MTL8000

Process I/O for Process Control

MTL8502 – PROFIBUS-DP BIM

Instruction Manual

Contents

INM8502–1 Nov 1998

BIM Software Release History

Software version	Date	Mod No.	Description of change
1.0	**Nov 98**	**–**	**New Issue**

Introduction

The MTL8000 Series - 8502-BI-DP - Bus Interface Module (BIM) provides the interface between a **PROFIBUS_DP** master and up to 32 MTL8000 Series I/O modules. It mounts on a purpose-built carrier that provides connections to the I/O modules and also to the local area network (LAN). It is configured locally by connecting an IBM-compatible PC running the MTL8000 Configurator package.

About this manual

This manual provides information about the MTL8000 I/O sub-system and how it communicates with a PROFIBUS-DP host and is organised as follows:

PROFIBUS BIM operation

A description of MTL8000 operating modes. These include both normal and failure conditions.

PROFIBUS Data Mapping

How a PROFIBUS master gains access to the MTL8000 I/O and Status data. This section is subject to revision as facilities are added to the BIM.

Recommended Set-up for Host Communications

Information on how best to set up host communications with the system.

Appendix A Field Removal & Replacement of Modules

This section provides advice on removal and replacement of BIM, Power Supply and I/O modules, especially in hazardous areas.

Appendix B The GSD File

This contains a copy of the device data file used during configuration of the PROFIBUS network.

Assumptions

The reader is assumed to be a control engineer or technician, who needs to set up the master to communicate with the BIMs connected to it, and maintain the system during operation.

It is also assumed that the system has been specified according to the **System Specifier's Guide** and installed and wired according to instructions in the **Installation Guide**.

Note that set up details are provided in the **Configurator Instruction Manual**.

Terminology

Modules/Devices

I/O modules are often referred to as 'devices', especially when referring to their internal data and software. The reader should be aware that the terms 'module' and 'device' are interchangeable and *either* is acceptable.

Hexadecimal Numbers

Hexadecimal (base 16) numbers are used in this manual and different methods are sometimes used to denote them. This has arisen through both international and historical differences and the reader is advised to acquaint him/her self with the three methods used.

The prefix '0x' is used, particularly in the GSD file (Appendix B), to precede a hexadecimal byte, e.g. '0x2F' = 47 decimal. Tables may contain '(hex)' in the heading to indicate the use of hexadecimal numbers and individual numbers can also be followed by the character 'H' to indicate a hex value, e.g. 00H.

Related literature

The reader is directed to the PROFIBUS standard EN 50170. This is the standard for the protocol and includes the specifications originally contained in E DIN 19245.

Full information is available from the PROFIBUS Organisation. A range of technical and general information is also available from their web site at http://www.profibus.com/.

In addition, The following literature, produced by MTL, may be of assistance to the reader of this manual:

AN8000	MTL8000 System Specifier's Guide
EPS8000	Data Sheets, Process I/O for general purpose & Division 2/Zone 2 hazardous areas
INM8000	Installation Guide
INM8450	BIM Configurator Software

Further useful information can also be found in the book "PROFIBUS-DP" by Manfred Popp (ISBN 3-7785-2676-6).

PROFIBUS BIM Operation

MTL8000 Overview

General

The MTL8000 comprises a Bus Interface Module (BIM) and up to 32 I/O modules, along with associated power supplies. The BIM communicates with the I/O modules via the “Railbus” communications link in the carrier.

PROFIBUS BIM communications and configuration

Figure 1 shows a typical configuration for an MTL8000 system where it links to the host system (DCS, PLC or PC) over a single link. PROFIBUS-DP supports RS485 transmission technology implemented as a shielded, twisted-pair copper cable. This technology is easy to handle and install.

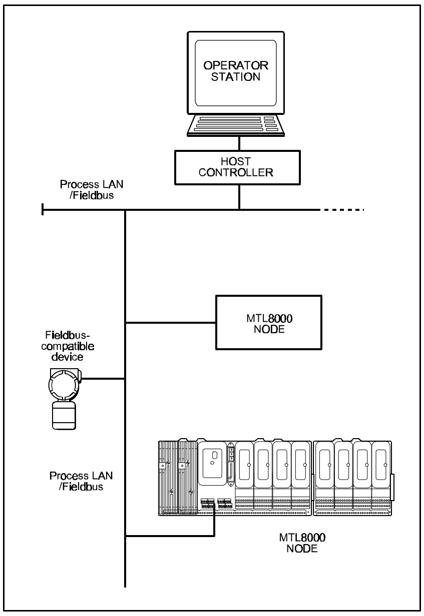


Figure 1 - Typical MTL8000 system

When the node is powered up for the first time, the BIM identifies the installed modules, but will not begin operation until correctly configured by the Configurator. The configuration is stored in the BIM's non-volatile memory (NVM).

The Configurator software runs on a PC under Windows™ 95, 98 or NT. One of the PC’s RS232 ports (e.g. COM1) is connected, via a special cable (MTL part no. 8460-CA-CF), to the D-connector on the top of the BIM. Configuration over the LAN is planned for the future. For further details on configuring the BIM see the MTL publication **INM8450** - BIM Configuration Software, Instruction Manual.

The host establishes communications with the node based upon the PROFIBUS power-up/reset procedures. Once communication with the host is established the node provides module data on a cyclic basis. This consists of input and output states, diagnostic information, HART-based data, etc.

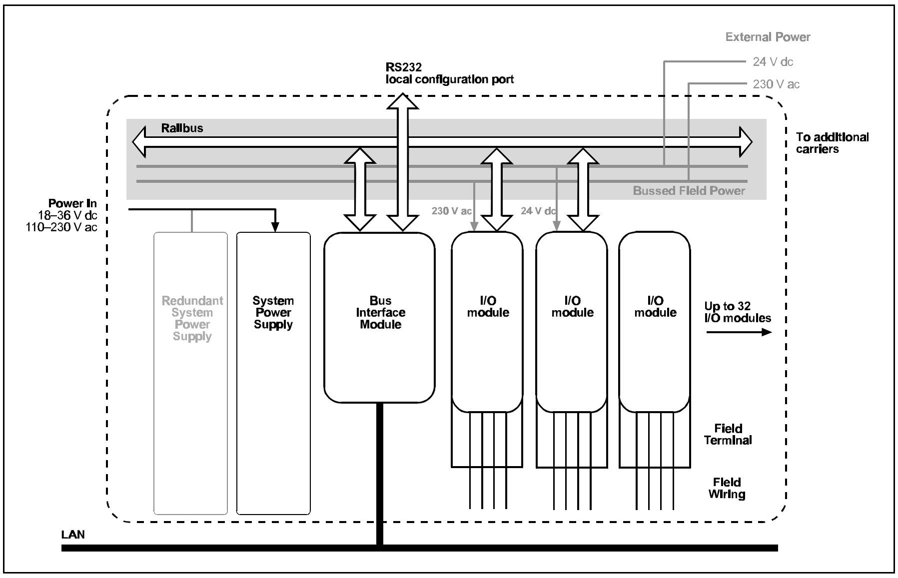


Figure 2 Schematic node architecture

A node architecture schematic is shown in Figure 2 above. The information from the I/O modules is transferred to and from the communication module (BIM) via the Railbus. The Railbus is a fast, serial data bus with parallel addressing and extends over the full length of the node to a maximum length of 6 metres. The I/O modules can be polled by the BIM for a regular refresh of data or they can be configured to send 'new-data' only. All data from HART devices is passed through the Railbus to the BIM and is made available to the host via the node's LAN port.

Node operation

At each node, the input modules constantly monitor, linearise and digitise their respective field signals, and make them available to the node's internal bus (Railbus).

The BIM continually scans the I/O modules via the Railbus and builds up a map of the values of the input variables.

The host controller exchanges data with the BIMs on a cyclic basis **receiving** field input data and **writing** analog and discrete output data.

If a node identifies a problem, it can tell the host that it has diagnostic information to send and the host then collects this data at the next update.

Data update mechanisms

Data updates are made available to the LAN via three independent and asynchronous mechanisms:

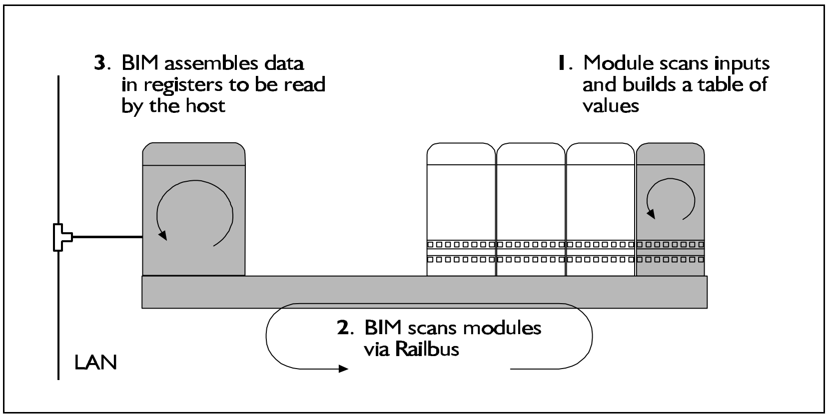


Figure 3 - Asynchronous data update loops

- Each module functions autonomously and updates its I/O at a rate according to its specification.
- Data is exchanged between the module and the BIM over the Railbus communications link according to the set-up which may be "Normal" or "New Data" mode.
- Data is exchanged between the Host controller and the BIM according to the LAN communications mechanism.

The health of the Railbus is monitored continuously by the modules and the BIM reports Railbus errors. A module adopts '*failsafe*'* mode if there is a perceived failure. Such a failure is indicated by lack of activity over a preset interval ("Failsafe Timeout"). Similarly, the BIM monitors the LAN communication activity and deduces a failure - and adopts '*failsafe*' mode - if there is no activity within a preset interval ("Communications Lost Timeout").

These mechanisms ensure maximum integrity of the system.

* '*failsafe*' – When shown in this way the term refers to the MTL8000 state not the PROFIBUS state that (unfortunately) uses the same name.

BIM Scan Lists

I/O data is refreshed automatically, but the rate at which it is refreshed is defined by the user (e.g. every 500 msec). Three different rates are available and, as the BIM is configured, every channel in use is assigned to one of these three scan rates to form a 'scan list'. The scan lists are factory named as high priority (HP), medium priority (MP) and low priority (LP) but the user can decide what time values should be assigned to them. There are no defaults and so values must be assigned before the BIM will accept the configuration.

When choosing the rates, the user must also be aware of the amount of time that will be consumed by the refresh process. If a scan list uses a refresh rate of 300 msec then the refresh process for the named channels is initiated every 300 msec. As a simple example, consider Figure 4 in which all high priority (HP) channels are being refreshed every 300 msec.

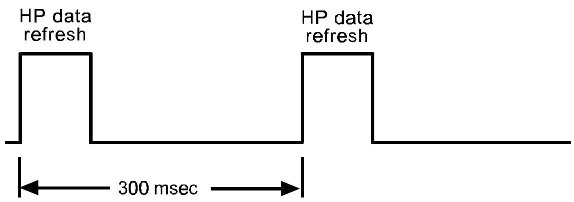


Figure 4 – HP scan rate timing

Note that all channels *on the list* are refreshed during one 300 msec period. Consequently, all channels must be refreshed inside the 300 msec time slot. If all channels cannot be refreshed in 300 msec then more time must be made available, i.e. the refresh rate reduced.

When selecting other, slower, scan lists, time must be allowed for those activities without overloading the BIM. This can be checked/monitored using bit 12 of the input Status Word (see page 12). In Figure 4 there is time between HP refreshes for other refresh activities to take place.

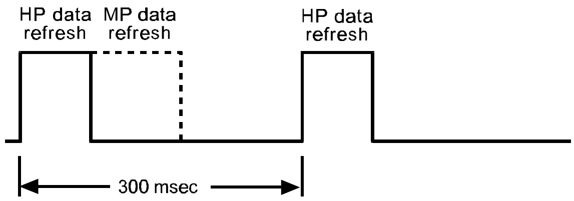


Figure 5 – HP and MP scan rate timing

Figure 5 shows a medium priority (MP) scan list refreshing its data. It is not occurring as frequently as the HP, but there is time, when required, *between* HP refresh cycles for this to occur.

Some modules have two types of data to send to the BIM, e.g. analog input data and HART data, which need quite different refresh rates. To meet this requirement two types of variable have been defined, primary and secondary. The user cannot change how these variables have been assigned. In other words, a user cannot make a secondary variable into a primary one, they are factory defined, but the user *can* choose which of the three scan lists the variables will appear in.

Primary variables usually require frequent updates; 4-20mA flow inputs and discrete I/Os are typical examples, and these will tend to be put on the high priority scan list. The Secondary variables tend to be slower-moving, such as temperature values or HART variables etc. and will usually be put on the medium or low priority list.

Other internal scan lists are used for health monitoring and detection of newly inserted modules. The status of faulty modules is checked every 10 seconds, and newly inserted modules will be detected within 30 seconds of insertion.

Operating States

I/O Module operating states

I/O Modules can adopt any one of the following three states:

Normal

This is when there is a healthy transfer of data to and from the BIM. Individual channels may be configured to be either normally active or normally inactive using the MTL8450 Configurator; for example, the inactive state would be appropriate for channels which are either unused or temporarily out of service.

Power-up

On power-up or reset the module initially adopts a de-energised state until it establishes normal communication with the BIM. It then responds to data transfers from the BIM and outputs are set to the pre-defined default/power-up state

Default/power-up "cold-start" states may be individually defined for each output channel via the Configurator.

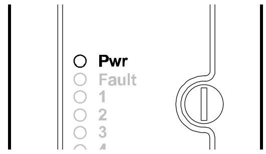
'Failsafe'

Under various fault conditions, in particular the loss of Railbus communications with the BIM, the module will adopt a pre-defined *'failsafe'* state when the Failsafe Timeout period is exceeded. This can also occur if the BIM itself adopts the *'failsafe'* state, because a consequence of BIM fail-safe is the halting of Railbus communications. This would happen, for example, if LAN communications failed. The *'failsafe'* state of the I/O module is configurable independently of the default/power-up state, and channels may be set to either retain last value or force to a specific value. *'Failsafe'* modes and Failsafe Timeout periods can be set with the Configurator. *'Failsafe'* mode (and indication) can be inhibited by setting the Failsafe Timeout period to zero.

I/O module status indication

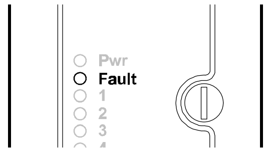
The status of the I/O modules may be deduced from observing the LEDs on their front panels as follows; note that colours and legends follow NAMUR NE44 except for labelling ”fault” instead of ”error”.

Power LED - Green



Off	On	Flashing
Power Fail	Power OK	N/A

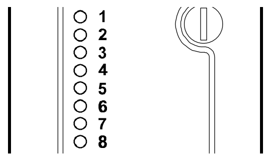
Fault LED - Red



Off	On	Flashing
Normal	• Fail-safe, • A/D error on AI • BFP failure	Initialisation error

BFP = Bussed Field Power

Channel LEDs - Yellow



I/O type	Function	Off	On	Flashing
AI	I/P status	O/C (channel inactive or active and no alarm)	OK	Alarm (HH/LL alarm, loss of HART signal or A/D error)
Temp	I/P status	O/C (channel inactive or active and no alarm)	OK	Alarm (H/L alarm, O/C or A/D error)
AO	O/P status	O/C & inactive	OK	O/C & active, or error (incl. loss of HART signal)
DI	I/P status	Low	High (incl. latched)	N/A
DO	O/P status	Low or Inactive	High & Active	N/A

BIM operating states

The BIM can adopt one of several states as follows:

Normal

This is when there is a healthy transfer of data over the LAN and to and from the I/O modules

Power-up

On power up the BIM performs a self-test and initialises with fail-safe mode reset. The BIM then detects whether or not it has a valid configuration stored in Non Volatile Memory (NVM), and proceeds accordingly:

If a previous configuration exists

Initially, the I/O modules assume de-energised states then the BIM configures the I/O modules according to the stored configuration with outputs set to default/power-up values. Subsequently, the modules respond to any commands received over the LAN via the BIM.

If there is no previous configuration

The BIM configures itself based on no modules being present and no scan list(s) specified.

'Failsafe'

The BIM adopts a *'failsafe'* state on the loss of LAN communications, the Configurator cable is connected locally to the RS232 port. The *'failsafe'* mode can be forced or reset using the Configurator software. *'Failsafe'* mode in the BIM automatically triggers *'failsafe'* mode in all the I/O modules, provided the latter have been configured for *'failsafe'*.

When the LAN restarts the BIM will reset and re-commence operation (see note 2).

Notes:

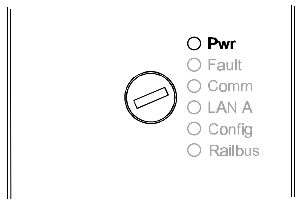
1. When the PC Configurator cable is connected to the BIM the loss of communications 'trigger' is inhibited and it will not adopt a *'failsafe'* mode for this reason. This is intended to prevent unnecessary output changes during commissioning, when LAN communications may be interrupted intentionally. BIM *'failsafe'* on loss of LAN communications, may be inhibited during normal operation (even when the cable is removed) by fitting a shorting link between pins 1 and 4 on the BIM connector. To achieve this, the shorting link must be fitted within 10 seconds of removing the Configurator cable or less than one minute after power-up.

2. A future release of software will add the option to modify this behaviour so that recovery is only on command from the host.

PROFIBUS BIM status indication

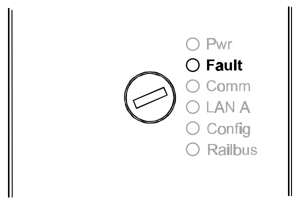
BIM status may be deduced from observing the LEDs on the front panel as follows:

Power LED - Green



Off	On	Flashing
Power Fail	Power OK	Not defined (error)

Fault LED - Red

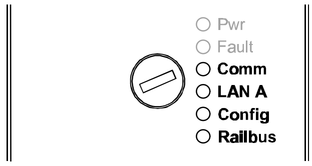


Off	On	Flashing
Normal	Failsafe or Fault*	Not defined (error)

** The BIM "Fault" LED will also light if the Configurator port cable is not fitted with an "Enabling link". Use MTL configuration cable - part no. 8460-CA-CF. See also INM8450 – BIM Configuration Software manual.*

The Red Fault LED ON while all Yellow LEDs are OFF indicates that the watchdog has tripped causing the CPU to be held in reset. It will remain in this condition until power to the BIM is switched off and then re-instated. A future release will provide the option to “trip-and-try-again”

Other LEDs – Yellow



Function	Off	On	Flashing
Comm	Internal Comms Failure	Internal Comms OK	On Power-up, otherwise not defined (i.e. error)
LAN A	Power OFF	LAN activity	Slow flash (approx. 1 per 2 secs) = no LAN activity
Config	Not defined (error)	Configurator connected	Configurator not connected.
Railbus	Railbus Fault	Railbus OK	Not defined (error)

Failure Conditions & Diagnostics

Two of the key features of the MTL8000 are its comprehensive diagnostic capability and its ‘*failsafe*’ mechanisms. The Host controller is able to detect failure of a component in the I/O sub-system and identify whether the problem is at BIM, module or channel level.

The following tables summarise various fault conditions and LED indication, along with information on diagnostics and what might be inferred about the problem.

Status and diagnostic information may also be obtained over the LAN communications link and this is described in more depth in the data mapping tables provided in a later section.

I/O channel fault

BIM LED status:	**Fault** LED = OFF (i.e. Normal)
Module LED status:	Flashing (fault dependent, analogue modules only)
Symptoms:	I/O module data discrepancy with respect to plant I/O
LAN diagnostic data:	Discrete or Analog channel status may show anomaly
Rectification:	Rectify external fault

Module fault

BIM LED status:	**Fault** LED = OFF (i.e. Normal); possibly all lights OFF
Module LED status:	**Fault** LED = ON (i.e. ‘failsafe’)
Symptoms:	Outputs adopt fail-safe values
LAN diagnostic data:	Diagnostics telegram byte 12, bit 0 = 1
Rectification:	Replace module; follow hot-swap procedure

Railbus fault

BIM LED status:	**Railbus** LED = OFF (i.e. Normal)
Module LED status:	**Fault** LED (Red) = ON (Fail-safe)
Symptoms:	Outputs adopt fail-safe values
LAN diagnostic data:	Diagnostics telegram byte 12, bit 1 = 1
Rectification:	Check Carrier and extender cables; otherwise suspect BIM

BIM fault

BIM LED status:	**Fault** LED = ON; Yellow LEDs = OFF indicates Watchdog tripped.
	LAN A LED = **Fast** flashing (2 per sec) = LAN fault condition.
Module LED status:	**Fault** LED = ON (*'Failsafe'*)
Symptoms:	Outputs adopt *'failsafe'* values; BIM may "trip & try again" according to configuration
LAN diagnostic data:	LAN comms failure
Rectification:	Replace BIM; system will adopt default/power-up state on restart

LAN Comms fault

BIM LED status:	**LAN A** LED = Flashing; **Fault** LED = ON
Module LED status:	**Fault** LED = ON (*'Failsafe'*)
Symptoms:	Outputs adopt fail-safe values
LAN diagnostic data:	LAN comms failure
Rectification:	Check Host and LAN cabling/converters

Configuration fault

BIM LED status:	**Config** LED = OFF; **Fault** LED = OFF
Module LED status:	**Fault** LED = Flashing (unconfigured)
Symptoms:	I/O does not update; or possible download errors
LAN diagnostic data:	Diagnostics telegram byte 12, bit 1 = 1
Rectification:	Clear BIM, check and reload configuration; system will adopt default/power-up state on restart

PROFIBUS data mapping

In other PROFIBUS literature the reader may find the terms dataframe and telegram. These terms have the same meaning and are interchangeable when talking about the Data Unit section of a PROFIBUS communication.

PROFIBUS-DP uses a cyclic update technique to enable a master to communicate with the individual slaves. If more than one master is connected to the network then a token is passed between them to control their access to the network but only one master can have write access to a slave.

In order to communicate effectively, the host and the BIM must each be configured to exchange a particular *volume* of data and also *interpret* the data in the same. Structuring the messages 'in the same way' means ensuring that each of them knows what each word means and in what order they can be expected.

The BIM configuration software creates this structure automatically from the module configuration so that I/O data is placed in the dataframe in module order. A descriptive text file is created by the Configurator which itemises the module types, their slot positions and channel numbers. This file also contains an 'offset' figure for each channel which indicates the position in the dataframe where a channel's data is located.

The default byte order within a dataframe word is '**Motorola**' format, i.e. the most significant byte is sent first. If your system uses 'Intel' format, which reverses this byte order, contact MTL for advice on how it can be accommodated.

All examples in this document are presented in Motorola format and as if the data is travelling to the left and so the leftmost byte would be received first.

I/O Data Frame

The data frame contains the field I/O data (and HART I/O data, if any) for **each module in turn**. In addition, the first word of the data frame contains bitmapped information that is used to display internal states in the case of input messages, or to control the BIM's scanning process in the case of output messages.

A PROFIBUS dataframe, from an MTL8000 node, will contain some of the following data types.

Type	Length	Comment
Status word	1 word	First word in input frame
Control word	1 word	First word in output frame
Analogue I/O field data	1 word per channel	For any enabled channel
Discrete I/O field data	1 word per module	In an 8 channel module, the data is in the upper (or most significant) byte of the word
HART-variable data	2 words per variable	For each variable enabled
HART status information	1 word per channel	Only required if HART variables are being used

(1 word = 2 bytes = 16-bits)

A standard **input** message (IW) starts with a Status word followed by the input data from the modules.

- Status word
- Module field data (+ HART data)

Status word	**First I/P module data**	**Second I/P module data**	**Third I/P module data**		
1					**244 (max.)**

A standard **output** message (QW) starts with a Control word followed by the output data from the modules.

- Control word
- Module field data

Control word	First O/P module data	Second O/P Module data	Third O/P module data		
1					244 (max.)

For each of these dataframes, the length is configurable up to a maximum of 244 bytes with an overall limit of 420 bytes for any single input/output exchange. These limitations are imposed by the PROFIBUS ASIC within the BIM.

The data sequence takes **each *active* channel of each module in numerical order**. If a channel is configured as *disabled (i.e. not active)* then it is completely ignored.

If a channel has HART-variables enabled then **the analog field data for that channel is followed immediately by its HART data**, in turn.

The HART Communication Status (1 byte) and the HART Device Status (1 byte) are carried in the DP I/O frame because a diagnostics telegram that contains them cannot be constructed. They appear in the DP I/O frame only if HART capability is specified for a given channel.

Status and Control Words

The first word of an ***input*** data frame is called the Status Word. Bits 10, 9, 1 and 0 are the only ones used (currently) in this 16-bit input word. If any of these bits are set (i.e. = 1) the meaning can be interpreted from the following table:

Status Word															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Bit #	Description
10	**Scan time not sufficient** Data is possibly being lost during read or write
9	**Defective module detected** May be one or more
1	**Configuration in progress** This bit is set after power up during reading of the User Defined NVM data
0	**Scanning process active** This bit is set as long as the BIM is being polled via the LAN interface

The first word of an **out*put*** data frame is called the Control Word. Bit 0 is the only one (currently) used in this 16-bit output word. If this bit is set (i.e. = 1) the BIM will be polled by the master.

Control Word															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Bit #	Description
0	**Scan BIM** - When set by the host, this bit starts the BIM scanning process and prevents the BIM from going into 'failsafe' mode

Analog I/O Field Data

One 16-bit word is used for each *enabled* channel. If the channel is not enabled using the configuration process then it is not included in the dataframe. The format of the data (signed or unsigned) and the scaling is described in the section titled Data Representation.

Discrete I/O Field Data

One 16-bit word is used for each *enabled* module. Each channel of a 16 channel module being represented by one of the bits.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Channel #	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

8 channel modules use the upper byte of the word

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Channel #	8	7	6	5	4	3	2	1								

HART Status and Data

Status

One 16-bit word is used for the HART comms and status information whenever one or more channels is *enabled*.

Data

Two 16-bit words are used per variable for each enabled channel. These represent each variable as a 32-bit floating point value.

Channel Parameters by I/O module type

The following table shows the channel parameters for the I/O module types. For each type of module the data size/format is shown, whether it is a primary (P) or secondary (S) variable and which of the dataframe/telegram types is used to pass the information.

(us) = unsigned integer
(s) = signed integer
(fp) = floating point

Channel Parameters	Format per channel	Prim/Sec variable	Frame type		
			Input	Output	Diag.
Discrete modules					
DI Field Input Data	1 bit	P	✓		
DO Field Output Data	1 bit	P		✓	
Discrete channel status	1 bit	P			✓
Analog modules					
AI Field Input Data	16-bit (us)	P	✓		
Temp Field Input Data	16-bit (s)	P	✓		
AO Field Output Data	16-bit (us)	P		✓	
HART Variables	32-bit (fp)	S	✓		
HART Comms & Status	16-bit	S	✓		
Analog Channel Status	8-bit	P			✓

Diagnostics data

PROFIBUS-DP provides a special mechanism for the transmission of slave diagnostic data to the master.

The master can request diagnostic data from the slave but a request can also be initiated by the slave if there are events that require the transmission of diagnostic data. If the slave indicates to the master that diagnostic data is available, the controlling master is required to request the diagnostics telegram within the next data cycle, instead of the I/O-data. Therefore, it is essential not to initiate a diagnostics transfer unless there is a real need for it, otherwise the PROFIBUS-DP I/O refresh rate slows down. (See also EN 50170.)

There are two types of diagnostic data, **static** and **extended**, both of which are generated by the slave to indicate to a ProfiBus master the state of the slave application. Static diagnostics are used to report BIM anomalies but if I/O modules have anomalies then extra bytes must be added to the static diagnostic data, hence the name extended diagnostics.

Enough data can be carried in one extended diagnostics telegram to report anomalies from one I/O module. Consequently, if more than one module has anomalies, a diagnostics telegram will be sent for each module. When the anomaly is cleared, this fact also will be reported to the host.

Static diagnostics

The static diagnostics for the 8502 PROFIBUS BIM consist of the 'standard' six diagnostics bytes plus an additional, seventh, byte that identifies how many bytes of extended diagnostic data are available.

Byte 1:

Bit #	Name	Meaning
7	Diag.master_lock	BIM is parameterised by another master
6	Diag.prm_fault	Wrong parameterisation (ID no., etc.)
5	Diag.invalid_slave_response	Fixed and set to zero (0)
4	Diag.not_supported	The requested service is not supported by the BIM
3	Diag.ext_diag	BIM has extended/external diagnostics
2	Diag.config_Fault	Configuration data does not match
1	Diag.station_not_ready	Station not ready for data exchange
0	Diag.station does not exist	This is set by the master

Byte 2:

Bit #	Name	Meaning
7	Diag.deactivated	Set by the master
6	–	Reserved
5	Sync_mode	Sync command received
4	Diag.freeze_mode	Freeze command received
3	Diag.WD_ON	DP Watchdog active
2	–	1 (fixed)
1	Diag.stat_diag	Static diagnosis
0	Diag.Prm_req	BIM has to be parameterised

Byte 3: Bits 0..6 are reserved, bit 7 indicates that more diagnostic information is available than will fit into the area provided.

Byte 4: Diag.master_add (address of the parameterising master)

Byte 5: Slave Ident. number high byte

Byte 6: Slave Ident. number low byte

Byte 7: Number of bytes of extended diagnostics data

Extended diagnostics

The extended diagnostic data begins with the value 00 (hex) in byte 8. Further bytes show the module status, with bits derived from the Slot Status and the Channel Status Registers

The total length of the diagnostics telegram has been chosen to be a maximum of 32 bytes – this ensures compatibility with older DP masters that were limited to 32. Module status information is not placed in DP I/O frames.

The two (minor) exceptions to this rule are:

- the Status/Control Word placed at the start of the I/O frame and
- the HART Communication Status and Device Status words - that are placed into the frame as the first bytes of the HART channel data

and the latter is only true for channels that have HART data to communicate.

BIM software ensures that any relevant status information is sent in a diagnostics telegram before invalid I/O data is sent.

While collecting I/O data, the BIM also checks for I/O module anomalies. If any are detected, it will not copy the I/O data it has just read into the PROFIBUS data telegram but will request status information which it loads into the following diagnostics telegram format.

Byte #	Name
8	00 (hex)
9	**Slot number** (Value between 1 and 32)
10	**Device ID - High Byte** (see **Device ID** table, below)
11	**Device ID - Low Byte** (see **Device ID** table, below)
12	**Slot Status Byte** (Bit 7 – Bit 2: reserved (0))
	Bit 1: Set to 0 for normal mode or 1 if module is in fail-safe state
	Bit 0: Set to 0, if module is initialised and OK, else set to 1
13 ...20	**Channel Status bytes** (see description that follows) Number depends on module type - 8 bytes as a maximum.
21..32	reserved (0)

If any of the bytes 12 to 20 are not zero the BIM sends an 'Extended Diagnostics Available' message to the master, which should then request the data. During this time the device data (for all channels) is "frozen" pending resolution of the anomaly.

If all of the bytes 12...20 are zero, the diagnostics telegram is discarded and the updating of the I/O data starts again immediately.

In the case of output modules, the diagnostics handshake does not affect the I/O data stream from the PROFIBUS I/O dataframe to the BIM-API, i.e. no data is "frozen". The Railbus system handles the module output behaviour in the event of failures.

Device ID

The device ID number uniquely identifies the module type and is carried in bytes 10 and 11of the extended diagnostics. The first byte (byte 10) is usually '00'H.

I/O module part number	Type	ID (hex)	Data length (words)
8101-HI-TX	Analog input	00 96	1 per **channel**
8104-AO-IP	Analog output	00 BE	1 per **channel**
8105-HI-TX	Analog input	00 8D	1 per **channel**
8106-HO-IP	Analog output	00 8E	1 per **channel**
8109-DI-DC	Discrete input	00 52	1 per module
8110-DI-DC	Discrete input	00 53	1 per module
8111-DI-AC	Discrete input	00 54	1 per module
8112-DI-AC	Discrete input	00 55	1 per module
8113-DI-AC	Discrete input	00 56	1 per module
8114-DI-AC	Discrete input	00 57	1 per module
8115-DO-DC	Discrete output	00 2B	1 per module
8116-DO-AC	Discrete output	00 29	1 per module
8117-DO-DC	Discrete output	00 2A	1 per module
8118-DO-AC	Discrete output	00 28	1 per module

The previous table shows the device ID numbers. It also shows how much telegram 'space' is required by each device to transfer its data. Analog devices need 1 word (16-bits) **per channel** whereas a discrete device only requires one word for the whole device. In fact, discrete devices only require half a word, i.e. one byte.

Channel Status bytes (13 . . 20)

The number of channel status bytes and their content depends upon the type of device (byte 10 and 11) used in the named slot (byte 9).

Discrete modules

There is no status information associated with Discrete Output (DO) modules and so the channel status bytes relate only to Discrete Input (DI) modules.

An 8-channel DI module only requires one status byte (byte 13) because each channel is represented by one of the 8 **bits**.

0 = Good data - (Stable)   1 = Bad data - (Unstable)

The stability, or consistency of the module data is decided by the device's input de-bounce algorithm.

Analog Inputs

Each channel uses one byte to describe the current status.

Bit#	Name	Description
7	HartStatusChange*	Toggles when Tx device status changes
6	A/D Error	1 = A/D conversion failure, 0 = Fault cleared
5	HartNoComm *	1 = lost HART comms, 0 = Fault cleared
4	HartComm5Err *	1 = > 5% HART comms. errors, 0 = Cleared
3	HHAlrm	1 = Hi Hi Alarm set, 0 = Alarm cleared
2	HAlrm	1 = Hi Alarm set, 0 = Alarm cleared
1	LAlrm	1 = Lo Alarm set, 0 = Alarm cleared
0	LLAlrm	1 = Lo Lo Alarm set, 0 = Alarm cleared

* Parameters supported only by the 4–20mA HART Analog Input Module.

Temperature Inputs

Each channel uses one byte to describe the current status.

Bit#	Name	Description
7	Resolution	N/A
6	Resolution	N/A
5	–	
4	A/D Error	1 = A/D error set, 0 = A/D error cleared
3	–	
2	Sensor O/C	1 = Sensor O/C set, 0 = Sensor O/C cleared
1	HAlrm	1 = Hi Alarm set, 0 = Alarm cleared
0	LAlrm	1 = Lo Alarm set, 0 = Alarm cleared

Analog outputs

Only bit 0 of the byte is used to describe the current status.

Bit#	Name	Description
7	–	–
6	–	–
5	–	–
4	–	–
3	–	–
2	–	–
1	–	–
0	Output O/C	1 = Output O/C, 0 = Output normal

Examples

To illustrate the structure of the data, two examples of diagnostics telegrams are provided here. The meaning for each is provided using the information from the preceding pages (starting on page 14). Note that the data is shown in hexadecimal format.

Diagnostics telegram - Example 1

```
08 0C 00 01 07 2D 1A 00 04 00 BE 00 01 01 01 01 01 01 01 01 AA AA
AA AA AA AA AA AA AA AA AA AA
```

Byte #	Data	Meaning
1 (S)	08	BIM has extended diagnostic data to send
2 (S)	0C	The watchdog is active
3 (S)	00	All of the diagnostic information is contained in one telegram
4 (S)	01	The address of the parameterising master is 01
5 (S)	07	High byte of slave address
6 (S)	2D	Low byte of slave address ∴ BIM address is 07 2D (hex)
7 (S)	1A	26 bytes of extended data + 6 static = 32 byte structure
8 (E)	00	Always '00'
9 (E)	04	Slot (I/O module) number 4
10 (E)	00	Device ID high byte
11 (E)	BE	Device ID low byte ∴ type is 8104-AO-IP
12 (E)	00	Device is initialised and in 'normal' mode
13 (E)	01	Channel 1- output is open circuit
14 (E)	01	Channel 2 - output is open circuit
15 (E)	01	Channel 3 - output is open circuit
16 (E)	01	Channel 4 - output is open circuit
17 (E)	01	Channel 5 - output is open circuit
18 (E)	01	Channel 6 - output is open circuit
19 (E)	01	Channel 7 - output is open circuit
20 (E)	01	Channel 8 - output is open circuit
21-32	AA	Packing to make up the 32 byte structure

(S) static diagnostic data (E) extended diagnostic data

Diagnostics telegram - Example 2

```
08 0C 00 01 07 2D 1A 00 03 00 96 00 40 40 40 40 40 40 40 40 AA AA
AA AA AA AA AA AA AA AA AA AA
```

Byte #	Data	Meaning
1 - 8	-	As example 1
9 (E)	03	Slot (I/O module) number 4
10 (E)	00	Device ID high byte
11 (E)	96	Device ID low byte ∴ type is 8101-HI-TX
12 (E)	00	Device is initialised and in 'normal' mode
13 (E)	40	Channel 1- A/D conversion error
14 (E)	40	Channel 2 - A/D conversion error
15 (E)	40	Channel 3 - A/D conversion error
16 (E)	40	Channel 4 - A/D conversion error
17 (E)	40	Channel 5 - A/D conversion error
18 (E)	40	Channel 6 - A/D conversion error
19 (E)	40	Channel 7 - A/D conversion error
20 (E)	40	Channel 8 - A/D conversion error
21-32	AA	Packing to make up the 32 byte structure

Data Representation

Discrete Values

This data is generally held as single bits. However some status information is actually encoded numerically in one or two bytes

Analog Values

These are generally stored as 16-bit integers that may be either signed or unsigned, depending on parameter type. Specific data types are explained as follows:

Analog Input & Output Data

Analog I/O data is represented by a 16-bit positive integer (0-65535) corresponding to the full range of the A/D or D/A converter, 0–25mA.

i.e. Current (mA) = 25 x Raw Value / 65535

Thus the relationship between 4–20mA, percent of span and raw data for the key values is:

mA	Percentage of Span	Raw Data
0	-25.0	0
4	0.0	10486
20	100.0	52428
25	131.25	65535

Temperature Input Data (including mV & ohms)

Data for low level inputs is represented by a 16-bit, signed (2's complement) integer (-32768 to +32767). This corresponds to the range minus span to plus span, where the span corresponds to the upper range in physical units. Translation between physical units and raw data is:

Input value = Raw Data x Upper range / 32767

The upper ranges for the supported input types are as follows:

THC/mV inputs

Input type	Lower range	Upper range	Units
*mV	0	120	mV
B	0	1820	°C
E	–270	1000	°C
J	–210	1200	°C
K	–270	1372	°C
N	–270	1300	°C
R	–50	1767	°C
S	–50	1767	°C
T	–270	400	°C
W_3	0	2320	°C
W_5	0	2320	°C

* not currently supported

RTD / Resistance inputs

Input type	Lower range	Upper range	Units
*Ohms	0	600	Ohms
PT100	–220	850	°C
jPT100	–200	510	°C
Ni120	–80	320	°C

* not currently supported

HART Variables

Up to four variables per channel are available for a HART device via Universal Command 3. These can be defined for any channel, of a module that supports them, using the Configurator software.

Recommended set-up for Host Communications

The PROFIBUS host should be configured for efficient communications and this section identifies some of the considerations that will help the user in optimising data transfer both for the process I/O data and also the associated Status and Diagnostic data.

Module grouping

Sound installation practice suggests grouping modules on the carrier according to their type. This simplifies wiring and helps to ensure efficient communications.

BIM status

Overall BIM status is not yet implemented.

Module status

The PROFIBUS BIM reports any module exceptions as they occur by using a diagnostic transmission. Figure 6 below indicates how module health (status) is monitored for input and output modules. The host control strategy should take account of possible module failure and take action accordingly to ensure a safe recovery.

Note that the handling of PROFIBUS diagnostic messages, although implemented in standard interface components, may require application specific configuration in the host system for decoding.

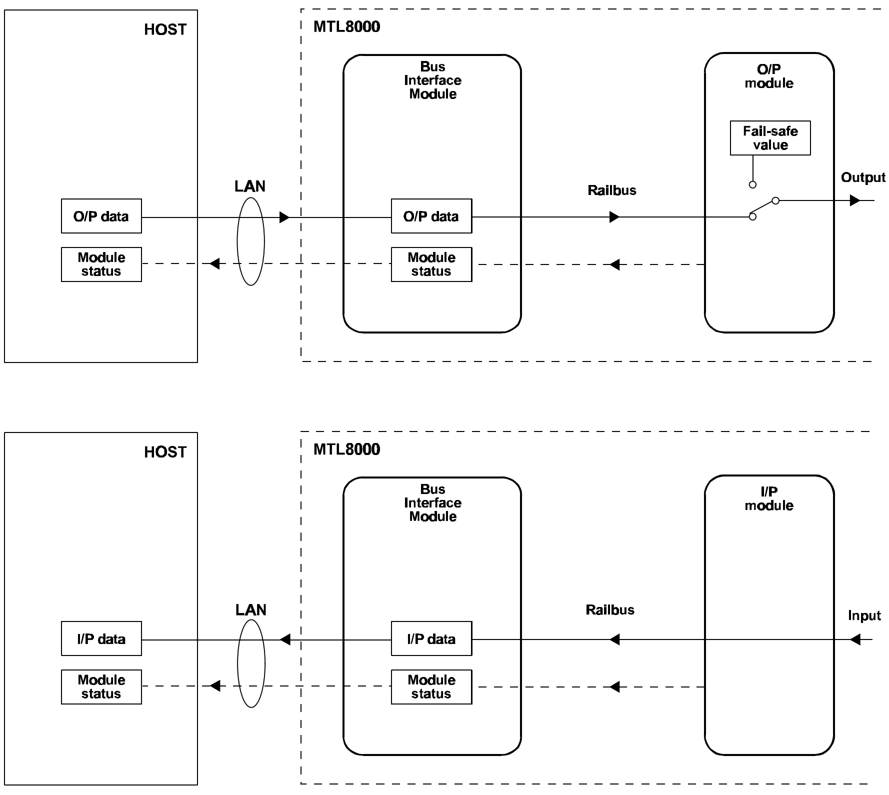


Figure 6 - Monitoring module "health"

Normal operation

Output

Host writes O/P data to BIM which transfers it to the module

Input

Host reads I/P data from BIM as transferred from the module

Faulty module operation

Module fault detected in diagnostic message.

Output

O/P module adopts pre-configured fail-safe state

Host should then write a safe output value to the BIM (normally fail-safe value as above) to ensure that the subsequent resumption of normal operation is “bumpless”.

Input

I/P value is no longer being updated

Host should take appropriate action to ensure safe operation

The host should wait for the module status to return to normal.

The process of return to normal operation will depend upon what caused the fault:

Transient module fault - module recovers automatically

Failed module - replacement module will initialise automatically

BIM in fail-safe - BIM resets automatically on re-establishment of PROFIBUS data exchange

On recovery, the BIM will write the current data to the module (output) or read the newest data from the module (input).

Note: In a future release a LAN command will be available to recover a module or BIM from a fail-safe state.

Channel status

The current ‘general purpose/non-IS’ system provides limited status and diagnostic information as explained below.

The **Analog Channel Status** data provides 8 bits per channel which may be interrogated for details on individual channel operation:

Analog inputs	Can indicate A/D error, as well as alarm status (if configured) and HART status. **Note:** An A/D error can be caused by failure of the external bussed field power.
Temperature inputs	Can indicate an A/D error, as for analog inputs, as well as alarm status (if configured).
Analog outputs	Can indicate open circuit output.

The **Discrete Channel Status** data is not currently available.

Note: Forthcoming modules, that accommodate IS field wiring, will provide detection of open/short circuit, ground faults etc.

Appendix A Field Removal & Replacement of Modules

A key benefit of the MTL8000 is its ability to allow faulty components to be replaced without powering down or stopping the system. The BIM and I/O modules can be replaced in the field under power-on conditions ("*hot-swapping"*), even in Division 2 and Zone 2 hazardous areas. This permits the MTL8000 to continue to function normally when modules are being changed, giving improved system availability.

I/O Module replacement

A defective I/O module may be replaced without switching off the internal system (Railbus) power supply. However, there are certain precautions to be considered, especially when the equipment is located in Class I, Division 2 and Zone 2 hazardous areas:

Discrete Output modules

All DO modules must have an isolation switch for *Bussed Field Power* when used. When changing such modules the *Bussed Field Power* should first be switched off. Failure to do this may result in arcing at the field terminal block, especially with AC outputs driving inductive loads. This can result in damage to the I/O module or connectors, and may present an ignition risk in hazardous locations.

For DO module types having *unpowered* outputs, the source of field power must, similarly, be isolated before removing or replacing the module.

Discrete Input modules

The field circuits of DI modules that use 115/230V wetting voltage must also be isolated before hot-swapping. This applies both to the *Bussed Field Power* circuit on *module-powered* versions and to the source of field power on *sinking* versions.

Note: In Division 2 or Zone 2 applications, the *Bussed Field Power* for 24 V dc module-powered DI versions must also be de-energised before hot-swapping. Where an isolating switch is located within a hazardous area, it must be suitably protected by means of a recognised explosion-protection method.

After insertion, a replacement module will initially adopt an inactive state, which the BIM should detect within approximately 10 seconds. The BIM then loads the module configuration automatically, after which normal operation should resume.

If the BIM finds the module type to be different from that in its configuration file it will signal a device mismatch; this is achieved by *setting* bit 0 of diagnosic byte 12 (Slot Status Byte). The module then becomes inactive but with its Power LED (green) illuminated.

BIM replacement

The BIM may be replaced without switching off the main 'Railbus' power supply. A valid configuration may be loaded and stored to NVM in advance; in which case, it should "cold-start" normally with default/power-up values. Alternatively, the configuration may be loaded in-situ—taking appropriate precautions in hazardous areas—and the system cold-started as above.

Note: In Class I, Division 2 hazardous areas, the Local Area Network ('fieldbus') circuit must be de-energised before removing or replacing the BIM.

Power supply replacement

Where MTL8000 power supplies are operating in redundant, power sharing mode, a failed supply module may be replaced while power for the node is still provided by the other supply module or modules. However, the supply *input* to the failed supply must first be isolated before removal of the module from the carrier.

Note: In Class I, Division 2 or Zone 2 applications, where the isolating switch is located within a hazardous area, it must be suitably protected by means of a recognised explosion-protection method.

Appendix B: The GSD file

The GSD is a descriptive file required to configure a PROFIBUS device. It is supplied by the manufacturer and describes the characteristics of the device. It is also a particular requirement if the manufacturer wants to obtain certification for the device from the PROFIBUS User Organisation. A library of certified devices is published by PROFIBUS and this may be viewed at or downloaded from their web site at http://www.profibus.com/.

From a user's point of view, there is little need to do anything with it, other than to ensure that it is available to the PROFIBUS Class 2 Master during the configuration process. The contents of the GSD supplied are provided below for information.

Slave parameters

MTL8000 is a very flexible system and can support up to 32 modules. A module can contain up to 16 channels and some analog modules support 'smart' variables. The maximum amount of user data that can be carried within a single PROFIBUS-DP telegram is **244 bytes*** - after allowing for headers and error checking. This limit applies to input as well as output telegrams. **The number of modules that can be accommodated at one node is determined by this figure.**

WARNING: A single PROFIBUS-DP telegram may not be able to contain all of the parameters available from a *fully* populated node.

To illustrate this point, an analog module with one channel enabled and no HART data would require one 16-bit word. The same module with 8 channels plus HART data would require **80** words, where each channel would be made up of the following:

- one word — analog data
- one word — HART status
- eight words — two words per HART variable for possible four variables

80 words (160 bytes) is clearly a very large proportion of the total available. In comparison, discrete I/O modules, which use 1 (one) word per *module* (not channel) are easily accommodated

The PROFIBUS-DP interface also limits the overall number of bytes – input plus output – that can be accommodated in a transaction, to 420. This, of course, is less than the maximum of 2 x 244 and a check must be made, during configuration, to ensure that the total of input bytes and output bytes does not exceed 420.

Following the list of maximum byte lengths in the GSD file is a range of statements about input and output words for modules, i.e. "Module = . . . ". These are NOT references to the I/O modules of the MTL8000 series but comprise a range of data lengths for rapid selection with the PROFIBUS Configurator. A 13 word (26 bytes) input message could be accurately defined by selecting "8 Words IN + 4 Words IN + 1 Word IN". The same process can be applied to the output telegram.

Alternatively, because PROFIBUS-DP is so fast, one of the composite statements "X Words IN, Y Words OUT", that easily covers the size of input and output messages, could be used. Any unused words are packed with zeros but the effect upon system speed is negligible.

The whole GSD file starts on the next page.

* This data length might have to be reduced further because of the limited capacity of earlier host devices. Check the capacity of the host that will be used.

```
; Identification
; ==================================================================
; GSD File for MTL8502 Profibus DP Slave
; ==================================================================
;
;      COPYRIGHT:
;                      Measurement Technology LTD
;                      Power Court, Luton, Bedfordshire,
;                      ENGLAND LU1 3JJ
;                      Copyright 1998
;
; ==================================================================
; History       Reason                                   Name
; ==================================================================
; 09.02.1998    Created                                  SB
; 22.06.1998    Adapted                                  RAT
; 24.06.1998    Enhanced for multiple configs            RAT
; 26.06.1998    must not use cfgs with more than         RAT
;               244 bytes in or out
; 01.07.1998    separate ip/op sizes available now       RAT
; 09.08.1998    Change filename, Ident no, Model name,
;               Vendor name, S'ware release & Revision
;               changed to 6
;               (Last was 3, but some missing)           GJF
; 10.08.1998    Changed back to old (0x0008) ID          GJF
;               firmware has to changed.

; 27.08.1998    Firmware updated                         JTF
;               This versions is for all beta and
;               release product.
; ==================================================================
;

#Profibus_DP
GSD_Revision    = 8
Vendor_Name     = "Measurement Technology Ltd."
Model_Name      = "MTL8502 V1.0"
Revision        = "Revision 8"
Ident_Number    = 0x072D
Protocol_Ident  = 0
Station_Type    = 0
FMS_supp        = 0
Hardware_Release = "PCB716/1"
Software_Release = "V1.00"

9.6_supp       = 1
19.2_supp      = 1
93.75_supp     = 1
187.5_supp     = 1
500_supp       = 1
1.5M_supp      = 1
3M_supp        = 1
6M_supp        = 1
12M_supp       = 1
MaxTsdr_9.6    = 55
MaxTsdr_19.2   = 55
MaxTsdr_93.75  = 55
MaxTsdr_187.5  = 55
MaxTsdr_500    = 55
MaxTsdr_1.5M   = 55
MaxTsdr_3M     = 55
MaxTsdr_6M     = 55
MaxTsdr_12M    = 55
Redundancy     = 0
Repeater_Ctrl_Sig = 0
24V_Pins       = 0
```

```
; ================================================================
; SLAVE PARAMETERS
; ================================================================

Freeze_Mode_supp   = 0
Sync_Mode_supp    = 0
Auto_Baud_supp    = 1           ; DP slave will match master's Baud
Set_Slave_Add_supp = 0
User_Prm_Data_Len  = 0
Max_Diag_Data_Len  = 32         ; External - Extended Diag
Min_Slave_Intervall = 20        ; SPC3 spec.

Modular_Station     = 1
Max_Module          = 24        ; module list below
Max_Input_Len       = 244
Max_Output_Len      = 244
Max_Data_Len        = 420

Module= "1 Word IN "0x40, 0xC0
EndModule

Module= "2 Words IN "0x40, 0xC1
EndModule

Module= "4 Words IN "0x40, 0xC3
EndModule

Module= "8 Words IN "0x40, 0xC7
EndModule

Module= "16 Words IN "0x40, 0xCF
EndModule

Module= "32 Words IN "0x40, 0xDF
EndModule

Module= "64 Words IN "0x40, 0xFF
EndModule

Module= "80 Words IN "0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "96 Words IN "0x40, 0xFF, 0x40, 0xDF
EndModule

Module= "112 Words IN "0x40, 0xFF, 0x40, 0xEF
EndModule

Module= "122 Words IN "0x40, 0xFF, 0x40, 0xF9
EndModule

Module= "1 Word OUT "0x80, 0xC0
EndModule

Module= "2 Words OUT "0x80, 0xC1
EndModule

Module= "4 Words OUT "0x80, 0xC3
EndModule

Module= "8 Words OUT "0x80, 0xC7
EndModule

Module= "16 Words OUT "0x80, 0xCF
EndModule
```

```
Module= "32 Words OUT "0x80, 0xDF
EndModule

Module= "64 Words OUT "0x80, 0xFF
EndModule

Module= "80 Words OUT "0x80, 0xFF, 0x80, 0xCF
EndModule

Module= "96 Words OUT "0x80, 0xFF, 0x80, 0xDF
EndModule

Module= "112 Words OUT "0x80, 0xFF, 0x80, 0xEF
EndModule

Module= "122 Words OUT "0x80, 0xFF, 0x80, 0xF9
EndModule

Module= "16 IN, 16 OUT "0x80, 0xCF, 0x40, 0xCF
EndModule

Module= "16 IN, 32 OUT "0x80, 0xDF, 0x40, 0xCF
EndModule

Module= "16 IN, 48 OUT "0x80, 0xEF, 0x40, 0xCF
EndModule

Module= "16 IN, 64 OUT "0x80, 0xFF, 0x40, 0xCF
EndModule

Module= "16 IN, 80 OUT "0x80, 0xFF, 0x80, 0xCF, 0x40, 0xCF
EndModule

Module= "16 IN, 96 OUT "0x80, 0xFF, 0x80, 0xDF, 0x40, 0xCF
EndModule

Module= "16 IN, 112 OUT "0x80, 0xFF, 0x80, 0xEF, 0x40, 0xCF
EndModule

Module= "32 IN, 16 OUT "0x80, 0xCF, 0x40, 0xDF
EndModule

Module= "32 IN, 32 OUT "0x80, 0xDF, 0x40, 0xDF
EndModule

Module= "32 IN, 48 OUT "0x80, 0xEF, 0x40, 0xDF
EndModule

Module= "32 IN, 64 OUT "0x80, 0xFF, 0x40, 0xDF
EndModule

Module= "32 IN, 80 OUT "0x80, 0xFF, 0x80, 0xCF, 0x40, 0xDF
EndModule

Module= "32 IN, 96 OUT "0x80, 0xFF, 0x80, 0xDF, 0x40, 0xDF
EndModule

Module= "32 IN, 112 OUT "0x80, 0xFF, 0x80, 0xEF, 0x40, 0xDF
EndModule

Module= "48 IN, 16 OUT "0x80, 0xCF, 0x40, 0xEF
EndModule

Module= "48 IN, 32 OUT "0x80, 0xDF, 0x40, 0xEF
EndModule
```

```
Module= "48 IN, 48 OUT "0x80, 0xEF, 0x40, 0xEF
EndModule

Module= "48 IN, 64 OUT "0x80, 0xFF, 0x40, 0xEF
EndModule

Module= "48 IN, 80 OUT "0x80, 0xFF, 0x80, 0xCF, 0x40, 0xEF
EndModule

Module= "48 IN, 96 OUT "0x80, 0xFF, 0x80, 0xDF, 0x40, 0xEF
EndModule

Module= "48 IN, 112 OUT "0x80, 0xFF, 0x80, 0xEF, 0x40, 0xEF
EndModule

Module= "64 IN, 16 OUT "0x80, 0xCF, 0x40, 0xFF
EndModule

Module= "64 IN, 32 OUT "0x80, 0xDF, 0x40, 0xFF
EndModule

Module= "64 IN, 48 OUT "0x80, 0xEF, 0x40, 0xFF
EndModule

Module= "64 IN, 64 OUT "0x80, 0xFF, 0x40, 0xFF
EndModule

Module= "64 IN, 80 OUT "0x80, 0xFF, 0x80, 0xCF, 0x40, 0xFF
EndModule

Module= "64 IN, 96 OUT "0x80, 0xFF, 0x80, 0xDF, 0x40, 0xFF
EndModule

Module= "64 IN, 112 OUT "0x80, 0xFF, 0x80, 0xEF, 0x40, 0xFF
EndModule

Module= "80 IN, 16 OUT "0x80, 0xCF, 0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "80 IN, 32 OUT "0x80, 0xDF, 0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "80 IN, 48 OUT "0x80, 0xEF, 0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "80 IN, 64 OUT "0x80, 0xFF, 0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "80 IN, 80 OUT "0x80, 0xFF, 0x80, 0xCF, 0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "80 IN, 96 OUT "0x80, 0xFF, 0x80, 0xDF, 0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "80 IN, 112 OUT "0x80, 0xFF, 0x80, 0xEF, 0x40, 0xFF, 0x40, 0xCF
EndModule

Module= "96 IN, 16 OUT "0x80, 0xCF, 0x40, 0xFF, 0x40, 0xDF
EndModule

Module= "96 IN, 32 OUT "0x80, 0xDF, 0x40, 0xFF, 0x40, 0xDF
EndModule

Module= "96 IN, 48 OUT "0x80, 0xEF, 0x40, 0xFF, 0x40, 0xDF
EndModule
```

```
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EndModule

Module= "112 IN, 96 OUT "0x80, 0xFF, 0x80, 0xDF, 0x40, 0xFF, 0x40, 0xEF
EndModule
```

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