T-1

Web-enabled Precision Hall Probe

User Guide
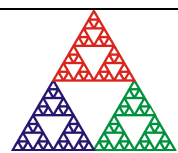
	Pyramid Technical Consultants, Inc.
	135 Beaver Street Suite 102, Waltham MA 02452 USA
	US: TEL: (781) 402 1700 ♦ FAX: (781) 402-1750 ♦ EMAIL: SUPPORT@PTCUSA.COM
	Europe: TEL: +44 1273 492002

1 Contents

2   Introduction

Thank you for your purchase of the T-1 Precision Hall probe system. The T-1 allows fast and accurate measurements of magnetic flux density from a compact and cost-effective unit. The active HP-1 probe is made from non-conducting materials to eliminate eddy current effects and uses tightly twisted signal lines and differential signals to give excellent noise immunity. An integrated sensor measures temperature right at the Hall element to provide accurate temperature compensation of the field reading. The standard configuration of T-1 and HP-1 probe allows fields up to +/- 28 kGauss (+/- 2.8 Tesla) to be measured at rates between 10 Hz and 25 kHz.
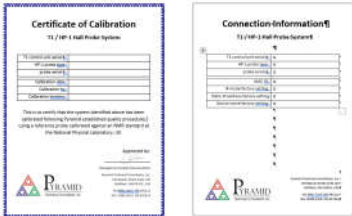
The T-1 control unit provides a standard network connection for control and readback to allow simple integration into control systems. The analog voltage output can be used to monitor the measured field via a meter, oscilloscope or digitizer.

Multiple T-1 units can be distributed to monitor magnetic field in multiple locations, and all communicate with a supervising computer system. The T-1 has a web page interface allowing any standard web browser to display the measurements. It is also easy to collect the data into your own software.

This User Guide provides the information you need to start making measurements with the T-1. More detailed information is provided in the T-1 Technical Manual.

3 What's in the box?

Unless your order was for a special configuration, you should have received the items shown below. If anything is missing or damaged, please contact your supplier.

T1 control unit	
HP-1 active Hall probe	
Connecting cable (part CAB-T1-6)	
Ethernet cable	
Universal power supply (part PSU24-25-1)	
Calibration certificate and connection information sheet	
USB drive with documentation and software	

The line cord for the power supply can be selected to suit your local mains connector type at time of order. The connector on the power supply end of the cord is an IEC C7 two conductor type.

4 Safety Information

The T-1 and HP-1 probe are designed for compliance with harmonized electrical safety standard EN61010-1:2000. They must be used in accordance with the specifications and operating instructions. Operators of the unit are expected to be qualified personnel who are aware of electrical safety issues. The customer's Responsible Body, as defined in the standard, must ensure that operators are provided with the appropriate equipment and training.

The unit is designed to make measurements in **Measurement Category I** as defined in the standard.

⚠️ ⚠️	The T-1 does not itself generate high voltages or magnetic fields. However, your application may involve measuring high fields in electromagnets and high voltages may present on electromagnet coils. Take special care when making measurements where high fields or voltages are involved.

The T1 must not be operated unless correctly assembled in its case. Only Service Personnel, as defined in EN61010-1, should attempt to work on the disassembled unit, and then only under specific instruction from Pyramid Technical Consultants, Inc. or their authorized distributors.

The T-1 unit is designed to operate from +24 VDC power, with a maximum current requirement of 250 mA. The HP-1 probe is powered by the T-1. A suitably rated power supply module is provided.

When installed in a permanent location, the T-1 unit should be grounded by secure connection to a grounded conducting surface. If the unit is mounted on an insulating surface, then one of the four mounting screws must be re-assigned as a grounding connection. An adaptor for DIN-rail mounting is available.

5 Intended use

The T-1 is intended for magnetic flux density measurement, particularly in electromagnets in networked systems. The field can be monitored at rates suited for real-time monitoring and field control. The probe design eliminates magnetic materials or conducting surfaces that would distort the measurement of AC fields. The HP-1 probe is particularly suited to measure the magnetic fields typical of ion beamlines which use conventional (non-superconducting) electromagnets and has the range and precision to perform well in many general field measurement applications. The probe is thin (less than 2.5 mm) but nevertheless stiff enough to allow it to be placed at a known and stable location in the field.

6 Operating environment

The T-1 and HP-1 probe have design features which make them tolerant of electrically noisy environments, but the place of use is otherwise assumed to be clean, sheltered and with a relatively small temperature range. The probe is tolerant of a moderate radiation background such as might be found along a particle accelerator beamline.

The T-1 has good precision combined with low levels of drift and aging. Nevertheless, for maximum accuracy in critical applications, the T-1 and probe should be re-calibrated every 1-2 years against a traceable reference.

7 Probe dimensions
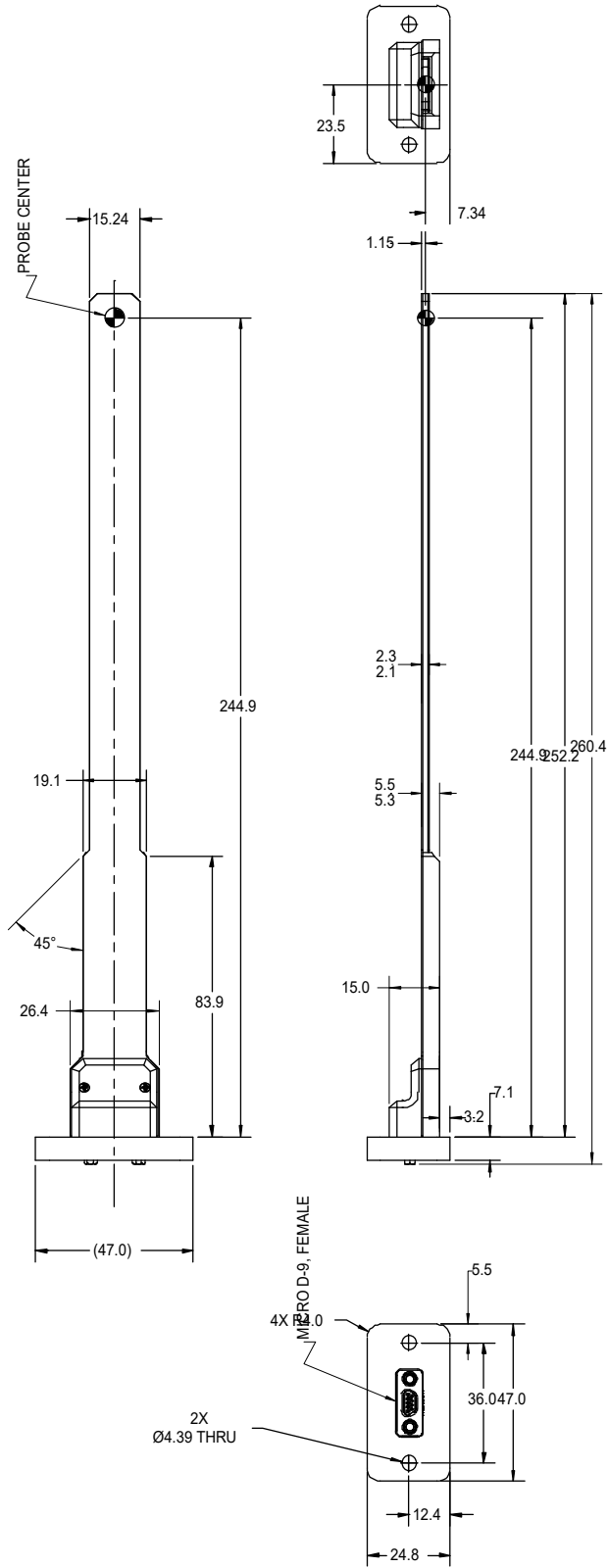
Standard HP-1 probe

8 Getting started

In order to read a magnetic field with the T1, you must assemble the components and then open the web browser to see the readings.

8.1 Connecting the parts

1) Find the cable that joins the T-1 to the HP-1 probe and connect each end. There is a standard 9-pin DSub connector on the T-1 and a micro D connector on the probe.

2) Plug the line cord into the power supply (the green LED on the supply will illuminate) and connect the threaded jack connector to the T-1. Connect to the line (110-240 VAC, 50-60 Hz) and check that the white LED on the T-1 illuminates.

You are now ready to connect to a network.

8.2 Connecting to a network

The T-1 connects to a wired network using a standard Ethernet RJ-45 port. It needs an IP4 address on your network. IP4 addresses look like this: "192.168.100.123", with each group of numbers limited to the range 0 to 255. In typical local networks the first three groups of numbers are the same and define a "subnet".

The last group of numbers are available for devices on the local subnet. Since 0 and 255 are reserved broadcasts and for devices like routers, that means the T-1 will need a number in the range 1 to 254. There are two ways to set this up. "DHCP" (Dynamic Host Configuration Protocol) is where a DHCP server on the network, usually a router, assigns an available address.

This address is not fixed and may be changed by the router when the T1 makes a new connection to the network. Static addresses on the other hand are set by the user and do not change. Static addresses are more usual in technical networks.

The T-1 is normally supplied set up with a specific static IP address. This address is given on the configuration sheet supplied with the unit. However, you can request a specific static address to be set and enabled when you place your order. You can also change the address once you are connected, or you can set the T-1 for DHCP address assignment.

8.2.1 Connecting using a static IP address

We recommend starting with the simplest communication setup. Make a direct connection from a computer to the T-1 with a standard Ethernet patch cable.

Since there is no router in this setup, you will need to set the IP address of the computer. The factory setting is shown on the connection sheet included with the product. If the static address of the T-1 is 192.168.1.44 for example, choose a setting in the same subnet apart from .44. For example, here are the Microsoft Windows dialogs for setting the computer to 192.168.1.100:

1. Edit the properties of the Ethernet adaptor.
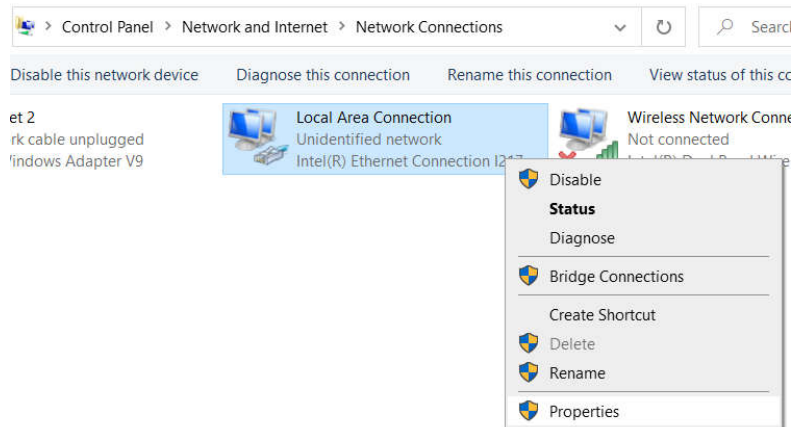
2. Edit the TCP/IPv4 Properties

Local Area Connection Properties   ✕

Networking | Sharing

Connect using:

Intel(R) Ethernet Connection I217-LM

[Configure...]

This connection uses the following items:

- ☑ Client for Microsoft Networks
- ☑ File and Printer Sharing for Microsoft Networks
- ☑ QoS Packet Scheduler
- ☑ Internet Protocol Version 4 (TCP/IPv4)
- ☐ Microsoft Network Adapter Multiplexor Protocol
- ☑ Microsoft LLDP Protocol Driver
- ☑ Internet Protocol Version 6 (TCP/IPv6)

[Install...] [Uninstall] [Properties]

Description

Transmission Control Protocol/Internet Protocol. The default wide area network protocol that provides communication across diverse interconnected networks.

[OK] [Cancel]

3. Select "Use the following IP address" and enter the IP address. Set the Subnet mask as shown.

Click "OK" and then "Close" to close the dialogs and make the new address effective.

Internet Protocol Version 4 (TCP/IPv4) Properties   ✕

General

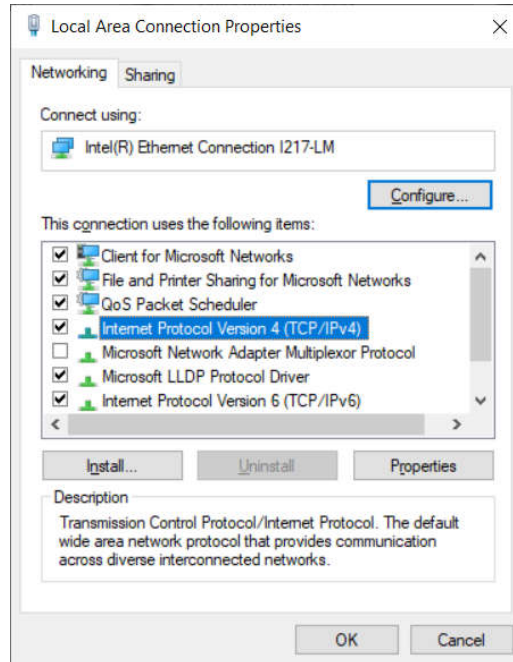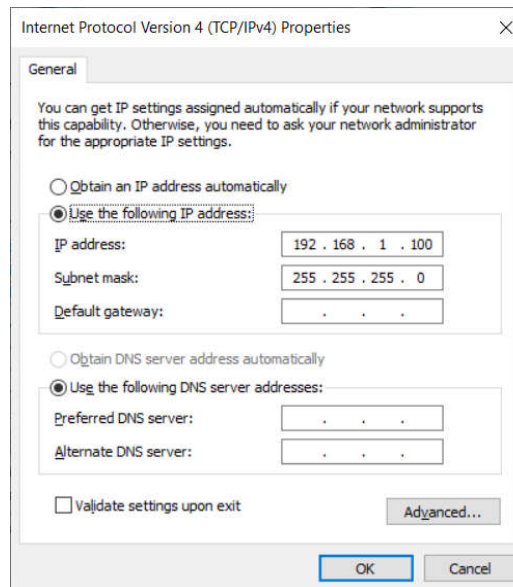You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

- ◯ Obtain an IP address automatically
- ◉ Use the following IP address:

IP address: 192 . 168 . 1 . 100

Subnet mask: 255 . 255 . 255 . 0

Default gateway: . . .

- ◯ Obtain DNS server address automatically
- ◉ Use the following DNS server addresses:

Preferred DNS server: . . .

Alternate DNS server: . . .

☐ Validate settings upon exit   [Advanced...]

[OK] [Cancel]

If you look at the amber and green LEDs on the T-1 Ethernet port and the cable is connected, you will see the amber light on and the green flickering when the T-1 is communicating. Now open a web browser such as Chrome, Edge, Firefox, Safari and type the static address of the T-1 into the URL field. The T-1 will deliver its web page showing the measured field, a graph of the field against time and various controls.
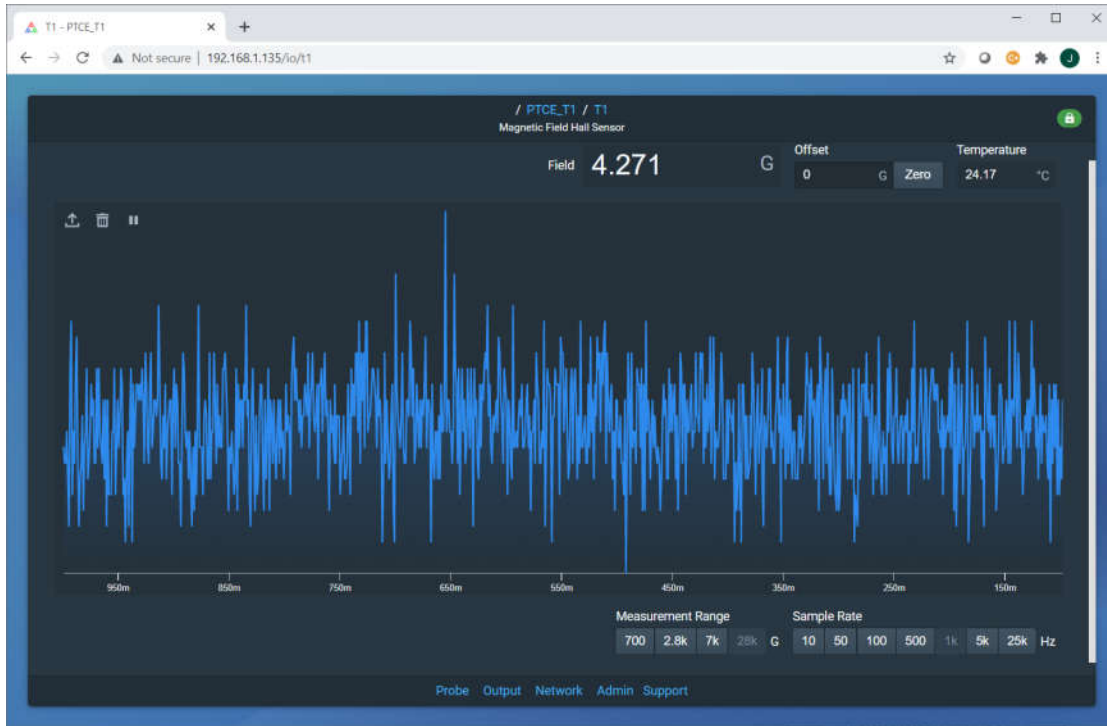
8.2.2 Connecting using DHCP address assignment

The local network must have a router to use this method. Using a standard Ethernet patch cable, connect the T-1 to the router or to a switch on the network.

Switch
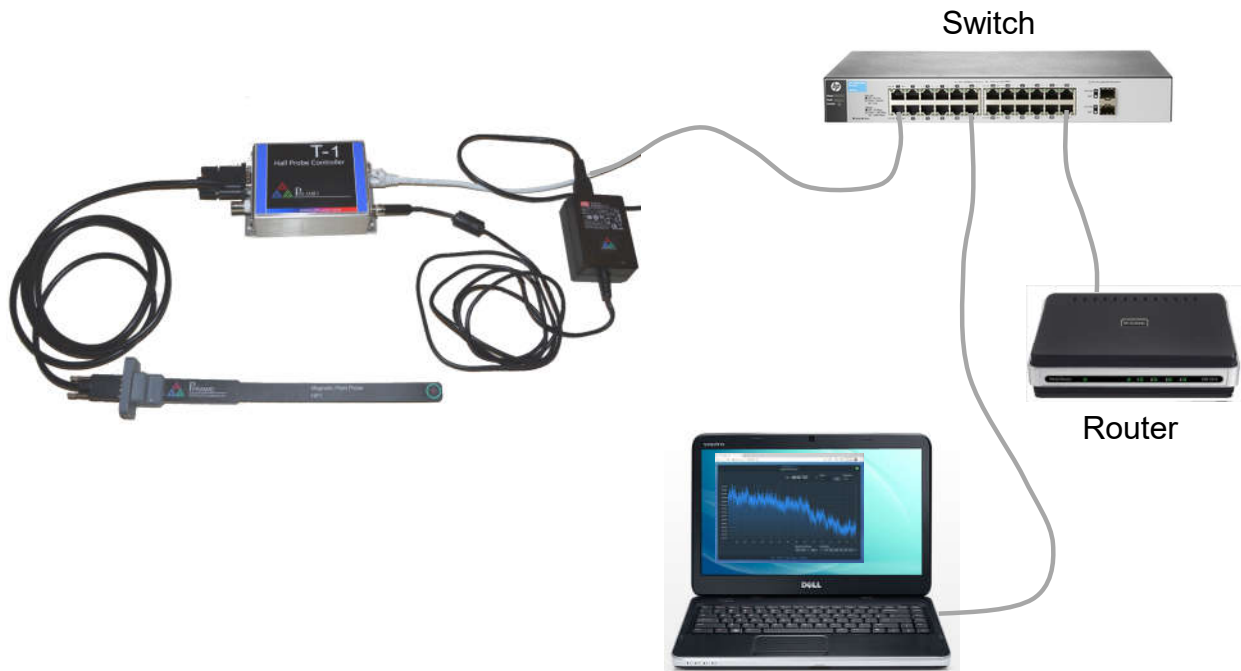
Router

To allow the T-1 to get an address from the router, it must be setup for DHCP. Open the "Network <···>" dialog from the link at the bottom of the T-1 web page:

Probe   Output   Network   Admin Support

Set the DHCP control on and click "Apply ✓".

/ PTCE_T1 / Network
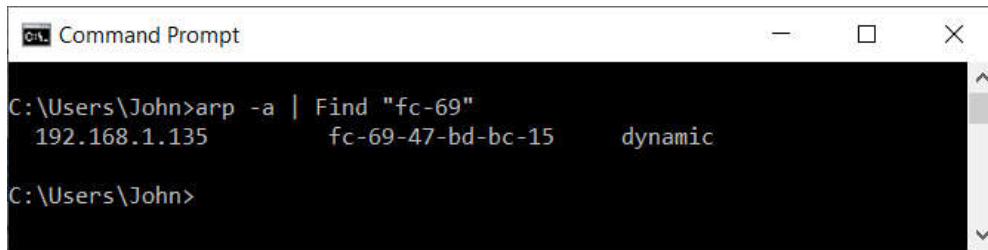Configure the network settings and connection

Ethernet

MAC address

fc:69:47:bd:bc:15

IPv4 Address

192.168.1.135

Automatic IP Settings (DHCP)

Static Address

192.168.1.20

Static Netmask

255.255.255.0

Advanced Settings

Hostname

PTCE_T1

Default Gateway

Apply ✓

Now when you reconnect to a network with a router, the T-1 will be assigned a new IP address. You need to discover this address in order to access the T-1 web page. There are various software utilities that allow a whole subnet to be searched. You can also log in to the network router and look for the T-1 in its table of connected devices. In Windows you can use the MAC ID to find the IP address. The MAC ID of the T-1 can be found on the connection information sheet supplied.

If you are using a Windows computer, open a command prompt by entering "cmd" into the Windows search box. If the MAC ID starts with fc-69 as an example, type in the command

```
arp -a | Find "fc-69"
```

The result will be a list of IP addresses for devices on the network with MAC IDs that start with fc-69. If there are multiple addresses in the response, use more of the MAC ID string to narrow the search.

On Linux systems the arp command is part of the net-tools package, which you may need to install in it is not present in the distribution you are using. The terminal command `arp -n` will return a list of IP addresses that are assigned to the MAC IDs of devices in the network address table.

Now you have the IP address of the T-1 you can enter it in the url field of a web browser to open the T-1 web page.
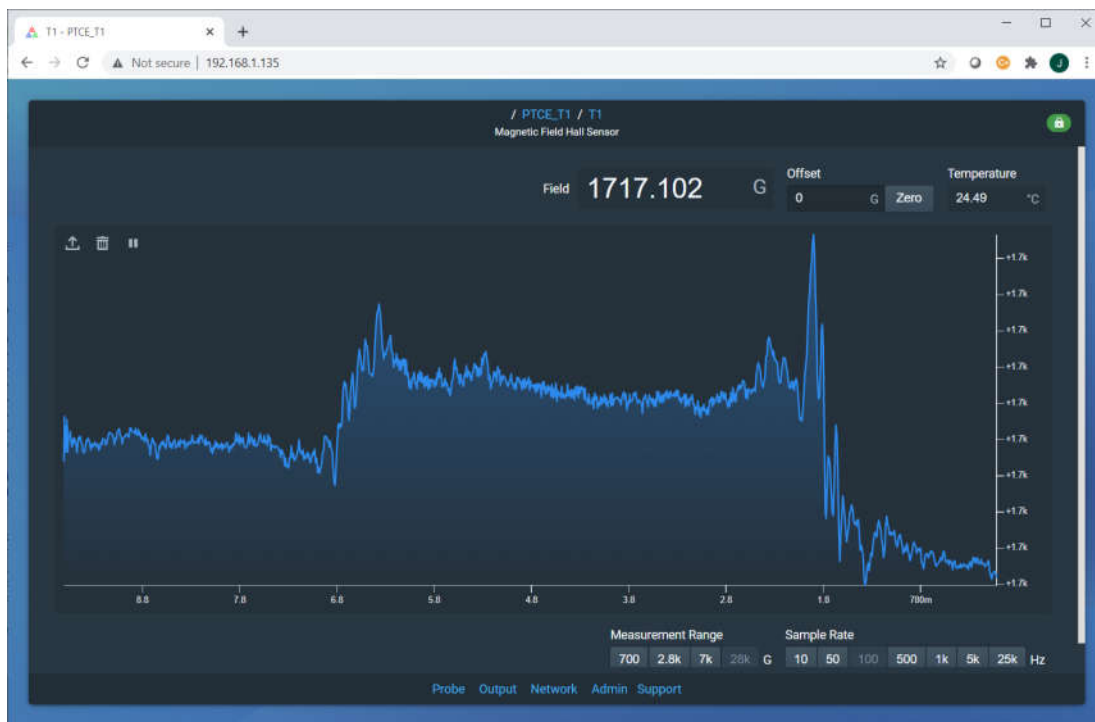
 TIP

On some networks the T-1 may fail to make network a connection first time. Generally re-connecting the Ethernet cable or disconnecting and reconnecting the power to the T-1 will allow the connection to be established.

 TIP

If you have set DHCP addressing and connect the T-1 and the computer to a network with no router, the T-1 will use its static address setting. A direct connection is a case of this type of network.

9   The web browser GUI

The T-1 will provide its web page to any browsers on the network. This can include Windows. Linux, MacOS and Android systems. It can serve multiple browsers at the same time on multiple client computers.

9.1   Data display and controls

The T-1 web GUI displays the magnetic field in units of Gauss. To convert to units of Tesla, divide the readings by 10,000. The T-1 is simple to operate with only two settings that affect data acquisition. The first is the sampling rate and the second is the measurement range.

 NOTE

The T-1 always starts up with the same settings it was using before it was shut down.

9.1.1 Sampling rate

The maximum measurement rate that the T-1 supports is 25,000 samples per second, or one every 40 microseconds. Lower rates can be selected down to 10 samples per second, or one every 100 milliseconds, and this is achieved by averaging multiple readings. Simply click on the required sampling rate and it changes immediately.

As is usual with any type of measurement, you need to choose the best compromise between sensitivity to fast changes in the measurement and the signal to noise ratio. The section later in this manual about sampling rate shows how this tradeoff works.

⚠️ **TIPS**

Use low sampling rate to make precise measurements of static or slowly changing magnetic fields.

Use high sampling rates to see fast changes in magnetic fields.

Use 10 Hz sampling to remove any effect of line voltages (50 or 60 Hz) on the readings.

9.1.2 Measurement range

The standard HP-1 active probe supplied with the T-1 measures up to +/- 28 kGauss, which is +/- 2.8 Tesla. Three more sensitive ranges are provided for measuring smaller fields, +/-7.0 kGauss (0.7 T), +/-2.8 kGauss (0.28 T) and +/-700 Gauss (70 mT). If the field exceeds the range, the displayed reading changes from blue to orange when the nominal full scale is exceeded, and red when the reading is saturated. This is illustrated below for the 2.8 kGauss range.

Valid reading

> Field 2787.365 G

Nominal range exceeded

> Field 2992.192 G

Saturated

> Field 3360.883 G

⚠️ **CAUTION**

A high magnetic field may be present but hidden by saturation. Check the colour of the displayed field reading and use the 28 kGauss range when necessary to ensure the reading is not saturated.

⚠️ **NOTE**

You will only encounter fields above 28 kGauss if your work involved superconducting magnets. Probes with higher field capability are available for the T-1.

9.1.3 Zero offset

If you want to measure a small field, or a small change in a larger field, it is helpful to remove the offset so you can focus on the small change. Clicking the "Zero" button stores the most recent reading and subtracts it from subsequent readings. The value being subtracted is displayed.
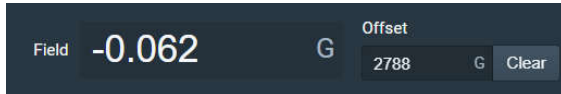
The zero offset is applied to all client computers watching the T-1. To return to normal measuring, click "Clear".

CAUTION

A high magnetic field may be present but hidden by zero offset. If in doubt, click "Clear" to remove the offset.

TIP

You can edit the offset value directly if you need to suppress a known background field.

9.1.4 Plotting control

The measured field is plotted continuously against time on an autoscaling graph. Up to 1000 readings are plotted. Once 1000 readings are in the data buffer, the oldest readings will be discarded as new readings come in. You can freeze the plot with the Hold button:

and resume with the start button   .

You can clear the data buffer and the graph and start it filling again with the Clear button:

.

If you are using a low sample rate, it takes longer for the buffer to fill.

TIP

If you pause the plotting on one client computer, this will not affect the graphs on other connected computers. If you change the measurement conditions such as range, sample rate or zero offset, this affects the T-1 itself and therefore shows on all connected devices.

9.1.5 Temperature

The HP-1 probe includes a temperature sensor at the probe tip and the reading is shown on the web browser screen. The readings are corrected for temperature however best accuracy will be

achieved if the temperature is closer to the initial factory calibration temperature which is in the range 20 to 25 C.

9.1.6 Exporting data

Clicking the Export button

freezes the data buffer and opens a dialog that allows you to store the buffer contents in csv format. The resulting file can be opened by any software that can read a csv format file, such as a spreadsheet program. The dialog box shows a sample of the buffer and allows you to rename the file, and change the numeric format of the field readings and the format of the timestamps.

Export Data ✕

Value	Auto ⬍	Seconds ⬍
-41.897385		0.000000
-43.6277		0.009990
-44.364746		0.019979
-44.002914		0.030968
-42.592377		0.040958

File Name   3-14-2021 5-46-28PM   💾 Save

NOTE

The T-1 gets the current date after a reboot if it can connect to a time server over the internet. If it cannot connect, it sets the current date to the start of year 2000 as a default. Remember this if you are use timestamps with the full date.

NOTE

The graph on the T-1 screen is plotted back in time from right (the most recent value) to left. The exported data is listed in increasing time order. To match the screen display you would need to plot the exported data the same way.

10 Making measurements

10.1 Mounting the probe

The HP-1 probe should be mounted so that the sensitive spot is located in the field you want to measure. Two clear holes for M4 screws are provided on the probe mounting flange to allow a stable position. The probe will measure the field component normal to the flat of the target spot graphic. The Hall element is under the red cross hair. It has a sensitive area of about 1.5 mm^2.

The field reading will be a positive value for a magnetic field vector entering the top surface of the probe, as shown below.
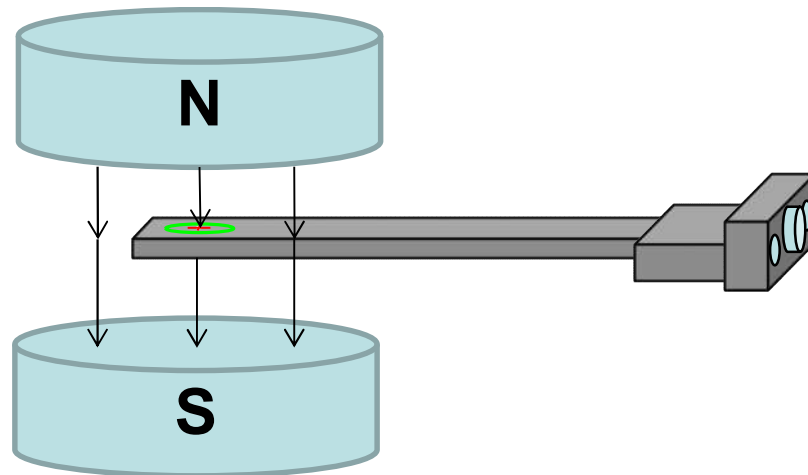
The probe mounting should prevent any tendency for movement or vibration, especially if the probe is measuring a fringe field where there is field curvature. If the field has significant AC components, the mounting should be non-conducting to avoid measurement errors due to eddy currents. The HP-1 probe itself is designed to make AC measurements: there are no metal components to support eddy currents and the low-level signals are carried in tightly twisted conductors.

10.2 Cable length

The HP-1 probe includes active electronics that boost the signal from the Hall element and send it to the T-1 in differential form. This permits a relatively long connection which may be helpful for some installations.

The standard probe cable is 6 foot (1.8 m) long. To increase the cable length, simply add a good quality 9-way screened cable terminated in a 9-pin DSub male at one end and 9-pin DSub female at the other. The cable should have all nine ways connected pin to pin. This type of cable is readily available pre-made in various lengths. The connection from the extension cable to the probe cable can be secured using 4-40 UNC threaded spacers.


The Ethernet connection from the T-1 can of course be very long if needed.

10.3 Sampling rate and measurement range

When investigating an unknown signal it is a good idea to look at with different sampling rates to see if there are AC components to the signal. But for a specific measurement application you will want to use the optimum sampling rate and range. The following example show the effect they have on measurements.

250 readings of a permanent magnet field of 6.155 kGauss were taken on the 7 kGauss range with different sampling rates. Note the following:

- The reading becomes less and less noisy as the sampling rate reduces, due to the averaging.

- The amount of time covered by the 250 readings changes from 10 msec to 25 seconds.

- It is possible to reproduce the low sampling rate data if you export the high sampling rate data and then average it with other software. However, this would require a lot of readings to be collected and analysed. To re-create the 10 Hz data, you would need to process 625,000 readings.
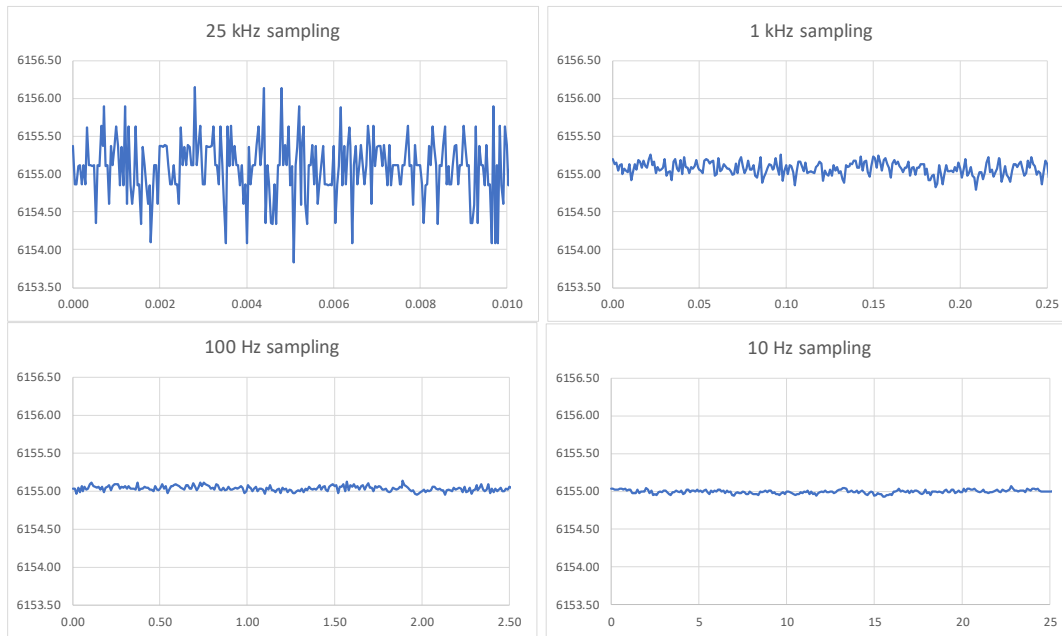
A quantitative to way to look at the effect of the effect of the averaging at different sampling rates is to look at the standard deviation of repeat readings. For the results in the plots above the standard deviation goes from 0.012% of the field reading down to 0.0005% (5 ppm) as the sampling rate is reduced from 25 kHz to 10 Hz.
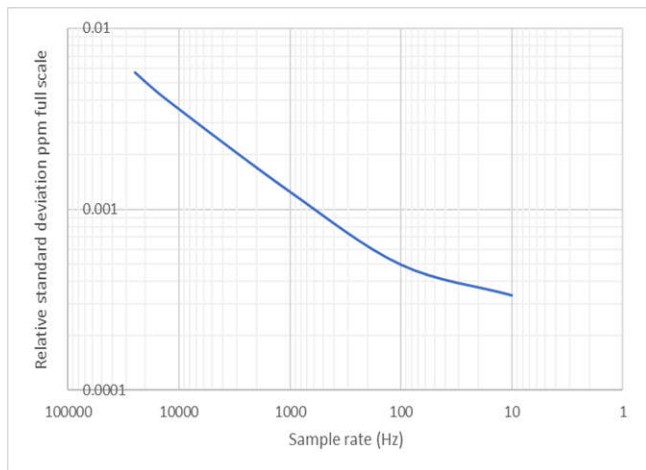
The excellent precision and stability of the Hall device and the analog circuitry means that the resolution of the digitization by the T-1 can appear in the results under some measurement conditions, particularly if the measured field is very stable.

The T-1 analog to digital converter has 16 bit resolution, or 15 bits for each of positive and negative polarity fields. For the example data below, the range setting for the permanent magnet measurement was changed from 7 kGauss to 28 kGauss. This means the digitization steps changed from 0.21 Gauss to 0.85 Gauss, and this is evident in data taken of stable fields at high

sampling rates. Reducing the sampling rate increases the effective resolution of the digitization so that the digitization effects disappear.
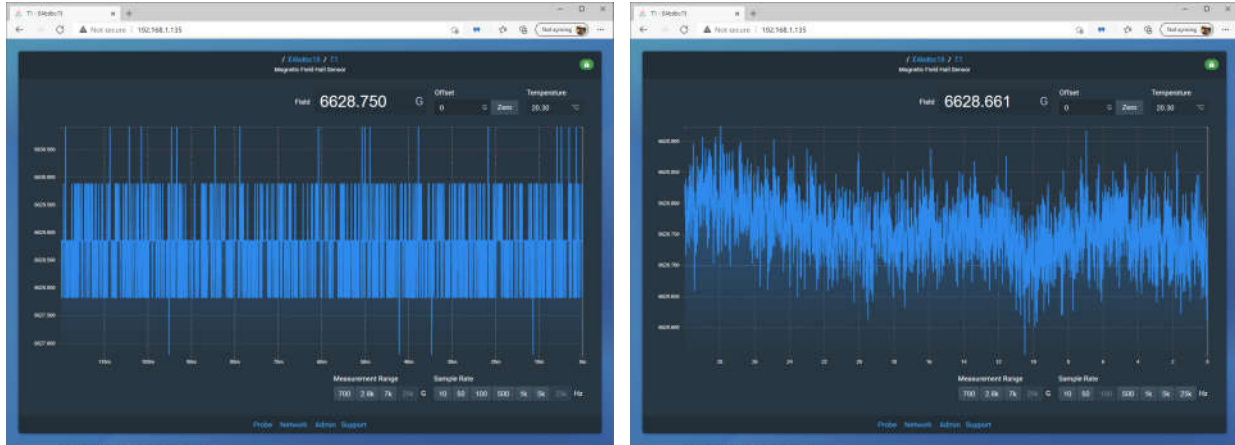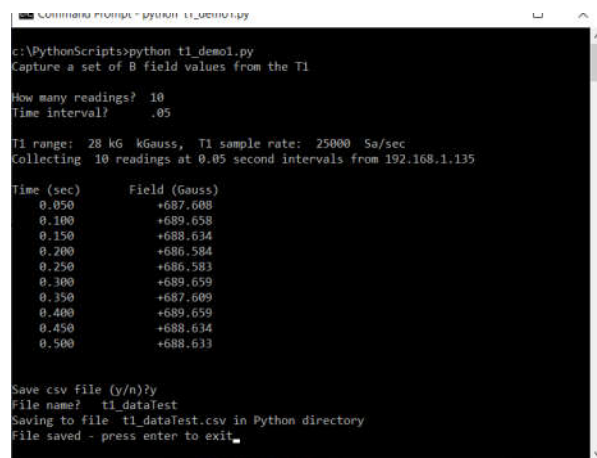

TIP

To avoid encountering digitization effects in your data, use a more sensitive range where possible, and a lower sampling rate.

11 Using your own software

The web interface of the T-1 allows computers, tablets and phones running different operating systems to communicate and take data. It also allows simple connection to other software running on those devices. The JSON format can be used to import data. In Python this could be done as follows to create a floating point value "vala".

```
# IP address of T1.  Change as needed.
ipaddr = "192.168.1.135"
t1_ip = "http://"+ipaddr
# Get field data from T1 html server
    ra = requests.get(t1_ip+"/io/t1/probe/field/value.json")
# Convert from text to float
    vala = ra.json()
```

11.1 Example Python script to collect a specified number of readings from the T-1


```
# Import libraries
import requests              # Call to html server - library has to be downloaded
import time                 # Timestamps
import csv                  # csv file handling

# IP address of T1.  Change as needed.
ipaddr = "192.168.1.135"
t1_ip = "http://" + ipaddr

# List files for results.  T1_data is a list of lists.
t1_data = []
t1_data_entry = []

# Prompt for number of readings and interval between readings
print ("Capture a set of B field values from the T1\n")
num = eval(input("How many readings?  "))
num = min(num,200)                          # Cap number of readings
interval = eval(input("Time interval?     "))
interval = max(interval,0.0003)             # Restrict smallest interval
print()
```

```python
# Define range settings
b_ranges = ['28 kG','7 kG','2800 G','700 G']

# Get range setting and translate
t1_range = requests.get(t1_ip + "/io/t1/configuration/range_select/value.json")
t1_range = t1_range.json()
t1_range = int(t1_range)-1
t1_range = b_ranges[t1_range]

# Get sample rate setting
t1_rate = requests.get(t1_ip + "/io/t1/configuration/rate/value.json")
t1_rate = t1_rate.json()

# Print header lines to console
print ("T1 range: ", t1_range," kGauss,  T1 sample rate: ",t1_rate," Sa/sec")
print ("Collecting ", num , "readings at", interval ,"second intervals from", ipaddr, "\n")
print ("Time (sec)        Field (Gauss)")

ctr = 0

# Collect values
while num > 0:
#----------------------------------------------------------------
# Get field data from T1 html server
    ra = requests.get(t1_ip + "/io/t1/probe/field/value.json")
# Convert from text to float
    vala = ra.json()
# Increment time counter
    tctr = (ctr+1)*interval
# Print to console
    print ("{:9.3f}         {:+12.3f}".format(tctr,vala))
# Add data to table
    t1_data_entry = [1, 2]
    t1_data_entry = [tctr, vala]
    t1_data [len(t1_data):] = [t1_data_entry]
# Step counters and wait to get next reading before looping
    num = num - 1
    ctr = ctr + 1
    time.sleep(interval)
#----------------------------------------------------------------

#  Prompt for csv file save
time.sleep(.5)
print("\n")
response = input("Save csv file (y/n)?")

if (response == 'y'):
    saveName = input("File name?  ")
    if (len(saveName) == 0):
        saveName = "t1_data"
    saveName = saveName + ".csv"
    print("Saving to file ", saveName, "in Python directory")
    with open(saveName, 'a', newline='') as csvFile:
        writer = csv.writer(csvFile)
        writer.writerow(["Time", "Field (G)"])
        writer.writerows(t1_data)
        writer.writerow([" "])
    csvFile.close()
    print("File saved - press enter to exit")
```
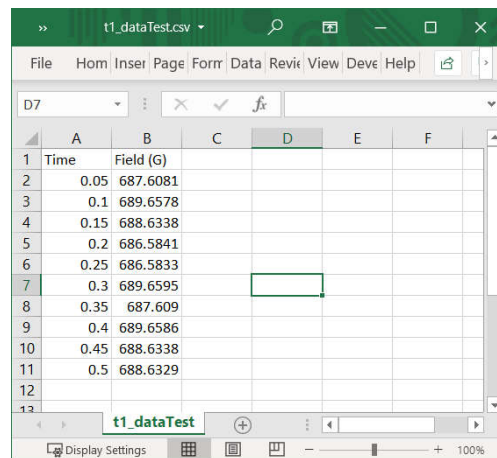
11.2 Example Python script to display the field in large text
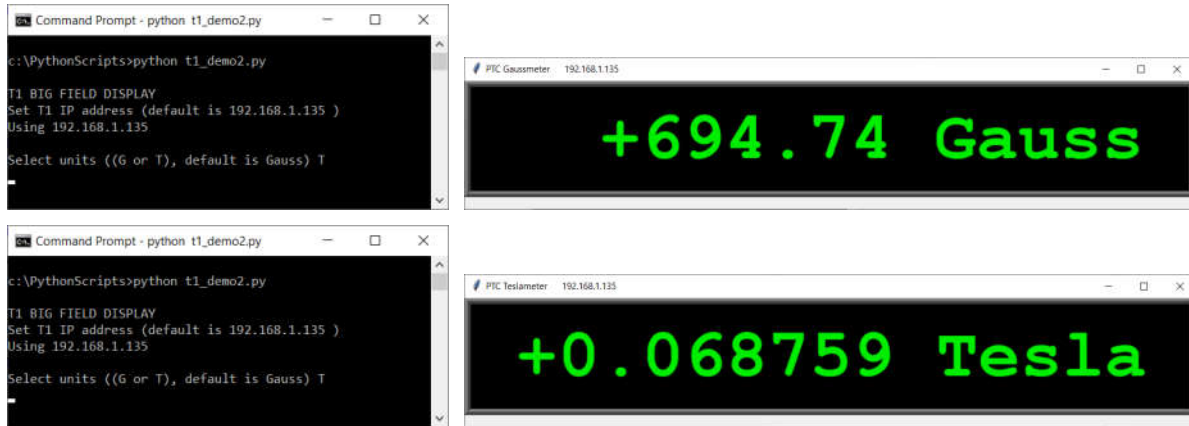

```python
import sys
import requests                  # Call to html server
import time                      # Timestamps
import tkinter
from tkinter import *

# Initial prompts in console
print ("\nT1 BIG FIELD DISPLAY"), print

# Get IP address for device here
defipaddr = "192.168.1.135"
print ("Set T1 IP address (default is",defipaddr,") ",end="")
ipaddr = input()
if ipaddr == "":
    ipaddr = defipaddr
print ("Using",ipaddr,"\n")
t1B_url = "http://"+ipaddr+"/io/t1/probe/field/value.json"

# Choose field units here
Units = "Gauss"
UnitMult = 1.0
UnitFmt = "{:+10.2f}"
print ("Select units ((G or T), default is Gauss) ",end="")
selUnits = input ()
if selUnits == "T" or selUnits == "t":
    Units = "Tesla"
    UnitMult = .0001
    UnitFmt = "{:+10.6f}"
# Heartbeat ticker
global pls, plsctr
pls = ["'"," "," "]
plsCtr = 1

t1B_url = "http://" + ipaddr + "/io/t1/adc/1/value.json"

# Get T1 ID
t1_Name = requests.get("http://" + ipaddr + "/io/ip/hostname/value.json")
# Set up field display window
B_window = Tk()
B_window_Title = "PTC " + Units + "meter   " + t1_Name + "   " + ipaddr
B_window.wm_title(B_window_Title)
B_window.minsize(900,168)


# Get first field reading
ra = requests.get(t1B_url)
vala = ra.json()
vala = vala * UnitMult
vala = str(UnitFmt.format(vala))
```

```python
# Loop to get repeat readings
def draw():
    global B_val
    B_val=Label(B_window,text=vala+" "+Units,height=1,width=16,justify="right",bd=8,font='Courier 68 bold',bg='black',fg='green2',relief='ridge',padx=32,pady=16)
    B_val.grid(row=0, column=0)

def updater():
# Update field value
# Set up flashing heartbeat
    global pls, plsCtr
    tic = pls[plsCtr+1]
    plsCtr = -plsCtr
# Get field reading and format
    ra = requests.get(t1B_url)
    vala = ra.json()
    vala = vala * UnitMult
    vala = str(UnitFmt.format(vala))
    B_val.configure(text=vala+" "+Units+tic,fg='green2')
    B_window.after(100, updater)

# Animate tk display
draw()
updater()
# Run forever
B_window.mainloop()
```

12 Monitor output

The T-1 can generates an analog voltage in the range -10 V to +10 V which is available on the BNC connector next to the probe connector. The voltage is on the central pin of the BNC connector with respect to the screen of the BNC.

Clicking the Output link opens a dialog that allows you to select the monitor function.
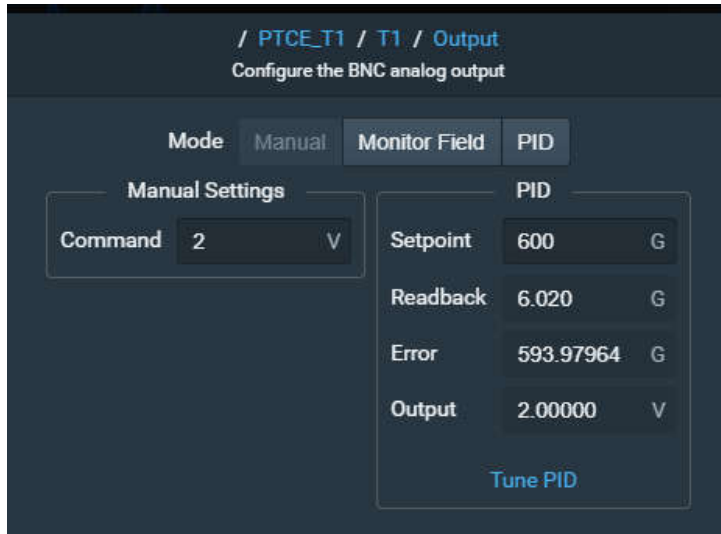
12.1 Monitor mode: Manual

In this mode you can set the monitor output voltage directly by altering the Command field. A typical use would be to control the output of a power supply providing current to an electromagnet.

 CAUTION

Take care not to enter a value that might exceed the allowable range for the power supply or that would produce a large magnetic field from the magnet when this is not the intention.

12.2 Monitor mode: Monitor field

In this mode the monitor output tracks accurately the field measurement. The scaling is arranged so that 10 V corresponds to full scale of the range in use. So for example, a field of -3000 G measured on the 7 kG range would give a voltage of

10 V x (– 3000 G / (7 x 1000 G)) = 4.29 V

The voltage can be monitored by a voltmeter or oscilloscope. The monitor output is not affected by the Ethernet communications or by other programs running on the client computers. It will in fact continue to track the measured field even if the Ethernet is disconnected.

This example shows the T1 measuring a 21 Hz magnetic field waveform with 25 kHz sampling with the monitor output connected to an oscilloscope.
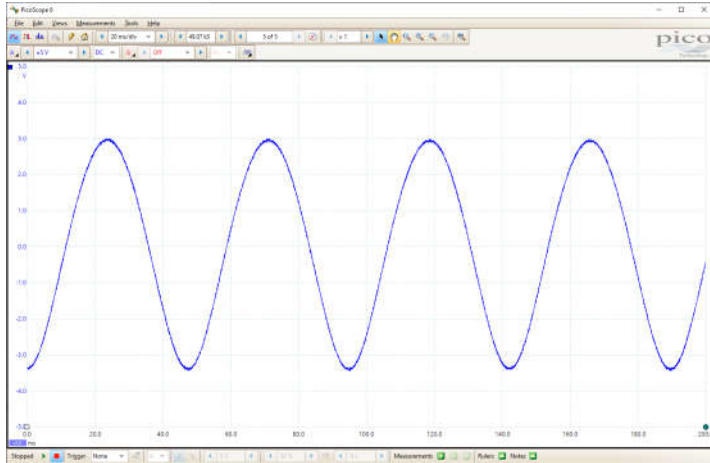
NOTE

The monitor output is created by the T-1 processor, which allows it to use the calibration parameters to achieve good accuracy. The output voltage is adjusted each time the T-1 makes a reading. If you are using a low sample rate and the field is changing you will see the resulting steps in the monitor voltage.

TIP

Use a high sampling rate if you want a good display of fast changing magnetic field on an oscilloscope or digitizer connected to the monitor output.

12.3 Monitor mode: PID

The PID mode allows the T-1 to act as a servo controller for electromagnets. This allows the magnet to be commanded to a specific exact field value, as measured by the T-1 probe. The accuracy and stability of the field setting is limited only by the accuracy, precision and stability of the field reading. Effects such as power supply drift and magnet hysteresis can be eliminated.

The monitor output is used by the servo controller software to control the current of the power supply to maintain the requested field value. The power supply must have an interface which allows its output current to be controlled by an analog voltage.

CAUTION

Do not use the PID mode unless you are experienced in the use and tuning of PID control loops. Incorrect operation could cause large and unexpected changes in the magnetic field and could even damage the power supply.

⚠️ **CAUTION**

An incorrectly tuned or malfunctioning servo controller linked to a power supply with high voltage compliance could result in high voltages appearing on magnet terminals. Ensure that people are kept clear of the supply and magnet unless it is known to be safe.

The PID controls are accessed through the Tune PID link. Contact Pyramid or your supplier if you plan to set up and tune a servo controller for an electromagnet.
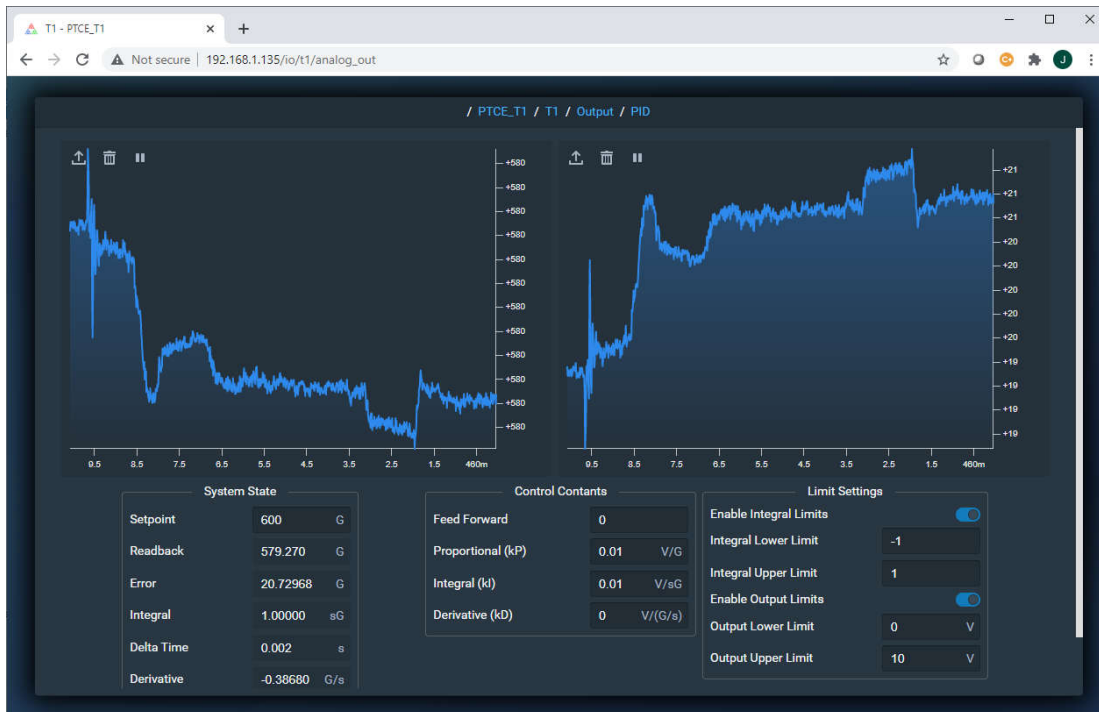
13 Utilities

13.1 Software updates

Pyramid issues updates to the T-1 embedded software to add new features and fix bugs. The update is provided as a compressed file with a name that includes the version ID number such as "IGX_1614813277.tar.gz". The new firmware can be uploaded from the Admin pop-up.

Simply browse your computer to find the new software file
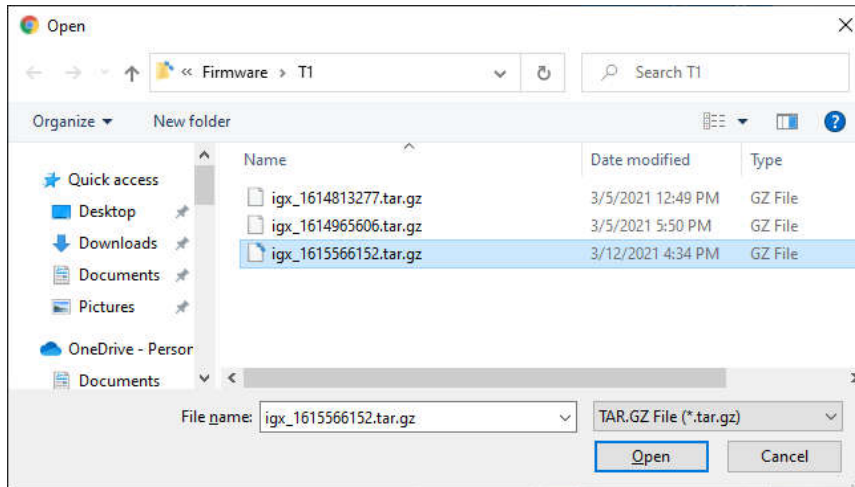
Then click Upload Firmware. The connection may appear to be lost for a while during the process, but on completion the new software will start to run. The version ID number should match the number in the file name. Click away from the pop-up to close it.

13.2 Device name

You can give your T-1 a unique device name that will help you to identify it in a network. Enter the name in the Device Name field in the Admin pop-up. When you reboot the device, you will see the new name.

Device Name	PTCE_T1
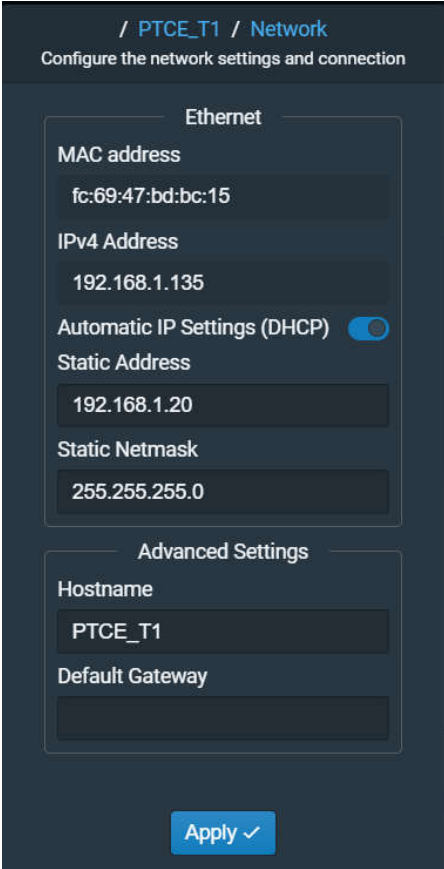
13.3 Rebooting

Sometimes it may be necessary to reboot the T-1. Turning the 24 V power off and on will of course completely restart the T-1. You can command a hard reset from the Admin pop-up. This will drop all connections to clients and re-boot the device. The soft reset will reset the application program, but the T-1 remains "alive during the process. You could for example maintain a ssh connection to the operating system throughout.

Soft Reset ↻   **Reboot** 🔌

13.4 Changing network settings

The network dialog allows you to switch between DHCP and static addressing, and to set the static address. The T-1 will default to the static IP address if there is no router on the network.

/ PTCE_T1 / Network
Configure the network settings and connection

Ethernet

MAC address
fc:69:47:bd:bc:15

IPv4 Address
192.168.1.135

Automatic IP Settings (DHCP) 🔵

Static Address
192.168.1.20

Static Netmask
255.255.255.0

Advanced Settings

Hostname
PTCE_T1

Default Gateway

Apply ✓

13.5 Accessing support

If your T-1 is on a network with an internet connection, then clicking the Support button will take you directly to the Pyramid Help centre. Here you can post requests for new features, bug reports and general questions about using the T-1.

Pyramid Help Center / General Support

General Support

This portal is for general support of Pyramid products. Raise a request from the options bellow.

What can we help you with?

> **!** Technical support
> Need help installing, configuring, or troubleshooting? Select this to request assistance.

Summary *

Description *

14 Some background about magnetic measurements

14.1 Measures of Magnetic Field Strength

Hall probes measure the magnetic flux density (also called magnetic induction), but it is useful to see how this is related to other measures of the magnetic field.

There is a field around a current carrying conductor or a permanent magnet that exerts a force on other current carrying conductors, moving charged particles, and compass needles. The force is proportional to a measure of the field called the magnetic flux density. This is measured in tesla (T), or kg m s^{-2} A^{-1} m^{-1} = kg s^{-2} A^{-1} in SI base units. One tesla is a high field by everyday standards, and is typical of the field in the air gap of a particle beamline bending dipole electromagnet. The old cgs unit is the Gauss, and this is still widely used.

1 T = 10^4 Gauss

1 T = 10 kGauss

The Earth's magnetic field is around 0.5 Gauss at the surface of the Earth, varying with location from about 0.25 to 0.65 Gauss.

It is common to describe the resistance of an energetic charged particle to being deflected by a magnetic field by its magnetic rigidity, measured in tesla meters (Tm). A one Tm beam in a one T dipole field will bend with a radius of one meter. An example of a one Tm beam would be 46.75 MeV protons.

The magnetic flux Φ which gives rise to the magnetic flux density is measured in webers.

1 T = 1 Wb m^{-2}

The old cgs unit of magnetic flux is the maxwell, but this is rarely used (1 Wb = 10^8 Mx).

You can consider that the magnetic field arises from a magnetizing field, H, which is due to the motion of charged particles, usually electrons. In the SI system H is measured in amp per meter. A magnetizing field H produces a magnetic flux density

B = μH

where μ is the permeability of the local medium. In vacuum the permeability $\mu_0 = 4\pi \times 10^{-7}$ henry m^{-1}. The permeabilities of other materials are expressed relative to this. In ferromagnetic materials the relative permeability may be hundreds or thousands. Air has a relative permeability of very nearly one, so when you measure the B field with the T-1 system, you also get the H field in A m^{-1} after division by μ_0.

The old cgs unit for magnetizing field is the Oersted.

1 Oe = 1000/4π A m^{-1}

and in vacuum 1 Oe creates 1 Gauss.

14.2 Field vectors

The B field is a vector field, which you can decompose at any point into three orthogonal components. Magnetic field lines by convention to point from the north pole to the south pole of a magnet. A compass will point to the south pole of a magnet (thus there is a south magnetic pole at the Earth's magnetic north pole).
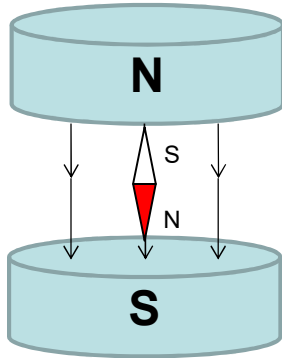
The HP-1 probe measures the field component that is perpendicular to the flat face of the probe, at the position of the red cross mark. If you orient the probe so that the field vectors point into the bulls eye, you will get a positive field reading, as shown below. The figure also shows the deflection direction of a positive ion beam for the illustrated field direction, and the conventional current direction in the coils of an electromagnet producing the field.

+ve field reading

+ve ions
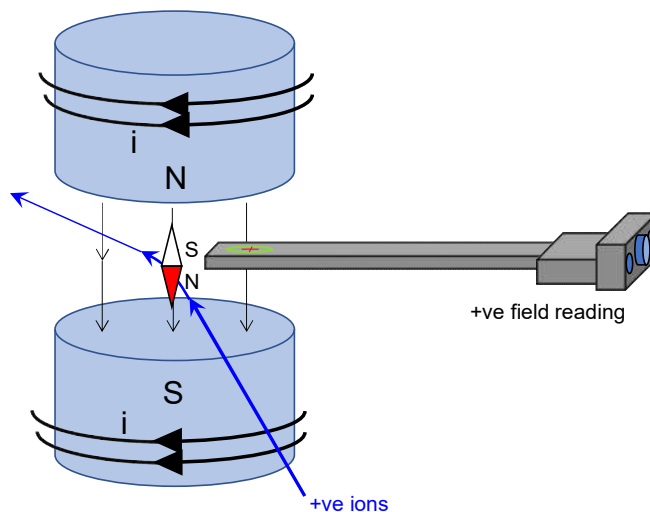
14.3 Rate of Change of Magnetic Flux Density

Any conductor loop which encloses an area through which the magnetic flux is changing with time will have a current induced in it. If the loop is not shorted, there will be a voltage induced

across the terminals that is the negative of the rate of change of B integrated over the surface area of the loop.

$$V = -\frac{d}{dt}\int_S B.ds$$

We can assume that the loop area is small enough that B is constant over its area, so we have

$$V = -\frac{dB}{dt}A$$

where is the area of the loop.

The resulting induced current magnitude and time profile will depend on the impedance of the loop. This effect is important when you are measuring AC fields. The HP-1 is carefully designed to prevent circulating induced currents that might affect its readings. You should take care that the position of the probe is not near conductive plates or loops that could affect the field reading unless you are deliberately trying to survey induced currents.

15 Fault-finding

Symptom	Possible Cause	Confirmation	Solution
Incorrect field readings	Probe orientation not as expected	Check orientation of the probe relative to the expected field direction.	Orient and secure the probe.
	Probe out of position	Check probe position	Locate and secure the probe.
	Probe is mounted inverted.	Check whether field has opposite polarity to that expected.	Mount the probe the right way up.
	Zero offset is in effect	Check offset value shown.	Clear zero offset
	Calibration incorrect or corrupted	Check reading of a known field.	Contact supplier or Pyramid Technical Consultants, Inc. to arrange recalibration
	Mechanical stress on probe Hall device.	Check mounting arrangement.	Mount the probe securely by without applying bending force.
	No probe connected.	Temperature reading is unrealistic. No response to magnetic fields.	Connect a probe
Unstable field reading	Field is actually changing	Check field by independent means.	n/a
	Probe position is unstable in a spatially varying field.	Check field by independent means, or by placing the probe in a known stable field.	Provide a mechanically stable probe mounting.
High noise levels	Sampling rate is too high for	Noise level reduces with	Use an appropriate rate for the

	signal being measured	sampling rate	signal.
	T-1 case not grounded.	Check continuity to local ground.	Make dedicated ground connection if mounting does not provide this.
	Field has unsuspected AC components.	Check field by independent means, or by placing the probe in a known stable field to confirm that it can make a clean measurement.	Eliminate interference at source, or filter out in data analysis.
	Line voltage pickup	Noise level drops sharply if sampling rate is set to 10 Hz	Check grounds and keep physical separation from line noise sources. Use 10 Hz sampling if possible
Monitor output responds slowly	Sampling rate is low.	Change rate.	Choose sampling appropriate to the required time resolution and noise levels
Monitor output not tracking field as expected	Monitor mode not set for field monitoring	Check mode setting.	Set mode correctly
Unable to communicate with T-1	Duplicate IP address setting	Check no other device in the network has the address.	Check that the address setting is not already in use on the network when setting a static address.
	New address has been assigned by DHCP.	Check address by searching for the MAC ID.	Set the correct current address in the client device.
	Bad Ethernet cable.	Try another cable.	Correct cabling.
	SD card not in slot in T-1 or does not have correct		Contact supplier for advice.

	software.		
Communications interruptions	Excess traffic on the Ethernet.	Try a direct connection to the client.	Use a network with less traffic.
	Other applications on the client PC taking CPU time.	Shut down other web pages and unnecessary programs.	Use a dedicated client computer for critical data taking.
Random changes to settings	Another client is communicating with the T-1.	Look for other clients. If there is a VPN access, turn this off. Make a direct connection to the client.	Run a single client only if changes cannot be allowed. Use a direct connection.

16 Maintenance

The T-1 system does not require routine maintenance. There are no user-serviceable parts inside the case of the control unit.

The calibration of the T-1 is very stable. However if you require re-calibration of the unit, traceable to a reference standard, please contact Pyramid Technical Consultants to arrange a return.

The T-1 is fitted with a 1.1 A automatically resetting positive temperature coefficient (PTC) fuse in the 24 VDC input. No user intervention is required if the fuse operates due to overcurrent. The fuse will reset when the overcurrent condition ends.

17 Returns procedure

Damaged or faulty units cannot be returned unless a Returns Material Authorization (RMA) number has been issued by Pyramid Technical Consultants, Inc. If you need to return a unit, contact Pyramid Technical Consultants at support@ptcusa.com, stating

- model

- serial number

- nature of fault

An RMA will be issued, including details of which service center to return the unit to.

18 Support

Manual and software driver updates are available for download from the Pyramid Technical Consultants website at **www.ptcusa.com**.   Technical support and access to the Pyramid feature request and bug tracking system is available through the Pyramid website at https://pyramidtc.atlassian.net/servicedesk/customer/portal/1.

You can also contact us by email at support@ptcusa.com or sales@ptcusa.com.   Please provide the model number and serial number of your unit, plus relevant details of your application.

19 Disposal

We hope that the T-1 and HP-1 give you long and reliable service. The product is manufactured to be compliance with the European Union RoHS Directive 2002/95/EC, and as such should not present any health hazard. Nevertheless, when your product has reached the end of its working life, you must dispose of it in accordance with local regulations in force. If you are disposing of the product in the European Union, this includes compliance with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC. Please contact Pyramid Technical Consultants, Inc. for instructions when you wish to dispose of the product.

20 Revision history

The release date of a Pyramid Technical Consultants, Inc. user guide can be determined from the document file name, where it is encoded yymmdd. For example, T1_UG_200705 would be a T1 user guide released on 5 July 2020.

Version	Changes
T1_UG_210224	First general release
T1_UG_210305	Update screens to match firmware update
T1_UG_210314	Revision to match firmware 21.03.121622 / 1615566152.
T1_UG_220531	Added HP-1 probe drawing