GMW

GROUP3

DTM-133
DIGITAL TESLAMETER
with IEEE-488 GPIB Interface
USER'S MANUAL

For units supplied with software DTM133.V1.0

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Thankyou 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.

Group3 has been designing and building magnetic field measuring equipment since 1983. We are constantly upgrading our products and support documentation. We welcome input from our customers, so if there are aspects of the instrument which you particularly like, or which you would like to see improved, please contact your Group3 supplier (see back page for a complete list) or Group3 directly with your suggestions to ***group3tech@compuserve.com***.

The Group3 website, ***http://ourworld.compuserve.com/homepages/group3tech*** contains details of all our products. This site is regularly updated, so check it from time to time to learn about recent developments.

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1. GENERAL DESCRIPTION

The DTM-133 Digital Teslameter offers accurate measurement of magnetic flux density, with direct digital readout in tesla or gauss. The instruments are light and compact, and the probes are easy to use. The DTM-133 has been engineered to withstand the severe electrical interference produced by high voltage discharge.

Options provide serial communications (RS-232C and fiber optic) or IEEE-488 interfacing for system applications.

FEATURES

Measures magnetic fields over four ranges up to 3 tesla with polarity indication; resolution up to 1 part in 6,000.

Range selection is manual or by selectable auto-ranging.

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 characteristics stored in memory chip contained in cable plug.

Accuracy is better than ±0.03% for the complete system, probe and instrument.

Temperature coefficient is better than 100ppm/°C for the overall system.

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

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

Front panel keys select the desired field range, and invoke the peak hold function to read the peak field value. The keys are also used to reset the peak hold, to zero the system, and to switch on auto-ranging. 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 when serial or IEEE-488 option is fitted. Filtering is switched internally.

With digital communications, the DTM-133 can deliver 30 readings per second.

Two digital communication options: serial (RS-232C and fiber optic) and 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 the 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 improved fiber optic cables.

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 select the field range, select 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.

An analog output gives instantaneous field value (0 to 9 kHz), not corrected for probe non-linearity.

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-133 SYSTEM

Specifications of DTM-133 with LPT-130 or MPT-132 Hall Probe.

Measurements	magnetic field density in tesla or gauss
Field ranges	0.3 0.6 1.2 3.0 tesla full-scale, 3 6 12 30 kilogauss full-scale, with polarity indication and selectable autoranging maximum calibrated field ±2.2 tesla, ±22 kilogauss
Resolution	1 in 12,000 of of bipolar span with digital filtering on

range	resolution	
	gauss	tesla
0.3 tesla	0.5	0.00005
0.6 tesla	1	0.0001
1.2 tesla	2	0.0002
3.0 tesla	5	0.0005

Accuracy	DTM-133 with LPT-130 or MPT-132 probe: ±(0.03% of reading + 0.03% of full-scale) max. at 25°C
Temperature stability	DTM-133 with LPT-130 probe: calibration: -100 ppm of reading/°C max. add -3ppm/°C for each meter of probe cable zero drift: ±(8 microtesla + 0.0015% of full-scale)/°C max.
Temperature stability	DTM-133 with MPT-132 probe: calibration: -100 ppm of reading/°C typical -140 ppm of reading/°C max. add -3ppm/°C for each meter of probe cable zero drift: ±(15 microtesla + 0.0010% of full-scale)/°C typical ±(40 microtesla + 0.0015% of full-scale)/°C max.
Time stability	±0.1% max. over 1 year
Measurement rate	30 fully corrected measurements per second
Display rate	10 display updates per second
Response time	full-scale change of field reading settles to within resolution in less than 0.2 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

Display	7-character 7-segment alphanumeric display
Indicators	8 back-lit legends for: 0.3, 0.6, 1.2, or 3.0 tesla range selected, peak hold mode on, digital filtering on, tesla/gauss units
Display modes	field, peak hold field
Digital filtering	field value filtering smooths out small fluctuations in the reading; large, rapid field changes are not filtered; internally switch selected.
Keys	2 keys select range, access peak hold display, load defaults zero field display, reset peak hold, select auto-ranging,
Analog output	instantaneous field analog: full-scale output: ±3V nominal source impedance: 1000Ω accuracy: ±10% bandwidth: 9kHz at -3dB, rolloff 3-pole 60dB/decade
On-board switches	digital filtering on/off, units (tesla or gauss)
Memory backup	user-entered data stored indefinitely in non-volatile memory

Power source

			DTM-133	DTM-133-_S	DTM-133-_G	
ac:	min	8V	0.65	0.75	1.1	A rms
	max	15V	0.3	0.35	0.5	A rms
dc:	min	10V	0.45	0.5	0.75	A dc
	max	19V	0.17	0.2	0.3	A dc

(because a switchmode regulator is used, input current falls as the voltage rises)
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 3.8.
L option: 115/208/230 V ac power input.

Enclosure	aluminum, 217 x 125 x 50 mm, textured finish, light tan color, tilt stand fitted to bench models
Ambient field	Maximum operating field for electronics package: 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	standard sensitivity transverse types: LPT-130, MPT-132 high sensitivity transverse types: LPT-230, MPT-230

Additional specifications with communication options

Digital interfacing	serial option: RS-232C and fiber optic; parallel option: IEEE-488 General Purpose Interface Bus
System orientation	Group3 Communication Loop (G3CL) using serial ports, simple loop for 31 devices, no multiplexer required; GPIB with IEEE-488 option.
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 carriage return/line feed; numerical and system status; data requested by commands; messages.
Serial bit rate	16 standard rates, switch selected, 50, 110, 134.5, 150, 200, 300, 600, 900, 1050, 1200, 1800, 2000, 2400, 4800, 9600, 19200 baud.
Fiber optic cable	Hewlett-Packard HFBR-3500, 60 meters max.
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 clear capability C0 no controller capability
GPIB connector	standard Amphenol 57-20240 with metric standoffs

ORDER CODES

Basic teslameters,
capable of four measurement ranges 0.3, 0.6, 1.2, 3.0 tesla full scale,
0.03, 0.06, 0.12, 0.3 tesla full scale for high sensitivity probes
support all LPT and MPT series probes, plugpack supplied except for option -L.

DTM-133 (recommended probes are LPT-130, LPT-230, MPT-132, MPT-230)

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**	
Serial data input/output, RS-232C & fiber optic: add suffix **S**	must select
IEEE-488 GPIB capability: add suffix **G**	one option

Example: DTM-133-DS

Probes

Four ranges, standard 2 meter cable

LPT-130	standard sensitivity	**LPT-230**	high sensitivity
MPT-132	probes	**MPT-230**	probes

Single range probes: add range suffix **-03, -06, -12, -30.**
Special probe cable lengths: add length suffix **-Xm** or **-Xs**,
for **X** substitute cable length in meters, 30 max.
m denotes unshielded cable, **s** denotes shielded cable.
Example: LPT-130-2m

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 chapter provides instructions for the basic operation of all members of the Group3 DTM-133 digital teslameter family and their companion LPT-130, LPT-230, MPT-132, and MPT-230 Hall probes. If your teslameter is a DTM-133-_S (serial communications option) or DTM-133-_G (IEEE-488 option), a later chapter will describe the use of the relevant digital communications features. For a summary of all current members of the product family, see page 2-4.

Users of teslameters without the front panel display and keys should ignore sections of this manual referring to these features. All other aspects of operation are identical.

Before using your DTM series 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.

3.2 INSTALLING THE PANEL MOUNT OPTION

Model DTM-133-P_ 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.1.

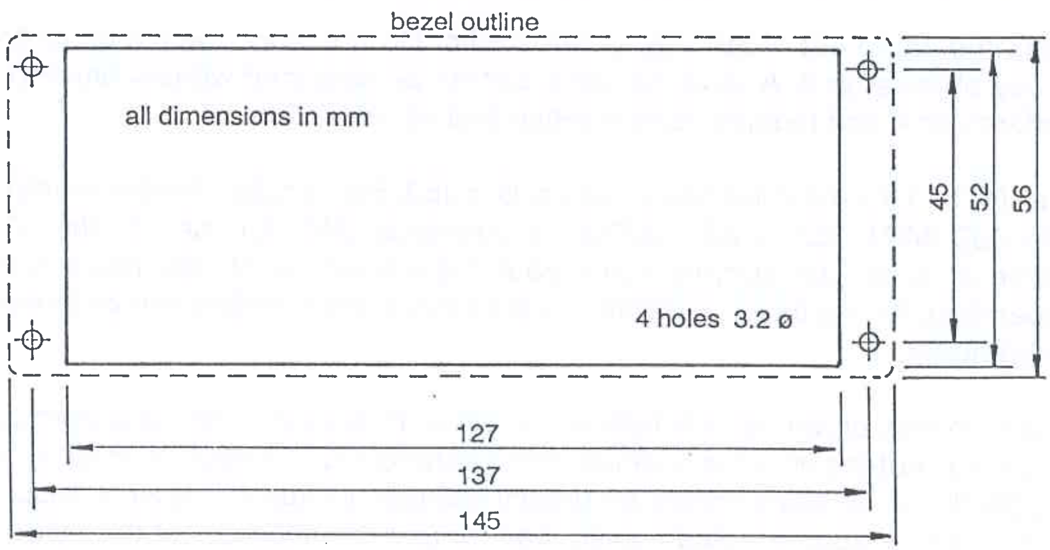


Fig.1. Panel Cutout Dimensions.

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 lockwashers, 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.

3.3 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.

The DTM-133 must be used with a Group3 Hall probe. Probe models LPT-130, LPT-230, MPT-132, or MPT-230 are the most suitable for use with the DTM-133. 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.

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. Probes can also be supplied with shielded cables for greatly reduced pickup of induced noise on the cable 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 3.8 of this manual.

With the DTM-133 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 teslameter, 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 instrument should be powered down, and then repowered while both keys are held down. This will restore default operating conditions.

When a probe is not connected to the DTM, the display reads **noProbE**.

3.4 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 source of ac or dc (either polarity) which meets the specification on page 2-2. The cable connector required for power connection to the DTM is generally available from electronics parts suppliers.

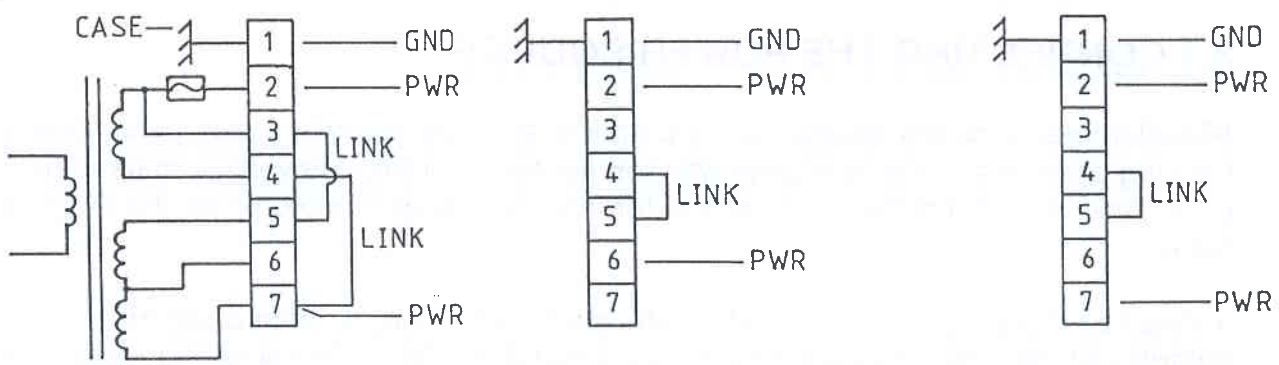
For extra immunity to damage and operational disturbance caused by serious high voltage sparking near the teslameter, the use of the Group3 model PS12D7 off-line switch-mode power supply and the Group3 ferrite kit part no. 11000036 is recommended. These accessories will greatly reduce the amount of electrical 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 3.8 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. 2. 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. 2 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.



115V	link 4 and 7 link 3 and 5 power 2 and 7 ground 1	208V	link 4 and 5 power 2 and 6 ground 1	230V	link 4 and 5 power 2 and 7 ground 1

Fig. 2. 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 **Group 3** for 2 seconds before field measurements appear.If the Hall probe is not plugged in, the field reading display is replaced with **noProbE**.

3.5 INTERNAL DIP SWITCHES

The main circuit board, under the top cover of the DTM-133, has a set of two DIP switches. The switch functions are listed in Table 1 below. For access to the switches, loosen the central screw and lift the cover off.

switch	function	OFF	ON
1	digital filtering	disabled	enabled
2	field units	tesla	gauss

Table 1. Internal DIP Switch Functions

The functions of switches 1 and 2 are described in full in section 4. The switches are scanned once a second, so the effects of changed settings can be observed immediately.

3.6 ANALOG OUTPUT

An analog output signal is available at the rear of the teslameter. This output is the Hall probe signal amplified to 3 volts full-scale, and gives an indication of the instantaneous field value from dc to 9kHz (-3dB), with a roll-off of 60dB/decade above 9 kHz. Field direction is indicated by the output voltage polarity. There is a small zero offset of 10 millivolts maximum, arising from the probe zero-field output and amplifier offsets. The output impedance is 1000 ohm with a 1nF capacitor to common for noise filtering.

The cable connector required is a Molex receptacle type M5051-2 fitted with M2759 terminals. Pin assignments are given below.

The analog output is not corrected for linearity errors.

pin	signal
1	ground
2	dc output

Table 2. Analog Output Connector Pin Assignments.

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. When the probe has shielded cable, 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 3.8 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 INSTALLATION TECHNIQUES FOR ELECTRICALLY NOISY ENVIRONMENTS

The DTM-133 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 must be shielded 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.

If you are using the serial communication features of the teslameter, take advantage of the noise immunity of the fiber optic facilities available, rather than using the wired RS-232C connection. Fiber optics were included in the DTM-133 for the express purpose of providing noise free communication in hostile applications. The fiber optic cables used with the DTM-133 are economical and convenient to use - simpler in fact than wiring. To interface the fiber optic cables to your computer or other data acquisition system, use a Group3 model FTR fiber optic adaptor.

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 easily be 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.

4. OPERATING INSTRUCTIONS

4.1 ZEROING

The DTM-133 digital teslameter has very stable zero field readings. 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".

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.

Before zeroing the system, connect the probe and apply power as described in sections 3.3 and 3.4. Allow 30 minutes for the instrument and probe to stabilize.

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.

Ambient temperature also has a slight effect on the probe zero. The probe should be zeroed at a temperature as close as possible to the temperature during service.

If the teslameter is set for autoranging (see page 4-4), zeroing is implemented simply by momentarily pressing both keys together. The display will flash **ZEro** while the teslameter cycles through all four ranges in turn, waiting for each range to stabilize before zeroing it. The whole process takes about 10 seconds. The range indicators show which range is selected. If a single-range probe is connected, only the one range will be selected and zeroed.

If autoranging is disabled, each range must be manually selected and zeroed. A range is selected by pressing the RANGE key. The four range indicators show the selected range. The RANGE key is used to select 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. 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.

Once the zeroing process has been completed, the internal processor will apply the appropriate correction to whichever range is selected.

Zero offsets calculated during the zeroing process are stored in non-volatile memory, and are retained while the power is off. Therefore the teslameter does not need re-zeroing simply because it has been powered down.

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.

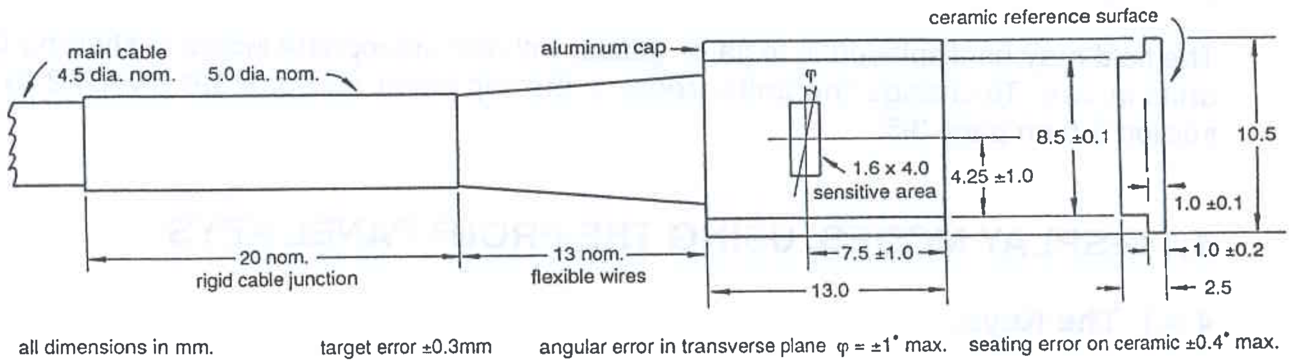
Keep the cable out of the way of foot traffic. Do not pinch the cable, or drop sharp or heavy objects on it. A severed cable cannot be re-joined without altering the probe's performance, and requires factory repair and re-calibration.

The LPT-130 and LPT-230 probes can be fitted to a Group3 probe holder part number 17000049. MPT-132 and MPT-230 probes fit probe holder part number 17000081. The holder protects the probe and provides additional cable strain relief.

The probe will measure the component of the field which is normal to the flat surface of the probe case. The point of maximum sensitivity is marked by a target printed on the top of the probe case. 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. 3 gives the probe head dimensions.

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 4.4.2b on page 4-5.

LPT-130 and LPT-230



MPT-132 and MPT-230

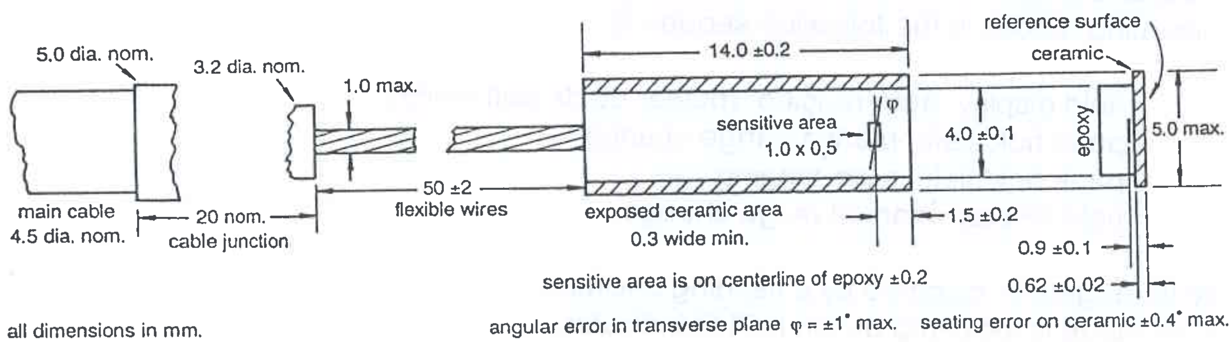


Fig. 3. Probe Dimensions.

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.

The DTM-133 has autoranging capability, and powers up in this mode. Autoranging can be enabled or disabled using the front panel MODE key. See section 4.4 below.

If autoranging is enabled, the teslameter will change to the next range up when the displayed reading reaches 105% of full scale on the current range. The next range down will be selected when the reading drops to 95% of full scale on the next lower range.

If autoranging is disabled, the operator must select the most appropriate range. 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 exceeds about 106% of full-scale, the message **o'rAnGE** will be displayed. Change to a higher range by pressing the RANGE key 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, remove the top cover and operate switch 2. See section 3.5 on page 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.

The MODE key, used on its own, switches the instrument between its operating modes, field and peak hold field, and auto-ranging. Pressing the MODE key brings up the operating modes in the following sequence:

field display auto-ranging (power-up default mode)
peak hold field manual range change
peak hold field auto-ranging
field display manual range change

Auto-ranging is indicated by a flashing decimal.
Hold mode is indicated by the HOLD indicator.

The RANGE key selects the range without changing the display mode. If a single-range probe is in use or if auto-ranging is enabled then the range cannot be changed.

The RANGE key is also used to reload system defaults, as follows:

remove power from the teslameter
press and hold the RANGE key
apply power to the teslameter
after the display lights, release the key
the display message **rESEt** confirms defaults reloaded.

Reloading defaults performs the following functions:

clears the zero offset on each range
returns the digital filter parameters to default values
returns the sampling rate to the default value

To zero the display, press the two keys together. The keys must be pressed close to simultaneously for zeroing to take place.

In the peak hold mode, pressing the keys together will reset the peak field reading.

4.4.2 Operating Modes.

a. Field display.

The teslameter powers up in auto-range, indicated by a flashing decimal.
Four ranges, 0.3, 0.6, 1.2, and 3.0 tesla full-scale, are selected automatically in auto-range, or manually in sequence by pressing the RANGE key when auto-ranging is off.
Four range indicators show the range in use.
With 230 probes, divide the full-scale range indicator by 10.
With all probes, the display shows the true field value. A minus sign is added to indicate reverse polarity fields.
Press the keys together to zero the display. The display shows **ZEro.**
In auto-range, all ranges are zeroed in turn, taking 10 seconds.
Field reading is filtered if selected by the internal switch - see p.3-5.
The FILTER indicator shows when filtering is enabled.

b. 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.

4.4.3 Display Messages

Power up message
The message **GrouP 3** appears in the display for 2 seconds when the teslameter is first powered. This message is followed by **SErIAL** if the serial communciations option is fitted, or **GPIb** if the GPIB IEEE-488 option is fitted.

Zero
The message **ZEro** appears when the teslameter is zeroed. See section 4.1.

No Probe
The message **noProbE** is displayed if the Hall probe is disconnected from the instrument. While the message is visible, all key functions are disabled.

Over-range
The message **o'rAnGE** appears if the field to be measured 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.

If autoranging is selected, steady over-ranging will occur only when full-scale of the highest range is exceeded.

If a single-range probe is in use, no range changing can occur.

Overflow
The message **o'FLo** is displayed if the computed value of the field reading exceeds the capacity of the display.

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.

If the overflow message appears on a DTM-133, it can usually be cleared by reloading defaults (see page 4-4). Otherwise, please contact the supplier of the teslameter.

Reset
The message **rESEt** appears for 1 second when default settings are reloaded, as described in section 4.4.1.

Error 1
This indicates that the main circuit board has no calibration eeprom chip and cannot be used with this software version.

4.5 DIGITAL FILTERING

The teslameter software includes a digital filtering algorithm which may be enabled by turning on internal DIP switch 1. See page 3-5. Filtering is useful for smoothing out small fluctuations in the field reading. When filtering is enabled, the FILTER indicator is lit.

In order to speed up the response to large field changes when filtering is on, a window is 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 default window width is 20 resolution increments on each side of the displayed field reading, for a total window width of 40 increments.

The digital filter performs the following computation:

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

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
and P is the period between field measurements.

Field measurements are made at a fixed rate of 30 per second, so P = 0.033.With the default value of J = 8, the filter time constant is 0.25 seconds. This gives a cut-off frequency in the displayed field reading of 0.64Hz.

5. IEEE-488 INTERFACING OPTION

5.1 IEEE-488 BUS CONNECTION

Connection to the IEEE-488 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 piggy-back 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.

Fig. 4 shows the IEEE-488 connector pin location and signal names as viewed on the teslameter rear panel. Table 3 is a listing of the pin assignments.

pin	symbol	description
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 3. IEEE-488 Connector Pin Assignments

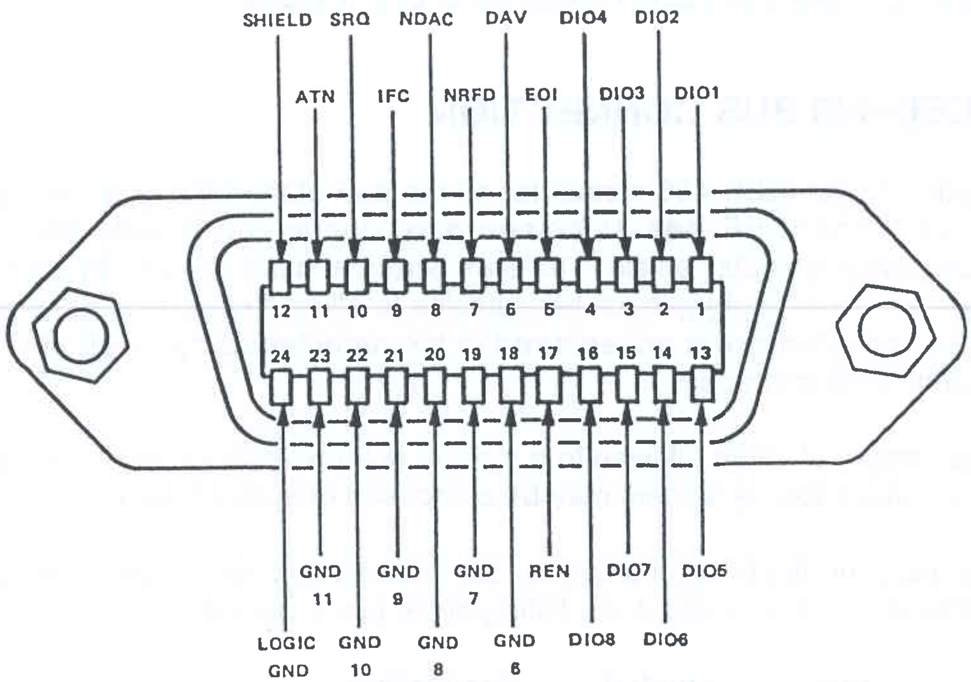


Fig.4. IEEE-488 Standard Connector.

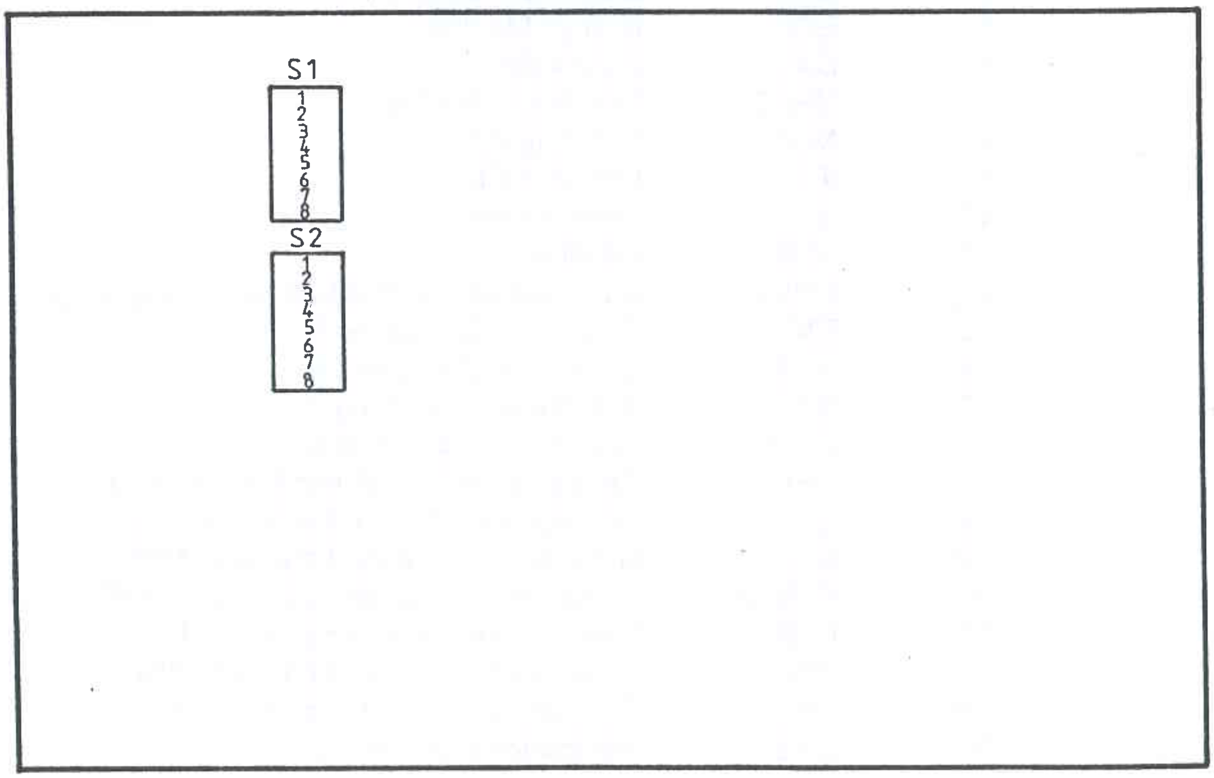


Fig.5. Location of IEEE-488 Board Switches.

5.2 IEEE-488 BOARD SWITCH SETTINGS

The IEEE-488 board in the teslameter 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, remove the bottom cover by loosening the single central screw. Refer to Fig. 5, page 5-2, for switch locations.

Switch functions are as follows:

S1 8-way DIP switch - sets device address on IEEE-488; sets talker-only mode.

S2 8-way DIP switch - selects operation mode and communication options.

Detailed switch settings are given in Table 4 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	not used		
S2-6	units symbol	no symbol	*symbol after data
S2-7	not used		
S2-8	not used		

* factory setting

Table 4. IEEE-488 Board 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 IEEE-488. 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 IEEE-488 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 IEEE-488 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 a 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 and S2-4 is shown in Table 5 below.

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

Table 5. String Terminator Switch Settings.

Check which terminator characters are required by the system controller and/or other devices in your IEEE-488 system, and set the switches accordingly.

S2-6 when ON causes the field units character T or G to be sent on the bus following numerical field values.

5.3 USING THE IEEE-488 GPIB INTERFACE

5.3.1 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).

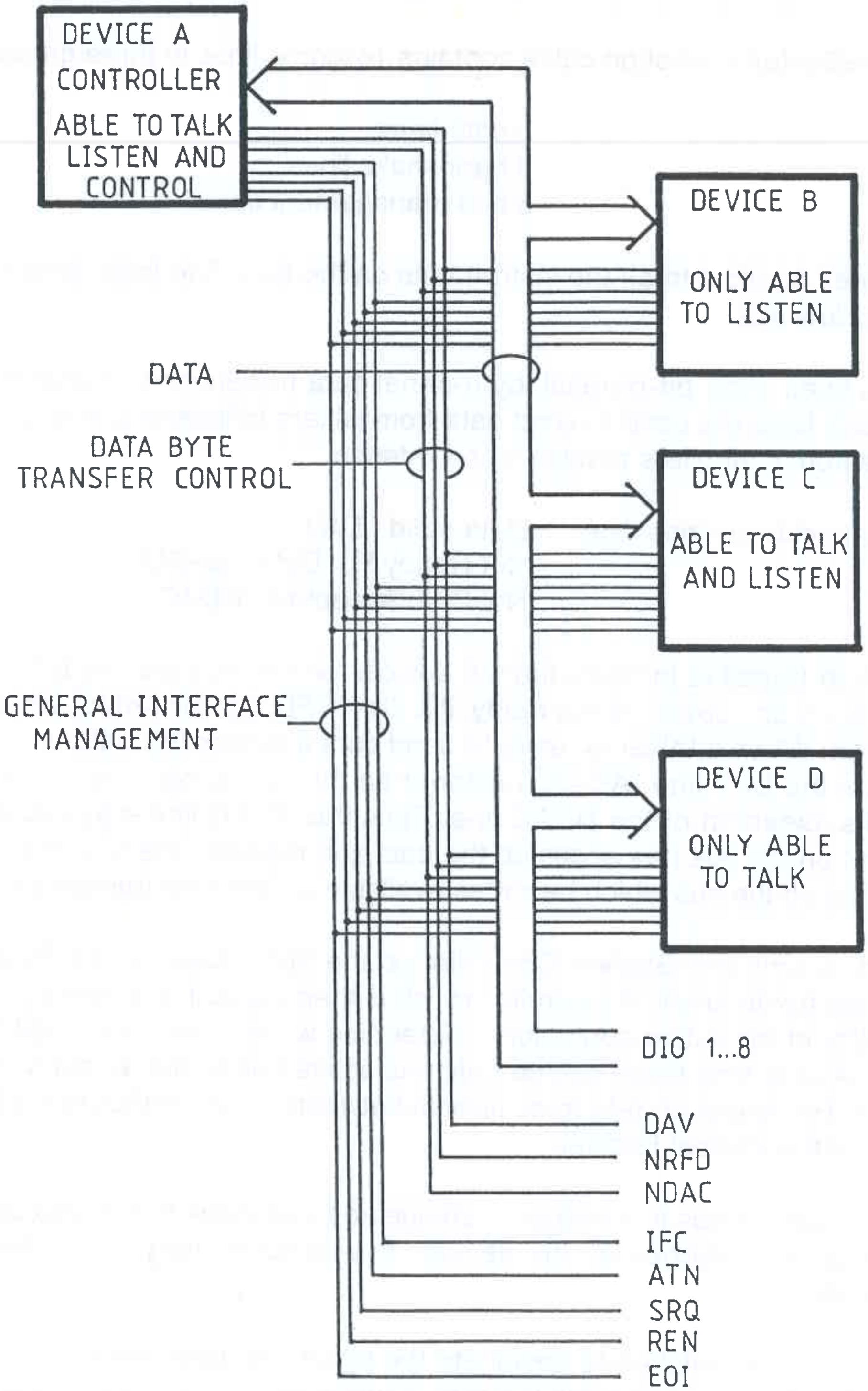


Fig.6. A Typical IEEE-488 System.

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: Data 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 codes, 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 6 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.

When the controller wants to make a device into a talker, it places the device's talk

decimal value	hex value	ASCII character	IEEE-488 mnemonic	description
			PCG	**Primary Command Group**
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
			LAG	**Listen Address Group**
32-62	20-3E	sp--->		Listen addresses 0 through 30
63	3F	?	UNL	Unlisten
			TAG	**Talk Address Group**
64-94	40-5E	@---^		Talk Addresses 0 through 30
95	5F	underscore	UNT	Untalk
			SCG	**Secondary Command Group**
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 6. IEEE-488 Command Codes.

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:

• a 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 initialized 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.

5.3.2 DTM-133-_G IEEE-488 Capability

The IEEE-488 Standard defines ten interface functions, some with as many as 28 allowable subsets. The DTM-133-_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 page 5-3. 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
4	04	EOT	SDC	Selected Device Clear
5	05	ENQ	PPC	Parallel Poll Configure
8	08	BS	GET	Group Execute Trigger
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 7. DTM-133-_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 reinitialized
serial poll byte and SRQ cleared
parallel poll unconfigured

5.3.3 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 Tables 8 and 9 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 ASCII alphabetical characters, in some cases followed by a decimal number represented by n in the table. If no number is entered where one is expected, zero will be entered automatically.

If an error message is returned, the command must be re-entered. The default values apply after system reset command CTRL X. For switch-selectable defaults, see Table 4, page 5-3.

TABLE 8. DTM-133-_G COMMANDS - ALPHABETIC LISTING

command	**description**
B<text><cr>	ASCII text (7 characters maximum) appears on teslameter display.
B<cr>	Cancel text mode, return to normal display.
D0	Turns OFF digital filtering.
D1	Turns ON digital filtering.
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.
GC	General function Continuous - teslameter measures continuously at 30 readings per second. This is the power-up default mode.
GV	General function Triggered - field is measured only on V command.
IA	Inspect auto ranging status - returns 0 for OFF, 1 for ON.
ID	Inspect Digital filtering status - returns 0 for OFF, 1 for ON.
IG	Inspect General function - returns C for continuous, V for triggered
IJ	Inspect filter factor - returns filter factor.
IK	Inspect sampling interval - returns interval in seconds between transmitted field values. 0 implies readings sent at maximum rate.
IN	Inspect display mode - returns H for hold display, N for normal.
IR	Inspect Range - returns 0 for the lowest range to 3 for the highest range.
IY	Inspect window - returns value of window within which filtering occurs.
IZ	Inspect zero - returns zero correction of selected range.
Jn	Filter factor - enters filter factor n. Default n = 8. Allowed n = 1, 2, 4, 8, 16, 32, 64, 128. Entered values from 2 to 128 are rounded to nearest allowed value. Filtering becomes more severe as n increases.

Kn	Sampling interval - enters interval between output field values. Default n = 0, every reading sent, rate is 30 per second; n = any positive number with 1 decimal place up to 6553.4, time in seconds between transmitted field values.
NH	Display mode: Hold - teslameter display shows peak field value.
NN	Display mode: Normal - teslameter displays instantaneous field value
P	Peak hold field - teslameter returns peak field value. Peak value is always available irrespective of display mode.
Q	Test teslameter front panel display.
Rn	Range selection: n = 0 through 3. R3 selects highest range. Default is least sensitive range, or range of single-range probe. Ignored if teslameter is in auto range mode. Returns error message if single-range probe is in use.
SB0	Autoranging OFF.
SB1	Autoranging ON. Default is autoranging ON.
SE0	Echo OFF - teslameter does not echo characters received.
SE1	Echo ON - every character received is echoed by teslameter.
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	SRQ line is not asserted when data is available.
SS1	SRQ line is asserted when data is available.
SU0	Turns OFF units symbol sent after field readings.
SU1	Turns On units symbol sent after field readings.
SZn	Set zero - enters zero offset n for the selected range; useful when the teslameter must be zeroed but using Z command is inconvenient; the correct zero offset must be known; can be obtained after Z command by using IZ, and should be noted for future use with SZ.
UFG	Units: field values displayed and transmitted in gauss. Default set by S2.
UFT	Units: field values displayed and transmitted in tesla. Default set by S2.
V	Triggers field measurement after triggered mode selected by GV.
WA	Returns uncalibrated raw field reading immediately after digitizing.
WE	Like WA except field reading has teslameter's internal calibration applied, but not corrected for probe errors.
WZ	Like WE except field reading is modified by user-entered zero.
Yn	Window - enters n = window within which digital filtering occurs. Maximum n = 255. Default ±20 resolution increments on current range.
Z	Zero - defines present field value as zero for selected range only.
CTRL B	returns single hex character 0 through F indicating the position of the baud rate selection switch; once the command has been given, changing the switch position does not alter the baud rate until some other command is sent.

CTRL D	returns an 18-bit binary number representing the states of the two DIP switches on the main board and the 16 DIP switches on the communications board. 0 = OFF, 1 = ON; once the command has been given, changing the switch position does not alter the baud rate until some other command is sent.
CTRL U	Restarts operating software as if DTM had been freshly powered up.
CTRL X	Load system defaults - all default values & modes reinstated. The message RESET is transmitted.

End of Table 8.

5.3.4 IEEE-488 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.

5.3.5 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.

TABLE 9. DTM-133-_G COMMANDS - LISTING BY FUNCTION

COMMUNICATIONS

An	Address - all following commands are acted on only by the unit of address n (n = 0 though 30) as set on internal switches.
Kn	Sampling interval - enters interval between output field values. Default n = 0, every reading sent, rate is 30 per second; n = any positive number with 1 decimal place up to 6553.4, time in seconds between transmitted field values.
IK	Inspect sampling interval - returns interval in seconds between transmitted field values. 0 implies readings sent at maximum rate.
SE0	Echo OFF - teslameter does not echo characters received.
SE1	Echo ON - every character received is echoed by teslameter.
SM0	Send mode: field readings sent when requested by F command only.
SM1	Send mode: field readings sent at intervals defined by Kn command. Default for unit on address 0 is set by S2-1.
SU0	Turns OFF units symbol sent after field readings.
SU1	Turns On units symbol sent after field readings.
UFG	Units: field values displayed and transmitted in gauss. Default set by S2.
UFT	Units: field values displayed and transmitted in tesla. Default set by S2.

FIELD VALUES

F	Field - teslameter returns a field value.
P	Peak hold field - teslameter returns peak field value. Peak value is always available irrespective of display mode.
WA	Returns uncalibrated raw field reading immediately after digitizing.
WE	Like WA except field reading has teslameter's internal calibration applied, but not corrected for probe errors.
WZ	Like WE except field reading is modified by user entered zero.

RANGE SELECTION

Rn	Range selection: n = 0 through 3. R3 selects highest range. Default is highest range, or range of single-range probe. Ignored if teslameter is in auto range mode. Returns error message if single-range probe is in use.
SB0	Autoranging OFF.
SB1	Autoranging ON. Default is autoranging ON.
IA	Inspect auto ranging status - returns 0 for OFF, 1 for ON.
IR	Inspect Range - returns 0 for lowest range through to 3 for highest range.

ZEROING

Z	Zero - defines present field value as zero for selected range only.
IZ	Inspect zero - returns zero correction of selected range.
EZ	Erase zero - cancels zero correction on current range.
SZn	Set zero - enters zero offset n for the selected range; useful when the teslameter must be zeroed but using Z command is inconvenient; the correct zero offset must be known; can be obtained after Z command by using IZ, and should be noted for future use with SZ.

FILTERING

D0	Turns OFF digital filtering.
D1	Turns ON digital filtering.
ID	Inspect Digital filtering status - returns 0 for OFF, 1 for ON.
Jn	Filter factor - enters filter factor n. Default n = 8. Allowed n = 1, 2, 4, 8, 16, 32, 64, 128. Entered values from 2 to 128 are rounded to nearest allowed value. Filtering becomes more severe as n increases.
IJ	Inspect filter factor - returns filter factor.
Yn	Window - enters n = window within which digital filtering occurs. Maximum n = 255. Default ±20 resolution increments on current range.
IY	Inspect window - returns value of window within which filtering operates.

PEAK HOLD MODE

P	Peak hold field - teslameter returns peak field value. Peak value is always available irrespective of display mode.
EP	Erase (reset) peak hold field value.
NH	Display mode: Hold - teslameter display shows peak field value. NN returns to normal mode.

TRIGGERING

GV	General function Triggered - field is measured only on V command. GC returns to normal mode.
V	Triggers field measurement after triggered mode selected by GV.
IG	Inspect General function - returns C for continuous, V for triggered

DISPLAY

UFG	Units: field values displayed and transmitted in gauss. Default set by S2.
UFT	Units: field values displayed and transmitted in tesla. Default set by S2.
NH	Display mode: Hold - teslameter display shows peak field value.
NN	Display mode: Normal - teslameter displays instantaneous field value
IN	Inspect display mode - returns H for hold display, N for normal.
B<text><cr>	ASCII text (7 characters maximum) appears on teslameter display.
B<cr>	Cancel text mode, return to normal display.
Q	Test teslameter front panel display.

SYSTEM & TESTNG

Q	Test teslameter front panel display.
CTRL B	returns single hex character 0 through F indicating the position of the baud rate selection switch; once the command has been given, changing the switch position does not alter the baud rate until some other command is sent.
CTRL D	returns an 18-bit binary number representing the states of the two DIP switches on the main board and the 16 DIP switches on the communications board. 0 = OFF, 1 = ON; once the command has been given, changing the switch position does not alter the baud rate until some other command is sent.
CTRL U	Restarts operating software as if DTM had been freshly powered up.
CTRL X	Load system defaults - all default values & modes reinstated. The message RESET is transmitted.

End of Table 9.

5.3.6 Error messages.

The following error messages are transmitted as a result of error conditions:

BAD OR MISSING EEPROM indicates that the main board has no calibration eeprom chip and cannot be used with this software version.

INVALID COMMAND ENTRY indicates that the command entered was illegal.

NUMBER TOO BIG indicates that the number entered in a command was too big.

POSITIVE NUMBER REQUIRED indicates erroneous entry of minus sign.

FIXED RANGE PROBE and AUTORANGING indicate an illegal attempt to change range.

The messages NO PROBE, OVERFLOW, and OVERRANGE duplicate the functions of these messages on the DTM display.

5.4 TRIGGERED OPERATION

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

The teslameter is set for triggered operation by entering the command GV. This stops continuous sampling of the field value.

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.

5.4.1 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 4.5.

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

5.4.2 Triggered operation timing

The teslameter starts sampling the field within 1.5ms after the V trigger command has been received. The field is sampled for a period of 8.3ms. After sampling, the value is digitized and computations are done.

The new field value is ready no later than 60msec after the V command is received. Do not request the new field value (using F) sooner than 60msec after the V command, or the old field value may be sent.

5.4.3 When the trigger command is ignored

The trigger command is ignored by teslameters which have not been initialized for triggering by the GV command.

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

5.4.4 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 trigger 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 trigger 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.

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