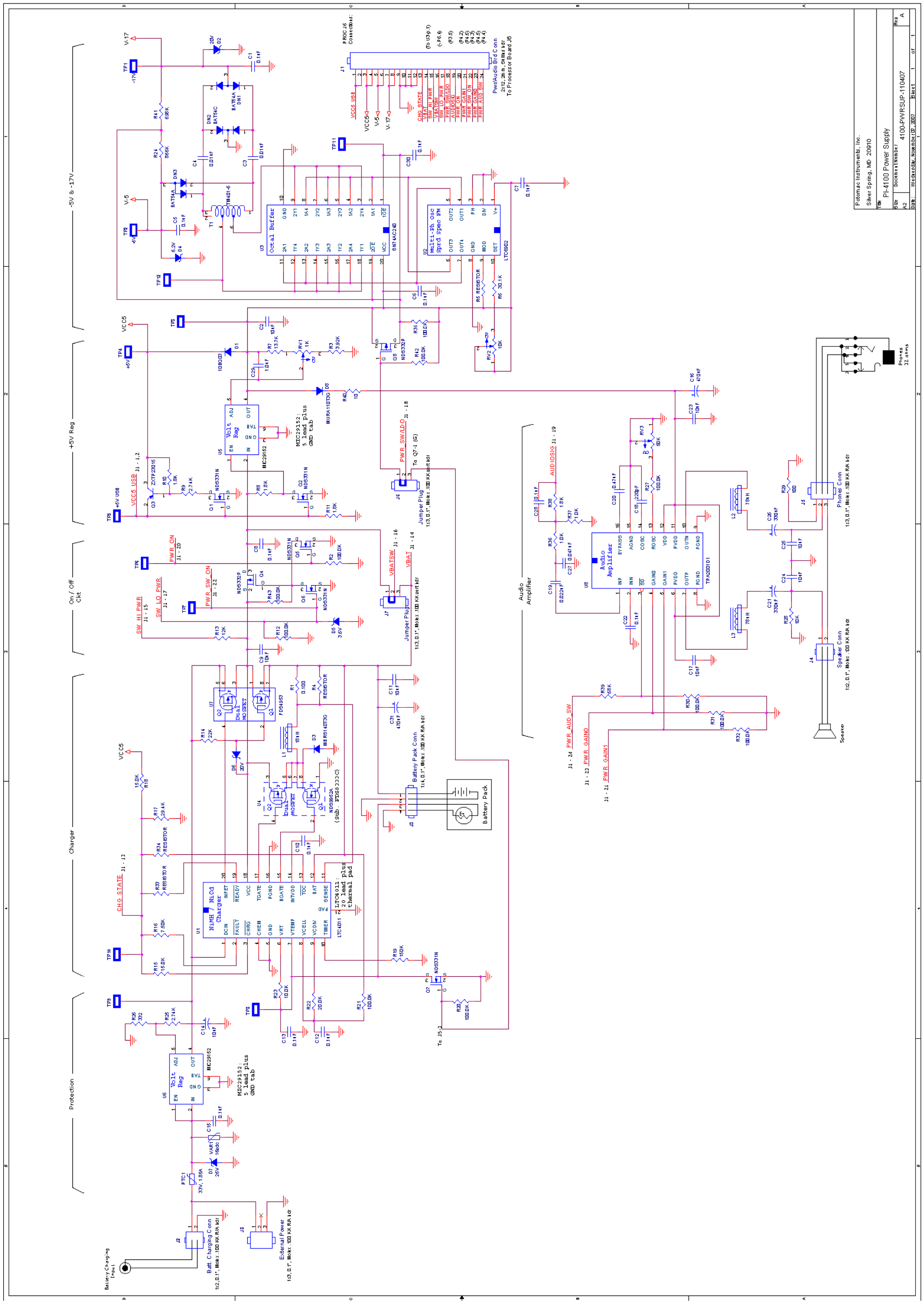

Figure 13   Power/Audio Board schematic

Appendix 1

Using the magnetic compass of the PI 4100

Proper operation of the PI 4100 dictates that, in order to make a measurement, the receiving loop antenna's vertical axis is to remain upright while the longitudinal axis is pointed at the center of the transmitting antenna. Since certain measurements will be made when the transmitting antenna is not visible to the operator, a magnetic compass is supplied as an integral component of the PI 4100 and it can be used for approximating the direction of proper antenna alignment.

At first thought it may seem that a magnetic compass is superfluous when the instrument also includes a Global Positioning Satellite (GPS) receiver. However, the user should quickly realize that the GPS receiver "knows" only its physical location on the earth. The PI 4100 program is, therefore, capable of calculating the True bearing to the transmitter antenna if transmitter coordinates have been entered into the PI 4100 transmitter data base. The GPS cannot "know" the direction that the PI 4100 loop antenna is pointed, for a given measurement, but the magnetic compass that is mounted on the antenna does enable the operator to track that information. However, if the operator is to gain the optimal precision from the magnetic compass, it is appropriate that he or she understand and compensate for differences between Compass Bearing (as indicated by a magnetic compass) and True Bearing which is displayed on the PI 4100 data screen.

A magnetic compass functions by allowing a free swinging magnet to align itself with the earth's magnetic flux lines that result from the flow of the earth's inner core. These flux lines extend between a Magnetic North Pole and a Magnetic South Pole. Magnetic poles differ from the geographic poles by several degrees. And, they move over time which means that the difference between Magnetic North and True North also changes. This difference is known as magnetic declination (or variation). Magnetic declination also varies from place to place and, like the position of the magnetic poles, it changes from time to time. It is carefully tracked by geologists around the world and the value of declination is published on some topographical maps and virtually all air and sea navigational charts. [If you wish to calculate magnetic declination at any location on earth, at any date from 1900 to 2010, for which you know the geographical coordinates (Latitude and Longitude) that information may be obtained from the U.S. National Oceanic and Atmospheric Administration's (NOAA) web site at the following internet address:

http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp]

If the PI 4100 operator enters the appropriate magnetic declination information when the entering the transmitter coordinates (via the Tx add menu or the Tx edit menu) the magnetic bearing to the station is displayed in the BRG ### º Mag block in the center left of the display.

There is one additional factor which must be considered with regard to "compass bearing" and its relationship to "magnetic bearing." Magnetic deviation may, or may not, exert an influence on magnetic heading to yield the final compass bearing. Magnetic deviation encompasses the combined magnetic field distortion effects caused by ferromagnetic material in close proximity to the compass. The effect of magnetic deviation is site specific and cannot be predicted accurately. Accordingly, it is important for the PI 4100 operator to understand that the magnetic bearing that is displayed on the display screen may differ, slightly, from the compass heading as indicated by the instrument's magnetic compass and that this difference can vary from one measurement location to the next.

The foregoing discussion is summarized by the two following, age old, formulas: Compass Bearing ± Deviation = Magnetic Bearing and Magnetic Bearing ± Declination = True Bearing.

(This page left blank)

Appendix 2

PI 4100 OPERATION QUICK REFERENCE

The 4100 has on-screen help for most operations. In the menu use up & down arrow keys to go to an item. To select a digit to change use left & right arrow keys. To change the digit value use up & down arrow keys.

Turn the 4100 on: Press POWER/BKLT until text appears.

Turn the backlight on/off: Short press of POWER/BKLT.

Turn the 4100 off: Press POWER/BKLT until text disappears, in approximately 2 sec.

Set frequency and get GPS-derived distance, azimuth, bearing, and time: Press MENU, press SELECT to get Tx select, choose frequency, press MENU two times.

Enter station data needed to get GPS-derived data: Press MENU, choose Tx add, follow on-screen help to enter the antenna latitude and longitude and the declination/variation. For declination go to: www.ngdc.noaa.gov/geomagmodels/Declination.jsp.

Set frequency: (no GPS-derived data) Press FREQ SET. Change frequency digits using on-screen help.

Preset a frequency: 1) Select the frequency in MENU - Tx select; 2) press FREQ PRESET; hold down an Fn key until a beep is heard.

Set frequency using presets: Press FREQ PRESET; give a short press of the Fn key for the frequency.

Listen to audio: Press AUDIO. To change the level through four steps press AUDIO for each change. To turn audio off press AUDIO for at least 2 sec. To use headphones and mute the speaker, plug phones into the rear jack.

Point the 4100 loop antenna using GPS-derived data: Note the on-screen BRG (bearing) reading and rotate the 4100 with the loop vertical until the compass reading equals the BRG reading.

Start a self-calibration: Set the frequency; hold down LPF until CAL in a box appears on the screen.

Reduce field strength reading variations: Short press of LPF, LPF1 on display changes to LPF2; for less variation and slower response press LPF again, display shows LPF3. To return to normal response press LPF again, display shows LPF1.

Hold a field strength reading on the display: Press HOLD. To exit hold press HOLD or SAVE.

Save a field strength reading: Press SAVE, enter SAVE screen data as desired per on-screen help, press SAVE again.

Enter SAVE screen data for later use: Press SAVE, enter data, press MENU.

Delete a measurement record: Press DELETE, go to the desired record, press SELECT to delete it.

Change the units in which field strength is displayed: Press MENU, go to Fld Str 1 or Fld Str 2, follow on-screen help.

View a spectrum showing dB below the carrier (dBc): Set the center frequency on the field strength screen and press MODE once.

View a spectrum showing dBc with peak hold: Do as for dBc above but press MODE two times. The 4100 needs a stable mount for this.

View a spectrum showing absolute field strength: Press MODE three times.

Change the spectrum span (sweep width): Press MENU, go to Spectrum kHz: 128 45, follow on-screen help.

Go to the field strength screen from a spectrum screen: Repeat presses of MODE until the field strength screen appears.

Measure a harmonic in dB below the carrier (dBc): Set the desired carrier frequency, position the 4100 for a field strength reading between 300mV/m and 3 V/m (110 - 130 dBuV/m), press MENU, go to Harmonic: 1 2 3 4 5, follow on-screen help to choose a harmonic and return to the field strength screen.

Measure RF voltage: Press MENU, go to Input: LoopAnt RF in. Press the right arrow key to change to RF in and press MENU. Connect the source to the rear RF In connector (Input R = 2500 Ohms, Vmax = 40 Vrms). To return to field strength reading press MENU, go to Input, press the left arrow key to change to LoopAnt, press MENU.

Display local time correctly: Press MENU, go to UTC Offset, enter the difference between UTC and local time (for US EST, enter -05h00m).

Use the loop antenna to drive a spectrum analyzer: Connect the RF Out connector to the spectrum analyzer input. The level for a 1 V/m (120 dBuV/m) field is 28 mVrms (89 dBuV) in 50 Ω ±0.5 dB, 200 kHz - 5 MHz. To obtain field strength from the analyzer display multiply by 35.5 or add 31 dB.

Check/Change the GPS datum: Press MENU, go to GPS Datum, follow on-screen help.

Set the time of non-use for automatic turnoff: Press MENU, go to Auto off:, follow on-screen help.

Check the need for battery charging: Read the battery voltage on the display at the upper right. Less than 7.0V indicates less than one hour of operation remaining. The 4100 turns itself off at 6.0V.

Charge the battery: Connect the charging supply output cord to the 4100's charging connector (rear, upper right, middle connector) and connect the line input power cord to the line. Or, connect the vehicle charging cord to the 4100 and to the vehicle lighter socket. A full charge takes three hours, a partial charge is OK, the 4100 can be on or off. Voltage required is 11-15V, negative ground, 1.3 A, 2.1 mm connector.

Replace the battery: Pull the battery door open (bottom of front panel) starting with the upper left corner. Pull the battery pack out, disconnect it (press on the tab at the battery side of the connector), connect the replacement pack, insert it with its cable to the right, and push the connector under the battery. Close the door, pressing its side edges and then its top edge until it snaps in all around.

Download measurement data to a computer: Install and open the 4100 Data Downloader program supplied. Connect a USB A to B cable with the B plug to the 4100 (rear, upper right, lower connector). The 4100 can be off; if it is on, it will go off when the cable is connected. Click the Download button specify a .csv file name and destination, and click Save. All data records in the 4100 are then downloaded. Open the .csv file in a spreadsheet program where selected items can go to a data sheet template. Downloader program buttons indicate other tasks it can do.

Get a dc output voltage proportional to field strength in dBuV/m**:** Connect to the RF In BNC connector. The open-circuit (no load) output level is 1.0 V at 100 dBuV/m.

Appendix 3

Sample Excel® Field Strength Measurements Report

This appendix gives step-by-step instructions for using the data report template for Microsoft Excel®, **4100 Data Report.xlt,** supplied on the PI4100 CDROM.

1) Copy the Excel® file **4100 Data Report.xlt** to your default Excel folder or as deemed appropriate
2) Start Excel
3) From within Excel, open the desired PI 4100 data file (xxxxxx.csv)
4) Move the cursor to highlight cell A1
5) Press and Hold the Shift Key
   a) Press the RIGHT arrow key until the highlighted area includes cell AC1
   b) Press the DOWN arrow key until the highlighted area includes :
      i) The entire block of data to be covered by the report or
      ii) A maximum of 23 data records
6) Release the Shift key
7) From the Menu Bar, click on "Edit"
   a) From the drop down menu click on "Copy"
8) Minimize the PI 4100 data file (xxxxxx.cvs)
9) Open the WORKBOOK TEMPLATE 1.xls file
10) Select Sheet 2
11) Move the cursor to highlight cell A1
12) From the Menu Bar, click on "Edit"
    a) From the drop down menu click on "Paste"
13) Select Sheet 1
14) Highlight meaningless data (from empty data cells, etc.) if any
    a) Press the Delete key
15) Preview the file as desired
16) Save this file under a new name
17) From the Menu Bar, click on "File"
    a) From the drop down menu click on "Save As"
18) Add additional comments or edit the header and records of renamed file, as desired, then save when you are finished
19) Print the new file as desired
20) Close the **4100 Data Report.xlt** file but <u>DO NOT SAVE CHANGES</u>

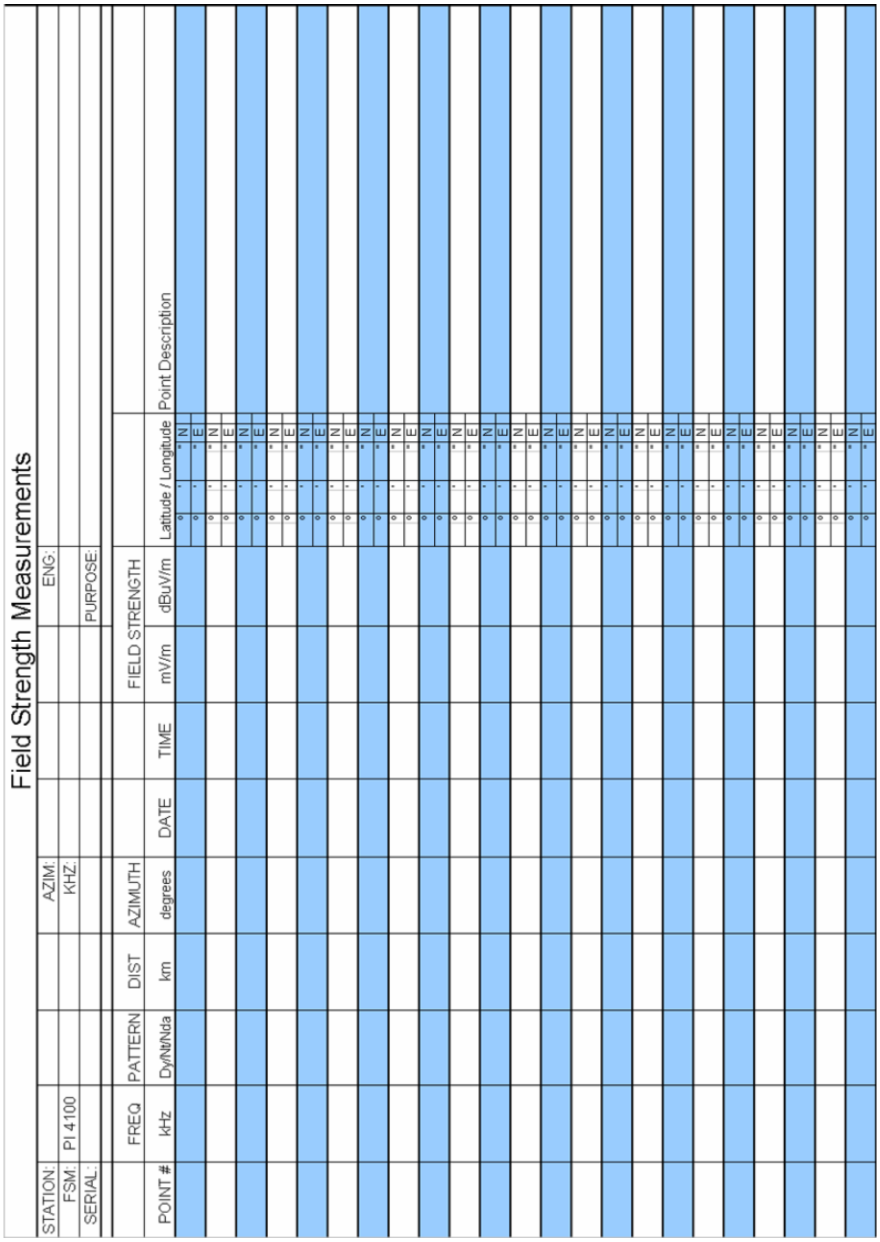

Figure 14. PI 4100 Data Report Template

Appendix 4

PI 4100 Accessories

Potomac Instruments recommends the following accessories for use with the PI 4100. Some are available from Potomac Instruments and some are available direct frAom their manufacturer. Contact Potomac for further information about any of them.

●**Hard Case** for transport and shipping, the **Pelican 1610:** This is a rugged hard plastic shipping/carrying case that will protect the PI 4100 from damage in transport. It isavailable from its manufacturer or dealers. Its outside dimensions are 25x20x12 inches, 63x50x30 cm. Refer to the web address pelicansuperstore.com/products/pelican-1610-case.html for details and for direct purchase from the manufacturer. The 1610 case requires a plastic foam insert with cutouts to fit the 4100. The foam insert in which the 4100 is shipped from the factory fits the Pelican 1610 case exactly and can be used without modification. This foam insert can also be purchased separately, see below.

●**Foam Insert, Part No. LM10529:** The Pelican 1610 case requires a plastic foam insert having cutouts to fit the PI 4100. This insert is available from Potomac Instruments.

●**Battery Pack, Part No. EPG-1068:** A spare/replacement rechargeable NiMH battery pack identical to the one supplied initially in the PI 4100. It is available from Potomac Instruments.

●**Charging Cable, Part No. LM10541:** A cable which plugs into a vehicle's cigarette lighter socket and the PI 4100's charging jack, identical to the one supplied with the unit. It is available from Potomac Instruments.

●**Unipod, Part No. UNIPOD:** A telescoping "leg" which screws into the PI 4100's tripod mount to support the unit's weight It is available from Potomac Instruments.

●**Tripod:** A tripod rated for at least 15 lb or 7 kg, having a 1/4"-20 mounting screw, is recommended. Potomac Instruments does not offer a specific model but can suggest one.

●**Headphones:** Any mono or stereo headphone set having practically any impedance and a 3.5 mm or 1/8 in. plug can be used. Potomac Instruments does not offer a specific model but can suggest one.

●**Soft carrying case:** When carrying the PI 4100 on foot, a soft case with shoulder strap can provide hands-free carrying and can protect the unit from dust and rain. A suggested model is the Timbuk2 Messenger, size large, which is available in several variations and custom colors on the web at timbuk2.com.

●**Remote Antenna Kit:** The PI 4100 can be operated with its loop antenna separated from the body of the unit by a cable having special adapters at its ends to connect to the antenna and the body. Self-calibration (4.2.3, p.20) operates in this mode and measurement accuracy is essentially the same as for normal operation for frequencies below 1800 kHz. A standard cable length of 25 ft is available, and other lengths are possible. The cable and adapters are available from Potomac Instruments as a kit; contact Potomac for further information.

Potomac Instruments, inc.

7309 Grove Road Unit D
Frederick, MD 21704, USA
+1-301-696-5550
http://www.pi-usa.com

PI 4100 User's Guide