



**DTM-151**  
**DIGITAL TESLAMETER**  
**with IEEE-488 GPIB Interface**  
USER'S MANUAL

For units supplied with software DTMS V6.0 & V7.0

05 August 2008

Thank you for purchasing and using a Group3 digital teslameter. We hope you will join the many hundreds of users worldwide who are enthusiastic about our products.

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The Group3 website, **www.group3technology.com** contains details of all our products. This site is regularly updated, so check it from time to time to learn about recent developments.

Group3 Technology Ltd.  
2 Charann Place, Avondale, Auckland 1026  
PO Box 71-111, Rosebank, Auckland 1348, New Zealand.  
Phone: +64 9 828 3358  
Fax: +64 9 828 3357  
Email: info@group3technology.com  
Web: <http://www.group3technology.com>

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# 1 GENERAL DESCRIPTION

The DTM-151-\_G Digital Teslameters offer accurate, high resolution measurement of magnetic flux densities, with direct digital readout in tesla or gauss, and IEEE-488 GPIB interfacing for system applications. The instruments are light and compact, and the probes are easy to use. The DTM-151 has been engineered to withstand the severe electrical interference produced by high voltage discharge.

This description includes features of the serial communications option which is an alternative to the IEEE-488 option. If your teslameter is the serial version, refer to the DTM-151-\_S User's Manual.

## FEATURES

Measures magnetic fields over four ranges up to 3 tesla with polarity indication; resolution up to 1 part in 600,000.

Used with special miniature Hall probe - easy to attach to magnet pole or other hardware. Probe holders are available as optional accessories.

Accuracy and temperature specifications include total system performance, probe and instrument. This is the only meaningful indication of measurement accuracy.

Probe is calibrated, with field and temperature characteristics stored in memory chip contained in cable plug.

Basic accuracy 0.01% of reading + 0.006% of full scale.

Microprocessor reads probe calibration data stored in probe connector and computes corrected field reading.

Temperature coefficient 10ppm/°C overall achieved using temperature sensor in probe. Microprocessor calculates corrected field reading.

Accuracy is verified against nuclear magnetic resonance (NMR) standard.

Probe calibration is verified at many field points, and a printed calibration table is supplied with every probe.

AC mode measures and displays time-varying fields between 8 Hz and 3000 Hz.

Front panel keys set the display to read the desired field range, to read the peak value of the field using the peak hold function, to show the ac field component, and to display the probe temperature.

Peak hold is implemented digitally, has zero sag.

Digital filtering of the displayed field reading suppresses short-term fluctuations. The filtering characteristic is non-linear; small field variations within a narrow window centered on the currently displayed value are filtered; large field changes are displayed immediately. Filter window and time-constant may be changed by remote command. Filtering is controlled by an internal switch.

Two digital communication options: *either* serial (RS-232C and fiber optic)  
*or* IEEE-488 General Purpose Interface Bus.

With the serial option, a single teslameter may be connected to standard RS-232C equipment, or up to 31 units may be interconnected on a Group3 Communication Loop (G3CL) and driven from computer or terminal.

Fiber optic ports duplicate functions of RS-232C signals, for electrical noise immunity and voltage isolation. Fiber optic links may be up to 60 meters in length, using Hewlett-Packard HFBR-3500 series fiber optic cables. Use a Group3 fiber optic repeater to extend communication distance.

The IEEE-488 option fully supports all relevant GPIB functions and commands, including full talker-listener capability, serial and parallel polling, service request, and talker-only.

ASCII control commands are accepted to modify the output data format, to change the rate of data transmission or to request transmission of a single field reading. Other commands set scaling and offset, select the field range, select ac and peak hold functions, turn on and off digital filtering and modify the filter characteristics. System status may be determined remotely.

The system can be operated in triggered mode where field measurements by one or more teslameters are triggered in synchronism with each other by external command.

Internal switches select serial data format and baud rate, device address, string terminators, filtering, field units in gauss or tesla, data format, service request action, EOI action, and perform system reset.

Two analog outputs are available: instantaneous field value (0 to 3 kHz), rectified time-varying (ac) component of field, (8 Hz to 3 kHz).

All model variations are available without display and keys for true 'black box' magnetic-field-to-computer interfacing.

A panel mount model with display is available.

## 2 SPECIFICATIONS OF DTM-151 SYSTEM

Specifications include LPT-141 or MPT-141 Hall Probe.

Measurements field value and time-varying (ac) component of field

Field ranges 0.3 0.6 1.2 3.0 tesla full-scale,  
3 6 12 30 kilogauss full-scale,  
with polarity indication  
maximum calibration field  $\pm 2.2$  tesla,  $\pm 22$  kilogauss

Resolution DC mode with digital filtering ON:  
  
1 in 600,000 of bipolar span as shown on front panel display.

range	display resolution		serial/GPIB resolution	
	gauss	tesla	gauss	tesla
0.3 tesla	0.01	0.000001	0.001	0.0000001
0.6 tesla	0.02	0.000002	0.01	0.000001
1.2 tesla	0.04	0.000004	0.01	0.000001
3.0 tesla	0.1	0.00001	0.01	0.000001

Resolution DC mode with digital filtering OFF, and AC mode:  
  
1 in 120,000 of bipolar full-scale span in display:

range	display resolution		serial/GPIB resolution	
	gauss	tesla	gauss	tesla
0.3 tesla	0.05	0.000005	0.001	0.0000001
0.6 tesla	0.1	0.00001	0.01	0.000001
1.2 tesla	0.2	0.00002	0.01	0.000001
3.0 tesla	0.5	0.00005	0.01	0.000001

20-bit digitising of field reading.

Accuracy DTM-151 with LPT-141 or MPT-141 probe:  
 $\pm 0.01\%$  of reading  $\pm 0.006\%$  of full-scale max. at  $25^{\circ}\text{C}$

Temperature Stability DTM-151 with LPT-141 or MPT-141 probe:  
calibration:  $\pm 10$  ppm of reading/ $^{\circ}\text{C}$  max.  
zero drift:  $\pm(1$  microtesla +  $0.0003\%$  of full-scale)/ $^{\circ}\text{C}$  max.

add  $-3$ ppm/ $^{\circ}\text{C}$  for each meter of probe cable

Time stability  $\pm 0.1\%$  max. over 1 year

Measurement rate	10 measurements per second
Response time	Full-scale change of displayed field reading settles to within resolution in less than 0.3 second (filtering off - see below)
Peak hold mode	Displays maximum field since mode entered or reset. Peak hold is implemented digitally with zero sag or decay.
AC mode	Displays time-varying (ac) component of field; frequency response: 8 Hz to 3 kHz at -3dB points. response time-constant: 0.2 seconds. average responding, reads rms value of sinusoidally-varying field. reading is not linearity or temperature corrected.
Display	7-character 7-segment alphanumeric display.
Indicators	8 back-lit legends for: 0.3 0.6 1.2 3.0 tesla range selected, peak hold mode on, digital filtering on, tesla/gauss field units.
Display modes	magnetic field, peak hold field, ac field, peak ac field
Digital filtering	field value filtering smoothes out small fluctuations in the reading; large, rapid field changes are not filtered; internally switch selected.
Keys	2 keys for range selection, access to display modes, zeroing field display, peak hold reset.
Digital interfacing	serial option: RS-232C and fiber optic. parallel option: IEEE-488 General Purpose Interface Bus.
Digital data format	ASCII input commands and output responses.
Commands	requests for field values, setting and inspection of display and control modes, field measurement triggering, entry of numerical values, setting units, output data format, and filter characteristics, test commands.
Output responses	field value in tesla or gauss followed by optional T or G and string terminator(s), system status, numerical data requested by commands, messages.



Serial bit rate	16 rates, switch selected, 50, 110, 134.5, 150, 200, 300, 600, 900, 1050, 1200, 1800, 2000, 2400, 4800, 9600, 19200 baud.
System orientation	Group3 Communication Loop (G3CL) using serial ports, simple loop for 31 devices, no multiplexer required; GPIB with IEEE-488 option.
Fiber optic cable	Hewlett-Packard HFBR-3500, 60 meters max. Fiber optic repeater available for extended communications.
On-board switches	serial baud bit rate selection, load defaults, device address, filtering, string terminators, data format, service request enable, EOI enable.
Analog outputs	dc output - instantaneous field analog: full-scale output: $\pm 3V$ nominal source impedance: $1000\Omega$ accuracy: $\pm 10\%$ bandwidth: 3kHz at -3dB, rolloff 3-pole 60dB/decade  ac output - rectified analog of time-varying (ac) field: frequency response: 8Hz to 3kHz at -3dB points time-constant: 0.2 seconds average responding, delivers rms value of sinusoidal field full-scale output: 3V nominal source impedance: $1000\Omega$ accuracy: $\pm 12\%$
IEEE-488 functions	SH1 source handshake capability AH1 acceptor handshake capability T5 talker (basic talker, serial poll, talk-only mode, unaddressed to talk if addressed to listen) TE0 no address extension talker capability L4 listener (basic listener, unaddressed to listen if addressed to talk) LE0 no address extension listener capability SR1 service request capability RL0 no remote local capability PP1 parallel poll capability (configured by controller) DC1 device clear capability DT1 device trigger capability C0 no controller capability
GPIB connector	standard Amphenol 57-20240 with metric standoffs

Memory back-up	user-entered data storage for 30 days with power off.
Power source	ac: min 8V at 0.7Arms, max 15V at 0.4Arms dc: min 9V at 0.5A, max 19V at 0.25A  ac line input plugpack supplied.  Power fuse on processor board: 1 amp antisurge 5 x 20mm  To obtain maximum spark protection, use PS12D7 power supply and ferrite kit 11000036. See section 3.9.  L option: 115/208/230 V ac power input.
Enclosure	aluminium, 217 x 125 x 50 mm, textured finish, light tan colour, tilt stand fitted to bench models.
Ambient field	Maximum operating field for instrument: 10 millitesla with single-range probe, 0.5 millitesla with multi-range probe.
Temperature range	0 to 50°C operating, absolute maximum temperature of probe 60°C.
Instrument weight	1.2 kg, shipping weight 2.5 kg.
Probes	LPT series, transverse types, sensitive area 4 x 1.6mm, probe head size: LPT-141 and LPT-231: 14 x 14 x 2.5 mm  MPT series, miniature transverse types, sensitive area 1.0 x 0.5mm, probe head size: MPT-132 MPT-230 MPT-141 MPT-231: 14 x 5 x 2 mm  Standard cable length: 2 meters. Special cable lengths to 30 meters. Probe cable is shielded.

## ORDER CODES

Basic teslameters,  
capable of four measurement ranges 0.3, 0.6, 1.2, 3.0 tesla full scale,  
support all LPT and MPT series probes, plugpack supplied except for option -L.

**DTM-151** (supports LPT-141, LPT-231, MPT-141, MPT-231 probes)

### Options

Bench style instrument with display: add suffix **-D** |  
Panel-mount version: add suffix **-P** | one of these options  
Without display, plugpack powered: add suffix **-N** | must be specified  
Without display, line voltage power: add suffix **-L** |  
IEEE-488 GPIB capability: add suffix **G** | must select  
Serial data input/output, RS-232C & fiber optic: add suffix **S** | one option

Example: DTM-151-DG

### Probes

Four ranges, standard 2 meter shielded cable

**LPT-141-2s** | standard sensitivity      **LPT-231-2s** | high sensitivity  
**MPT-141-2s** | probes                      **MPT-231-2s** | probes

Single range probes: add range suffix -03, -06, -12, -30.  
Special probe cable lengths: change length suffix to -Xs,  
   where X is the desired cable length in meters, 30 max.

Example: LPT-141-10s for 10 meter cable

### Accessories

fiber optic cable fitted with connectors, 60 meter length maximum.  
probe holders.  
fiber optic repeater, bidirectional, model **FOR-2PP**.  
fiber optic to RS-232C adaptor, model **FTR**.  
serial/GPIB adaptor, model **COM-488**.  
digital display for remote control & readout of field values, model **DPM**.  
rack panels, 3.5 inches high (2U), for rack mounting 1, 2, or 3 DTMs or DPMs.  
ferrite kit 11000036 for spark protection.  
power supply PS12D7 for spark protection.



## 3 SETTING UP

### 3.1 INTRODUCTION

This manual provides operating instructions for all members of the DTM-151 family of digital teslameters with IEEE-488 interfacing, and their companion LPT-141, LPT-231, MPT-141, and MPT-231 series Hall probes. For a summary of all current members of the product family, see page 2-5. These instructions are written for a teslameter with front panel display and keys, DTM-151-DG/PG. Users of teslameters without display and keys should ignore sections of this manual referring to these features. All other aspects of operation are identical. Before using your teslameter for the first time, please read through sections 3.2, 3.3, 4.1, 4.2, and 4.3 of this manual. This will give a quick introduction to basic operation of the instrument. If you have a teslameter without display, DTM-151-NG/LG, also read sections 3.4, 3.5, and 4.5. If you have the panel-mount version, DTM-151-PG, mounting instructions are to be found in section 3.8. For help regarding operation in electrically noisy areas, see section 3.9.

### 3.2 CONNECTING THE HALL PROBE

**Before handling the probe, please read the following:**

Group3 Hall probes are built to be as robust as possible for a small, precision device. However, it is most important that certain precautions be taken when handling and installing probes so that they are not damaged or destroyed, and to preserve their accurate calibration.

Mount the probe head so there is no pressure which will tend to bend or depress its ceramic rear surface. If the probe head is clamped, make sure the surface in contact with the ceramic is flat and covers the whole of the ceramic surface. Do not apply more force than is required to hold the probe in place. Any strain on the ceramic will alter the probe's calibration, and excessive force will destroy the Hall element inside.

When the probe head is mounted, the cable should be clamped firmly nearby so it cannot be torn away from the probe head if accidentally pulled. The flexible section adjacent to the probe head can be carefully folded to allow the cable to come away in any direction, but avoid repeated flexing of this section.

Keep the cable out of the way of foot traffic. Do not pinch the cable, or drop sharp or heavy objects on it. A severed cable cannot be re-joined without altering the probe's performance, and requires factory repair and re-calibration.

Your DTM must be used with a Group3 Hall probe. The probe may be one supplied with your teslameter, or it may have been obtained separately. In any case, calibration is preserved when probes are exchanged between instruments. In order to obtain specified performance, the DTM-151 should be used only with a -141 and -231 series probes.

The standard probe cable length is 2 meters. Probes with non-standard cable lengths up to 30 meters may be ordered from your Group3 supplier. The cable used for Group3 probes is shielded to reduce pickup of induced noise from external sources. Such noise may reduce the accuracy of the instrument, cause malfunctioning, or in extreme circumstances even result in damage to the internal circuitry. See section 3.9.

With the DTM unpowered, plug the probe connector into the instrument. The pin side of the plug is inserted into the large opening in the rear of the DTM, with the plug's label uppermost when the instrument is standing right way up. It is easy to find the correct mating position for the plug, and then push it fully home, but if any difficulty is experienced at first, remove the DTM's top cover by loosening the central screw and lifting the cover off. Now it is possible to see when the plug is centrally located and its overhang slides over the card-edge receptacle, ensuring that its pins engage correctly. Tighten the connector retaining screws finger tight. Do not leave these screws loose as they form part of the shielding system around the teslameter. The teslameter should always be used with both covers attached.

Always disconnect power from the teslameter before connecting or disconnecting the probe. If the probe connector is inserted or withdrawn with power on, data stored in memory may be corrupted, leading to erroneous field readings. If this happens, the defaults switch S2-8 should be switched ON then OFF while power is applied. See Fig. 3 and Table 1.

When no probe is connected to the DTM, the display reads **noProbE**.

### **3.3 CONNECTING THE POWER SOURCE**

All teslameter versions, except for the L option, are supplied with a plug-pack. Connect the plug-pack to a convenient ac power source, first checking the voltage marked on the plug-pack, and insert the cable connector into the power receptacle on the DTM rear panel.

Instead of the plug-pack, the unit can be powered by any convenient source of ac or dc (either polarity), 9 to 15 volts, capable of supplying 0.7A rms ac or 0.5A dc. The cable connector required for power connection to the DTM is a standard coaxial plugpack connector with 2.1mm centre hole and is generally available from electronics suppliers.

For extra immunity to damage and operational disturbance caused by serious high voltage sparking near the teslameter, the use of the Group3 model PS12D7 off-line switch-mode power supply and the Group3 ferrite kit part no. 11000036 is recommended. These accessories will greatly reduce the amount of electrical transient energy entering the teslameter. The ferrite kit includes a suppressor which fits to the probe cable near the point of entry to the teslameter to reduce the effects of transients picked up on the probe cable. For a full discussion of techniques to promote trouble free operation in electrically noisy environments, see section 3.9 of this manual.

## Powering the L option teslameter -

The L option will accept power input from the ac power line.

Access to the power input terminals of the L option is obtained by taking off the orange cover; remove the 3 fixing screws to release the cover.

Use 3-conductor power cord. For safety from electrical shock it is essential to provide a reliable ground connection to the DTM case. Make sure the ground wire is connected as shown in Fig. 1. Strip about 60 mm (2.5 in) of outer jacket from the cord, and strip 5 mm (3/16 inch) of insulation from the 3 wires. Pass the cord through the grommetted hole in the cover. Loosen the screw securing the cable clamp and pass the cord through the clamp. Tighten the clamp on the outer jacket. Terminate the wires and fit links according to the supply voltage as set out in Fig. 1 below. Replace the orange cover, making sure that wires are not pinched in the process. For safety reasons, do not operate the unit with the cover off.

Note that input power protection is provided by a thermal fuse wound into the power transformer. This fuse will open in the event of transformer overheating rather than on excess current. The power input must be connected as shown to include the thermal fuse in the circuit correctly. If a fault causes transformer overheating and subsequently the fuse opens, the transformer must be replaced with the genuine Group3 part.

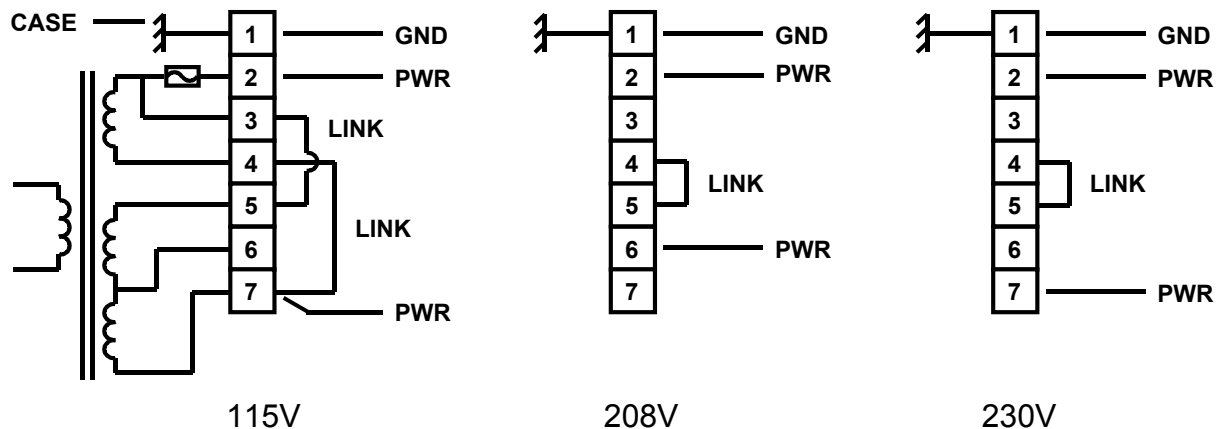


Fig. 1. Power Input Connections of the -L option

If desired, the wiring may be protected by installing an external fuse in the ac power feed. Suggested fuse ratings are 200 mA for 115 volts, or 100 mA for 208 and 230 volt operation.

When the unit is first powered up, the display shows **Group3** for 2 seconds before field measurements appear. If the Hall probe is not plugged in, the field reading display is replaced with **noProbE**.

### 3.4 GPIB CONNECTION

Connection to the GPIB connector on the rear of the DTM is made using cables as specified in the IEEE-488-1978 standard document. Briefly, the cable has 24 conductors with an outer shield. The connectors at each end are 24-way Amphenol 57 series or similar with piggyback receptacles to allow daisy-chaining in multiple device systems. The connectors are secured in the receptacles by a pair of captive locking screws with metric threads. The total length of cable allowed in a system is 2 meters for each device on the bus, or 20 meters maximum. A system may be composed of up to 15 devices. Table 1 is a listing of the GPIB connector pin assignments. Fig. 2 shows the connector pin location and signal names as viewed on the teslameter rear panel.

<b>pin</b>	<b>symbol</b>	<b>description</b>
1	DIO1	Data Input Output line 1
2	DIO2	Data Input Output line 2
3	DIO3	Data Input Output line 3
4	DIO4	Data Input Output line 4
5	EOI	End Or Identify
6	DAV	Data Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	SHIELD	Cable shield - connects to teslameter case
13	DIO5	Data Input Output line 5
14	DIO6	Data Input Output line 6
15	DIO7	Data Input Output line 7
16	DIO8	Data Input Output line 8
17	REN	Remote Enable - not used in teslameter
18	GND 6	Ground wire of twisted pair with DAV
19	GND 7	Ground wire of twisted pair with NRFD
20	GND 8	Ground wire of twisted pair with NDAC
21	GND 9	Ground wire of twisted pair with IFC
22	GND 10	Ground wire of twisted pair with SRQ
23	GND 11	Ground wire of twisted pair with ATN
24	GND	Teslameter logic ground

Table 1. GPIB Connector Pin Assignments



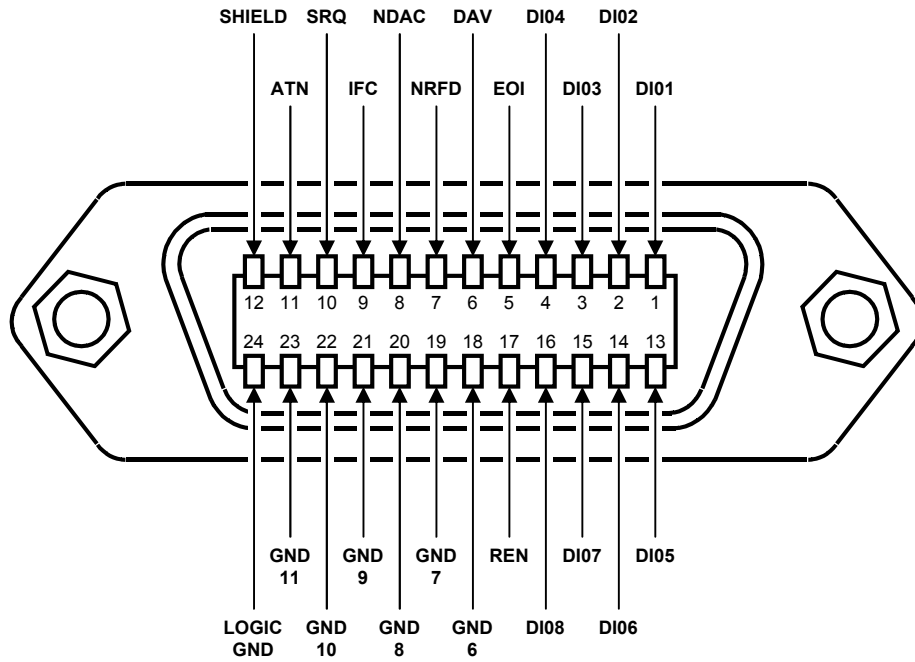


Fig. 2. IEEE-488 Standard Connector

### **3.5 INTERNAL DIP SWITCH SETTINGS**

The Processor Board in the DTM is provided with two sets of DIP switches, allowing the user to set up teslameter operation and communications according to system requirements.

To obtain access to the switches, turn the DTM over and take off the bottom cover by loosening the single central screw. Refer to Fig. 3 for switch locations.

Switch functions are as follows:

- S1 8-way DIP switch - sets device address on GPIB; sets talker-only mode.
- S2 8-way DIP switch - selects operation mode and communication options.

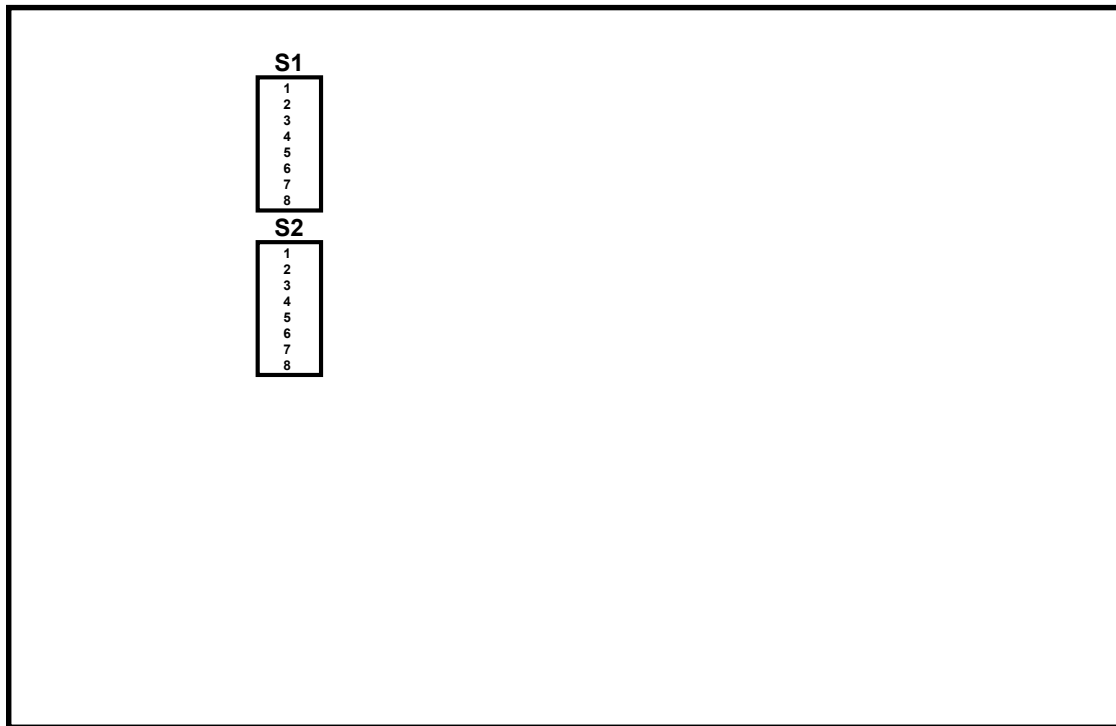


Fig. 3. Location of Processor Board Switches

Detailed DIP switch settings are given in Table 2 below.

switch	function	switch OFF	switch ON
S1-1	set device address	adds 0 to address	* adds 1 to address
S1-2	set device address	* adds 0 to address	adds 2 to address
S1-3	set device address	* adds 0 to address	adds 4 to address
S1-4	set device address	* adds 0 to address	adds 8 to address
S1-5	set device address	* adds 0 to address	adds 16 to address
S1-6	dual primary addressing	* disable	enable
S1-7	talker only mode	* talker/listener	talker only
S1-8	not used		
S2-1	service requests	disabled	* enabled
S2-2	EOI operation	EOI not asserted	* EOI asserted
S2-3	select terminator	* line feed	carriage return
S2-4	double terminator	* disabled	enabled
S2-5	field units	* tesla	gauss
S2-6	units symbol	no symbol	* symbol after data
S2-7	digital filtering	filtering OFF	* filtering ON
S2-8	defaults	* no action	defaults loaded
			<b>* factory setting</b>

Table 2. DIP Switch Functions

The switches are read by the processor once per second, so the effects of changed settings can be observed in real time.

S1-1 through S1-5 set the DTM address on the bus. A binary code is used, as shown in the table. Address 31 (all switches ON) is illegal.

S1-6 enables dual primary addressing of the teslameter on the GPIB. In this addressing mode the least significant bit of the device address is ignored, so that the device is activated by two adjacent addresses.

S1-7 when ON makes the teslameter a talker-only. In this mode it sends on the bus every field reading made. It does not respond to commands. This mode is useful in systems without a controller, where the teslameter readings are continuously sent to a listening device, such as a printer.

S2-1 through S2-6 are set according to the GPIB system requirements.

S2-1 is normally ON, which allows the teslameter to assert the SRQ line and the SRQ bit of the serial poll response. However, if the GPIB system controller routines are to run without interrupts, S2-1 should be switched OFF, thus disabling all SRQ action.

S2-2 controls the operation of the EOI bus management line. Normally the switch is ON, so EOI is asserted each time the teslameter sends a string terminator character on the bus, indicating the end of a response. With S2-2 OFF, the teslameter does not assert the EOI line.

S2-3 selects the character sent as string terminator. With the switch OFF, the terminator is the line feed character. When the switch is ON, carriage return is used.

S2-4 when ON introduces a pre-terminator character before the final string terminator selected by S2-3. The pre-terminator is the character not selected by S2-3. The terminator sequence as selected by S2-3,4 is as follows:

		S2-3	
		OFF	ON
S2-4	OFF	lf	cr
	ON	cr, lf	lf, cr

Table 3. String Terminator Switch Settings

Check which terminator characters are required by the system controller and/or other devices in your GPIB system, and set the switches accordingly.

S2-5 selects the field units used by the DTM: OFF for tesla, ON for gauss.

S2-6 when ON adds the field and temperature units characters T or G and C to the transmitted string after the numerical values.

S2-7 enables digital filtering of the field value when switched ON.

S2-8 allows the user to reload default settings, where all the numerical values entered by the operator are returned to their default values, and switch selectable functions are instated as set on the switches. To load defaults, switch S2-8 ON, wait 1 second, then switch OFF again. If the switch is left ON, defaults will be loaded each time the teslameter is powered up. The display shows the message **rESEt** each time defaults are loaded. When defaults are loaded on power up, the **rESEt** message follows the Group3 power up message.

The functions of S2-1,2,5,6,7,8 can be selected remotely on the bus by DTM commands. See Section 4.5.3. To revert to switch control, change the switch setting, wait 1 second, then switch to the desired position.

## 3.6 ANALOG OUTPUTS

### 3.6.1 Connectors

Two output signals are available at the rear of the teslameter. These signals are referred to as the dc and ac outputs, and are described below. The analog outputs are not corrected for linearity or temperature errors. The cable connector required is a Molex receptacle type M5051-4 fitted with M2759 terminals. It carries both outputs. Pin assignments are given below.

pin	signal
1	ground
2	ac output
3	ground
4	dc output

Table 4. Analog Output Connector Pin Assignments

### 3.6.2 DC Output

The dc output is the Hall probe signal amplified to 3 volts full-scale, and gives an indication of the instantaneous field value from dc to 3kHz (-3dB), with a roll-off of 60dB/decade. Field direction is indicated by the output voltage polarity. There is a small zero offset arising from the probe zero-field output and amplifier offsets. The output impedance is 1000 ohm with a 10nF capacitor to common for noise filtering.

### 3.6.3 AC Output

The ac output is a positive voltage analog of the time-varying or ac field component. To generate this output the instrument removes the dc component of the analog output described above, then full-wave rectifies any remaining ac component. The overall response to varying fields is 8Hz to 3kHz, and the rectified output has a time constant of 0.2 seconds. The rectifier circuit responds to the average value of the ac waveform, but is calibrated such that if the waveform is sinusoidal, the reading corresponds to its rms value. The output impedance is the same as for the dc output.

## 3.7 GROUNDING

All parts of the teslameter's metal case are connected together to form an integral electric shield around the circuitry inside. When the probe connector is plugged into the teslameter and the retaining screws are tightened, the probe connector case and the teslameter case are connected together and form an integral shield around the circuitry inside. The cable shield is added to the case shield and extends protection from electrical interference almost up to the probe head.

Because there is an internal connection between teslameter circuit common and the probe connector case, when the probe connector is engaged and the retaining screws tightened the teslameter circuit common will be connected to the case. Do **not** make an additional connection between circuit common and the case at any point, including at the RS-232C connector or at the G3CL connectors on serial teslameters, or at the GPIB connector on teslameters with the IEEE-488 option. Such additional connection will form a ground loop and may introduce errors in the measured field value.

The shielding provided with the above arrangement should be sufficient protection against EMI in most cases, especially when the probe cable is shielded. Sometimes it may be found helpful to ground the teslameter case to a good electrical ground point. Connection can be made to the case by inserting an appropriate lug or terminal under the head of one of the rear panel fixing screws.

Further protection from transient interference can be obtained by using model PS12D7 power supply in place of the usual plugpack supplied with the teslameter, and by installing the Group3 ferrite kit part no. 11000036. See section 3.9 of this manual.

For electrical safety, the case of the L version must be grounded through the third wire of the power input cord.

### 3.8 INSTALLING THE PANEL MOUNT OPTION

Model DTM-151-PG is supplied fitted with a special front bezel which has threaded studs to allow panel mounting. A panel mount support bracket (part 17000058) is included to help support the teslameter. Group3 can supply 19-inch wide, 2U (3.5") high rack panels to hold one, two, or three teslameters (parts 17000025, 17000026, and 17000027, respectively). Alternatively, the user can mount the teslameter in any panel of thickness up to 3/16" (4.76mm). Dimensions for the cutout and drilled holes are shown below in Fig. 4.

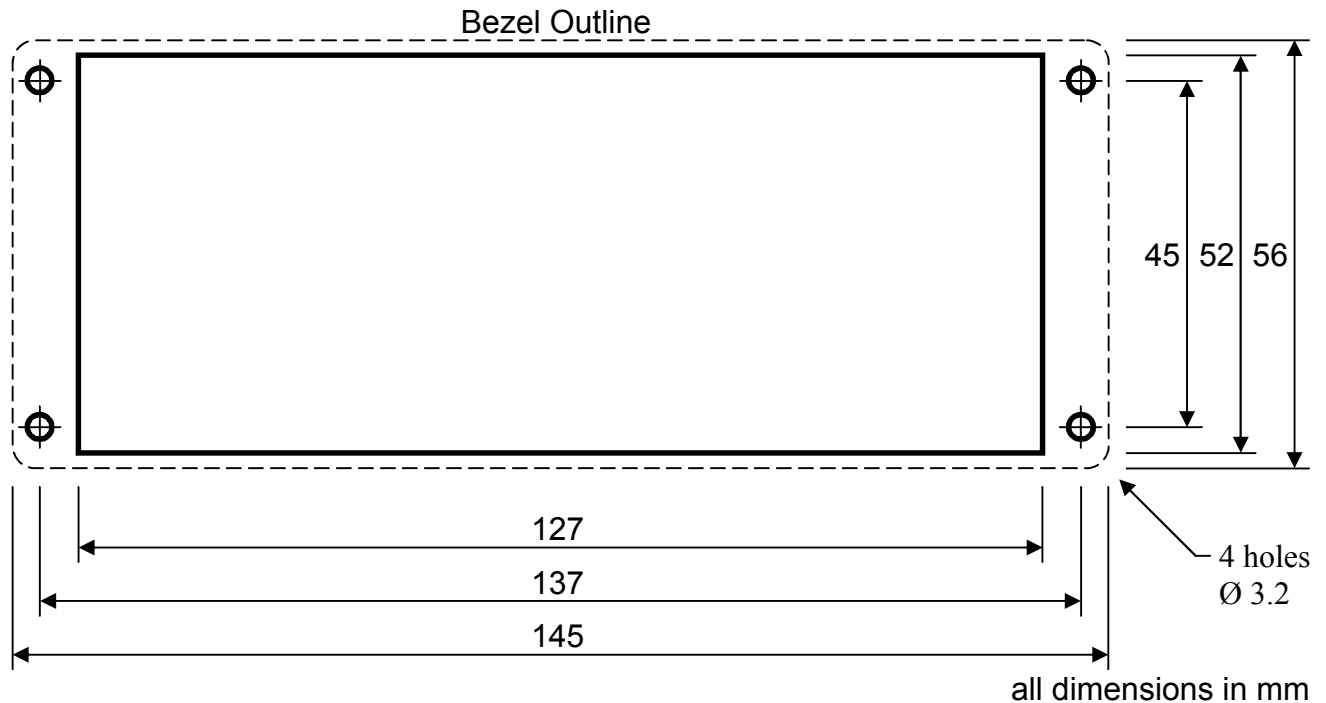


Fig. 4. Panel Cutout Dimensions

To fit the teslameter to the panel, first remove the nuts and washers from the bezel studs. Push the teslameter through the panel from the front, making sure all the studs fit through the small holes. While holding the teslameter in place, place the support bracket under the teslameter from the rear, pushing it up to the panel with the studs through the holes in the bracket. Put the flat washers on the studs, then the lock-washers, and finally screw on the nuts. Make sure the teslameter is resting on the bracket, then tighten the nuts, preferably using a long-stemmed nut driver.



### **3.9 INSTALLATION TECHNIQUES FOR ELECTRICALLY NOISY ENVIRONMENTS**

The DTM-151 is a precision electronic measuring device. Because of the nature of the measurements it is asked to do, it is frequently exposed to conditions that are considerably worse than are normally encountered by precision instruments. Therefore, the teslameter has been carefully engineered to be as immune as possible to sparks and other forms of interference through the use of several kinds of power input filtering and a special high-isolation switchmode power module built into its circuitry. The design has been verified by extensive testing, using high energy sparking in close proximity to both the teslameter instrument case and the probe. Nevertheless, due care should always be taken when installing the teslameter system.

The teslameter and its probe must be protected from any chance of receiving a direct hit by a high voltage discharge. The probe should have shielded cable if the meter is to be used in an electrically noisy environment. The cable shield is an RFI screen, not a high current path, so if there is any possibility of an arcing discharge hitting the probe area, then the probe head and part or all of the cable must be enclosed in a metal tube (non-magnetic near the probe head), or shielded in some other way.

The probe cable should be routed away from any power, high current or high voltage wiring. It should be shielded from any capacitively coupled noise effects. If the cable runs close to any section of the apparatus that could be subjected to a very rapid change of potential when a spark discharge occurs, then the probe cable may need additional shielding to prevent capacitive coupling of the noise.

The retaining jack screws designed to hold the probe connector onto the teslameter must be screwed up finger tight, as they form part of the electrical connection of the shield system. The woven braid of the probe cable is terminated to the probe connector case. The retaining screws then connect the probe connector case to the teslameter case.

The teslameter itself should be sited in a sheltered location, where it will not be exposed to spark discharges or radiated or capacitively coupled noise. The teslameter case is made of metal for shielding reasons. However, of necessity it is less than perfect, as apertures have to be left in the case for the display and various connectors etc. The unit is a precision measuring device, and should be treated with care, not subjected to adverse environmental conditions.

The plugpacks supplied with each teslameter should be plugged in to a clean mains power supply. Noise on the mains will work its way through the transformers and disturb the teslameter. Simple mains filters are readily available if there is only one mains supply for the whole machine. Route the low voltage lead away from high current or high voltage wiring. Ideally cut the low voltage lead to the minimum length required for the installation, and re-connect the plug to it.

## **Grounding the teslameter case**

The probe shield is terminated to the probe connector case, which is then connected by the retaining screws to the teslameter chassis. At this point the entire shield system is floating. In some installations it is beneficial to have the system floating, but most frequently it is sensible to have the shields grounded.

If the teslameter is panel mounted, then the case is almost certainly electrically connected to the control rack, and grounded that way. However if the teslameter is a bench unit, then the rubber and plastic feet on it will isolate the case. If the case does need to be grounded then loosen one of the screws on the back panel and put a grounding lug under the head of the screw. It is most convenient to use a 1/4inch (6.35mm) quick connect tab. The grounding wire can then be easily disconnected if the teslameter has to be moved. Use a heavy gauge, short wire to ground the unit to a substantial grounding point nearby. If the teslameter is sitting on metalwork, then it should really be grounded to that metalwork so it is at the same potential.

## Further Preventative Measures

If problems are still encountered, despite following the precautions detailed above, then there are some further things to try.

Tests have shown that, in an electrically noisy environment, the main path of noise entry to the teslameter is through the low voltage power supply input. The trouble could come from mains borne transients working their way through the plugpack transformer, or from interference picked up on the low voltage lead itself. The quickest and simplest fix for this problem is to wind the power lead several times through a ferrite core. Use a thick walled ferrite tube of substantial size - a simple small torroid is not nearly as effective. A suggested ferrite is the TDK part number HF70RH26x29x13. This is a tubular ferrite, 29 mm long, 26mm outside diameter, and 13mm inside diameter. Winding the power lead four times through this core, really close to the teslameter, significantly reduces noise upsets.

If the analog outputs are wired up, then shielded twisted pair should be used for all wiring, routed away from any high current or high voltage cabling. In a really noisy environment it can be beneficial to put this analog cabling through a ferrite tube for a few turns to suppress induced noise.

The probe cable itself can be passed through a ferrite core. The internal diameter will need to be sufficient to pass the probe head through. An MPT (miniature) probe head is nearly the same size as shielded cable (6.5mm diameter), but an LPT probe head needs an internal ferrite diameter of 14mm or more. Alternatively a split core ferrite variety can be used, such as TDK part HF70RU16x28x9. The core should be placed where the probe cable enters the probe connector, and optionally a second ferrite can be placed where the cable shield layer ends, approximately 300mm back from the probe head.

Group3 can supply an alternative power supply to be used instead of the usual plugpack. The alternative power supply is model PS12D7. It is a universal voltage (85 - 270V 50/60Hz) input, 12Vdc 7W output unit with excellent input-output isolation for noise and transients. The PS12D7 is DIN rail mounted. In conjunction with the PS12D7 we recommend the use of our ferrite kit, part no. 11000036, which implements the ferrite filtering measures described above. The kit consists of a 1.2 meter length of twin cord with a ferrite tube fitted. This cord is intended to connect between the PS12D7 and the teslameter. The kit also contains a split ferrite tube and housing for fitting to the probe cable.

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## 4 OPERATING INSTRUCTIONS

### 4.1 ZEROING

The DTM-151 digital teslameter has a very stable zero field reading. Nevertheless, it is good practice to zero the instrument on all ranges immediately prior to making critical field measurements. The zeroing process takes out residual zero errors in the Hall probe and the instrument's preamplifier "front-end".

The instrument must be zeroed if it has not been powered for 30 days or more, as there is a possibility that its memory back-up may have failed. Zeroing is mandatory if a different probe is to be used since the instrument was last zeroed. You should also zero the instrument when using it for the first time. The ac ranges must also be zeroed individually.

Before zeroing the system, connect up and apply power as described in sections 3.2 and 3.3. Allow 30 minutes for the instrument and probe to stabilise.

For absolute zeroing, place the probe in a zero-field region, either in a zero field chamber or inside a suitable magnetic shield, so that the probe is shielded from the earth's magnetic field and other stray fields.

If desired, a relative zero setting may be done; the instrument is zeroed after the probe is placed in its measurement position. Thus any ambient field is automatically subtracted from subsequent measurements. The probe should not be moved once zeroing is complete. About 5% of full-scale may be zeroed out without reducing full-scale span below specification.

The zero field reading is affected slightly by the presence of metal against the probe's back surface. If the probe is to be used clamped to a metal surface, or in a probe holder, it should be zeroed in the same situation. Allow the probe to stabilise thermally for a minute or two before zeroing.

A range is selected by pressing the RANGE key. The four range indicators show the selected range. The RANGE key selects the ranges in turn in the sequence 0.3, 0.6, 1.2, and 3.0 tesla. If a single-range probe is in use, the RANGE key will have no effect.

The zeroing process is implemented by pressing and releasing both keys together. Alternatively, press and hold either key while pressing the other key twice momentarily. The display will read **Zero** for a moment, indicating that zeroing has occurred.

The zeroing process should now be repeated for all the remaining ranges. Press the RANGE key to select another range, and zero this range by pressing both keys together, as above. After changing ranges, wait 1 or 2 seconds before zeroing. Continue until all the ranges have been zeroed.

To zero the ac ranges, first select the ac mode by pressing the MODE key once. "A" will appear at the left of the main display.

Now perform the zeroing function on all ranges, as described above.

Because the ac measurement circuitry has a 0.2 second time constant, allow the display to settle after changing ranges before zeroing.

Return to normal dc field display by pressing the MODE key 4 times. Once the zeroing process has been completed, the internal processor will apply the appropriate correction to whichever range is selected. It is recommended that the instrument be re-zeroed if the ambient temperature has changed significantly.

## **4.2 INSTALLING THE PROBE**

Group3 Hall probes are built to be as robust as possible for a small, precision device. However, it is most important that certain precautions be taken when handling and installing probes so that they are not damaged or destroyed, and to preserve their accurate calibration.

Mount the probe head so there is no pressure which will tend to bend or depress its ceramic rear surface. If the probe head is clamped, make sure the surface in contact with the ceramic is flat and covers the whole of the ceramic surface. Do not apply more force than is required to hold the probe in place. Any strain on the ceramic will alter the probe's calibration, and excessive force will destroy the Hall element inside.

When the probe head is mounted, the cable should be clamped firmly nearby so it cannot be torn away from the probe head if accidentally pulled. The flexible section adjacent to the probe head can be carefully folded to allow the cable to come away in any direction, but avoid repeated flexing of this section.

Keep the cable out of the way of foot traffic. Do not pinch the cable, or drop sharp or heavy objects on it. A severed cable cannot be re-joined without altering the probe's performance, and requires factory repair and re-calibration.

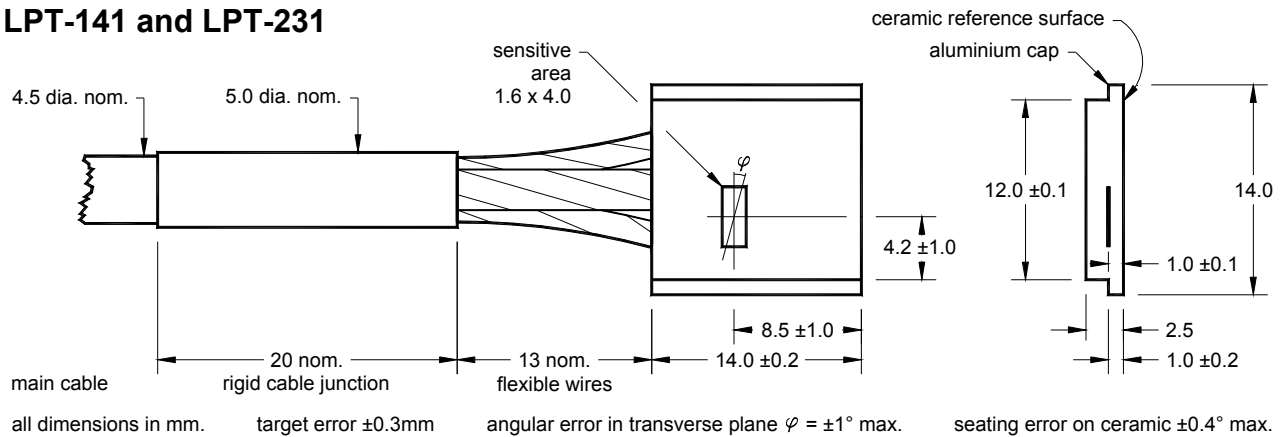
The probe can be fitted to a Group3 probe holder, part no.17000050 for the LPT-141 and LPT-231, part no.17000081 for the MPT-141 and MPT-231. Probe holders which orient the probe head to the axial position are also available from Group3 suppliers. The holders protect probes and provide additional cable strain relief. Alternatively, the probe can be clamped using the machined detail in each side of the metal cap.

The probe will measure the component of the field which is normal to the flat surface of the probe head. The point of maximum sensitivity is marked by a target printed on the top of the probe head. A positive indication will be obtained when the magnetic field vector enters this side of the probe. The target represents the tail of the vector arrow.

Magnetic field convention is that field lines are directed from an N pole to an S pole. Fig. 5 gives the dimensions of the two styles of probe, and shows the position of the most sensitive point.

If the exact direction of the magnetic field is unknown, its magnitude can be measured by putting the DTM in the peak hold mode, and slowly rotating the probe. As the probe turns and the measured field rises and falls, its maximum value is held on the display. See section 4.4.2.

### LPT-141 and LPT-231



### MPT-141 and MPT-231

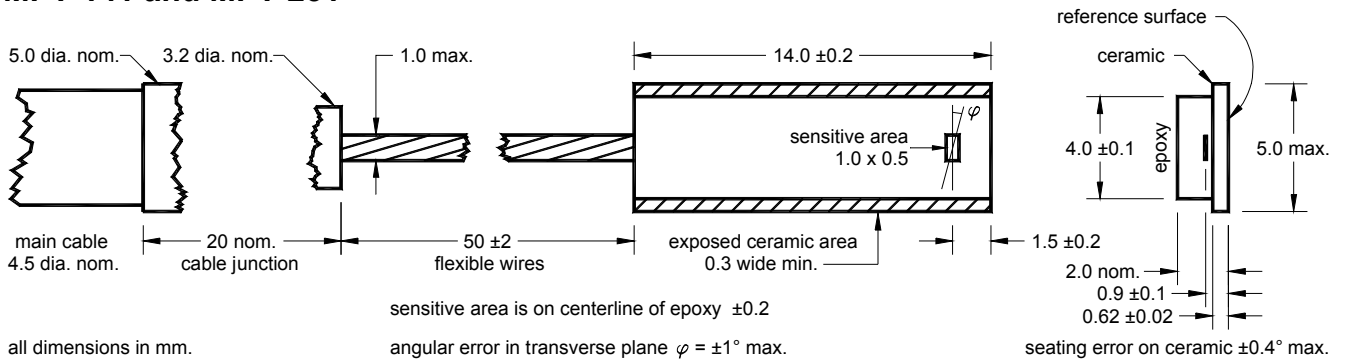


Fig. 5. Probe Dimensions

## 4.3 READING THE FIELD VALUE

The field value is read directly off the display. A negative sign indicates that the field direction is opposite to that described in section 4.2. For maximum resolution, select the lowest range which will display the field value. See sections 4.1 and 4.4 for range selection instructions. If the field reading is greater than full-scale, the message **o'rAnGE** will be displayed. Change to a higher range until the message clears. The field may be displayed in tesla or gauss, with the appropriate indicator showing the units in use. To change the units, see section 3.5.

## 4.4 DISPLAY MODES, USING THE FRONT PANEL KEYS

### 4.4.1 The Keys

Two front panel keys are used to control the teslameter. Changes of state occur as a key is released, not as it is depressed.

The MODE key, used on its own, rolls the instrument through the various operating modes in sequence: dc field, ac field, peak hold field, peak hold ac field, and probe temperature, as described in 4.4.2 below.

The RANGE key selects the range without changing the display mode.

The keys are pressed together (at the same time) to zero the display.

The same action is used to reset the display in the peak hold mode.

### 4.4.2 Operating Modes

a. Field (dc) display.

Four ranges, 0.3, 0.6, 1.2, and 3.0 tesla full-scale, are selected in sequence by pressing the RANGE key. Four range indicators show the range in use. If a high sensitivity probe is connected to the teslameter, the actual full-scale ranges are one tenth of those shown above, i.e. 0.03, 0.06, 0.12, and 0.3 tesla.

The magnetic field measurement is displayed with up to seven digits.

A minus sign is added to indicate reverse polarity fields.

Press the keys together to zero the display. The display shows **ZErO**.

Field reading is filtered if selected by the internal switch - see p.3-9.

b. AC field measurement, ranges and zeroing as above.

Shows the value of time-varying component of field.

This mode is indicated by A appearing in the left-hand display character.

c. Peak hold display, ranges as above.

Displays maximum field measurement taken, either polarity, since entering the mode, or since last reset.

HOLD indicator shows peak hold mode is operating.

If filtering is on, the filtered field value is held.

Reset is performed by pressing both keys together.

The peak value is also reset if the field polarity changes.

d. Peak ac measurement. Combination of b. and c. above.

e. Probe temperature display in degrees Celsius.



### 4.4.3 Display Messages

#### Power up message

The message **Group3** appears in the display for 2 seconds when the teslameter is first powered, or when a GPIB command restarts the operating software (see section 4.5.3).

#### No Probe

The message **noPrbE** is displayed if the Hall probe is disconnected from the instrument. While the message is visible, all key functions are disabled.

#### No Temperature Sensor

The message **noPrb°C** is displayed for 2 seconds after the Group3 power up message if the probe is not a temperature corrected type, e.g. LPT-130, LPT-230, MPT-132, MPT-230. The message is also displayed if the MODE key is pressed to display what would have been the probe temperature reading. This message warns the user that the field reading is not temperature corrected, and therefore the accuracy will be less than would be obtained with a temperature corrected probe (LPT/MPT-141/231).

#### Temperature Error

The message **Error°C** is displayed in place of the temperature reading if a temperature corrected probe is in use but there is a fault with the probe's temperature sensor or associated wiring or circuitry. Again, this is to warn the user that the field reading will not be to full accuracy.

#### Over-range

The message **o'rAnGE** appears when the DTM is displaying dc or ac field or is in peak hold, if the field measurement exceeds the instrument's input capacity. To clear the over-range message, select a higher range or reduce the magnetic field at the probe, or both if necessary. During over-range, all key operations are locked out, except for range selection.

#### Overflow

The message **o'FLo** is displayed in dc or ac field modes, or in peak hold mode, if the computed value of the field reading exceeds the capacity of the display, that is, if the number to be displayed is outside the range  $\pm 99999.9$ . In overflow, the instrument is not over-ranged, but rather the computed reading is too large to be displayed. However, if over-ranging occurs at the same time as overflow, then the over-range message is displayed preferentially. The usual cause of overflow is a large calibration factor, scale factor, or offset entered through the GPIB port. See section 4.5.3.

#### Reset

The message **rESEt** appears for 1 second when defaults are reloaded, either by a CTRL X command, or by switching S2-8 ON.

#### No Local Control

The message **noLOCAL** appears if a key is pressed when local control is locked out by the SO1 command. See Table 9 in section 4.5.3.

### **Address setting display**

With the teslameter in dc field display mode, when the MODE key is pressed twice very quickly the display shows **Addr nn** where *nn* is the address of the teslameter as set on switches S1-1 through S1-5. Press the mode key once again to cancel this display.

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## 4.5 USING THE IEEE-488 GPIB INTERFACE

### 4.5.1 General Purpose Interface Bus - Overview

The IEEE-488 standard describes a means of communication to and from programmable instruments through a standard bus and associated protocol called the General Purpose Interface Bus (GPIB). Any instrument manufactured to this specification will be able to communicate on the bus. Up to 15 instruments may be connected on the bus at any one time, and they are considered to be listeners (able to receive data), talkers (able to transmit data) or controllers (able to control and configure the bus).

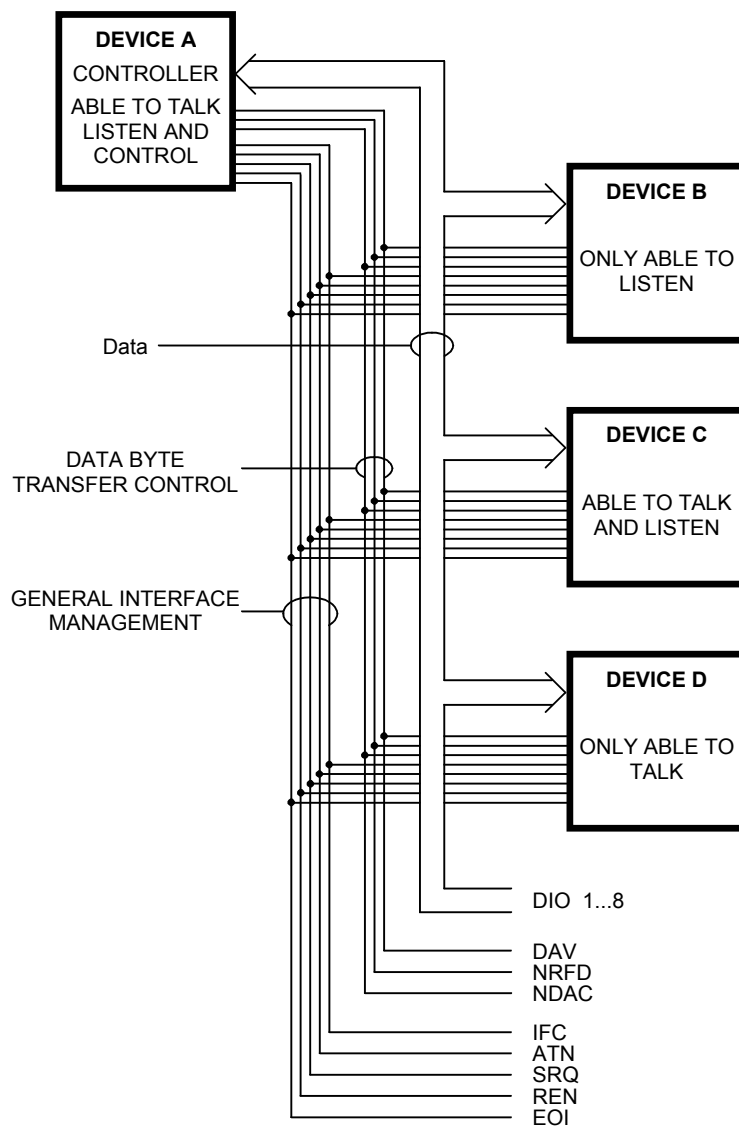


Fig. 6. A Typical IEEE-488 System

A typical IEEE-488 setup is shown in Fig. 6. This system contains a controller and a selection of talkers and listeners. However, a wide range of system complexity is possible, from systems with just one talker-only and one listener-only and no controller, to systems including several controllers linked with many talker/listener devices.

The IEEE-488 interconnection cable contains 16 signal lines in three groups:

- 8 data lines
- 3 handshake lines
- 5 bus management lines.

All these lines connect to all the instruments on the bus. The logic sense on the actual bus wires is low true.

The 8 data lines allow bit-parallel, byte-serial data transmission between units on the bus. The data lines are used to send data from talkers to listeners, and to send data and commands from controllers to talkers and listeners.

The three handshake lines are:

- Valid – DAV
- Not Ready For Data - NRFD
- Not Data Accepted - NDAC.

NRFD is high (false) to indicate that all devices on the bus are ready for the next data transmission. If any device is not ready, it pulls NRFD low (asserted), which inhibits data transmission. When a talker is ready to send data it places the data on the 8 data lines and asserts the DAV line. As each listener on the bus accepts and reads the data, it removes its assertion of the NDAC line. Thus the NDAC line stays asserted until the slowest unit on the bus has accepted the data and releases the line. Now the talker can take the data off the bus, which becomes available for the next transaction.

There can be only one System Controller on the bus. However the System Controller can pass control to another controller, which is then called the active controller. It is the responsibility of the active controller to determine which device can next talk and which can listen. At any time there can be only one active talker, but as many active listeners as desired. The speed of data transmission between talker and listener will be limited by the speed of the slowest listener.

Each device on the bus is assigned a unique address in the range 0 to 30. The address is usually set by switches on the device. The switches may be located on the back panel or internally.

When the controller wishes to designate the talker and listeners for the next sequence of bus transmissions, it asserts the bus management line called Attention (ATN) and then sends the appropriate talker and listener address commands to assign the desired talker and listener(s) required for the next transaction. The controller then releases the ATN line, thus allowing the talker to start sending its data on the bus. The ATN line distinguishes commands from data. When a controller is about to set up such a

transaction, it is normal practice first to send a single command, which causes all devices to unlisten.

Devices which have not been addressed to listen simply ignore the data being sent and so have no effect on the transmission.

When configuring a system, the controller can send commands to the other devices in one of three ways:

- 1) a command can be sent by asserting one of the 5 bus management lines; for example, asserting the Interface Clear (IFC) line resets the bus to an idle state irrespective of bus activity at the time;
- 2) a command can be sent by asserting the ATN line and placing the command on the data lines; the command is read by every device on the bus, with normal handshaking, as described above. An example of this is the Device Clear command which resets all devices on the bus to their specific predefined device-dependant states;
- 3) a command can be sent to specific devices. First the controller sends the listen address command of the devices which are to receive the command. Then the command itself is sent, to be received only by the devices addressed to listen.

Command messages are sent on the data bus using 7-bit ASCII code, and are distinguished from data messages by the state of the ATN line - ATN is asserted for commands. Command messages fall into four groups as shown in Table 5 below. The groups are the Primary Command Group, the Listen Address Group, the Talk Address Group, and the Secondary Command Group.

## **Address Commands**

When the controller wants to make a device behave as a listener, it places the appropriate listen address command on the bus. The command is given by

**listen address command = decimal 32 + device address**

For example, if the device address is decimal 18 (hex 12), then the decimal number 50 (hex 32, ASCII 2) is placed on the data lines as a binary coded 7-bit number, while the ATN line is held asserted. This causes the device whose address is decimal 18 to become a listener. In IEEE-488 parlance, the device is said to be "selected". Any or all devices on the bus, which have listener capability, may be in the selected state simultaneously.

decimal value	hex value	ASCII character	IEEE-488 mnemonic	description
			<b>PCG</b>	<b>Primary Command Group</b>
1	01	SOH	GTL	Go To Local
4	04	EOT	SDC	Selected Device Clear
5	05	ENQ	PPC	Parallel Poll Configure
8	08	BS	GET	Group Execute Trigger
9	09	HT	TCT	Take Control
17	11	DC1	LLO	Local Lockout
20	14	DC4	DCL	Device Clear
21	15	NAK	PPU	Parallel Poll Unconfigure
24	18	CAN	SPE	Serial Poll Enable
25	19	EM	SPD	Serial Poll Disable
			<b>LAG</b>	<b>Listen Address Group</b>
32-62	20-3E	sp--->		Listen addresses 0 through 30
63	3F	?	UNL	Unlisten
			<b>TAG</b>	<b>Talk Address Group</b>
64-94	40-5E	@---^		Talk Addresses 0 through 30
95	5F	underscore	UNT	Untalk
			<b>SCG</b>	<b>Secondary Command Group</b>
96-126	60-7E	'---~		Secondary Commands 0 through 30
96-111	60-6F	'---o	PPE	Parallel Poll Enable (SC0 thru SC15)
112	70	p	PPD	Parallel Poll Disable (SC16)
127	7F	DEL		ignored

Table 5. IEEE-488 Command Codes

When the controller wants to make a device into a talker, it places the device's talk address command on the bus. This command is given by:

**talk address command = decimal 64 + device address**

For example, a device whose address is decimal 18 has a talk address of decimal 82 (hex 52, ASCII R). At any time, only one device may be a talker.

To cause all listeners to stop listening, the controller sends the Unlisten command, decimal 63 (hex 3F, ASCII ?).

To stop the talker being a talker, the Untalk command is sent, i.e. decimal 95 (hex 5F, ASCII \_).

## Bus Management Lines

- ATN** Attention - asserted when the controller is sending commands.  
Not asserted while data is on the bus.  
Also used with EOI - see EOI below.
- IFC** Interface Clear - when asserted by the controller, all bus activity is unconditionally terminated and the System Controller regains active control if control has previously been passed to another controller. Any talkers or listeners are unaddressed.
- REN** Remote Enable - if asserted while a device listen address is on the bus, then the device will go into its remote mode.
- EOI** End Or Identify - dual function.
- 1) when output from a talker, indicates the end of a multi-byte message when asserted during transmission of the last byte.
  - 2) during parallel polling, the controller asserts EOI and ATN simultaneously. This causes each device, which has been configured for parallel poll to place its status on the appropriate status line.
- SRQ** Service Request - asserted by a device when it requires attention from the controller. The controller responds by servicing the device in an appropriate way. Often the service request is used to indicate that the device has data ready to be sent. The controller is not obliged to respond to the service request, but the device will hold the line asserted until it has been serviced.

## Service Requests

Often IEEE-488 compatible devices have the ability to generate a service request when they require some action on the part of the active controller. A service request is usually issued when the device has completed a task, or if an error condition has occurred. To request service, the device asserts the SRQ line. This usually causes an interrupt in the active controller, so it enters an interrupt service routine, which services the event. In general, the service routine will take the following actions:

- 1) determine which device is requesting service (parallel poll)
- 2) ascertain the action required (serial poll)
- 3) execute the required action
- 4) re-enable interrupts
- 5) return to the task in hand before being interrupted.

The SRQ line is released by the device when the serial poll is performed.

## Serial Polling

When a serial poll is done on a device, it causes the device to output a byte which indicates its status or condition. Each bit indicates the status of some device-dependant parameter. Usually data line 7 reflects the status of the SRQ line.

## Parallel Polling

The fastest way for the active controller to ascertain the status of several devices on the bus is to perform a parallel poll. The devices to be polled must have parallel poll capability and must have been previously configured by the controller. During a parallel poll each configured device responds by placing its status on its own designated bus data line. More than one device can respond on each data line.

The data line assigned to a device and the logic sense of the response is configured by a PPOLL CONFIGURE sequence, as follows:

- 1) The device is addressed to listen
- 2) The Parallel Poll Configure command PPC, hex 05, is sent
- 3) The Parallel Poll Enable code is sent. This code belongs to the Secondary Command Group, decimal 96 to 111. In this code bits 6 and 7 are always set. Bits 1, 2, and 3 carry a binary code to specify which of the 8 data lines the device will use to send its status, and bit 4 is used to determine the logic sense of the status. For example, if bits 1 through 4 were all 0, the device would place 0 on data line 1 during a parallel poll if its status response were in the affirmative.
- 4) The Unlisten command is sent

Now if the controller executes a parallel poll by asserting the ATN and EOI lines simultaneously, the configured device(s) respond as described above and the controller reads the data lines.

The parallel poll response can be disabled in two ways:

- Parallel Poll Unconfigure (PPU) command from the controller will cause all devices on the bus to ignore subsequent parallel polling. The devices are not addressed to listen before this command.
- The PPC command followed by Parallel Poll Disable (PPD) will disable parallel polling only in devices which have been selected (addressed to listen).



## Device Clear and Selected Device Clear

A device on the bus is cleared by sending a Device Clear Command. The device is then initialised to a pre-defined, device-dependant state. There are two forms of this command; the Device Clear command (decimal 20) causes all devices on the bus to be cleared, whereas the Selected Device Clear command (decimal 4) clears only devices selected to listen.

## Talker-Only Mode

If a device is set to be a talker-only, it will output data on the bus, using normal handshaking, whenever it has data to send. This mode is useful in simple systems where a talker-only is connected to one or more listener-only devices without the need for a controller. A talker-only cannot receive data and it cannot be programmed through the bus.

## Listener-Only Mode

A listener-only can only receive data. It cannot be programmed through the bus, nor can it output data. For example, a printer as a listener-only will continuously print all data it receives.

For full details on the IEEE-488, see the IEEE standard 488-1978.

### 4.5.2 DTM-151-\_G IEEE-488 Capability

The IEEE-488 Standard defines ten interface functions, some with as many as 28 allowable subsets. The DTM-151-\_G teslameters support the interface functions as listed below. See also Appendix C of the IEEE-488-1978 Standard.

- SH1 source handshake capability
- AH1 acceptor handshake capability
- T5 talker (basic talker, serial poll, talk-only mode, unaddressed to talk if addressed to listen)
- TE0 no address extension talker capability
- L4 listener (basic listener, unaddressed to listen if addressed to talk)
- LE0 no address extension listener capability
- SR1 service request capability
- RL0 no remote local capability
- PP1 parallel poll capability (configured by controller)
- DC1 device clear capability
- DT1 device trigger capability
- C0 no controller capability

In general, the teslameter may act as a listener to receive commands from a system controller, and as a talker to send field readings and other responses to the controller and other listening devices in the bus system.

The teslameter may be set by means of an internal switch to act as a talker-only. See section 3.5. This mode is used in systems which have no system controller, in which the teslameter continuously sends field readings on the bus to listener-only devices, for example printers, terminals, or the Group3 COM-488 IEEE-488 to Serial Adaptor, which converts the bus traffic to serial data format.

The teslameter responds to the following command messages on the bus. This is a subset of the complete repertoire of bus commands given earlier.

decimal value	hex value	ASCII character	IEEE-488 mnemonic	description
1	01	SOH	GTL	Go To Local
4	04	EOT	SDC	Selected Device Clear
5	05	ENQ	PPC	Parallel Poll Configure
8	08	BS	GET	Group Execute Trigger
17	11	DC1	LLO	Local Lockout
20	14	DC4	DCL	Device Clear
21	15	NAK	PPU	Parallel Poll Unconfigure
24	18	CAN	SPE	Serial Poll Enable
25	19	EM	SPD	Serial Poll Disable
32-62	20-3E	sp--->		Listen addresses 0 through 30
63	3F	?	UNL	Unlisten
64-94	40-5E	@---^		Talk Addresses 0 through 30
95	5F	underscore	UNT	Untalk
96-111	60-6F	'---o	PPE	Parallel Poll Enable (SC0 thru SC15)
112	70	p	PPD	Parallel Poll Disable (SC16)

Table 6. DTM-151-\_G IEEE-488 Command Codes

The Device Clear and Selected Device Clear commands perform device-specific functions. In the teslameter these commands cause the following to occur:

- normal field display selected
- highest range selected if 4 range probe is in use
- peak hold value reset
- triggered mode cancelled
- IEEE-488 I/O buffers cleared
- IEEE-488 software reinitialised
- serial poll byte and SRQ cleared
- parallel poll unconfigured

### 4.5.3 DTM commands

In addition to the IEEE-488 commands listed in the previous section, the teslameter responds to a set of DTM commands, which are listed in Table 7 below. These commands are in the form of ASCII coded data, which are sent to the teslameter by the system controller on the bus. Note that DTM commands are data as far as the bus is concerned and are not to be confused with IEEE-488 commands. The distinguishing feature is that with IEEE-488 commands the controller asserts the ATN line.

The commands are in the form of one to three characters, in some cases followed by a decimal number represented by n in the table. Such numeric commands must be terminated by a carriage return <cr> character. If no number is entered where one is expected, the command is ignored. A decimal point is not required in whole number entries. Numerical values entered by commands are retained in non-volatile memory when power is off. Default values shown below apply after system reset command CTRL X or if S2-8 is ON. The processor automatically executes a reset if the memory back-up has failed after more than 30 days without power applied.

Switch-selectable defaults are instated on power-up, reset, and when a switch setting is changed. See Table 2, section 3.5.

All responses from the teslameter start with a space character. Decimal numbers include a decimal point. Some are in exponential format.

If an error message is returned, the complete command must be re-entered.

**TABLE 7. DTM-151-\_G IEEE-488 COMMANDS**

<b>command</b>	<b>description</b>
B<text><cr>	Displays ASCII text on teslameter display; 7 characters maximum.
B<cr>	Cancel text mode, return to normal display.
Cn	Calibrate - calls up the calibrate function and defines the current field measurement as equal to the entered value n. Command applies to the range selected only. Separate calibration factors are stored for each range. Default: field measurement not modified (calibration factor = 1).
D0	Turns OFF digital filtering.
D1	Turns ON digital filtering. Default set by S2-7.
EC	Erase calibration - sets calibration factor to 1 on current range.
EL	Erase scale factor - sets scale factor to 1 (all ranges).
EO	Erase offset - sets offset to 0 (all ranges).
EP	Erase (reset) peak hold field value.
EZ	Erase zero - cancels zero correction on current range.
F	Field reading - requests a field reading from the teslameter.
GA	General function AC - puts teslameter in ac field measurement mode.
GD	General function DC - puts teslameter in dc field measurement mode.
GC	General function Continuous - teslameter measures continuously.
GV	General function Triggered - teslameter measures when triggered by V.
IC	Inspect calibration factor - Returns calibration factor as mantissa and exponent.

ID	Inspect digital filtering status - returns 0 for OFF, 1 for ON.
IG	Inspect general function - returns two letters: D for dc field mode or A for ac mode, followed by C for continuous or V for triggered measurements.
IJ	Inspect filter factor - returns filter factor as mantissa and exponent.
IK	Inspect sampling interval - returns interval in seconds between output field readings. 0 implies readings sent at maximum rate.
IL	Inspect scale factor - returns current scale factor.
IN	Inspect display mode – returns: H for hold display N for normal field display T for temperature display
IO	Inspect offset - returns current value of offset.
IR	Inspect range – returns: 0 for 0.3 tesla range 1 for 0.6 tesla range 2 for 1.2 tesla range 3 for 3.0 tesla range
IY	Inspect window - returns current value of window within which digital filtering operates.
IZ	Inspect zero - returns current zeroing offset added to field values.
Jn	Filter factor - enters filter factor n. Default n = 41. n = 0 or 1, no filtering n > 1, filtering more severe as n increases, max. 65534. 0 < n < 1, reading overshoots.
Kn	Sampling interval - enters interval between output field values. Default n = 0, every reading sent, rate is 10 samples/second; n = any integer, time in seconds between output field values, maximum n = 65534 (approx. 18 hours).
Ln	Scale - computes a scale factor to make the field reading equal to the entered value n. The one scale factor applies to all ranges. The computed scale factor may be in the range -9.9999 to 9.9999. Default: field measurement not modified (scale factor = 1).
NH	Display mode: hold - teslameter display shows peak dc or ac field.
NN	Display mode: normal - teslameter display shows current field value.
NT	Display mode: temperature - teslameter display shows temperature.
On	Offset - calls up offset mode and enters offset, which is added to all field readings. Default = 0. n in range -79999.9 to +79999.9. The one offset applies to all ranges.
P	Peak hold field - requests a peak field reading from the teslameter.
Q	Test teslameter front panel display.
R0	Range selection, selects 0.3 tesla range.
R1	Range selection, selects 0.6 tesla range.
R2	Range selection, selects 1.2 tesla range.
R3	Range selection, selects 3.0 tesla range.
SCn	Set calibrate - enters calibration factor n for the selected range;

	Like Cn, but enters factor, not desired field reading. Default n = 1.
SE0	Turn OFF EOI line assertion when string terminator is sent.
SE1	Turn ON EOI line assertion. Default set by S2-2.
SFn	Put in a simulated field to replace the measured reading. See note p.4-17.
SLn	Set scale - enters scale factor n for all ranges; Like Ln, but enters factor, not desired field reading. Default n = 1.
SM0	Send mode: field readings sent when requested by F command only.
SM1	Send mode: field readings sent at intervals defined by Kn command.
SS0	Turns off SRQ line assertion when data is available.
SS1	Turns on SRQ line assertion. Default set by S2-1.
STn	Put in a simulated temperature to replace the real reading. See note below.
SU0	Turns OFF units symbol sent after field and temperature readings.
SU1	Turns ON units symbol sent after field and temperature readings. Default set by S2-6.
SWAn	Put in a simulated raw field at the ADC output. See note below.
SWEn	Put in a simulated raw field after EEPROM calibration. See note below.
SWZn	Put in a simulated raw field after zeroing. See note below.
SZn	Set zero - enters a zero offset n for the selected range.
T	Temperature - requests a temperature reading from the teslameter.
UFG	Units: field values displayed and sent in gauss.
UFT	Units: field values displayed and sent in tesla. Default set by S2-5.
V	Triggers field measurement after triggered operation selected by GV.
WA	Raw field - returns uncalibrated field reading direct from ADC.
WE	Returns raw field reading after teslameter internal calibration.
WZ	Like WE, but field reading has user-entered zero offset applied.
X	Cancels simulated field and temperature.
Yn	Window - enters n = window within which digital filtering occurs. Default 1 gauss. Maximum n = 65534.
Z	Zeroing - calls up zeroing mode and defines current field reading as zero for selected range only. The ranges are individually zeroed. Default sets zeroing offset to zero.
CTRL D	Returns a 16-bit binary number representing the states of the 16 DIP switches, 0 = OFF, 1 = ON; once the command has been given, changing the switches does not alter the teslameter operating mode until some other command is sent.
CTRL U	Restarts operating software as if teslameter had been freshly powered up.
CTRL X	Reload defaults - all default values reinstated. Message RESET is sent.

Note: SFn, STn, SWAn, SWEn, SWZn modes are cancelled by GPIB commands SDC and DCL – see Table 6, section 4.5.2.

#### 4.5.4 GPIB Messages

The following error messages are transmitted under the circumstances described:

**INVALID COMMAND ENTRY** - the command entered did not comply with Table 7.

**NUMBER TOO BIG** - the number entered in a command was too big.

**POSITIVE NUMBER REQUIRED** - erroneous entry of minus sign.

**DIVIDE BY ZERO** - a command entered a number which gave this arithmetic error.

**RESET** - defaults were reloaded by CTRL X command or switching S2-8 ON.

**NO TEMPERATURE PROBE** - a temperature reading was requested from a non-temperature corrected probe.

**BAD TEMPERATURE READING** - a temperature reading was requested from a temperature corrected probe, but the temperature sensor or associated circuitry is giving an invalid reading.

**FIXED RANGE PROBE** - an attempt was made to change the range with a single range probe connected to the teslameter.

**NO PROBE** - a field reading was requested when a probe was not connected.

**OVERFLOW** - the computed field value was outside the range  $\bar{n}99999.9$ .

**OVER RANGE** - the current field being measured is too high for the selected range.

#### 4.5.5 GPIB Handshaking

Once a handshake sequence has begun on the bus it should always be allowed to finish in a normal fashion. If it is stopped part way through by an asynchronous bus take-over, then an IFC uniline command should be issued before another handshake sequence is initiated. If the second handshake starts with ATN false before the IFC, while the teslameter is in the listener state, the device will not read from the bus correctly and will have to be reset. When the controller performs a serial poll on the teslameter, it must ensure completion of the handshake for the status byte. If it does not do this the device's ability to function as a talker is adversely affected until such time as the controller places the teslameter into the SPAS (serial poll active state) and completes the handshake for the serial poll status byte.

#### 4.5.6 Serial Poll

A serial poll is performed on a device, in this case a teslameter, for two reasons:

- to check on its status by decoding the byte output in response to the serial poll, and
- to reset the SRQ line.

In systems employing interrupts (SRQ function is enabled), the serial poll will usually be performed after a parallel poll has indicated which device issued the SRQ. Performing the serial poll will immediately reset the SRQ line. Data must be read from the teslameter by the bus before the device is able to assert the SRQ line again.

The status byte from the teslameter in response to the serial poll has 2 bits assigned to indicate its status:

- the least significant bit, which appears on bus line DIO1, indicates that the device has data available if asserted, and
- the next to most significant bit, on line DIO7, reflects the status of the SRQ line.

The status bit in the serial poll response will always be asserted if there is data available to be read. The SRQ bit is reset to the false state after the serial poll, and is only re-enabled when data is read from the teslameter.

## 4.6 DIGITAL FILTERING

The digital teslameter software includes a digital filtering algorithm which may be invoked by an internal switch or by remote command. See sections 3.5 and 4.5.3. Filtering is useful for smoothing out small fluctuations in the field reading.

In order to speed up the response to large field changes when filtering is on, a window can be set to define a band about the current displayed field value. Filtering will only occur while the unfiltered field value remains within the window. If the field value changes rapidly enough, the filtered field reading will not be able to follow fast enough to keep the unfiltered value within the window, and filtering is temporarily disabled. This allows the field reading to follow large rapid field changes, while providing good filtering of constant or slowly varying fields.

The window width can be set using the Y command. See Table 7, section 4.5.3. The value entered is the half-window on either side of the current field reading. The default value on system reset is 1 gauss, for a total window width of 2 gauss, independent of range.

The digital filter takes the field readings before processing by zero, calibrate, offset, and scale functions, and filters the values by performing the following computation:

$$F(\text{new}) = F(\text{old}) + \frac{F - F(\text{old})}{J}$$

where F(old) is the previous field reading display  
F(new) is the updated field reading display  
F is the most recent unfiltered field reading  
J is the filter factor.

The effective time constant of the filter is dependent upon both the rate at which field measurements are made and the value of J, according to the formula:

$$T = P / \{\ln[J/(J-1)]\}$$

where T is the filter time constant  
P is the period between field measurements.

Field measurements are made at a fixed rate of 10 per second, so  $P = 0.1$ . A default value of 41 for J is effective when the DTM is reset with the CTRL X command or S2-8. This gives an effective time constant of 4 seconds. The filter time constant may be changed by entering a new value of J using the Jn command. See section 4.5.3.



## 4.7 TRIGGERED OPERATION

Triggering allows one or more teslameters to make synchronised field measurements on demand.

The teslameter is set for triggered operation by entering the command GV.

Once the GV command has been entered, there are two ways of triggering a field measurement:

- Send the IEEE-488 Group Execute Trigger (GET) command. This invokes the device trigger capability of the teslameter's IEEE-488 interface, and is implemented by placing the GET code (decimal 8) on the data lines and asserting the ATN line.
- Enter the command V, as follows:
  - 1) Address as listeners all the teslameters which are to be triggered.
  - 2) Send the teslameter command V. As with all other teslameter commands, the V is sent as ASCII data on the bus without the ATN line asserted.

The two triggering methods produce identical results, except that the GET command triggers all teslameters which have been set for triggering by GV, while V triggers only those units which have been addressed to listen.

The new measurement will immediately appear on the teslameter display, and can be read out via the bus by entering the F command. Alternatively, if the teslameter is set for continuous transmission with the SM1 command after being set for triggered operation, then following V or GET the device will issue a service request (if service request is enabled). The device can then be parallel polled and the field value read without needing the controller to send the F command.

As a useful diagnostic aid while a system is being set up, the effects of the GV, V, and GET commands on the teslameter can be observed directly by removing its top cover and watching the LED on the analog board. During normal continuous operation the LED will be seen to flash about twice per second. After the GV command the LED will stop flashing. Then each time the GET or V command is given, the LED will flash once. Continuous operation is restored using the GC command.

The following sections describe details of triggered operation.

### **4.7.1 Digital filtering with triggered operation**

If filtering is ON, then each time a measurement is triggered the filtering algorithm will calculate a new field value for display and transmission, as described in section 4.6.

The effective time-constant will depend on the timing of the V commands.

If the field values obtained on triggering are required to reflect only the field at the time of triggering and not contain any history, then filtering should be turned OFF.

### **4.7.2 Triggered operation timing**

The teslameter stores a new field value from 0 to 10ms after the V is received. After storing, computations are done.

The new field value is ready no later than 175msec after the V command is received. Do not request the new field value (using F) sooner than 175msec after the V command, or the old field value may be sent.

### **4.7.3 When the V command is ignored**

The V command is ignored by teslameters which have not been initialised for triggering by the GV command.

The V command is ignored by teslameters which have been initialised for triggering, if the command is received while the device is still in the process of making a measurement in response to a previous V command.

### **4.7.4 Zeroing while in triggered mode**

If the teslameter is zeroed, either with the keys or by remote command, while in the triggered mode, a new zero offset will be calculated and stored, using the last field measurement made. The effect of the zero operation will be reflected in the next field measurement, when the V command is given.

To ensure the most accurate zero, it is best to place the teslameter in continuous mode with filtering on, allow time for the display to settle, then give the zero command.

The unit will zero correctly in triggered mode if first the V command is given while the probe is in zero field with filtering off; then the Z command (or pressing both keys together) will zero the instrument.

## 5 TECHNICAL

The schematics, component overlays, and parts lists of the four circuit boards in the DTM-151 GPIB interfacing teslameter and probe are provided for general reference. It is not recommended that the user attempt repair or servicing because in many cases replacing parts will affect the calibration of the instrument. In case of trouble or malfunction we strongly recommend that the user first contact the local distributor or Group3 directly for advice as to the best procedure for addressing the problem. Group3 may be contacted at the address below:

Group3 Technology Ltd.,

Physical address: 2 Charann Place, Avondale, Auckland 1026, New Zealand.

Postal address: P.O. Box 71-111, Rosebank, Auckland 1348, New Zealand.

Tel. +64 9 828 3358 Fax +64 9 828 3357.

email: [info@group3technology.com](mailto:info@group3technology.com)

website: <http://www.group3technology.com>

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**The remainder of this chapter has been removed.**

**This chapter will be made available upon request  
and at the discretion of Group.**

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# Group3 Technology Ltd - DISTRIBUTORS & REPRESENTATIVES

## Australia & New Zealand

**Group3 Technology Ltd.**  
2 Charann Place  
Avondale Auckland New Zealand  
Tel: +64 9 828 3358 Fax: +64 9 828 3358  
email: info@group3technology.com website: www.group3technology.com

## European Region

### United Kingdom

**Pulse Power & Measurement Ltd**  
65 Shrivenham Hundred Business Park  
Watchfield, Swindon, Wiltshire, SN6 8TY, UK  
Tel: +44 (0)1793 784389 Fax: +44 (0)1793 784391  
email: mryan@ppm.co.uk website: www.pmpower.co.uk

### Denmark, Sweden, Norway, Finland, Iceland, Belgium, Holland, Italy, Turkey, Russia, India Danfysik A/S

Møllehaven 31, P.O. Box 29, DK-4040 Jyllinge, Denmark.  
Tel. +45 4679 0000 Fax +45 4679 0001 Contact: Erik Steinmann  
email: es@danfysik.dk website: www.danfysik.com

### Germany, Poland, Czech & Slovak Republics, Ukraine

**Schaefer Technologie GmbH**  
Mörfelder Landstrasse 33, D-63225 Langen, Germany.  
Tel. +49 6103 79085 Fax +49 6103 71799 Contact: Martin Schaefer  
email: info@schaefer-tec.com website: www.schaefer-tec.com

### Switzerland, Austria

**Schaefer-Tec AG**  
Badimatte 21, Postfach 431, CH-3422 Kirchberg, Switzerland  
Tel. +41 34 423 70 70 Fax +41 34 423 70 75 Contact: Martin Bossard  
email: ch@schaefer-tec.com website: www.schaefer-tec.com

### France, Spain, Portugal

**Schaefer-Techniques Sarl**  
1, Rue du Ruisseau Blanc, F-91620 Nozay, France  
Tel. +33 1 6449 6350 Fax +33 1 6901 1205 Contact: Christophe Dubegny  
email: info@schaefer-tech.com website: www.schaefer-tech.com

### Italy

**Schaefer Italia SRL**  
Via Minzoni, 57, I-45100 Rovigo, Italy  
Tel. +39 0425 460 218 Fax +39 0425 462 064 Contact: Paulo Bariani  
email: italia@schaefer-tec.com website: www.schaefer-tec.com

## Singapore

**Automated Micron Assembly Pte Ltd**  
629 Aljunied Road #07-14  
Cititech Industrial Building, Singapore  
Tel: 65-6846-2118 Fax: 65-6842-5015  
email: amaasia@singnet.com.sg website: www.amaasia.net

## South Korea

**Komitec**  
#664-1 Shin Dong  
Gumi City KyungSang North Province, South Korea  
Tel: +82-544-533766 Fax: +82-544-552061  
email: sales@komitec.com website: www.komitec.com

## China

**Joint Systems Co.**  
Room 718, HangGangFuChun Business Mansion, ShenNan Blvd.  
Shenzhen, China 518040 Contact: Typhoon Xiang  
Tel. +86 755 8829 9771 Fax +86 755 8829 9776  
email: sale@gaussmeter.com.cn website: www.gaussmeter.com.cn

## India

**Transact India Corporation**  
5/1A, Grants Building, Arthur Bunder Road, Colaba, Mumbai 400 005, India  
Tel. +91 22 2285 5261, or 2283 4962 extn 22, or 2202 8735 Fax +91 22 2285 2326  
email: trans@vsnl.com Contact: Arish Patel arish@transact.co.in direct dial +91 22 563 64866

## Israel

**Scientific Products & Technology 3000 Ltd.**  
P.O. Box 3629, Petach Tikva 49130, Israel  
Tel. +972 3 901 4479 Fax +972 3 901 4481 Contact: Rafael Thaler  
email: info\_spt@netvision.net.il website: www.spt.co.il

## Japan

**Hakuto Company Ltd., Scientific Equipment Department,**  
1 - 13, Shinjuku 1-chome, Shinjuku-ku, Tokyo 160-8910, Japan  
PO Box 25 Tokyo Central 100-8691  
Tel. +81 3 3225 8051 Fax +81 3 3225 9011 website: www.hakuto.co.jp  
email: takahashi-shunsuke@hakuto.co.jp Contact: Mr Shunsuke Takahashi

## United States & Canada

**GMW Associates** - magnets, magnetic instrumentation, control systems

955 Industrial Road, San Carlos, CA 94070.

P.O. Box 2578, Redwood City, CA 94064, U.S.A.

Tel. +1 650 802 8292 Fax +1 650 802 8298 Contact: Brian Richter

email: [brian@gmw.com](mailto:brian@gmw.com) website: [www.gmw.com](http://www.gmw.com)

**VI Control Systems** - LabVIEW programming, control systems

2173 Deer Trail, Los Alamos, NM 87544.

Tel. (505) 662 1461 Fax (866) 422 2931 Contact: Neal Pederson

email: [np@vicontrols.com](mailto:np@vicontrols.com) website: [www.vicontrols.com](http://www.vicontrols.com)

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## Manufacturer

**Group3 Technology Ltd.,**

2 Charann Place, Avondale, Auckland 1026, New Zealand.

P.O. Box 71-111, Rosebank, Auckland 1348, New Zealand.

Tel. +64 9 828 3358 Fax +64 9 828 3357

email: [info@group3technology.com](mailto:info@group3technology.com) website: [www.group3technology.com](http://www.group3technology.com)