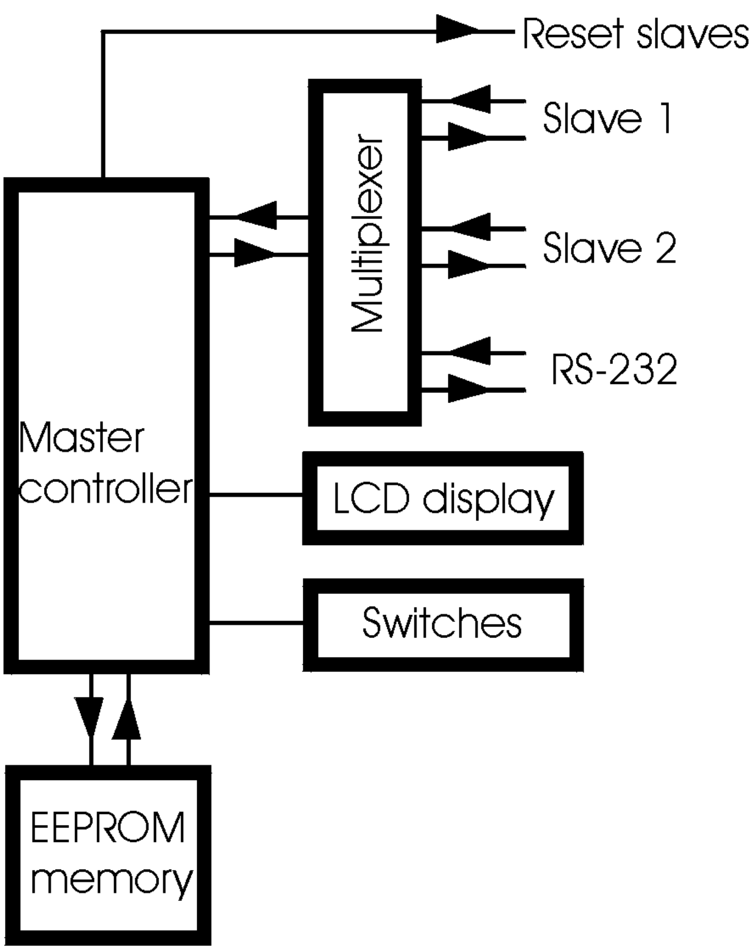
Gradiometer

Introduction

The 56 page document previously published by me on the Web describes, in a general way, the design of a gradiometer using two proton-precession magnetometer sensors. This document describes an implementation based on those design principles.



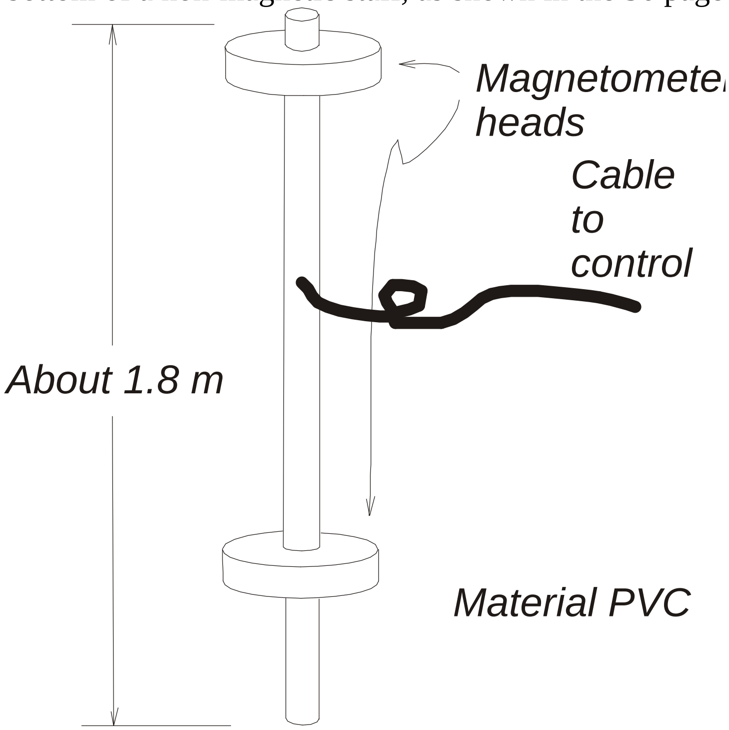
Block diagram of Gradiometer

The basic gradiometer block diagram is shown below. The two slave units are each, simply, the 'stand-alone' proton-precession magnetometer described on my Web site. The function of the master controller is to provide an interface between the human operating the instrument and the slave PPM's which make the measurements. The human input is via a bank of push-button switches for input and an LCD display for output. There is also an RS-232 serial interface between the master unit and an external computer. This is used to transfer stored data, perhaps from a series of operations in a particular area, from the gradiometer to an external computer.

I will start by describing the general operation of the instrument and then describe, in more detail, the functions of the various parts of the instrument. A complete circuit diagram is included in this document.

Operation of the gradiometer

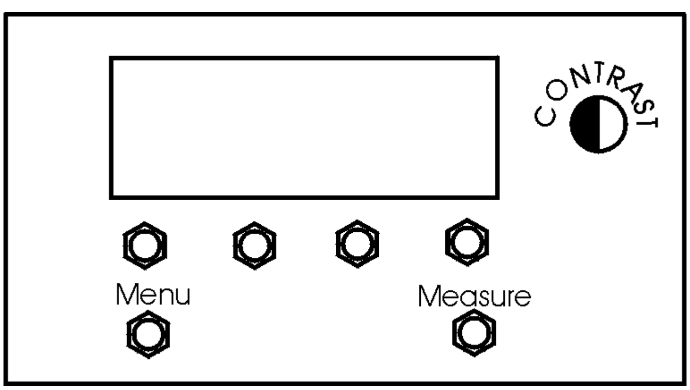
This gradiometer is meant to be hand-operated with the two sensors at the top and bottom of a non-magnetic staff, as shown in the 56 page document and reproduced here.



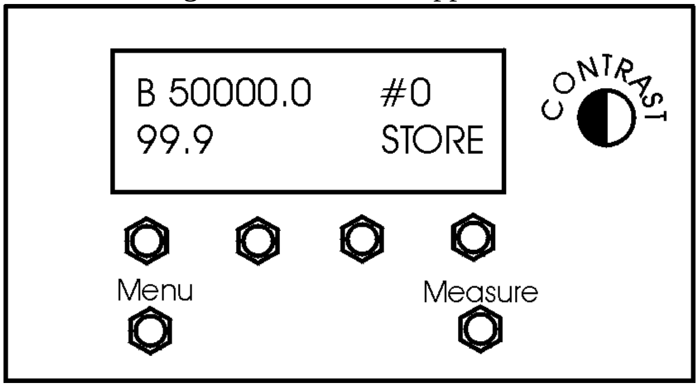
The control box has, on its top surface, a two-line LCD display and six push-button switches. All the operations of the unit are controlled through these six switches. Because the instrument is fairly complex, these six switches have functions which depend on a number of menus shown in the LCD display.

There is no ON-OFF switch. Power is applied to the instrument by connecting the battery and the instrument is turned off by disconnecting the battery.

The layout of the panel of the control box is shown below. Of the six switches, two always have the same function. These are the bottom two switches. That on the left, selects which menu appears on the LCD. This governs the operating mode of the instrument. That on the right starts a measurement when the instrument is in a mode where measurements are allowed. The remaining four switches have a function which is indicated by the line just above them in the LCD display. The knob controls the contrast of the LCD display. It would be convenient not to have to worry about this but a field instrument is used in light conditions varying from bright sunlight to near darkness illuminated by flashlights. This control allows you to set the display to be as clear as possible under these widely varying conditions.



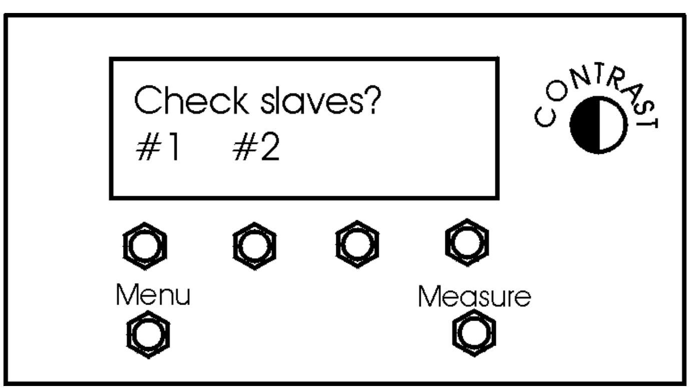
When the instrument is turned on, a logo, “DJ Gradiometer” flashes briefly on the top line of the display and then them instrument goes into its main operating mode. The LCD display will look like that shown in the next illustration. The top line shows the measured magnetic field of the upper of the two sensors on the staff. When the



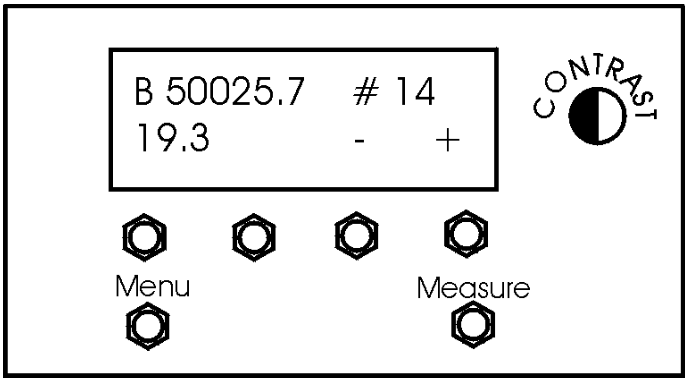
instrument is first turned on, as no measurement has been made, it will show a value of 50000.0 nT. The number following the '#' symbol the end of the top line is the number of measurements which have been stored in the internal memory. This memory is not volatile (i.e., it remains even when the power has been turned off) and therefore this number will show the number of measurements stored previously if some have been stored.

The second line shows the difference between the bottom sensor and the top sensor in the last measurement made. When turned on initially, this will read 99.9. At the end of the second line, the word ,'STORE', is shown. This is above the last switch in the row under the display so it indicates that this switch is to be pressed if you want to store the measurement presently being displayed into the non-volatile memory. Obviously, we would not want to press this till after a new measurement had been made. Pressing the 'Measure' switch will start a new measurement. If the 'Store' switch is subsequently pressed, the values will be stored into non-volatile memory and the number shown will increase by one. The instrument has the capability to store 4096 separate measurements.

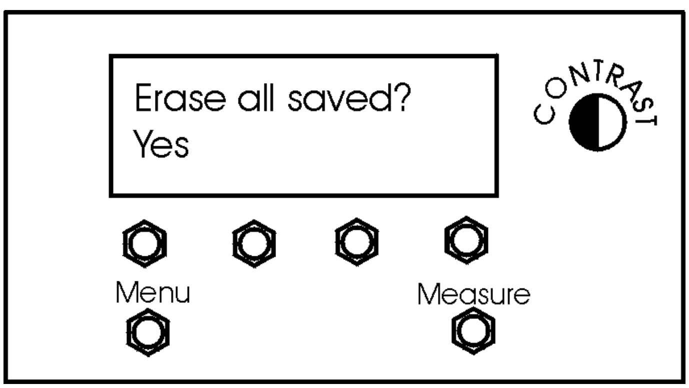
This basic operating mode is the main mode of the instrument. The difference shown, being the magnetic field at the lower sensor minus the magnetic field at the upper sensor will be positive if the lower magnetic field is stronger than the top magnetic field. This is the case when there is some ferro-magnetic material closer to the bottom sensor than to the top sensor. Therefore, if the staff is placed, for example, over a ferrous meteorite, the difference reading will be positive. If the instrument happens to be under an overhanging ledge containing some ferrous material, the difference reading will be negative.



If the 'Menu' button is pressed, the instrument will go into a diagnostic mode to allow one to check the operation of the two slave processors. The display is that shown next. Pressing the button just under the #1 checks for the correct operation of slave magnetometer #1 (the top one) whereas pressing the button under the '#2" checks for the operation slave #2 (the bottom one). These diagnostics only work correctly if the slaves have been operated at least once since the power was turned on. If you select this menu just after turning on the power and before any new measurements have been made, the instrument will respond with a message that the slaves have not been turned on. The normal response, assuming that the slaves have been turned on, is that the particular slave has responded correctly. If it does not, the response will be to that effect. This operating mode is useful if you get some strange readings – you can see if the slave magnetometers are working properly or not.



Pressing the 'Menu' button again brings you to a menu which allows you to look at previous measurements stored in the internal non-volatile memory. The control panel will look like that on the left. The number at the end of the top line is the number of the stored measurement. In this case, it is number 14. The values shown are those of that particular measurement. There is a minus sign above the third button in the top row. Pressing this will decrement the measurement number so that, in this case, you can look at measurement number 13. Pressing it again will give you measurement number 12 and so on. Pressing the number at the end of the top row under the plus sign will increment the measurement number you can look at. You can use these two buttons to cycle through all the measurements stored in the non-volatile memory.



Pressing the 'Menu' button again will bring you to the last mode which allows you to erase the non-volatile memory. The control panel will look like that to the left. If you press the button under the 'Yes', it will lead you to another menu asking the question again with the 'Yes' over a different button. Pressing any other button will bring you back to the main operating menu without erasing the non-volatile storage. In all, you have to press the correct button ***four times in a row*** in order to actually erase the memory. At any time along the way, pressing any other button brings you out of this mode without erasing the memory. This rather elaborate procedure is to ensure that you don't accidentally erase the memory. After a long day in the field, it is easy to make mistakes. The long process necessary to erase the memory ensures that you can't do it accidentally – you have to be fairly determined to do so.

To summarize, the main operating mode is controlled by the first menu that appears. You can cycle through the menus by pressing the ‘Menu’ button. The second menu allows you to check the operation of the slave magnetometers. The third menu allows you to look back through the stored values in memory. The fourth menu allows you to erase the stored values in memory.

Also part of the interface to the outside world is the RS-232 interface designed to let you send all the values stored in the memory to an outside computer for future reference. The plug is compatible with the normal 9-pin Type-D connector used as the serial port on most PC clones. All that is needed is a cable with a male 9-pin Type-D connector on one end and a female on the other. You will need some sort of ‘terminal’ program running in the external computer because you need to send commands to the instrument. The instrument works at 9600 baud. Sending is an ‘n’ or ‘N’ causes the instrument to send back the number of internally stored measurements in its memory. Sending the instrument a ‘d’ or ‘D’ causes it to send out the measurements one after another. Each measurement is the two values of magnetic field measured at each of the sensors followed by an ASCII CR (carriage return) character. Thus, if there were, for example, three measurements in memory and you sent the instrument a ‘D, it would respond by sending back:

50123.4 50234.1<CR>
50110.1 50123.1<CR>
50234.1 49999.9<CR>

In each measurement, the first number is the value measured at the top sensor and the second is that measured at the bottom sensor. Most terminal programs allow you to save files of inputted data and you would normally want to save the results for future reference.

Each line has 16 characters in it and the storage capability of the instrument is 4096 measurements. Thus, if the memory were completely full, it would have to send out 4096*16 characters – a total of 65536 characters. At 9600 baud, it takes about 1 mS to send a character. Therefore, in this case, to send out all the memory would take about 65 seconds, give or take. This is not unreasonable.

Comments about various parts of the instrument

The LCD display

LCD displays are widely available from a number of suppliers. The interface has been pretty well standardized and they mostly use a set of Hitachi integrated circuits to actually drive the display. The instrument uses a display which shows two lines of sixteen characters each. It is a matter of taste but I consider it advisable to get the display with the largest characters possible for a field instrument. Normal displays have rather small characters but it is an option to get much larger ones. There are a number of suppliers for LCD displays and suggestions will be given later.

The switch bank

The switches are simple single-pole, single-throw push button switches. For a field instrument, dust is a problem so it is worthwhile to buy good quality enclosed switches rather than the cheaper kind you find in Radio Shack stores, etc. C&K make a good quality switch and they are cited in the parts list. Most electronic suppliers (Digikey, Newark, Mouser) carry C&K switches.

The RS-232 interface

In this instrument, the RS-232 interface is provided by a Maxim TTL to RS-232 converter IC. The Type-D connector on the instrument is 9-pin female.

The serial EEPROM memory

The internal non-volatile data storage is provided by an Atmel AT25256 integrated circuit. This circuit can store 32K bytes of information and keeps the information intact when the power is removed. Each measurement takes 8 bytes – four for each sensor. Therefore, the 32K bytes provided space for 4K measurements.

Construction

As described in the 56 page document referred to earlier, the relay modules were built into the central portion of the staff roughly equidistant from the two sensor heads. Each of the sensors is connected to a circuit which is the same as that drawn for the 'stand-alone' magnetometer. A cable from the staff goes to the control box. It is plugged into the control box by a 9-pin Type-D connector. Any suitable connector will do but it should not have any ferrous parts and the pins must be capable of carrying the polarizing current to each of the two sensor heads. For my sensors, the total current draw during polarization was just less than 4 Amperes. Because each sensor is polarized and switched simultaneously, the relay signals from only one slave processor (either one, it doesn't matter) can be used.

With the exception of the relays and associated circuits which are located in the centre portion of the staff, all the remaining electronics are located in the control box. A photo of this is shown in Figure 1. The box is a plastic ‘utility’ box which is about 7.5”x4.5”x2.5” and was bought at Radio Shack. There’s nothing magical about the size; there has to be enough room for the display, the six push-button switches and the electronics.

The electronics was built on 3.5”x4.5” pc-boards using the technique I showed in the ‘stand-alone’ document. Since there are two sensors, you need two complete circuits of pre-amplifiers, intermediate amplifiers, tuned amplifiers, etc. I built the two pre-amps and the following intermediate amplifiers on one board, the tuned amplifiers and comparators on another. These two boards were stacked on top of one another using aluminum spacers and aluminum screws. The digital electronics (two slaves, master and associated circuitry) was wire wrapped on a third board. I found it convenient to have the front panel connected to the microprocessor wire wrapped board using ribbon cables and connectors on the wire wrapped board. The power input connection was a coaxial power connector of the type you find on small consumer electronic devices. Be sure to get a large enough one to handle the current. The connector has to be able to handle the total polarization current. When not polarizing, the current drain is less than 100 mA.

The circuit is just two complete ‘stand-alone’ magnetometers followed by the master controller which controls the two ‘slave’ units as shown earlier. There are some modifications to the stand-alone circuitry but they are minor. The various modules making up the whole are shown in the diagram GR_connection.PDF. The preamplifier, intermediate amplifier and tuned amplifiers are identical to those in the stand-alone PPM. The relay module, slave microprocessors are changed slightly from their stand-alone equivalents. The remaining figures complete the complete circuit diagram. All the construction ***caveat***s described in the stand-alone document should be followed.

With the exception of the master microprocessor and the memory IC, all the parts are widely available from suppliers like Digikey, Mouser or Newark. The author will supply a programmed MASTER microprocessor, the AT25256 memory IC and the DS1233 IC for $60 plus $3 PP (USD) plus a parts list. Send cash or money order to:

J.A. Koehler
RR2, Site 292, C56
Courtenay, BC, V9N-5M9
CANADA