ROADS AND MARITIME SERVICES

TRAFFIC SYSTEMS

SPECIFICATION No. TSI-SP-003

COMMUNICATIONS PROTOCOL
FOR ROADSIDE DEVICES

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RECORD OF AMENDMENTS

Version	Summary	Date	Approved
1.0	Original, based on specification RTA-CPS	4 October, 2002	Mgr, TSI
2.0	Second Issues ▪ Multiple changes	14 April, 2008	Mgr, TSI
2.1	Third issue: ▪ Multiple changes	26 June, 2008	Mgr, TSI
3.0	Fourth issue: ▪ Multiple changes	25 July, 2012	A/Mgr, TSI
3.1	Fifth issue: ▪ Multiple changes	6 February,2013	A/Mgr, TSI
3.2	▪ Minor editorial changes. ▪ New Clause 3.6.3.30 inserted for command “Sign set extended graphics frame” and references updated throughout the document in clauses Cl.3.6.3.24, 3.6.3.29, 3.6.4 and 3.6.5. Subsequent clauses to 3.6.3.30 have been renumbered. ▪ Clause C.2 Added 3 new error codes ▪ Replaced the acronym VSLS with ISLUS.	18 November 2016	Internal use only. Not for approval.
3.3	▪ Minor editorial changes. ▪ Clause 3.6.3.12 “Sign Set Graphics Frame” changed to align with draft SA TS 5719. ▪ New Clause 3.6.3.30 renamed as “Sign Set High Resolution Graphics Frame” and sign maximum dimensions clarified. References updated throughout the document. ▪ New Clauses 3.6.3.31 "Sign Configuration Request", 3.6.3.32 "Sign Configuration Reply" and 3.6.3.33 "Sign Display Atomic Frames" added. ▪ Clauses subsequent to 3.6.3.33 have been renumbered.	16 January 2017	Internal use only. Not for approval.
3.4	Main changes include: ▪ General: restored references to VSLSs as well as ISLUSs. ▪ Reformat of headers and footers. ▪ Foreword deleted. ▪ Clause 1.4 deleted references to old RDP documentation and added reference to SA TS 5719.	7 April 2017	Internal use only. Not for approval.

	▪ Clause 1.6 added definitions for “group”, “interlocking”, “Referencing Specification”, “Word” in the context of this document. Also clarified categories of signs capable of displaying graphics. ▪ Clause 2.1 updated to cover contemporary communications technologies.amended. ▪ Clause 2.4.4 renamed. ▪ Clause 3.2 revised. ▪ Clause 3.3.2.4 detail added. ▪ Clause 3.3.2.5 detail added. ▪ Clause 3.6.3.12 deleted references to 1-bit, 2-bit, nibble or byte encoded colour intensities and related text. Added deprecation of message in preference to SIGN SET HIGH RESOLUTION GRAPHICS FRAME message. ▪ Clause 3.6.3.15 added reference to SIGN DISPLAY ATOMIC FRAMES message. ▪ Clause 3.6.3.23 added reference to maintaining a blank display. ▪ Clause 3.6.3.29 clarified references to advanced graphics sign. ▪ Clause 3.6.3.32 added note relating to SA TS 5719 and no support for CMSs. ▪ Clause 3.6.3.50 (formerly 3.6.3.46) clarified numbers of and assignment information for Manufacturer Specific Messages. ▪ Clause 3.6.5 MI code columns added. ▪ Appendix C.2 note amended with reference to SA TS 5719 ▪ Appendix D message example clarifieded.		
3.5	Main changes include: ▪ Record of amendments clarified. ▪ Cl.1.6 amended sign category descriptions. ▪ Cl.3.6.3.12 delete the deprecation on its use for new design signs. ▪ Cl.3.6.3.29 add reference to high resolution graphics signs.	27 April 2017	Submitted for approval
4.0	Approved version of 3.5, converted to pdf	1 May 2017	a/ Principal Mgr, ITS
4.1	Main changes include:	20 June 2017	Submitted

	▪ Appendix C.1 additional error codes allocated ▪ Appendix C.2 additional error codes allocated. .		for approval
5.0	Approved version of 4.1, converted to pdf	28 June 2017	a/ Mgr, TSI

C O N T E N T S

1. INTRODUCTION

1.1 Purpose

This Specification covers a standard communications protocol for use by the Roads and Maritime Services for its deployment of roadside devices, including variable message signs (VMS), variable speed limit signs (VSLS), integrated speed limit and lane use signs (ISLUS), environmental and weather stations, and highways advisory radio (HAR).

The roadside device communications protocol is an asynchronous, half-duplex protocol designed to be independent of the communications medium. This enables operation on different types of data circuits such as multipoint/point-to-point and switched/non-switched systems.

The roadside device communications protocol provides the following:

- Link establishment and verification of the parties at each end of the link (session management).
- Message sequencing.
- A suite of application messages to cover all message types used for a variety of roadside ITS devices.
- Transfer of application messages including error detection and correction (by the use of checksums and re-transmission).

1.2 Scope

This Specification defines the protocol to be used to communicate with variable message signs (VMS), variable speed limit signs (VSLS), integrated speed limit and lane use signs (ISLUS), environmental/weather stations and highways advisory radio (HAR). Where necessary, the functionality required to implement the protocol is described.

1.3 Overview

This Specification contains the following main sections:

- Section 2 provides a background description of a system incorporating variable message signs (VMS) and gives examples of some possible physical arrangements. The key issues considered in the design of the communications protocol are then discussed. These issues include the roles of the master and the

slaves, system security, sign address and broadcast address, protocol adaptability and transparency, and error-free operation.

- Section 3 describes the various protocol layers based on the OSI reference model. This includes definitions of the physical layer, and detailed descriptions of the data-link protocol and the mechanism for connection establishment. A definition of a suite of application messages is given, followed by a number of examples.

The protocol defined in this Specification applies to both multi-drop and point-to-point communications links (refer to Clause 3.2).

1.4 Compatibility with Other Specifications and Systems

An earlier version of this specification formed the basis for Australian Technical Specification SA TS 5719:2017 “Communications protocol for dynamic message signs and road weather information systems”. As far as possible additions to this specification are intended to be compatible with SA TS 5719:2017.

The clause items pertaining to Environmental/Weather Stations are generally in conformance with NTCIP1204 v2.06 (2002) “Environmental Sensor Station (ESS) Interface Protocol”.

A major exception is the format used for the representation of negative values. Sign-magnitude format is used to represent negative values, particularly negative temperatures. This differs from the NTCIP standards which use two’s complement format for consistency with SNMP, upon which the NTCIP standards are based.

The RMS Communications Protocol TSI-SP-003 uses the sign-magnitude format to provide backwards compatibility with existing environmental stations and weather stations which report 65535 (0xFFFF) or 255 (0xFF) signed integer values to indicate a sensor as “not present of faulty”.

The following are some more examples:

Temperature	Decimal value	Hexadecimal value
+30.5º C	305	0x0131
+0.5º C	5	0x0005
0º C	0	0x0000
-0.5º C	-5	0x8005
-30.5º C	-305	0x8131
Sensor not present or faulty	-32767	0xFFFF

Note that -0º C (represented by 0x8000) is numerically valid but shall not be used by new design equipment.

1.5 Compliance with this Specification

Where this Specification is referenced by another RMS specification or document and compliance with the applicable parts of this Specification is required or intended, those parts of the communications protocol described in this Specification shall be implemented in full.

NOTE: For messages/commands that the device does not support, the device must be able to respond appropriately in accordance with the Protocol.

All parts of and all descriptions in this Specification relating to characteristics, functions and operation of the communications protocol, regardless of the manner in which they are expressed in this document, shall be construed as mandatory requirements unless the context explicitly shows otherwise.

1.6 Definitions and Glossary of Terms

For the purposes of this Specification, the following definitions and abbreviations shall apply:

ASCII	-	American Standard Code for Information Interchange
CMCS	-	Central Management Computer System
controller	-	Means device controller
CRC	-	Cyclic redundancy check
device controller	-	On-site control equipment that controls the roadside device of interest
EIA	-	Electronic Industries Association
group	-	Multiple ITS devices which are intended to be configured and activated together. Refer to Clause 3.6.2 for additional information.
HAR	-	Highways advisory radio
ID	-	Identification or identification code
IMS	-	Incident Management System
interlocking	-	A device controller function that prevents the display of particular combinations of information (generally across multiple ITS

		devices) which could create a hazard to road users. For example in the case of an ISLUS, this could refer to particular combinations of symbols and/or speed limits on adjacent signs over a single carriageway that are considered to be dangerous, logically conflicting or ambiguous. *NOTE: The details of such functionality and combinations are normally defined in the device specifications and are out of the scope of this Specification.*
ISDN	-	Integrated Services Digital Network
ISO	-	International Standards Organisation
ISLUS	-	Integrated speed and lane use signs
ITS	-	Intelligent transport system(s), or Intelligent transportation system(s)
master	-	Unless the context dictates otherwise, means the remote host computer system that communicates or in the process of establishing communications with the device controller
MI Code	-	Message Information Code
NSW	-	New South Wales
NTCIP	-	National Transportation Communications for ITS Protocol
OSI	-	Open System Interconnection
PSTN	-	Public switched telephone network
RDP	-	Road Data Processor
Referencing Specification	-	The document or specification that stipulates or requires compliance with this Specification (TSI-SP-003) in full or in part
RMS	-	Roads and Maritime Services, which is a New South Wales Government agency
RTA	-	The former Roads and Traffic Authority of New South Wales, which was replaced by Roads and Maritime Services
sign controller	-	A device controller for sign(s)
TIA	-	Telecommunications Industry Association

TMC	-	Transport Management Centre
VMS	-	Variable message sign
VSLS	-	Variable speed limit sign
Word	-	In the context of this specification, a “word” comprises 2 bytes.

RMS has deployed a variety of signs which are capable of displaying text and/or graphics. Signs capable of displaying graphics fall into three categories and are distinguished by their supported display dimensions and method of reporting these to the control system. These three categories are as follows:

Graphics sign	-	A type of sign capable of displaying graphics with dimensions of up to 255 x 255 pixels. Refer to Clause 3.6.3.29 for additional information.
Advanced graphics sign	-	A type of sign capable of displaying graphics with dimensions specified not in pixels, but in characters. This permits displays of size up to 255 x 255 *characters* based on the sign’s default character matrix and inter-character spacing. Refer to Clause 3.6.3.29 for additional information.
High resolution graphics sign	-	A type of sign capable of displaying graphics with dimensions of up to 65535 x 65535 pixels. Refer to Clauses 3.6.3.30 to 3.6.3.32 for additional information.

2. GENERAL DESCRIPTION

2.1 Physical System Layout

The complete system consists of:

a) a management and control system (master),

b) communications link,

c) roadside ITS device controllers (slaves) and their dependent ITS devices.

Examples of management and control systems include but are not limited to:

a) the NSW Transport Management Centre's (TMC) Incident Management System (IMS). As of early 2017 this comprises the Central Management Computer System (CMCS) and the Road Data Processor (RDP),

b) a road operator's management and control system,

c) a standalone control computer, or

d) a local or remote engineering terminal.

This Specification only covers the communications protocol between the master and slaves as defined above. The communications protocol between the device controller and the ITS device or devices is not covered by this Specification. The communications protocol between RMS's RDP and CMCS are not covered by this Specification

This communications protocol may be used over serial data links or when suitably encapsulated over IP-based networks. Details of such encapsulation do not form part of this Specification.

The master communicates with the roadside device controller (slave) using this protocol. In turn, the device controller communicates with the dependent ITS device or devices. While in many cases the device controller may control only one ITS device, there are many scenarios where the device controller controls many ITS devices, e.g. signs. Refer to Clause 3.6.2 for more details.

2.2 Master and Slaves

Communications are initiated from the master only.

2.3 System Security

Switched links are vulnerable to deliberate or accidental connection to unauthorised users. To enable the master to communicate with device controllers via switched networks (eg, over PSTN, ISDN or radio using modems) without compromising the security of the system, a link establishment procedure is used. This link establishment procedure enables each party to verify the identity of the other before commands are actioned.

Although it is possible to limit the access to the roadside devices using a distinct password for each device, this simple method can be compromised with relative ease. The protocol, instead, uses a link establishment procedure based on a password generation algorithm. This algorithm takes a random number generated by one side in the link, and performs a series of logical operations on it. This calculation is performed by the master and the device controller simultaneously. The communications link is established only if the two parties produce the same password. This method of password protection means that every time the link is established a different password is used. Further protection is gained by making some of the parameters in the password generation algorithm configurable by the system owner.

A detailed description of the link establishment procedure is given in Clause 3.4. An example password generation code is shown in Appendix B.

2.4 Protocol Attributes

2.4.1 Device Controller Address

As a consequence of having multiple destinations, some form of addressing is needed in order to specify the desired destination.

To support multiple roadside device arrangements on the same communication link, each device controller has a unique address. A device controller is required to acknowledge and respond to messages from the master containing its address and ignore messages containing other addresses. In addition, each device controller is required to respond to broadcast messages as described in Clause 2.4.2.

The address of each device controller is configurable by software or hardware means.

The maximum number of addressable devices is 256 (addresses 0 to 255), less any addresses assigned by the system owner to be broadcast addresses.

2.4.2 Broadcast Messages

A number of roadside devices of the same type (e.g., VSLSs, ISLUSs) connected on the same link may have to change their status simultaneously in response to an event. This is accomplished by means of a broadcast message.

A broadcast is a message sent by the master simultaneously to all the device controllers on a link. In response to a broadcast message the device controllers are required to take action but must not respond with an acknowledge. Typically, after a broadcast message requesting a certain action is sent, the master will poll each of the device controllers to confirm that the broadcast message has been accepted (i.e. actioned upon). Any application message can be sent with a broadcast address.

The roadside device controllers have a broadcast address. When a broadcast message is sent by the master, the ADDR field in the packet contains the broadcast address instead of a specific device controller address. The broadcast address of each device controller is configurable by software or hardware means.

More than one broadcast address may be assigned by the system owner in the network of connected devices. For example on a motorway, westbound VMSs may be assigned a particular broadcast address while eastbound VMSs may be assigned a different broadcast address.

2.4.3 Transparency

The protocol has been designed to be independent of the communications media. This allows a single set of application messages to be used to exchange data with all device controllers regardless of the physical arrangement. As a result, the messages passed on a permanent multi-drop link are the same as those used over a point-to-point switched link.

2.4.4 Data Integrity

Error control is implemented using checksum checks for every data packet at both the source and the destination. The correct order of messages sent and received is preserved using sequencing fields included in every transmitted packet. Error correction is accomplished by re-transmission of unacknowledged data packets.

3. PROTOCOL LAYERS

3.1 Introduction

The International Standards Organisation (ISO) Standard 7498 defines the 'Open System Interconnection (OSI) Reference Model'. This model outlines seven layers for data transmission:

1) Physical Layer - Deals with mechanical and electrical interfaces. The physical layer is described in Clause 3.2.

2) Data Link Layer - The Data Link Layer deals with the mechanism for communicating data over the link. It breaks the input data up into data packets, transmits the packets sequentially and processes the acknowledgment fields sent back by the other party. This is discussed in Clause 3.3.

3) Network Layer - Attaches network address and provides suitable routing. This is treated in Clause 3.3.2.

4) Transport Layer - Provides reliable, in-sequence, transfer of data regardless of reliability of lower levels. This is treated in Clause 3.3.2.

5) Session Layer - Establishes, manages and maintains connections between cooperating applications. The session layer is considered in Clause 3.4.

6) Presentation Layer - Deals with the syntax or semantics of the information transmitted. This is considered in Clause 3.3.1.

7) Application Layer -. Describes the mapping of application level information to message level data and describes the role of the application in the link. The application layer is described in Clause 3.6.

3.2 Physical Link

The logical, electrical and mechanical aspects of the communications interface shall be in accordance with the requirements of the Referencing Specification.

3.3 Data-Link Protocol

The data link shall be configured as per the table below:

Parameter	**Value**
Baud Rate	300, 1,200, 2,400, 4,800, 9,600, 19,200, 38,400, 57,600,

Parameter	Value
	115,200 bps selectable
Data Bits	7, 8 selectable
Stop Bits	1, 2 selectable
Start Bits	1
Parity	None
Bit Sequence	LSB first (bits numbered 1 to 8)
Sync	Asynchronous
Line Usage	Half Duplex

3.3.1 Data Presentation

All data except for ASCII control characters shall be ASCII Hex encoded using upper case characters. Refer to Appendix D for a message example.

Valid ASCII for transmission of ASCII Hex is 0 to 9 and A to F.

Note: When using ASCII Hex, a one byte field is transmitted in two bytes. eg, the byte 1A Hex is transmitted as ASCII 1 and ASCII A.

Any word value field is transmitted with the most significant byte first.

The following ASCII Control characters are used for management of data transactions:

Hex	Mnemonic	Description
01	“SOH”	Start of Header
02	“STX”	Start of Text
03	“ETX”	End of Text
04	“EOT”	End of Transmission
06	“ACK”	Acknowledge
15	“NAK”	Negative Acknowledge

3.3.2 Data Transfer

There are two types of packets that can be sent during the data transfer phase: data packets and non-data packets. Both types of packets contain control characters, message sequencing fields, an address field and a checksum field. Data packets also contain the application message (as detailed in Clause 3.5)

All exchanges of data between the master and a slave, the device controller, are processed upon request of the master (as detailed in Clause 2.4.2).

3.3.2.1 Message Sequencing

The protocol described in this Specification uses two distinct packet sequence numbers, designated N(R) and N(S).

N(R) and N(S) are one byte fields in the range 0-255.

The sequence number N(R) is used by both the master and slave in their messages to the other party. Since if a transmission by one party to another is not successful then it is repeated until successful, N(R) signifies the number of valid data packets that have been successfully received by each party. Refer to Clause 3.5 for an example of an exchange of datalink messages.

Specifically, for transmitted data packets and non-data packets from the slave to the master, N(R) signifies the number of valid data packets that have been successfully received from the master and that the next packet to be received from the master is expected to have this field set to this value.

For transmitted data packets from the master to the slave, N(R) signifies the number of valid data packets that have been successfully received from the slave and that the next packet to be received from the slave is expected to have this field set to this value plus one. The exception to this rule is that when the value of N(R) in the received packet is 255, the expected value of N(R) in the next packet to be received is 1, not 0.

Data packets (only) also have a sequence number field, N(S). N(S) contains the sequence number of the data packet being transmitted (sent).

The sequence numbers N(R) and N(S) are checked by both the master and the slave when a session is active, except for the Start Session command. A session is only active after the master receives an application layer Acknowledge from the slave in response to a Password command. If a session is not active, N(R) and N(S) are

ignored. If a session is not active (i.e. the slave is off-line), N(R) and N(S) may be set to zero.

The sequence numbers are reset to zero each time a link is established and then cycle between 1 and 255.

For broadcast messages, the slave checks sequence numbers. Both the master and slave ignore sequencing with the master not incrementing the sequence number for broadcasts.

3.3.2.2 Address Field

All data packets have an address field (referred to as 'ADDR'). This is a one byte field containing the address of the destination slave. Packets sent from the master to the slave and from the slave to the master both contain the address of the slave.

The ADDR field may also contain a broadcast address that is shared by some or all slaves on a multi-drop link.

3.3.2.3 Cyclic Redundancy Check (CRC)

All packets have a 16 bit Checksum field. The Checksum method used in the roadside device protocol is the CRC-CCITT polynomial. This method of error detection was designed to catch all single and double errors, all errors with an odd number of bits, all burst errors of length 16 or less, 99.997% of 17-bit error bursts and 99.998% of 18-bit and longer bursts.

During data transfer, the originator calculates the CRC on all data bytes in the packet except the ETX control byte and the CRC bytes themselves, and appends the result to the end of the packet. The destination calculates the CRC on all the bytes including the CRC bytes but excluding the ETX control character. If the data is received correctly the result of the CRC calculation at the receiving end should be 0000 Hex.

A procedure to perform the CRC-CCITT calculation is given below:

Packets are fed to the CRC generator one byte at a time. At the start of a new packet the accumulator is reset and the calculation proceeds using a 16-bit data register and a 16-bit accumulator.

When a new data byte is received, all the bits in the data register are reset and the data byte is loaded into the high order byte of the register.

- An 'exclusive OR' operation is performed between the data register and the accumulator.

- If the most significant bit of the result is ‘logic 0’, the contents of the accumulator is shifted left logical to form the new accumulator.
- If the most significant bit of the result is ‘logic 1’, the contents of the accumulator is shifted left logical and ‘exclusively ORed’ with the polynomial $X^{16} + X^{12} + X^5 + X^0$ to form the new accumulator.
- The content of the data register is shifted left logical.

The process is cycled 8 times (one for each bit of the received byte) for each byte in the byte stream. The result in the accumulator after the last byte has been completely processed is the CRC.

As an example, if the data bytes are:

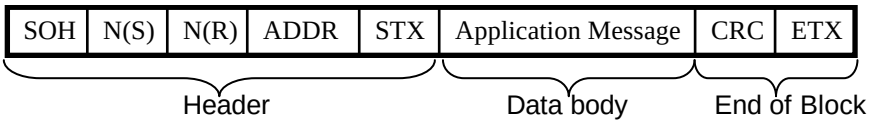
(0AH), (03H), (3EH), (44H), (46H), (48H), (4AH), (B3H), (BEH), (DCH) and (DDH), the CRC would be 440EH, with the most significant byte in the CRC (44H) transmitted first.

The code to perform the CRC calculation (including the above example) is given in Appendix A.

3.3.2.4 Data Packets

Data to be exchanged is framed into packets. Each packet is comprised of a header, a data body and an end of block information. The header starts with ‘SOH’ (Start of Header) followed by the two sequence numbers N(S) and N(R) as detailed in Clause 3.3.2.1, and the address of the slave. The end of the header is an ‘STX’ (Start of Text) to indicate that data follows. The data is placed after the ‘STX’ character and ended with a two byte CRC. The ‘ETX’ (End of Text) character marks the end of the data packet.

All data packets are of the following format:

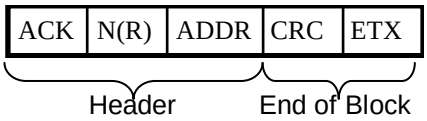


Refer to Appendix D for an example of a complete data packet.

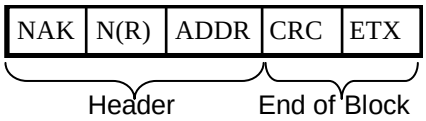
3.3.2.5 Non-Data Packets

There are two types of Non-Data packets, the ACK packet and the NAK packet. Both these packets contain a sequencing character (N(R)) followed by the address of the slave. The non-data packets also contain a CRC field to ensure that the address field is received correctly. The ‘ETX’ character marks the end of the packet.

1) Packet acknowledgment - Sent by the slave only when a data packet from the master has been received correctly.



2) Packet Reject - Sent when a packet is rejected eg, because of a sequence error or corrupted data. A packet reject can be sent by both the master and the slave.



3.3.2.6 Re-Transmission

A packet acknowledgment timer T0 is used by the master to determine if a data packet has not been acknowledged. This timer is restarted each time a data packet is sent by the master to the slave.

Data packets are re-transmitted if:

- Timer T0 expires before an acknowledgment is received.
- A negative acknowledge is received.

A configurable 'window size' N specifies the maximum number of times that a data packet can be re-transmitted. If the limit is exceeded, the master disconnects the link.

The master re-transmits the last transmitted data packet if it receives a negative acknowledge from the slave. The slave depends on the master to initiate time-out recovery.

The values of T0 and N typically depend on the physical arrangements, the quality of the transmission line as well as the type of device. A T0 value of 360 ms with N = 3 is appropriate for a simple point-to-point connection at 9,600 bps for a text-only VMS.

3.4 Session Management

3.4.1 Data Link Establishment

A valid link establishment procedure must be completed before data, other than heartbeat polling and heartbeat poll response, can be exchanged between the master and the device controller.

The master initiates the data link establishment sequence by sending a 'START SESSION' command to the device controller. The device controller responds with a 'PASSWORD SEED' message, which contains an 8 bit randomly generated number (between 0 and 255).

The password generation algorithm converts the eight bit 'password seed' into a sixteen bit password as follows:

(a) An 8 bit 'Seed Offset' is added to the password seed.

(b) The new 8 bit password seed is placed in a 16 bit register with bits 9 to 16 set to zero.

(c) Bits 6, 8 and 9 are exclusively ORed and the result is set aside.

(d) The register is shifted left one position.

(e) The one bit result of the exclusive OR calculation is added to the modified seed to generate an interim password.

(f) The interim password is then used again as the input of the algorithm.

(g) The process (steps (c) to (f) above) is cycled 16 times before a ‘Password Offset is added to it to form the final password.

(h) The ‘Password Offset’ is a 16 bit number, which can be configured at the device controller by hardware or software means.

The ‘Seed Offset’ and ‘Password Offset’ are provided by RMS for configuration at the time of installation/commissioning.

EXAMPLE

An 8 bit password seed of 43 Hex will result in the following operations:

A 'seed offset' of 22 Hex is added to 43 Hex to give 65 Hex. This number is cycled 16 times as shown below

Cycle	Binary	Hex	Bit 6	Bit 8	Bit 9	EX OR
0	0000000001100101	65	1	0	0	1
1	0000000011001011	CB	0	1	0	1
2	0000000110010111	197	0	1	1	0
3	0000001100101110	32E	1	0	1	0
4	0000011001011100	65C	0	0	0	0
5	0000110010111000	CB8	1	1	0	0
6	0001100101110000	1970	1	0	1	0

Cycle	Binary	Hex	Bit 6	Bit 8	Bit 9	EX OR
7	0011001011100000	32E0	1	1	0	0
8	0110010111000000	65C0	0	1	1	0
9	1100101110000000	CB80	0	1	1	0
10	1001011100000000	9700	0	0	1	1
11	0010111000000001	2E01	0	0	0	0
12	0101110000000010	5C02	0	0	0	0
13	1011100000000100	B804	0	0	0	0
14	0111000000001000	7008	0	0	0	0
15	1110000000010000	E010	0	0	0	0
16	1100000000100000	C020				

Assuming the ‘password offset is 5A5A Hexadecimal, C020H + 5A5AH = 11A7A. The 16 bit password is thus **1A7A** (take the 16 least significant bits).

The final password is sent to the device controller in a ‘PASSWORD’ command as a response to the ‘PASSWORD SEED’ message. The device controller performs the same calculation and if it receives the correct password the link is established. Once the link is established, the sequencing numbers N(S) and N(R) are set to zero and the device controller is considered ‘on-line’.

Examples of code to perform the link establishment algorithm are given in appendix B.

3.4.2 Data Link Termination

On completion of a communications session, the master sends the ‘END SESSION’ command to the device controller. Once this command has been received, the device controller is considered 'off-line' and the link establishment procedure must be completed before a new session can begin.

In addition, the device controller has a timer T1 that is restarted each time a packet is received. If the timer expires the device controller changes its status to 'off-line' (i.e. the session terminates). The timer shall be configurable and has a default value of 120 seconds.

3.4.3 Heartbeat Polling

A HEARTBEAT POLLING message is sent repeatedly by the master to each slave in the link. The slave responds with a device specific STATUS REPLY message which contains status information. Heartbeat polling is sent to all devices in the link regardless of whether they are ‘on-line’ or not. The frequency of heartbeat polling depends on the type of link and device types on the link

3.5 Example of Datalink Message Exchange

Master To Device Controller	Device Controller To Master	Comment
		Network link established
START SESSION Command		Request to start session
	ACK	Protocol ACK
	PASSWORD SEED Message	Slave responds with password seed
PASSWORD Command		Master sends password
	ACK	Protocol ACK
	*ACK	Application layer ACK
Data, N(S) = 0 N(R) = 0		First data exchanged with N(R) and N(S) set to zero
	ACK, N(R) = 1	Protocol ACK
	*ACK, N(S) = 0 N(R) = 1	Application layer ACK, slave is on-line
Data, N(S) = 1 N(R) = 1		Master sends data packet
	ACK, N(R) = 2	Protocol ACK
	Data, N(S) = 1 N(R) = 2	Slave responds with data packet
Data, N(S) = 3 N(R) = 2		Sequence error
	NAK, N(R) = 2	NAK (protocol layer only)
Data, N(S) = 2 N(R) = 2		Data re-sent
	ACK, N(R) = 3	Protocol ACK
	*ACK, N(S) = 2 N(R) = 3	Application layer ACK, slave is still on-line
Data, N(S) = 3 N(R) = 3		Master sends data packet
		Slave fails to respond OR response message fails to reach master before timer T0 expires
Data, N(S) = 3 N(R) = 3		Master resends data packet after timer T0 expires
	ACK, N(R) = 4	Protocol ACK
	*ACK, N(S) = 3 N(R) = 4	Application layer ACK, slave is still on-line
END SESSION Command, N(S) = 4 N(R) = 4		Terminate session
	ACK, N(R) = 5	Protocol ACK
	*ACK, N(S) = 4 N(R) = 5	Application layer ACK, slave is off-line

Note: *ACK represents an application layer acknowledge, while ACK is the protocol layer acknowledge.

3.6 Application Layer

3.6.1 Introduction

The following clauses describe the functions available to monitor and control roadside devices. This includes the format of each command sent by the master, and the possible responses from the slaves.

NOTE: The messages used for environmental stations and weather stations have been derived from objects documented in the NTCIP (National Transportation Communications for ITS Protocol) standard applicable at the time. That NTCIP standard has since been significantly revised which in turn has led to some revisions to this Specification.

3.6.2 General Requirements

The following requirements apply throughout the message descriptions:

- All data is based on an octet which is defined as 8 bits where bit 1 (LSB) is the first bit transmitted in the octet and bit 8 (MSB) is the last bit transmitted in the octet.
- All application layer messages start with a one byte Message Information (MI Code).
- A device controller may control a number of devices, either as a single individual device, or as part of a group of devices. Note that a device controller may control a combination of individual devices and device groups. For signs, the sign ID field refers to the actual signs whereas the group ID refers to signs that have been grouped together so that all signs in the same group shall display the same information via one single command. The same applies for other types of devices. In the protocol, commands to the device controller include the group ID field (eg, sign group 1), while device controller replies include the individual device ID fields (eg, sign 1 & 2).
- For a device controller with only one device, the group ID and sign ID are both one (usually for Variable Message Signs). Where a device controller has many devices, but with one device per group, the group ID always equals the device ID (usually for Variable Message Signs). For a device controller with four devices but grouped in pairs, two group IDs and four device Ids exist (if group 1 is defined to be devices 1 and 2, then group 2 would be defined as devices 3 and 4). Note that the grouping of devices usually applies to Variable Speed Limit Signs where the two signs on each side of the carriageway are grouped together so that both signs show identical displays. Unless otherwise

stated for a particular command, a group ID of zero shall apply to all groups, that is, all devices.

- The following terminology is used to describe the type of messages used:

  Command a message requiring a reply.

  Reply a message responding to a command.

3.6.3 Application Layer Messages

3.6.3.1 Reject

Direction: Controller to Master

Message Size: 3 bytes

Description: A REJECT reply is sent whenever a device controller is unable to carry-out a command or when a corrupted application message is received. A REJECT message is effectively an application layer NAK. The 'application error code' contains a number which identifies the error. A list of application error codes is given in appendix C.

When the master receives a REJECT message the application software responds according to the application error code. If an unrecoverable error occurs at the device controller, the application software running on the master should ensure that the communications don't lock-up. This can be done by limiting the number of application message retries.

Example: If a device controller which is not 'on-line' is sent a message other than an HEARTBEAT POLL command, the device controller responds with a REJECT message with the MI Code of the rejected message and the application error code 01 (indicating 'off-line').

Content:

Position	Bytes	Value	Description
1	1	MI Code	00h
2	1	BYTE	Rejected MI Code
3	1	BYTE	Application error code (see appendix C)

3.6.3.2 Acknowledge (*ACK)

Direction: Controller to Master

Message Size: 2 bytes

Description: Certain messages are acknowledged at the application layer by containing the MI code of the message being acknowledged. See 3.6.5 for a complete list of messages acknowledged in this way.

Content:

Position	Bytes	Value	Description
1	1	MI Code	01h
2	1	BYTE	Acknowledged MI Code

3.6.3.3 Start Session

Direction: Master to Controller

Message Size: 1 byte

Description: The START SESSION command is used to open a session in the device controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	02h

Comments:

- A Start Session command received while online shall cause the existing session to be closed before opening the new session.

3.6.3.4 Password Seed

Direction: Controller to Master

Message Size: 2 bytes

Description: The PASSWORD SEED reply is sent by the device controller as a reply to the START SESSION Command.

Content:

Position	Bytes	Value	Description
1	1	MI Code	03h
2	1	BYTE	Randomly generated number

3.6.3.5 Password

Direction: Master to Controller

Message Size: 3 bytes

Description: The PASSWORD command contains a 16 bit number calculated from the password seed. A correct password establishes a communication session between the master and the device controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	04h
2	2	WORD	Password

3.6.3.6 Heartbeat Poll

Direction: Master to Controller

Message Size: 1 byte

Description: The HEARTBEAT POLL command is sent by the master, periodically, to all the slaves on the link. The HEARTBEAT POLL is the only message sent to device controllers which are 'off-line' as well as to those which are 'on-line'.

Content:

Position	Bytes	Value	Description
1	1	MI Code	05h

3.6.3.7 Sign Status Reply

Direction: Sign Controller to Master

Message Size: Variable

Description: The SIGN STATUS REPLY message is sent by the sign controller to the master as a response to a HEARTBEAT POLL Command. The SIGN STATUS REPLY Message contains the basic status information of the sign controller and the signs attached to it.

Content:

Position	Bytes	Value	Description
1	1	MI Code	06h
2	1	BYTE	'off-line'/'on-Line' status (0/1)
3	1	BYTE	application error code (see Appendix C)
4	1	BYTE	day (1-31)
5	1	BYTE	month (1-12)
6	2	WORD	year (1-9999)
8	1	BYTE	hours (0-23)
9	1	BYTE	minutes (0-59)
10	1	BYTE	seconds (0-59)
11	2	WORD	controller hardware checksum
13	1	BYTE	controller error code (see Appendix C)
14	1	BYTE	number of signs attached to the sign controller.
15	1	BYTE	*sign ID
16	1	BYTE	*sign error code (see Appendix C)
17	1	BYTE	*sign disabled/enabled (0/1)
18	1	BYTE	*frame ID displayed (0 if no frame is displayed)
19	1	BYTE	*revision - identifies the modification level of the frame
20	1	BYTE	*message ID displayed (0 if no message is displayed)

Position	Bytes	Value	Description
21	1	BYTE	*revision - identifies the modification level of the message
22	1	BYTE	*plan ID displayed (0 if no plan is displayed)
23	1	BYTE	*revision - identifies the modification level of the plan

*field may be repeated depending on the number of signs attached to the sign controller.

Comments:

- The application error code field indicates the current application error. If no error exists, this field is set to zero.
- The controller and sign error code fields indicate the current error (fault) present in the controller or sign. When a change in fault status occurs (fault occurrence or clearance), the error code field shall be updated to trigger the retrieval of the fault log by the master. If no error (fault) exists, this field is set to zero, and indicates to the master that all faults are cleared for the respective controller or sign. If other faults are still active, the error code field shall be set to one of those error codes. If the error code cannot be set to a different value, FF Hex shall be used.
- The controller hardware checksum is used to check the sign controller's memory. The master uses this to verify that the sign controller's memory locations have not changed. Set Frame, Set Message and Set Plan return a Status Reply as these commands affect the sign controller hardware checksum. Note that in some instances the System Reset command affects the hardware checksum. In these instances, the master must send a Heartbeat Poll to obtain the new hardware checksum.

3.6.3.8 End Session

Direction: Master to Controller

Message Size: 1 byte

Description: The END SESSION command is used to close a session in the device controller. Once the session is terminated, the only messages exchanged between the master and the controller are HEARTBEAT POLL and the device specific STATUS REPLY.

Content:

Position	Bytes	Value	Description
1	1	MI Code	07h

3.6.3.9 System Reset

Direction: Master to Controller

Message Size: 3 byte

Description: The SYSTEM RESET command is used to reset the device controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	08h
2	1	BYTE	group ID - zero for device controller or non-zero for a specific device or group of devices
3	1	BYTE	reset level

Comments

For Signs:

- A reset level of zero shall blank the display, turn off the conspicuity devices (if on), set to automatic dimming mode, de-activate any active frame or message and enable the sign group. Where the group ID is zero, these actions shall be applied to all attached signs.
- A reset level of one shall perform all the actions associated with a reset level zero in addition to disabling all plans. Where the group ID is zero, these actions shall be applied to all attached signs.
- A reset level of two shall perform all the actions associated with a reset level one in addition to resetting all faults and the fault log. Reset level two only applies to a group ID of zero.
- A reset level of three shall perform all the actions associated with a reset level two in addition to clearing of all frames, messages and plans. Reset level three only applies to a group ID of zero.

- A reset level of 255 shall perform all the actions associated with a reset level three in addition to restoring to factory settings. Factory settings shall include the seed offset, password offset, baud rate, parity, etc but not the device address. Reset level 255 only applies to a group ID of zero. Reset level 255 shall not cause the device controller to change to the off-line state.

For Environmental/Weather Stations:

NOTE: The group ID is always zero for all reset levels for environmental/weather stations.

- A reset level of zero is not used.
- A reset level of one is not used.
- A reset level of two shall perform all the actions associated with a reset level one in addition to resetting all faults and the fault log.
- A reset level of three shall perform all the actions associated with a reset level two in addition to clearing of all environmental/weather thresholds and the environmental/weather event log.
- A reset level of 255 shall perform all the actions associated with a reset level three in addition to restoring to factory settings. Factory settings shall include the seed offset, password offset, baud rate, parity, etc but not the device address. Reset level 255 shall not cause the device controller to change to the off-line state.

For HAR:

NOTE: The group ID is always zero for all reset levels for HAR.

- A reset level of zero shall stop the broadcast, de-activate any active strategy and enable the HAR.
- A reset level of one is not used.
- A reset level of two shall perform all the actions associated with a reset level one in addition to resetting all faults and the fault log.
- A reset level of three shall perform all the actions associated with a reset level two in addition to clearing of all voice data files and strategies.
- A reset level of 255 shall perform all the actions associated with a reset level three in addition to restoring to factory settings. Factory settings shall include the seed offset, password offset, baud rate, parity, etc but not the device address. Reset level 255 shall not cause the device controller to change to the off-line state.

3.6.3.10 Update Time

Direction: Master to Controller

Message Size: 8 bytes

Description: The UPDATE TIME command is used to update the real time clock in the device controller. In a multi-drop arrangement, the UPDATE TIME Message is typically broadcast (sent using the broadcast address) to all the slaves in the link.

Content:

Position	Bytes	Value	Description
1	1	MI Code	09h
2	1	BYTE	Day (1-31)
3	1	BYTE	Month (1-12)
4	2	WORD	Year (1-9999)
6	1	BYTE	Hours (0-23)
7	1	BYTE	Minutes (0-59)
8	1	BYTE	Seconds (0-59)

3.6.3.11 Sign Set Text Frame

Direction: Master to Sign Controller and Sign Controller to Master (bidirectional)

Message Size: Variable

Description: The SIGN SET TEXT FRAME message is used to store a frame in the memory of the sign controller. The number of frames that can be stored in the controller's memory and the maximum size of the frames vary according to the sign. The protocol allows a maximum of 255 pre-set frames, where:

- Frame number 00 Hex cannot be set and always means to reinstate the display from the current active plan or blank the sign if no plan is active.
- Frames 01 up to FF Hex can be pre-set using the SIGN SET TEXT FRAME Command.

This message is also used by the controller to report stored text frames.

Content:

Position	Bytes	Value	Description
1	1	MI Code	0Ah
2	1	BYTE	frame ID - identifies the frame as it is stored in the sign controller's memory
3	1	BYTE	revision - identifies the modification level of the frame
4	1	BYTE	font
5	1	BYTE	colour
6	1	BYTE	conspicuity devices
7	1	BYTE	number of alphanumeric characters in frame
8	variable	BYTE	text frame
…	2	WORD	message CRC - calculated for all the bytes in the application message

Comments

- Manufacturers may define other fonts by contacting RMS. Font zero is reserved for the sign's default character font. The codes for fonts are as follows:

Font	Value
Default	0
Fixed Width (Text)	1
Proportional	2
Bold	3
Double Height	4
Full Height	5

- The codes for colour are as follows:

Colour	Value	Colour	Value
Default	0	Blue	5
Red	1	Magenta	6
Yellow	2	White	7
Green	3	Orange	8
Cyan	4	Amber	9

- A colour of zero means the sign's default colour.
- The conspicuity devices (warning lanterns) are four lanterns, one placed in each corner of the sign. The speed annulus is the red ring around the speed limit numerals.
- The codes for the conspicuity devices are as follows:

Conspicuity Devices	Value	Speed Annulus	Value
Off	xxxxx000	Off	xxx00xxx
Up/Down	xxxxx001	Flashing	xxx01xxx
Left/Right	xxxxx010	On	xxx10xxx
Wig/Wag	xxxxx011		
All Flash	xxxxx100		
All On	xxxxx101		

- If the sign operator wishes to display 'free text' on a sign, the application software running on the master machine will send the sign controller a SIGN SET TEXT FRAME Command followed by a SIGN DISPLAY FRAME Command. To support 'free text', the sign controller shall allocate a number of frame and message IDs which are reserved for free text.
- The controller shall respond with this message when responding to a Sign Request Stored Frame/Message/Plan command from the master.

3.6.3.12 Sign Set Graphics Frame

Direction: Master to Sign Controller and Sign Controller to Master (bidirectional)

Message Size: Variable

Description: The SIGN SET GRAPHICS FRAME message is used to store a graphics frame in the memory of the sign controller. The number of frames that can be stored in the controller's memory and the size of the frames vary according to the sign. The protocol allows a maximum of 255 frames, where:

- Frame number 00 Hex cannot be set and always means to reinstate the display from the current active plan or blank the sign if no plan is active.
- Frames 01 up to FF Hex can be pre-set using the SIGN SET GRAPHICS FRAME Command.

Signs capable of displaying graphics are treated as a matrix of pixels where each pixel either has two possible. The graphics message sent to the sign controller specifies for each pixel whether it is OFF or what colour to display if it is ON.

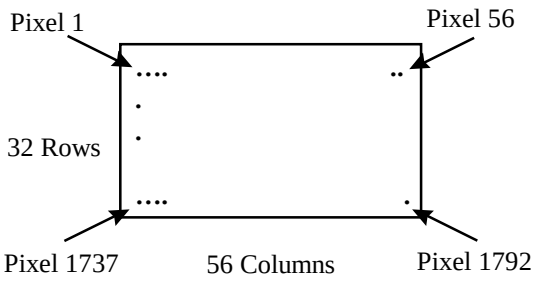
This message is also used by the controller to report stored graphics frames.

Content:

Position	Bytes	Value	Description
1	1	MI Code	0Bh
2	1	BYTE	frame ID - identifies the frame as it is stored in the sign controller's memory
3	1	BYTE	revision - identifies the modification level of the frame
4	1	BYTE	number of rows of pixels in sign
5	1	BYTE	number of columns of pixels in sign
6	1	BYTE	colour
7	1	BYTE	conspicuity devices
8	2	WORD	length of graphics frame in bytes
10	variable	BYTE	graphics frame
…	2	WORD	message CRC - calculated for all the bytes in the application message

Example:

The example display below is a 32 X 56 pixel matrix:



Comments:

- The codes for colour are as follows:

Colour	Value	Description
Default	00h	Monochrome with 1-bit colour depth
Red	01h	Monochrome with 1-bit colour depth
Yellow	02h	Monochrome with 1-bit colour depth
Green	03h	Monochrome with 1-bit colour depth
Cyan	04h	Monochrome with 1-bit colour depth
Blue	05h	Monochrome with 1-bit colour depth
Magenta	06h	Monochrome with 1-bit colour depth
White	07h	Monochrome with 1-bit colour depth
Orange	08h	Monochrome with 1-bit colour depth
Amber	09h	Monochrome with 1-bit colour depth
Multiple colours	0Dh	Multiple colours for images

- A colour of zero means the sign's default colour.
- For monochrome signs and signs with 1-bit colour depth (i.e. operating with the colour values 00h to 09h), using the above example display, the graphics frame is transmitted as follows:

  Byte 1: [Pixel 8, Pixel 7, Pixel 6, Pixel 5, Pixel 4, Pixel 3, Pixel 2, Pixel 1]

  Byte 2: [Pixel 16, Pixel 15, Pixel 14, Pixel 13, Pixel 12, Pixel 11, Pixel 10, Pixel 9]

  .....

  Byte 223: [Pixel 1784, Pixel 1783, Pixel 1782, Pixel 1781, Pixel 1780, Pixel 1779, Pixel 1778, Pixel 1777,]

  Byte 224: [Pixel 1792, Pixel 1791, Pixel 1790, Pixel 1789, Pixel 1788, Pixel 1787, Pixel 1786, Pixel 1785]

- Where signs are required to display 'multiple colours' for images (i.e. operating with the colour value 0Dh), the codes for colour are as follows:

Colour	Value in Nibble
Pixel off	0h
Red	1h
Yellow	2h
Green	3h
Cyan	4h
Blue	5h
Magenta	6h
White	7h
Orange	8h
Amber	9h

Using the above example display, the graphics frame is transmitted as follows:

Byte 1: [Pixel 2, Pixel 1];

Byte 2: [Pixel 4, Pixel 3];

…..

Byte 896: [Pixel 1792, Pixel 1791].

- A sign not capable of supporting the commanded colour operation shall respond so accordingly to the Master.
- For monochrome signs, where the pixel matrix is not a multiple of eight pixels, the last byte of the graphics frame shall have any remaining bits set to zero, such that the number of bits in the graphics frame is a multiple of eight.

  There is no requirement for the number of pixels in a row, or the number of pixels in a column to be a multiple of eight.
- The conspicuity devices (warning lanterns) are four lanterns, one placed in each corner of the sign. The speed annulus is the red ring around the speed limit numerals.
- The codes for the conspicuity devices are as follows:

Conspicuity Devices	**Value**	**Speed Annulus**	**Value**
Off	xxxxx000	Off	xxx00xxx
Up/Down	xxxxx001	Flashing	xxx01xxx
Left/Right	xxxxx010	On	xxx10xxx
Wig/Wag	xxxxx011		
All Flash	xxxxx100		
All On	xxxxx101		

- The controller shall respond with this message when responding to a SIGN REQUEST STORED FRAME/MESSAGE/PLAN command from the master.

3.6.3.13 Sign Set Message

Direction: Master to Sign Controller and Sign Controller to Master (bidirectional)

Message Size: Variable, up to 16 bytes

Description: The SIGN SET MESSAGE is used to store a sequence of up to 6 frames in the memory of the sign controller. The protocol allows a maximum of 255 messages.

This message is also used by the controller to report stored messages.

Content:

Position	Bytes	Value	Description
1	1	MI Code	0Ch
2	1	BYTE	message ID - identifies the message as it is stored in the sign controller's memory
3	1	BYTE	revision - identifies the modification level of the message
4	1	BYTE	transition time between frames (in seconds x 0.01)
5	1	BYTE	frame 1 ID
6	1	BYTE	frame 1 ON time (in seconds x 0.1)
7	1	BYTE	frame 2 ID
8	1	BYTE	frame 2 ON time (in seconds x 0.1)
9	1	BYTE	frame 3 ID
10	1	BYTE	frame 3 ON time (in seconds x 0.1)
11	1	BYTE	frame 4 ID
12	1	BYTE	frame 4 ON time (in seconds x 0.1)
13	1	BYTE	frame 5 ID
14	1	BYTE	frame 5 ON time (in seconds x 0.1)
15	1	BYTE	frame 6 ID
16	1	BYTE	frame 6 ON time (in seconds x 0.1)

Comments:

- Message number 00 Hex cannot be set and always means to reinstate the display from the current active plan or blank the sign if no plan is active.
- A non-zero transition time shall cause a blanking of the complete display. Frames which are permanently on shall also be blanked.
- A message must contain at least one frame definition. A frame ID number of zero indicates that no more frames (ID numbers and ON times) follow within the message. This allows a message to consist of less than six frames.
- Where the last frame definition (frame ID and on time) contains a frame ON time of zero, this frame shall remain continuously on. As an example, Message 1 consists of Frame 10, ON time 10

seconds, and Frame 20, ON time zero seconds. When Message 1 is displayed, Frame 10 appears only for 10 seconds, and then Frame 20 appears from then on. Note that a Message is still reported back to the master in the Status Reply.

- Overlaying of frames is achieved by OR-ing the ON pixels of the individual frames.
- Where any but the last frame definition (frame ID and on time) contains a frame ON time of zero, this frame shall be overlaid with the other frames in the message. As an example, Message 1 consists of Frame 10, ON time zero seconds (shows an accident symbol), Frame 20, ON time two seconds (shows ACCIDENT AHEAD), and Frame 30, ON time two seconds (shows SLOW DOWN). When Message 1 is displayed, the accident symbol appears permanently on with the alternating text ACCIDENT AHEAD/SLOW DOWN. Another example, which uses the overlay feature to display multiple colours, could be defined as Frame 1, ON time zero seconds (shows red ring), Frame 2 ON time zero seconds (shows 60), to obtain a 60 km/h speed sign on a multi-colour sign.
- Length errors shall be reported by the sign controller where a message has no frame definitions or when a message is terminated by zero and further frames are defined afterwards.
- The controller shall respond with this message when responding to a Sign Request Stored Frame/Message/Plan command from the master.

3.6.3.14 Sign Set Plan

Direction: Master to Sign Controller and Sign Controller to Master (bidirectional)

Message Size: Variable, up to 40 bytes

Description: The SIGN SET PLAN message is used to store a plan of up to six frames or messages (or a combination) in the sign controller's memory. A plan can be programmed on a daily basis or weekly basis.

This message is also used by the controller to report stored plans.

Content:

Position	Bytes	Value	Description
1	1	MI Code	0Dh

Position	Bytes	Value	Description
2	1	BYTE	plan ID - identifies the plan as it is stored in the sign controller's memory
3	1	BYTE	revision - identifies the modification level of the plan
4	1	BYTE	day of the week*
5	1	BYTE	frame/message - indicates whether the next field refers to a frame (1) or a message (2). If zero (0), no subsequent frame/message definitions occur.
6	1	BYTE	frame/message 1 ID
7	1	BYTE	frame/message 1 start time - hour (0-23)
8	1	BYTE	frame/message 1 start time - minute (0-59)
9	1	BYTE	frame/message 1 stop time - hour (0-23)
10	1	BYTE	frame/message 1 stop time - minute (0-59)
11	1	BYTE	frame/message - indicates whether the next field ends the plan definition or refers to a frame or a message (0/1/2)
12	1	BYTE	frame/message 2 ID
…	…	…	…
39	1	BYTE	frame/message 6 stop time - hour (0-23)
40	1	BYTE	frame/message 6 stop time - minute

*day of the week is a bitwise field where bits 1, 2, 3, 4, 5, 6 and 7 represent Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday respectively. Bit 8 is unused. For the plan to operate daily, the day of week field is set to 7Fh.

Comments:

- Plan number 00 Hex is invalid.
- Setting the frame/message ID to zero causes the sign to blank for the period specified by the start and stop times.
- A plan must contain at least one frame or message definition. A frame/message value of zero indicates that no more frames or messages follow within the plan. This allows a plan to consist of less than six frames/messages.

- Length errors shall be reported by the sign controller where a plan has no frame or message definitions or when a plan is terminated by a zero and further frame or message definitions are defined afterwards.
- The start time always uses the day of week field to obtain the start day. The stop time follows on from the start time and day. Eg, 20:00 to 20:00 on Monday and Wednesday means to activate from Monday 8:00pm to Tuesday 8:00pm and from Wednesday 8:00pm to Thursday 8:00pm.
- Each plan need not be contiguous (i.e.: the start time need not follow on from the previous stop time).
- The controller shall respond with this message when responding to a Sign Request Stored Frame/Message/Plan command from the master.

3.6.3.15 Sign Display Frame

Direction: Master to Sign Controller

Message Size: 3 bytes

Description: The SIGN DISPLAY FRAME command is used to instruct the sign controller to display pre-stored frame in the specified group. The frame is displayed continuously.

- Frame number 00 Hex cannot be displayed and always means to reinstate the display from the current active plan or blank the sign if no plan is active.

Content:

Position	Bytes	Value	Description
1	1	MI Code	0Eh
2	1	BYTE	group ID
3	1	BYTE	frame ID - identifies the frame as it is stored in the sign controller's memory

Comments:

- To instruct the sign controller to display different pre-stored frames on different signs in the specified group refer to the ‘SIGN DISPLAY ATOMIC FRAMES’ command.

3.6.3.16 Sign Display Message

Direction: Master to Sign Controller

Message Size: 3 bytes

Description: The SIGN DISPLAY MESSAGE command is used to instruct the sign controller to display a pre-stored message in the specified group. The message is displayed continuously.

- Message number 00 Hex cannot be displayed and always means that after the current message completes reinstate the display from the current active plan or blank the group or sign if no plan is active.

Content:

Position	Bytes	Value	Description
1	1	MI Code	0Fh
2	1	BYTE	group ID
3	1	BYTE	message ID - identifies the message as it is stored in the sign controller's memory

3.6.3.17 Enable Plan

Direction: Master to Controller

Message Size: 3 bytes

Description: The ENABLE PLAN command is used to instruct the device controller to enable a pre-stored plan in a specified group. The plan remains in force until disabled.

A plan that is enabled can run per its configured schedule, unless overridden, by a SIGN DISPLAY FRAME or SIGN DISPLAY MESSAGE command.

Content:

Position	Bytes	Value	Description
1	1	MI Code	10h
2	1	BYTE	group ID - the group where the plan is to be enabled
3	1	BYTE	plan ID - identifies the plan as it is stored in the device controller's memory

Comments:

- Plan number 00 always disables all enabled plans on the single group specified. Notwithstanding, an active plan cannot be disabled by the command which shall be rejected and not acted upon (i.e. no enabled plans shall be disabled).
- For HAR, the group ID is always zero.
- Although many plans may be enabled at the same time only one plan can be active at a time.
- To enable plans on multiple groups, the command must be sent to each group.

3.6.3.18 Disable Plan

Direction: Master to Controller

Message Size: 3 bytes

Description: The DISABLE PLAN command is used to instruct the device controller to disable a pre-stored plan in a specified group.

Content:

Position	Bytes	Value	Description
1	1	MI Code	11h
2	1	BYTE	group ID - the group where the plan is to be disabled
3	1	BYTE	plan ID - identifies the plan as it is stored in the device controller's memory

Comments:

- Plan number 00 always disables all enabled plans on the single group specified. An active plan cannot be disabled by the command. In all such cases, the command shall be rejected and not acted upon (i.e. any other enabled plans that are covered by the command but not currently active shall remain enabled).
- For HAR, the group ID is always zero.
- To disable plans on multiple groups, the command must be sent to each group.

3.6.3.19 Request Enabled Plans

Direction: Master to Controller

Message Size: 1 byte

Description: The REQUEST ENABLED PLANS command is used to determine what plans are enabled in the device controller. The device controller shall respond with a REPORT ENABLED PLANS reply.

Content:

Position	Bytes	Value	Description
1	1	MI Code	12h

3.6.3.20 Report Enabled Plans

Direction: Controller to Master

Message Size: variable

Description: REPORT ENABLED PLANS is used to report which plans are enabled in the device controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	13h
2	1	BYTE	number of entries to follow
3	1	BYTE	*group ID - identifies the group where the plan is enabled

Position	Bytes	Value	Description
4	1	BYTE	*plan ID - identifies the plan as it is stored in the device controller's memory

*field may be repeated depending on the number of enabled plans.

Comments:

- For HAR, the group ID is always zero.
- This message also applies if the same plan is enabled on more than one group.

3.6.3.21 Sign Set Dimming Level

Direction: Master to Sign Controller

Message Size: variable

Description: The SIGN SET DIMMING LEVEL command is used to instruct the sign controller to set the luminance level in the specified groups to either automatic mode or manual mode with the specified level.

Content:

Position	Bytes	Value	Description
1	1	MI Code	14h
2	1	BYTE	number of entries to follow
3	1	BYTE	*group ID
4	1	BYTE	*automatic/manual dimming mode (0/1)
5	1	BYTE	*luminance level (1-16)

*field may be repeated depending on the number of entries.

Comments:

- Where the dimming mode is set to automatic, the luminance level is ignored.
- Luminance levels range from 1 (minimum sign intensity) to 16 (maximum sign intensity).

- For a device controller with multiple device groups, a group ID of zero applies to all groups, that is, all devices.

3.6.3.22 Power ON/OFF

Direction: Master to Controller

Message Size: variable

Description: The POWER ON/OFF command is used to instruct the device controller to turn ON or OFF the power for the specified groups.

Content:

Position	Bytes	Value	Description
1	1	MI Code	15h
2	1	BYTE	number of entries to follow
3	1	BYTE	*group ID
4	1	BYTE	*turn power OFF/ON (0/1)

*field may be repeated depending on the number of entries.

Comments:

- For HAR, the group ID is always zero.
- For Environmental/Weather Stations, the group ID indicates which sensor to power on or off as defined in Fault Log Reply (3.6.3.26).
- For a device controller with multiple device groups, a group ID of zero applies to all groups, that is, all devices.

3.6.3.23 Disable/Enable Device

Direction: Master to Controller

Message Size: variable

Description: The DISABLE/ENABLE DEVICE command is used to instruct the device controller to disable or enable the specified groups.

Content:

Position	Bytes	Value	Description
1	1	MI Code	16h
1	1	BYTE	number of entries to follow
2	1	BYTE	*group ID
3	1	BYTE	*disable/enable device group (0/1)

*field may be repeated depending on the number of entries.

Comments:

- For HAR, the group ID is always zero.
- For Environmental/Weather Stations, the group ID indicates which sensor to enable or disable as defined in Fault Log Reply (3.6.3.26).
- For a device controller with multiple device groups, a group ID of zero applies to all groups, that is, all devices.
- For a disabled group , all controller and device group operations are as normal except for the following: the display for the sign group is blanked and for HAR, no broadcasts are permitted . In this instance, for signs, the controller still reports the current active frame, message and/or plan, and accepts commands to set the signs in the group while maintaining a blank display for the disabled group or sign.

3.6.3.24 Sign Request Stored Frame/Message/Plan

Direction: Master to Sign Controller

Message Size: 3 bytes

Description: The SIGN REQUEST STORED FRAME/MESSAGE /PLAN command is used to instruct the sign controller to send the master the content of a stored frame, message or plan. The sign controller shall respond with a SIGN SET TEXT FRAME, a SIGN SET GRAPHICS FRAME, a SIGN SET HIGH RESOLUTION GRAPHICS FRAME, a SIGN SET MESSAGE or a SIGN SET PLAN.

Content:

Position	Bytes	Value	Description
1	1	MI Code	17h
2	1	BYTE	frame/message/plan (0/1/2)
3	1	BYTE	frame/message/plan ID

Comments:

- The response from the sign controller shall be identical to the original frame, message or plan as transmitted previously by the master. Under no circumstances shall the sign controller convert text frames to graphic frames, graphic frames to text frames, or character and line justification to the stored frame.

3.6.3.25 Retrieve Fault Log

Direction: Master to Controller

Message Size: 1 byte

Description: The RETRIEVE LOG ENTRY command is used to retrieve the fault log stored in the device controller's memory.

Content:

Position	Bytes	Value	Description
1	1	MI Code	18h

3.6.3.26 Fault Log Reply

Direction: Controller to Master

Message Size: variable

Description: The FAULT LOG REPLY message is a list of the last (up to 20) recorded entries in the fault log, stored in the device controller's memory.

Content:

Position	Bytes	Value	Description
1	1	MI Code	19h
2	1	BYTE	number of entries to follow (0-20)
3	1	BYTE	*ID – depends on controller type, see comment below
4	1	BYTE	*entry number field - cycles between 0 and 255
5	1	BYTE	*day of month (1-31)
6	1	BYTE	*month (1-12)
7	2	WORD	*year (1-9999)
9	1	BYTE	*hour (0-23)
10	1	BYTE	*minute (1-59)
11	1	BYTE	*second (1-59)
12	1	BYTE	*error code (see appendix C)
13	1	BYTE	*fault clearance/fault onset (0/1)

*field may be repeated depending on the number of entries.

Comments:

- ID depends on the type of controller as follows:

  Signs — Sign Controller Fault - ID is zero; Specific Sign Fault - ID is non-zero.

  HAR — ID is always 0.

  Environmental/Weather — ID indicates which sensor the fault is associated with, according to the following:

Value	Sensor
0	Environmental/Weather station itself
1	Pressure sensor
2	Temperature sensor
3	Visibility sensor
4	Precipitation sensor
5	Air quality sensor
6	Pavement sensor
7	Wind sensor
8	Water Depth sensor

- A maximum of only twenty entries is allowed in the Fault Log Reply, with the most recent entry appearing first in the list and the oldest appearing last.
- The fault list is a historical (archive) log of fault occurrences and clearances. The log is a first-in-first-out log. When the log is full and a new entry is added to the list, the oldest entry is removed.
- Each time an entry is added to the log, the entry number field is incremented. The entry number starts at zero, increments to 255, then rolls over to zero and continues. The entry number field may be used to determine how many new fault log entries have been added since the log was last retrieved, or how many fault log entries have been lost (i.e.: more than 20 fault entries have been added).
- Note that the current sign or controller fault error code is available in the SIGN STATUS REPLY and SIGN EXTENDED STATUS REPLY, HAR Status Reply and ENVIRONMENTAL/WEATHER STATUS REPLY messages. In the event that some messages have been lost, the only indication that the master will ever see that certain faults have been cleared may be when the current sign or fault error code is set to zero, meaning that no faults are active on the relevant device. If the master finds that this error code is zero it should automatically clear any outstanding faults.

3.6.3.27 Reset Fault Log

Direction: Master to Controller

Message Size: 1 byte

Description: The RESET FAULT LOG command is used to reset the fault log stored in the device controller's memory.

Content:

Position	Bytes	Value	Description
1	1	MI Code	1Ah

3.6.3.28 Sign Extended Status Request

Direction: Master to Sign Controller

Message Size: 1 byte

Description: The SIGN EXTENDED STATUS REQUEST command is used to instruct the sign controller to provide a detailed (i.e. “extended”) status report. The sign controller shall respond with a SIGN EXTENDED STATUS REPLY message.

Content:

Position	Bytes	Value	Description
1	1	MI Code	1Bh

3.6.3.29 Sign Extended Status Reply

Direction: Sign Controller to Master

Message Size: Variable

Description: The SIGN EXTENDED STATUS REPLY message is used to report the complete status of the sign controller and its attached signs.

Content:

Position	Bytes	Value	Description
1	1	MI Code	1Ch
2	1	BYTE	'off-line'/'on-line' status (0/1)
3	1	BYTE	application error code (see appendix C)
4	10	BYTE	manufacturer code details
14	1	BYTE	day (1-31)
15	1	BYTE	month (1-12)
16	2	WORD	year (1-9999)
18	1	BYTE	hours (0-23)
19	1	BYTE	minutes (0-59)
20	1	BYTE	seconds (0-59)
21	1	BYTE	controller error code (see appendix C)
22	1	BYTE	number of signs
23	1	BYTE	*sign ID
24	1	BYTE	*sign type - text (0), graphics (1) advanced graphics (2).
25	1	BYTE	*For text sign: Number of lines of characters; *For graphics sign: Number of rows of pixels (where the graphics sign is based on a 7x5 (vertical x horizontal) character matrix and 2-pixel inter-line spacing); *For advanced graphics signs: Number of lines of characters (based on the sign's default character matrix and inter-line spacing)

Position	Bytes	Value	Description
26	1	BYTE	*For text signs: Number of columns of characters; *For graphics sign: Number of columns of pixels (where the graphics sign is based on a 7x5 (vertical x horizontal) character matrix and 2-pixel inter-character spacing); *For advanced graphics sign: Number of columns of characters (based on the sign's default character matrix and inter-character spacing)
27	1	BYTE	*sign error code (see appendix C)
28	1	BYTE	*automatic/manual dimming mode (0-1)
29	1	BYTE	*luminance level
30	1	BYTE	*For text and graphics signs: Length of lamp/LED status field in bytes; *For advanced graphics sign: Length of display attributes and faulty pixel count, and lamp/LED status, in bytes
31	variable	BYTE	*For text and graphics signs: Lamp/LED status; *For advanced graphics sign: Display attributes and faulty pixel count, and lamp/LED status
…	2	WORD	message CRC - calculated for all the bytes in the application message

*field may be repeated depending on the number of signs attached to the sign controller.

Comments:

- The 'off-line'/'on-line' status field shall always have the value 01 Hex as the SIGN EXTENDED STATUS REPLY can be retrieved only when the sign is on-line.
- The application error code field indicates the current application error. If no error exists, this field is set to zero.
- The manufacturer code details are abbreviated and indicates the supplier's name, sign type and firmware version.

- The controller and sign error code fields indicate the current error (fault) present in the controller and sign respectively. When a change in fault status occurs (fault occurrence or clearance), the error code field shall be updated to trigger the retrieval of the fault log by the master. If no error (fault) exists, this field is set to zero, and indicates to the master that all faults are cleared for the respective controller or sign. If other faults are still active, the error code field shall be set to one of those error codes. If the error code cannot be set to a different value, FF Hex shall be used.
- A sign type of text (consisting of character modules only) indicates that the sign supports only text frames.
- A sign type of graphics (consisting of matrix modules) indicates that the sign supports both text and graphics frames.
- A sign type of advanced graphics (consisting of matrix modules) indicates that the sign supports both text and graphics frames. This type of sign supports graphics frames but is dimensioned in characters, rather than in pixels. This sign type permits displays of size up to 255 x 255 characters based on the sign's default character matrix and inter-character spacing.
- A sign type of high resolution graphics shall respond as if it was an advanced graphics sign.
- The display attributes and faulty pixel count data are required only for advanced graphics signs, and are to be transmitted immediately before the lamp/LED status in the following order:

Order of Transmission	Content	Value
1	Number of pixels per horizontal line for the complete display	WORD
2	Number of pixels per column for the complete display	WORD
3	Number of pixels per horizontal line of the default character matrix	BYTE
4	Number of pixels per column of the default character matrix	BYTE
5	Inter-character spacing in pixels based on the default character matrix	BYTE
6	Inter-line spacing in pixels based on the default character matrix	BYTE

Order of Transmission	Content	Value
7	Number of component colours (e.g. RGB, RGBW, RGBY) for each pixel	BYTE
8	Overall colour depth in 'number of bits'	BYTE
9	*Total number of faulty pixels	WORD
10	Lamp/LED status	See details below

* If the 'Total number of faulty pixels' is higher than can be stored in a WORD (2 bytes) then the maximum value of a WORD shall be transmitted.

- For a fibre-optic sign, the lamp/LED status field reports the status of each lamp. Each bit indicates the status of an individual lamp. A bit value of one indicates that the lamp is faulty.
- For a fibre-optic sign with ten lamps, the lamp/LED status field is transmitted as follows:

  Byte 1: [Zero, Zero, Zero, Lamp 5A, Lamp 4A, Lamp 3A, Lamp 2A, Lamp 1A]

  Byte 2: [Zero, Zero, Zero, Lamp 5B, Lamp 4B, Lamp 3B, Lamp 2B, Lamp 1B]

- For a LED sign, the lamp/LED status field reports the status of each LED module. Each bit indicates the status of an individual LED module, where a module consists of a number of pixels. A bit value of one indicates that the LED module is faulty. A bit value of zero indicates that the LED module is not faulty or is not present.
- For a LED sign, the bit position indicates the LED module number that is faulty. Therefore, for a LED sign with twenty LED modules, the lamp/LED status field is transmitted as follows:

  Byte 1: [Module 8, Module 7, Module 6, Module 5, Module 4, Module 3, Module 2, Module 1]

  Byte 2: [Module 16, Module 15, Module 14, Module 13, Module 12, Module 11, Module 10, Module 9]

  Byte 3: [Zero, Zero, Zero, Zero, Module 20, Module 19, Module 18, Module 17]

3.6.3.30 Sign Set High Resolution Graphics Frame

Direction: Master to Sign Controller and Sign Controller to Master (bidirectional)

Message Size: Variable

Description: The 'SIGN SET HIGH RESOLUTION GRAPHICS FRAME' message is used to store a graphics frame in the memory of the sign controller where the display size is not larger than 65535 x 65535 pixels. The number of frames that can be stored in the controller's memory and the size of the frames vary according to the sign. The protocol allows a maximum of 255 frames, where:

(a) Frame number 00 Hex cannot be changed and always means to reinstate the display from the current active plan or blank the sign if no plan is active.

(b) Frames 01 up to FF Hex can be preset using the 'SIGN SET HIGH RESOLUTION GRAPHICS FRAME' command.

Signs capable of displaying graphics are treated as a matrix of pixels where each pixel either has two possible states (monochrome signs or signs with 1-bit colour depth), or has multiple possible states in different colours and colour intensities (colour signs with multi-bit colour depths). The graphics message sent to the sign controller specifies for each pixel whether it is ON or OFF (for signs with two state pixels), or what colour to display (for multi-colour signs).

The Graphics Message is either bitwise, two-bit-wise, nibble-wise or byte-wise coded with each bit, two-bit, nibble or byte representing a pixel.

This message is also used by the controller to report stored high resolution graphics frames.

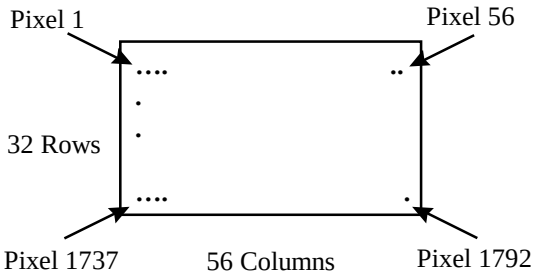
Content:

Position	Bytes	Value	Description
1	1	MI Code	1Dh
2	1	BYTE	frame ID - identifies the frame as it is stored in the sign controller's memory
3	1	BYTE	revision - identifies the modification level of the frame
4	2	WORD	number of rows of pixels in sign
6	2	WORD	number of columns of pixels in sign

Position	Bytes	Value	Description
8	1	BYTE	colour
9	1	BYTE	conspicuity devices
10	4	DOUBLE WORD	length of graphics frame in bytes
14	variable	BYTE	graphics frame
…	2	WORD	message CRC - calculated for all the bytes in the application message

Example:

The example display below is a 32 X 56 pixel matrix:



Comments:

- The codes for colour are as follows:

Colour	Value	Description
Default	00h	Monochrome with 1-bit colour depth
Red	01h	Monochrome with 1-bit colour depth
Yellow	02h	Monochrome with 1-bit colour depth
Green	03h	Monochrome with 1-bit colour depth
Cyan	04h	Monochrome with 1-bit colour depth
Blue	05h	Monochrome with 1-bit colour depth

Colour	Value	Description
Magenta	06h	Monochrome with 1-bit colour depth
White	07h	Monochrome with 1-bit colour depth
Orange	08h	Monochrome with 1-bit colour depth
Amber	09h	Monochrome with 1-bit colour depth
Multiple colours	0Dh	Multiple colours for road signs and other images
24-bit RGB	0Eh	24-bit RGB (red, green and blue) with an 8-bit colour depth

- For monochrome signs and signs with 1-bit colour depth (i.e. operating with the colour values 00h to 09h), using the above example display, the graphics frame is transmitted as follows:

  Byte 1: [Pixel 8, Pixel 7, Pixel 6, Pixel 5, Pixel 4, Pixel 3, Pixel 2, Pixel 1]

  Byte 2: [Pixel 16, Pixel 15, Pixel 14, Pixel 13, Pixel 12, Pixel 11, Pixel 10, Pixel 9]

  .....

  Byte 223: [Pixel 1784, Pixel 1783, Pixel 1782, Pixel 1781, Pixel 1780, Pixel 1779, Pixel 1778, Pixel 1777,]

  Byte 224: [Pixel 1792, Pixel 1791, Pixel 1790, Pixel 1789, Pixel 1788, Pixel 1787, Pixel 1786, Pixel 1785]

- Where signs are required to display ‘multiple colours’ for road signs and other images (i.e. operating with the colour value 0Dh), the codes for colour are as follows:

Colour	Value in nibble
Pixel off	0h
Red	1h
Yellow	2h
Green	3h

Colour	Value in nibble
Cyan	4h
Blue	5h
Magenta	6h
White	7h
Orange	8h
Amber	9h

Using the above example display, the graphics frame is transmitted as follows:

Byte 1: [Pixel 2, Pixel 1];

Byte 2: [Pixel 4, Pixel 3];

…..

Byte 896: [Pixel 1792, Pixel 1791].

- Where signs are required to operate at an overall 24-bit RGB tri-colour depth, using the above example display, the graphics frame shall be transmitted as follows:

Pixel 1:	Red component value -	Byte 1;
	Green component value -	Byte 2;
	Blue component value -	Byte 3;
Pixel 2:	Red component value -	Byte 4;
	Green component value -	Byte 5;
	Blue component value -	Byte 6;

.....

Pixel 1791:	Red component value -	Byte 5371;
	Green component value -	Byte 5372;
	Blue component value -	Byte 5373;
Pixel 1792:	Red component value -	Byte 5374;
	Green component value -	Byte 5375;
	Blue component value -	Byte 5376;

- A sign not capable of supporting the commanded colour system operation shall respond so accordingly to the Master. For the purpose of this requirement, a sign capable of supporting a higher colour depth shall support a commanded lower colour depth.

- For monochrome signs and signs with 1-bit colour depth (i.e. operating with the colour values 00h to 09h), where the pixel matrix is not a multiple of eight pixels, the last byte of the graphics frame shall have any remaining bits set to zero, such that the number of bits in the graphics frame is a multiple of eight.

  There is no requirement for the number of pixels in a row, or the number of pixels in a column to be a multiple of eight.

- The conspicuity devices (warning lanterns) are four lanterns, one placed in each corner of the sign. The speed annulus is the red ring around the speed limit numerals.
- The codes for the conspicuity devices and speed annulus are as follows:

Conspicuity Devices	**Value**	**Speed Annulus**	**Value**
Off	xxxxx000	Off	xxx00xxx
Up/Down	xxxxx001	Flashing	xxx01xxx
Left/Right	xxxxx010	On	xxx10xxx
Wig/Wag	xxxxx011		
All Flash	xxxxx100		
All On	xxxxx101		

- A frame that is active or part of an active message or an enabled plan shall not be changed.
- The controller shall respond with this message when responding to a SIGN REQUEST STORED FRAME/MESSAGE/PLAN command from the master.

3.6.3.31 Sign Configuration Request

Direction: Master to device controller

Message size: 1 byte

Description: The ‘SIGN CONFIGURATION REQUEST’ requests the device controller to respond with its sign configuration.

Content:

Position	Bytes	Value	Description
1	1	MI Code	21h

Comments:

No additional requirements.

3.6.3.32 Sign Configuration Reply

Direction: Device controller to master

Message size: Variable

Description: The ‘SIGN CONFIGURATION REPLY’ message is used to report the configuration details of the device controller and its attached signs.

Content:

Position	Bytes	Value	Description
1	1	MI Code	22h
2	10	BYTE	Manufacturer code details
12	1	BYTE	Number of groups
13	1	BYTE	* Group ID
14	1	BYTE	* Number of signs
15	1	BYTE	** Sign ID
16	1	BYTE	** Sign type
17	2	WORD	** Sign width
19	2	WORD	** Sign height
21	1	BYTE	* Number of signature data bytes
--	Variable	BYTE	** Group signature byte (see Note)

* Field may be repeated for every group.

** Field is repeated for each group depending on the number of sign IDs or signature.

NOTE: If in interlocking mode, the signature data describes the interlocking rules implemented. The data is manufacturer-specific data bytes.
If not in interlocking mode, the number of signature data bytes shall be zero.

Comments:

(a) All signs with the same group ID shall have the same type, width, and height.

(b) The sign type field shall be encoded as:

Value	Description
0	Text
1	Sign graphics (mono)
2	Sign graphics (multiple colours)
3	Sign graphics (24-bit colour)
4	Reserved

(c) The sign width and height fields shall configured as:

Sign type	Width	Height
Text	Number of columns of characters	Number of lines of characters
Sign graphics (mono)	Number of columns of pixels	Number of rows of pixels
Sign graphics (multiple colours)	Number of columns of pixels	Number of rows of pixels
Sign graphics (24-bit colour)	Number of columns of pixels	Number of rows of pixels

NOTE: The sign type, width and height fields differ from those of the the equivalent message in SA TS 5719 in that they do not provide support for CMSs.

3.6.3.33 Sign Display Atomic Frames

Direction: Master to device controller

Message size: Variable

Description: The 'SIGN DISPLAY ATOMIC FRAMES' command is used to instruct the device controller to display the pre-stored frames for each of the signs in the group. The frames are displayed continuously.

Content:

Position	Bytes	Value	Description
1	1	MI Code	2Bh
2	1	BYTE	Group ID
3	1	BYTE	Number of signs in the group
4	1	BYTE	Sign ID *
5	1	BYTE	Frame ID *

* Field may be repeated depending of the number of signs.

Comments:

The number of signs specified shall match the configuration in the group controller.

3.6.3.34 HAR Status Reply

Direction: HAR Controller to Master

Message Size: 21 bytes

Description: The HAR STATUS REPLY message is sent by the HAR controller to the master as a response to a HEARTBEAT POLL Command. The HAR STATUS REPLY Message contains the basic status information of the HAR controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	40h

Position	Bytes	Value	Description
2	1	BYTE	'off-line'/'on-line' status (0/1)
3	1	BYTE	Application error code (see Appendix C)
4	1	BYTE	Day (1-31)
5	1	BYTE	Month (1-12)
6	2	WORD	Year (1-9999)
8	1	BYTE	Hours (0-23)
9	1	BYTE	Minutes (0-59)
10	1	BYTE	Seconds (0-59)
11	2	WORD	Controller hardware checksum
13	1	BYTE	Controller error code (see Appendix C)
14	1	BYTE	HAR disabled/enabled (0/1)
15	2	WORD	Voice ID playing (0 if none)
17	1	BYTE	Revision – identifies the modification level of the voice data
18	2	WORD	Strategy ID active (0 if none)
20	1	BYTE	Revision – identifies the modification level of the strategy
21	1	BYTE	Strategy status (see below)

Comments:

- The application error code field indicates the current application error. If no error exists, this field is set to zero.
- The controller error code field indicates the current error (fault) present in the controller. When a change in fault status occurs (fault occurrence or clearance), the error code field shall be updated to trigger the retrieval of the fault log by the master. If no error exists, this field is set to zero, and indicates to the master that all faults are cleared for the HAR.
- The controller hardware checksum is used to check the HAR controller's memory. The master uses this to verify that the HAR controller's memory locations have not changed. HAR Set Voice Data and HAR Set Strategy return a Status Reply as these commands affect the HAR controller hardware checksum. Note that in some instances the System Reset command affects the

hardware checksum. In these instances, the master must send a Heartbeat Poll to obtain the new hardware checksum.

- A strategy is made up of a sequence of voice files as defined by the HAR Set Strategy message. When a strategy is active, the strategy ID indicates which is active and the voice ID indicates which part of the strategy is currently playing. If no part is playing then the voice ID is zero. When no strategy is active (i.e. strategy ID is zero) then the voice ID must be zero.
- If a strategy is active then the Strategy Status byte indicates its current status as follows:

Value	Status
1	Strategy is playing
2	Strategy is preparing to play
3	Strategy is not playing. The Application error code shall indicate the reason why.

3.6.3.35 HAR Set Voice Data

Direction: HAR Controller to Master / Master to HAR Controller (bidirectional)

Message Size: Variable

Description: The HAR SET VOICE DATA message is used to store a voice file in the memory of the controller. The number of voice files that can be stored in the controller's memory and the maximum size of the voice file vary according to the controller. The protocol allows a maximum of 65535 pre-set voice files, where:

- Voice ID number 00 Hex cannot be used as it is used to indicate no voice file is playing
- Voice IDs from 01 up to FFFF Hex can be stored in the controllers memory using the HAR SET VOICE DATA message.

This message is also used by the controller to report stored voice data.

Content:

Position	Bytes	Value	Description
1	1	MI Code	41h (Incomplete) or 42h (Complete). See below.
2	2	WORD	Voice ID

Position	Bytes	Value	Description
4	1	BYTE	Revision Number
5	1	BYTE	Format
6	1	BYTE	Conspicuity Devices
7	1	BYTE	Sequence Number
8	2	WORD	Number of bytes to follow
10	Variable	BYTE	The voice file fragment in this message

Comments:

- A voice file is transferred in one of a number of file formats:

Format	Value
Uncompressed WAV	0
Compressed WAV	1
MPEG Layer 3 Audio (MP3)	2
Real Audio Streamed Content (RAW)	3

- The codes for the conspicuity devices are as follows:

Conspicuity Devices	Value	Speed Annulus	Value
Off	xxxxx000	Off	xxx00xxx
Up/Down	xxxxx001	Flashing	xxx01xxx
Left/Right	xxxxx010	On	xxx10xxx
Wig/Wag	xxxxx011		
All Flash	xxxxx100		
All On	xxxxx101		

- The complete file may be transferred in a number of HAR SET VOICE DATA messages. Where this is the case then this is done by sending a series of HAR SET VOICE DATA (incomplete) messages followed by one HAR SET VOICE DATA (complete) message.

- The Sequence Number field is used to provide error free transfer of the voice file fragment. Sequence numbers start from 0 for the first message and increment for each message sent.
- When a HAR controller receives a HAR SET VOICE DATA (Incomplete) message with the correct sequence number it returns a HAR VOICE DATA ACK message.
- When a HAR controller receives a HAR SET VOICE DATA (Complete) message with the correct sequence number it returns a HAR STATUS REPLY message.
- If a HAR controller receives a message with a Sequence Number that is out of sequence it must behave as follows:

  1) If a message has already been received with the same sequence number, the new message is just discarded.

  2) Otherwise, the message is rejected and a HAR VOICE DATA NAK message is returned to the master.

- If a master continues to receive HAR VOICE DATA NAK messages (e.g. 3 in a row, although this should be configurable in the master), then it will abandon the download (and start again).
- It shall not be possible to Set Voice Data that is part of the currently active strategy, unless that strategy is not playing.
- The controller shall respond with this message when responding to a HAR Request Stored Voice/Strategy/Plan command from the master.

3.6.3.36 HAR Set Strategy

Direction: Master to HAR Controller and HAR Controller to Master (bidirectional)

Message Size: Variable

Description: The HAR SET STRATEGY message is used to store a voice strategy in the memory of the controller. A strategy is an ordered sequence of voice ids that make up a message to be transmitted by the HAR controller. The number of strategies that can be stored in the controller's memory and the maximum number of the voice ids that make up a strategy vary according to the HAR controller. The protocol allows a maximum of 65535 pre-set strategies, where:

- Strategy ID number 00 Hex cannot be used as it is used to indicate no strategy is active.

- Strategy IDs from 01 up to FFFF Hex can be stored in the controllers memory using the HAR SET STRATEGY message.

This message is also used by the controller to report stored strategies.

Content:

Position	Bytes	Value	Description
1	1	MI Code	43h
2	2	WORD	Strategy ID
4	1	BYTE	Revision Number
5	1	BYTE	Number of Voice IDs to follow
6	2	WORD	*Voice ID

*field may be repeated depending on the number of Voice IDs.

Comments:

- The order in which the Voice IDs appear in the message is the order in which to play the associated Voice files.
- It shall only be possible to Set a Strategy that is not active, or active but not playing.
- The controller shall respond with this message when responding to a HAR Request Stored Voice/Strategy/Plan command from the master.

3.6.3.37 HAR Activate Strategy

Direction: Master to HAR Controller

Message Size: 3 bytes

Description: The HAR ACTIVATE STRATEGY command is used to activate a voice strategy stored in the memory of the controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	44h
3	2	WORD	Strategy ID

Comments:

- When a Controller receives a HAR ACTIVATE STRATEGY message it must complete playing the sequence of voice files for its current strategy before it starts play the voice files for the newly requested one.
- If Strategy ID Zero is requested, then this is treated as a stop to the current strategy, i.e. no new strategy is started. The HAR STATUS REPLY message shall indicate that the strategy is still the active one, but that it is not playing as it has been stopped by the master.

3.6.3.38 HAR Set Plan

Direction: Master to HAR Controller and HAR Controller to Master (bidirectional)

Message Size: Variable, up to 40 bytes

Description: The HAR SET PLAN message is used to store a plan of up to six strategies in the HAR controller's memory. A plan can be programmed on a daily basis or weekly basis.

This message is also used by the controller to report stored plans.

Content:

Position	Bytes	Value	Description
1	1	MI Code	45h
2	1	BYTE	plan ID - identifies the plan as it is stored in the HAR controller's memory
3	1	BYTE	revision - identifies the modification level of the plan
4	1	BYTE	day of the week*
5	2	WORD	strategy 1 ID
7	1	BYTE	strategy 1 start time - hour (0-23)
8	1	BYTE	strategy 1 start time - minute (0-59)
9	1	BYTE	strategy 1 stop time - hour (0-23)
10	1	BYTE	strategy 1 stop time - minute (0-59)

Position	Bytes	Value	Description
11	2	WORD	strategy 2 ID
…	…	…	…
39	1	BYTE	strategy 6 stop time - hour (0-23)
40	1	BYTE	strategy 6 stop time - minute

*day of the week is a bitwise field where bits 1, 2, 3, 4, 5, 6 and 7 represent Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday respectively. Bit 8 is unused. For the plan to operate daily, the day of week field is set to 7Fh.

Comments:

- Plan number 00 Hex is invalid.
- A plan must contain at least one strategy definition. A strategy value of zero indicates that no more strategies follow within the plan. This allows a plan to consist of less than six strategies.
- Length errors shall be reported by the HAR controller where a plan has no strategy definitions or when a plan is terminated by a zero and further strategy definitions are defined afterwards.
- The start time always uses the day of week field to obtain the start day. The stop time follows on from the start time and day. Eg, 20:00 to 20:00 on Monday and Wednesday means to activate from Monday 8:00pm to Tuesday 8:00pm and from Wednesday 8:00pm to Thursday 8:00pm.
- Each plan need not be contiguous (i.e.: the start time need not follow on from the previous stop time).
- The controller shall respond with this message when responding to a HAR Request Stored Voice/Strategy/Plan command from the master.

3.6.3.39 HAR Request Stored Voice/Strategy/Plan

Direction: Master to HAR Controller

Message Size: 5 bytes

Description: The HAR REQUEST VOICE/STRATEGY/PLAN command is used to request a voice data, strategy or plan stored in the memory of the controller. The HAR controller shall respond with a

HAR SET VOICE DATA, HAR SET STRATEGY OR HAR SET PLAN message.

Content:

Position	Bytes	Value	Description
1	1	MI Code	46h
2	1	BYTE	Voice/Strategy/Plan (0/1/2)
3	2	WORD	Voice/Strategy/Plan ID
5	1	BYTE	Sequence Number

Comments:

- When requesting a Voice ID, the master will use the sequence number field to indicate which fragment it requires. It will start at sequence number 0, and will continue requesting fragments by incrementing the sequence number until it receives a HAR SET VOICE DATA (complete) message from the controller indicating this is the last fragment of the voice file.
- If the controller receives a request with a sequence number indicating it is for a fragment it has already sent and the fragment is still in its communications buffer, it shall resend the fragment.
- If the controller receives a request with a sequence number indicating it is for a fragment it has already sent and the fragment is no longer in its communications buffer, or the sequence number indicates a fragment such that it would have to omit some fragments of the voice message, then the controller shall respond with a HAR VOICE DATA NAK message.
- If a master continues to receive HAR VOICE DATA NAK messages (e.g. 3 in a row, although this should be configurable in the master), then it will abandon the upload (and start again).
- When requesting a Strategy or Plan, the Sequence Number is not used and should be set to Zero.

3.6.3.40 HAR Set Voice Data ACK

Direction: HAR Controller to Master

Message Size: 4 bytes

Description: The HAR SET VOICE DATA ACK message is used to acknowledge the receipt of a Voice Data fragment.

Content:

Position	Bytes	Value	Description
1	1	MI Code	47h
2	2	WORD	Voice ID
4	1	BYTE	Sequence Number

Comments:

- The sequence number shall indicate the sequence number of the last HAR SET VOICE DATA message the controller received correctly.

3.6.3.41 HAR Set Voice Data NAK

Direction: HAR Controller to Master

Message Size: 4 bytes

Description: The HAR SET VOICE DATA NAK message is used to indicate a bad sequence number received either in a HAR SET VOICE DATA message or a HAR REQUEST VOICE/STRATEGY message received from the master.

Content:

Position	Bytes	Value	Description
1	1	MI Code	48h
2	2	WORD	Voice ID
4	1	BYTE	Sequence Number

Comments:

- The Sequence Number shall indicate the Sequence Number of the last HAR SET VOICE DATA or HAR REQUEST VOICE/STRATEGY message the controller received correctly.

3.6.3.42 Environmental/Weather Status Reply

Direction: Environmental/Weather Station Controller to Master

Message Size: 30 bytes

Description: The ENVIRONMENTAL/WEATHER STATUS REPLY message is sent by the environmental/weather station controller to the master as a response to a HEARTBEAT POLL command. The ENVIRONMENTAL/WEATHER STATUS REPLY message contains the basic status information of the Environmental/Weather station controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	80h
2	1	BYTE	'off-line'/'on-Line' status (0/1)
3	1	BYTE	Application error code (see appendix C)
4	1	BYTE	Day (1-31)
5	1	BYTE	Month (1-12)
6	2	WORD	Year (1-9999)
8	1	BYTE	Hours (0-23)
9	1	BYTE	Minutes (0-59)
10	1	BYTE	Seconds (0-59)
11	2	WORD	Controller Hardware Checksum
13	1	BYTE	Controller error code (see appendix C)
14	1	BYTE	Supports Thresholds Flag (0 – doesn't support Threshold Definition or the Event Log; 1 - does support them)
15	1	BYTE	Current Event Log Sequence Number
16	1	BYTE	Pressure Sensor Present (0 – not present, 1 – enabled, 2 – disabled)
17	1	BYTE	Temperature Sensor Present (0 – not present, 1 – enabled, 2 – disabled)
18	1	BYTE	Visibility Sensor Present (0 – not present, 1 – enabled, 2 – disabled)

Position	Bytes	Value	Description
19	1	BYTE	Precipitation Sensor Present (0 – not present, 1 – enabled, 2 – disabled)
20	1	BYTE	Air Quality Sensor Present (0 – not present, 1 – enabled, 2 – disabled)
21	1	BYTE	Pavement Sensor Present (0 – not present, 1 – enabled, 2 – disabled)
22	1	BYTE	Wind Sensor Present (0 – not present, 1 – enabled, 2 – disabled)
23	1	BYTE	Water Depth Sensor Present (0 – not present, 1 – enabled, 2 – disabled)
24	1	BYTE	Reserved for Future Sensor (0 – not present, 1 – enabled, 2 – disabled)
…	…	…	…
30	1	BYTE	Reserved for Future Sensor (0 – not present, 1 – enabled, 2 – disabled)

Comments:

- The application error code field indicates the current application error. If no error exists, this field is set to zero.
- The controller error code field indicates the current error (fault) present in the controller or its sensors. When a change in fault status occurs (fault occurrence or clearance), the error code field shall be updated to trigger the retrieval of the fault log by the master. If no error exists, this field is set to zero, and indicates to the master that all faults are cleared for the controller.
- The controller hardware checksum is used to check the environmental/weather station controller's memory. The master uses this to verify that the environmental/weather station controller's memory locations have not changed. The Environmental/Weather Threshold Definition returns a Status Reply as this command affects the environmental/weather station controller hardware checksum. Note that in some instances the System Reset command affects the hardware checksum. In these instances, the master must send a Heartbeat Poll to obtain the new hardware checksum.
- The environmental/weather station controller must use the Support Thresholds Flag defined in this message to indicate to the master whether it supports downloading of thresholds for environmental/weather parameters and the generation of environmental/weather events when environmental/weather

parameters pass the defined thresholds. If this field is set to a 1 then the environmental/weather station must support the ENVIRONMENTAL/WEATHER THRESHOLD DEFINITION, REQUEST THRESHOLD DEFINITION, REQUEST ENVIRONMENTAL/WEATHER EVENT LOG, ENVIRONMENTAL/WEATHER EVENT LOG REPLY and RESET ENVIRONMENTAL/WEATHER EVENT LOG messages.

- The current event log sequence number shall be used to indicate the sequence number of the most recent entry in the Environmental/Weather Event Log. The master uses this to determine when new environmental/weather events have been generated and whether to poll for the Environmental/Weather Event Log. If the environmental/weather station controller does not support environmental/weather thresholds then this value must always be zero.
  A value of 255 may indicate an empty or full log.
- The environmental/weather station must use the other fields in this message to indicate which sensors are connected to it and hence what its reporting capabilities are.

3.6.3.43 Request Environmental/Weather Values

Direction: Master to Environmental/Weather Station Controller

Message Size: 1 byte

Description: The REQUEST ENVIRONMENTAL/WEATHER VALUES command is used to request the current environmental/weather parameter values as reported by the sensors connected to the environmental/weather station controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	81h

3.6.3.44 Environmental/Weather Values

Direction: Environmental/Weather Station Controller to Master

Message Size: 125 bytes

Description: The ENVIRONMENTAL/WEATHER VALUES message is sent in response to a REQUEST ENVIRONMENTAL/WEATHER VALUES command from the master and is used to return the current

environmental/weather parameter values as reported by the sensors connected to the environmental/weather station controller.

Content:

Position	Bytes	Value	Description
1	1	MI Code	82h
2	2	WORD	Atmospheric Pressure in 1/10s of millibars. Set to 65535 if pressure sensor is not present or faulty
4	2	WORD	Wind Speed in 0.1m/s increments. Set to 65535 if wind sensor is not present or faulty
6	2	WORD	Wind Direction in degrees from True North. Set to 361 if wind sensor is not present or faulty
8	2	WORD	Max Wind Gust Speed in 0.1m/s increments. Set to 65535 if wind sensor is not present or faulty
10	2	WORD	Max Wind Gust Direction in degrees from True North. Set to 361 if wind sensor is not present or faulty
12	2	WORD	Dry Bulb Temperature in 1/10s of degrees Celsius. Range is -1000 to +1000. Value in Sign-Magnitude Format. Set to -32767 if temperature sensor is not present or faulty
14	2	WORD	Wet Bulb Temperature in 1/10s of degrees Celsius. Range is -1000 to +1000. Value in Sign-Magnitude Format. Set to -32767 if temperature sensor is not present or faulty
16	2	WORD	Dewpoint Temperature in 1/10s of degrees Celsius. Range is -1000 to +1000. Value in Sign-Magnitude Format. Set to -32767 if temperature sensor is not present or faulty
18	2	WORD	Maximum Temperature in last 24 hours in 1/10s of degrees Celsius. Range is -1000 to +1000. Value in Sign-Magnitude Format. Set to -32767 if temperature sensor is not present or faulty

Position	Bytes	Value	Description
20	2	WORD	Minimum Temperature in last 24 hours in 1/10s of degrees Celsius. Range is -1000 to +1000. Value in Sign-Magnitude Format. Set to -32767 if temperature sensor is not present or faulty
22	1	BYTE	Relative Humidity in percent. Set to 101 if precipitation sensor is not present or faulty
23	2	WORD	Snow Depth (unpacked on roadway) in centimetres. Range is 0 to 3000. Set to 65535 if precipitation sensor is not present or faulty
25	2	WORD	Snowfall Rate in 10^{-7}m/s. Set to 65535 if precipitation sensor is not present or faulty
27	1	BYTE	Reserved for Future Sensor Levels. Set to 255 if precipitation sensor is not present or faulty. [Formerly used for Ice Thickness]
28	7	BYTE	Time at which most recent precipitation started. See comment below for structure.
35	7	BYTE	Time at which most recent precipitation ended. See comment below for structure.
42	2	WORD	Total precipitation in the last hour in 1/10s of kg/m^2 (equivalent to 1/10s of millimetres for rain at 3.98 degrees Celsius). Set to 65535 if precipitation sensor is not present or faulty
44	2	WORD	Total precipitation in the last 24 hours in 1/10s of kg/m^2 (equivalent to 1/10s of millimetres for rain at 3.98 degrees Celsius). Set to 65535 if precipitation sensor is not present or faulty

Position	Bytes	Value	Description
46	2	WORD	Horizontal Visibility in 1/10s of metres. Range is 0 to 65530 (equivalent to 6.553km). Set to 65531 if 6.554km < range < 9.999km Set to 65532 if 10.000km < range < 19.999km Set to 65533 if 20.000km < range < 49.999km Set to 65534 if 50.000km < range < 99.999km Set to 65535 if visibility sensor not present or faulty
48	1	BYTE	Present Weather indication, see comment below for values.
49	1	BYTE	Surface Status, see comment below for values.
50	2	WORD	Surface Temperature in 1/10s of degrees Celsius. Range is -1000 to +1000. Value in Sign-Magnitude Format. Set to -32767 if pavement sensor is not present or faulty
52	2	WORD	Surface Freezepoint in 1/10s of degrees Celsius. Range is -1000 to +1000. Value in Sign-Magnitude Format. Set to -32767 if pavement sensor is not present or faulty
54	1	BYTE	Surface Black Ice Status. See comment below for values.
55	1	BYTE	Carbon Monoxide Level in parts per million. Set to 255 if air quality sensor not present or faulty
56	1	BYTE	Nitrous Oxide Level in parts per million. Set to 255 if air quality sensor not present or faulty
57	1	BYTE	Nitrogen Dioxide Level in parts per billion (i.e. 10^9). Set to 255 if air quality sensor not present or faulty
58	2	WORD	Sulphur Dioxide Level in parts per billion (i.e. 10^9). Set to 65535 if air quality sensor not present or faulty
60	1	BYTE	Ozone Level in parts per 100 billion (i.e. 100 x 10^9). Set to 255 if air quality sensor not present or faulty

Position	Bytes	Value	Description
61	1	BYTE	Reserved for future Sensor. Set to 255 if sensor not present or faulty.
62	1	BYTE	Reserved for future Sensor. Set to 255 if sensor not present or faulty.
63	2	WORD	Water depth in centimetres. Set to 65535 if water level sensor not present or faulty.
65	2	WORD	Ice Thickness in centimetres. Set to 65535 if precipitation sensor is not present or faulty [Formerly at Position 27.]
67	1	BYTE	Reserved for Future Sensor Levels Set to 255 if not present or faulty
…	…	…	…
125	1	BYTE	Reserved for Future Sensor Levels Set to 255 if not present or faulty

Comments:

- The time structure for precipitation start time and precipitation end time are as for Bytes 4 to 10 of the Environmental/Weather Status Reply message. If the precipitation sensor is not present or faulty then all bytes shall be set to 0xFF. If there has been no precipitation since start-up, the start and end times shall be set to 01-Jan-2001 00:00:00.
- Present Weather indication shall be one of the following values:

Value	Weather Condition
100	Nothing significant to report
130	Fog
140	Precipitation [no longer supported; see Note]
141	Precipitation, slight or moderate [no longer supported; see Note]
142	Precipitation, heavy [no longer supported; see Note]
143	Liquid precipitation, slight or moderate [no longer supported; see Note]

Value	Weather Condition
144	Liquid precipitation, heavy [no longer supported; see Note]
145	Solid precipitation, slight or moderate [no longer supported; see Note]
146	Solid precipitation, heavy [no longer supported; see Note]
147	Freezing precipitation, slight or moderate [no longer supported; see Note]
148	Freezing precipitation, heavy [no longer supported; see Note]
160	Rain [no longer supported; see Note]
161	Rain, not freezing, slight
162	Rain, not freezing, moderate
163	Rain, not freezing, heavy
164	Rain, freezing, slight
165	Rain, freezing, moderate
166	Rain, freezing, heavy
167	Rain (or drizzle) and snow, slight [no longer supported; see Note]
168	Rain (or drizzle) and snow, moderate or heavy [no longer supported; see Note]
170	Snow [no longer supported; see Note]
171	Snow, slight
172	Snow, moderate
173	Snow, heavy
174	Ice pellets, slight [no longer supported; see Note]
175	Ice pellets, moderate [no longer supported; see Note]
176	Ice pellets, heavy [no longer supported; see Note]
239	Blowing snow, impossible to determine whether snow is falling or not

Value	Weather Condition
247	Dense fog, visibility 60 - 90 meters [no longer supported; see Note]
248	Dense fog, visibility 30 - 60 meters [no longer supported; see Note]
249	Dense fog, visibility less than 30 meters [no longer supported; see Note]
255	Visibility sensor not present of faulty.

NOTE: Certain values in the Present Weather indication are no longer supported in this Specification for new design equipment. This is because they are no longer supported in the relevant NTCIP standard (NTCIP 1204) upon which the weather station messages were originally based and consequently will not be supported in new-build equipment.

For TMC legacy systems, the RDP will convert/map all those values which are no longer supported to the value 'Other' in the NTCIP standard for onward transmission to the Central Management Computer System (CMCS). This Specification does not cover the protocol used between the RDP and CMCS.

- Surface Status shall be one of the following values:

Value	Surface Condition
1	Other Condition not indicated below
2	Pavement sensor faulty or not present
3	Dry
4	Wet
5	Chemically Wet
6	Reserved. [Formerly 'Snow Or Ice'.]
7	Absorption
8	Dew
9	Frost
10	Reserved. [Formerly 'Absorption at dewpoint'.]

Value	Surface Condition
11	Trace moisture
12	Ice warning (≡ ice present)
13	Ice watch (≡ ice possible)
14	Snow warning (≡ snow present)
15	Snow watch (≡ snow possible)

- Surface Black Ice Status shall be one of the following values:

Value	Black Ice Condition
1	Other Condition not indicated below
2	No Ice
3	Black Ice
4	Pavement sensor faulty or not present

3.6.3.45 Environmental/Weather Threshold Definition

Direction: Master to Environmental/Weather Station Controller and Environmental/Weather Station Controller to Master (bidirectional)

Message Size: Variable

Description: The ENVIRONMENTAL/WEATHER THRESHOLD DEFINITION message is used to set the thresholds for a particular environmental/weather parameter. The environmental/weather station controller uses these thresholds to generate environmental/weather events and record them in the environmental/weather event log.

This message is also used by the controller to report stored thresholds.

Content:

Position	Bytes	Value	Description
1	1	MI Code	83h
2	1	BYTE	Environmental/Weather Parameter Type. See Comment below for the set of applicable values.
3	1	BYTE	Number of Thresholds to follow
4	2	WORD	*Threshold Value
6	1	BYTE	*Rising/Falling threshold (0/1)

*field may be repeated depending on number of thresholds

Comments:

- If the environmental/weather station controller does not support configuration of environmental/weather thresholds and the generation of the environmental/weather event log, it must set the Support Thresholds Flag in the Environmental/Weather Status message to zero (see Clause 3.6.3.38).
- If the environmental/weather station controller does support thresholds, it must set the Support Thresholds Flag in the Environmental/Weather Status message to One and support at least 3 rising and 3 falling thresholds for each environmental/weather parameter.
- If an environmental/weather parameter has no thresholds, the Number of Thresholds to Follow field is set to zero, and the message ends. That is, the Threshold Value and Rising/Falling Threshold fields are not transmitted.
- For a rising threshold, the environmental/weather station controller must generate an event when an environmental/weather parameter is increasing such that it is greater than or equal to the threshold. Where an environmental/weather parameter passes more than one threshold, an event shall be generated for each threshold.
- For a falling threshold, the environmental/weather station controller must generate an event when an environmental/weather parameter is decreasing such that it is less than or equal to the threshold. Where an environmental/weather parameter passes more than one threshold, an event shall be generated for each threshold.
- To ensure that the Environmental/Weather Station has exactly the same threshold definitions as the master, the master

downloads an Environmental/Weather Threshold Definition for all threshold types. This includes threshold types that the Environmental/Weather Station may not support (because of not having the appropriate sensor). This is performed to ensure the consistency of the data set used to calculate the checksum.

- The controller shall respond with this message when responding to a Request Threshold Definition command from the master.
- Environmental/Weather Parameter Type must be one of the following values:

Value	Environmental/Weather Parameter
1	Atmospheric Pressure
10	Dry Bulb Temperature
11	Wet Bulb Temperature
12	Dewpoint Temperature
13	24hour Maximum Temperature
14	24hour Minimum Temperature
20	Horizontal Visibility
21	Present Weather indication
30	Relative Humidity
31	Snow Depth
32	Snowfall Rate
33	Ice Thickness
34	One Hour Precipitation
35	24hour Precipitation
40	Wind Direction
41	Wind Speed
42	Maximum Wind Gust Speed
43	Maximum Wind Gust Direction
50	Surface Status
51	Surface Temperature
52	Surface Freezepoint
53	Surface Black Ice

Value	Environmental/Weather Parameter
60	Carbon Monoxide Level
61	Nitrous Oxide Level
62	Nitrogen Dioxide Level
63	Sulphur Dioxide Level
64	Ozone Level
66	Water depth

Comments:

- The omission of value 65 is intentional.

3.6.3.46 Request Threshold Definition

Direction: Master to Environmental/Weather Station Controller

Message Size: 2 bytes

Description: The REQUEST THRESHOLD DEFINITION command is used to request a set of thresholds for a particular environmental/weather parameter.

Content:

Position	Bytes	Value	Description
1	1	MI Code	84h
2	1	BYTE	Environmental/Weather Parameter Type.

Comments:

- Environmental/Weather Parameter type is as defined for the ENVIRONMENTAL/WEATHER THRESHOLD DEFINITION command (see Clause 3.6.3.41).

3.6.3.47 Request Environmental/Weather Event Log

Direction: Master to Environmental/Weather Station Controller

Message Size: 1 byte

Description: The REQUEST ENVIRONMENTAL/WEATHER EVENT LOG command is used to request the environmental/weather event log.

Content:

Position	Bytes	Value	Description
1	1	MI Code	85h

3.6.3.48 Environmental/Weather Event Log Reply

Direction: Environmental/Weather Station Controller to Master

Message Size: variable

Description: The ENVIRONMENTAL/WEATHER EVENT LOG REPLY message is used to return the environmental/weather event log.

Content:

Position	Bytes	Value	Description
1	1	MI Code	86h
2	1	BYTE	Number of entries to follow (0-20)
3	1	BYTE	*entry number field – cycles between 0 and 255
4	1	BYTE	*Day (1-31)
5	1	BYTE	*Month (1-12)
6	2	WORD	*Year (1-9999)
8	1	BYTE	*Hours (0-23)
9	1	BYTE	*Minutes (0-59)
10	1	BYTE	*Seconds (0-59)
11	1	BYTE	* Environmental/Weather Parameter Type
12	1	BYTE	*Rising/Falling threshold (0/1)
13	2	WORD	*Threshold Value

*field may be repeated depending on the number of entries.

Comments:

- The event log is only supported by a environmental/weather station controller if it supports the definition of environmental/weather thresholds. An entry shall be placed in the log whenever a threshold is exceeded. Refer to the Environmental/Weather Threshold Definition message (see Clause 3.6.3.41).
- The Threshold Value is the actual sensor reported value that caused the event to be generated (not the threshold value defined in the Threshold Definition). Where the actual sensor reported value passes through more than one threshold, more than one event shall be logged. For a falling value, the Threshold Value shall be the defined threshold minus one. For a rising value, the Threshold Value shall be the defined threshold plus one. For example, consider a sensor value dropping from 550 to 90, with falling thresholds defined as 500 and 100. In this case, the event log shall contain two entries each with the same time but with the first entry having a value of 499 and the second entry having a value of 90.
- A maximum of only twenty entries is allowed in the Environmental/Weather Event Log Reply, with the most recent entry appearing first in the list and the oldest appearing last.
- The event list is a historical (archive) log of environmental/weather threshold events. The log is a first-in-first-out log. When the log is full and a new entry is added to the list, the oldest entry is removed.
- Each time an entry is added to the Environmental/Weather Event Log, the entry number field is incremented. The entry number starts at 255 for an empty log (after each reset of the log), increments to zero; then increments to 255 and then rolls over to zero and continues. The entry number field may be used to determine how many new event log entries have been added since the log was last retrieved, or how many event log entries have been lost (i.e. more than 20 fault entries have been added).

3.6.3.49 Reset Environmental/Weather Event Log

Direction: Master to Environmental/Weather Station Controller

Message Size: 1 byte

Description: The RESET ENVIRONMENTAL/WEATHER EVENT LOG command is used to reset the environmental/weather event log stored in the Environmental/Weather Station Controller's memory.

Content:

Position	Bytes	Value	Description
1	1	MI Code	87h

3.6.3.50 Manufacturer Specific Messages

Direction: Master to Controller and/or Controller to Master as assigned by the Manufacturer.

Message Size: Variable

Description: MANUFACTURER SPECIFIC MESSAGES are a set of MI Codes reserved solely for a device manufacturer's own use.

Up to 16 such messages are available for each manufacturer.

All proposed MI code assignments for MANUFACTURER SPECIFIC MESSAGES shall be submitted for approval by the RMS Manager Traffic Technology before implementation.

The Manufacturer shall assign the direction(s) applicable for each MI code.

Content:

Position	Bytes	Value	Description
1	1	MI Code	F0 to FFh

3.6.3.51 Reserved MI Codes

Message Information Codes C0h to DFh are reserved and allocated to other use (for PIDs).

3.6.4 Summary of Message Information Codes

The following table gives a summary of the Message Information (MI) codes:

Message Name	MI Code (Hex)	Applicable Device Types
Reject Message	00	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Acknowledge (*ACK)	01	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Start Session	02	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Password Seed	03	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Password	04	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Heartbeat Poll	05	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Sign Status Reply	06	VMS,VSLS,ISLUS
End Session	07	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
System Reset	08	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Update Time	09	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Sign Set Text Frame	0A	VMS,VSLS,ISLUS
Sign Set Graphics Frame	0B	VMS,VSLS,ISLUS
Sign Set Message	0C	VMS,VSLS,ISLUS
Sign Set Plan	0D	VMS,VSLS,ISLUS
Sign Display Frame	0E	VMS,VSLS,ISLUS
Sign Display Message	0F	VMS,VSLS,ISLUS
Enable Plan	10	VMS,VSLS,ISLUS,HAR
Disable Plan	11	VMS,VSLS,ISLUS,HAR
Request Enabled Plans	12	VMS,VSLS,ISLUS,HAR
Report Enabled Plans	13	VMS,VSLS,ISLUS,HAR

Message Name	MI Code (Hex)	Applicable Device Types
Sign Set Dimming Level	14	VMS,VSLS,ISLUS
Power ON/OFF	15	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Disable/Enable Device	16	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Sign Request Stored Frame/Message/Plan	17	VMS,VSLS,ISLUS
Retrieve Fault Log	18	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Fault Log Reply	19	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Reset Fault Log	1A	VMS,VSLS,ISLUS,HAR,Environmental/ Weather
Sign Extended Status Request	1B	VMS,VSLS,ISLUS
Sign Extended Status Reply	1C	VMS,VSLS,ISLUS
Sign Set High Resolution Graphics Frame	1D	VMS,VSLS,ISLUS
Sign Configuration Request	21	VMS,VSLS,ISLUS
Sign Configuration Reply	22	VMS,VSLS,ISLUS
Sign Display Atomic Frames	2B	VMS,VSLS,ISLUS
HAR Status Reply	40	HAR
HAR Set Voice Data (Incomplete)	41	HAR
HAR Set Voice Data (Complete)	42	HAR
HAR Set Strategy	43	HAR
HAR Activate Strategy	44	HAR
HAR Set Plan	45	HAR
HAR Request Stored Voice/Strategy/Plan	46	HAR

Message Name	MI Code (Hex)	Applicable Device Types
HAR Set Voice Data ACK	47	HAR
HAR Set Voice Data NAK	48	HAR
Environmental/Weather Status Reply	80	Environmental/Weather
Request Environmental/Weather Values	81	Environmental/Weather
Environmental/Weather Values	82	Environmental/Weather
Environmental/Weather Threshold Definition	83	Environmental/Weather
Request Threshold Definition	84	Environmental/Weather
Request Environmental/Weather Event Log	85	Environmental/Weather
Environmental/Weather Event Log Reply	86	Environmental/Weather
Reset Environmental/Weather Event Log	87	Environmental/Weather
[Reserved MI codes]	C0 to DF	[Allocated to other use]
Manufacturer Specific Messages	F0 to FF	VMS,VSLS,ISLUS,HAR,Environmental/ Weather

3.6.5 Summary of Commands and Responses

The following table shows the expected response from the device controller to each master command:

Message Name	MI	Expected Response	MI
Start Session	02	Password Seed	03
Password	04	*ACK	01
Heartbeat Poll	05	Sign Status Reply HAR Status Reply Environmental/Weather Status Reply, as relevant	06 40
End Session	07	*ACK	01
System Reset	08	*ACK	01
Update Time	09	*ACK	01
Sign Set Text Frame	0A	Sign Status Reply	06
Sign Set Graphics Frame	0B	Sign Status Reply	06
Sign Set High Resolution Graphics Frame	1D	Sign Status Reply	06
Sign Configuration Request	21	Sign Configuration Reply	22
Sign Display Atomic Frames	2B	Sign Status Reply	06
Sign Set Message	0C	Sign Status Reply	06
Sign Set Plan	0D	Sign Status Reply	06
Sign Display Frame	0E	*ACK	01
Sign Display Message	0F	*ACK	01
Enable Plan	10	*ACK	01
Disable Plan	11	*ACK	01
Request Enabled Plans	12	Report Enabled Plans	13
Sign Set Dimming Level	14	*ACK	01
Power ON/OFF	15	*ACK	01
Disable/Enable Device	16	*ACK	01

Message Name	MI	Expected Response	MI
Sign Request Stored Frame/Message/Plan	17	Sign Set Text Frame, Sign Set Graphics Frame, Sign Set High Resolution Graphics Frame, Sign Set Message or Sign Set Plan, as relevant	0A 0B 1D 0C 0D
Sign Extended Status Request	1B	Sign Extended Status Reply	1C
Retrieve Fault Log	18	Fault Log Reply	19
Reset Fault Log	1A	*ACK	01
HAR Set Voice Data (InComplete)	41	HAR Voice Data ACK, HAR Voice Data NAK, as relevant	47 48
HAR Set Voice Data (Complete)	42	HAR Status Reply, HAR Voice Data NAK, as relevant	40 48
HAR Set Strategy	43	HAR Status Reply	40
HAR Activate Strategy	44	*ACK	01
HAR Set Plan	45	HAR Status Reply	40
HAR Request Stored Voice/Strategy/Plan	46	HAR Set Strategy, HAR Set Voice Data (Incomplete & Complete), HAR Set Plan, HAR Voice Data NAK, as relevant	43 41 42 45 48
Request Environmental/Weather Values	81	Environmental/Weather Values	82
Environmental/Weather Threshold Definition	83	Environmental/Weather Status Reply	80
Request Threshold Definition	84	Environmental/Weather Threshold Definition	83
Request Environmental/Weather Event Log	85	Environmental/Weather Event Log Reply	86
Reset Environmental/Weather Event Log	87	*ACK	01

3.6.6 Example of Application Layer Exchange

The following table shows an application layer exchange example:

Master to Slave	**Slave to Master**	**Comment**
Start Session		
	Password Seed	
Password		
	*ACK	Link Established
Heartbeat Poll		
	Status Reply	
Extended Status Request		
	Extended Status Reply	
End Session		
	*ACK	Disconnect Data Link
Heartbeat Poll		
	Status Reply	
Extended Status Request		
	Reject	No Link Established

* * * * * * * *

APPENDIX A – CRC CALCULATION

The following is Pascal code to carry out the CRC calculation.

```
function packetCRC: string; {this function sends a packet of bytes to the CRC generator to}
                                                    {find the CRC of the packet}

var

i: array[1..11] of byte;

Accumulator: word; {16 bit}

Index: integer;

begin

  i[1] := $0A;

  i[2] := $03;

  i[3] := $3E;

  i[4] := $44;

  i[5] := $46;

  i[6] := $48;

  i[7] := $4A;

  i[8] := $B3;

  i[9] := $BE;

  i[10] := $DC;

  i[11] := $DD;

  Accumulator := 0;

  for Index := 1 to 11 do

    Accumulator := CRCGenerator(i[index], Accumulator);{do this for each byte in the packet}

  packetCRC := IntToHex(Accumulator, 4); {the result is a string of 4 hex characters. This is}
                                                    {the CRC of the packet}

end;
```

```
function CRCGenerator(Data: Word; Accum: Word): Word;
const
CRC_CCITT = $1021; {This is the CRC-CCITT polynomial}
var
index: integer;
begin
  Data := Data SHL 8; {the incoming byte becomes the high order byte in the register}
  for index := 0 to 7 do
  begin
    if((Data xor Accum) and $8000) = $8000 then {check msb}
      Accum := (Accum SHL 1) xor CRC_CCITT
    else
      Accum := Accum SHL 1;
    Data := Data SHL 1;
  end;
CRCGenerator := Accum;
end;
```

* * * * * * * *

APPENDIX B – PASSWORD GENERATION

The following is Pascal code to carry out the password generation procedure.

```
function password: string;     {Generates a password in reply to a password seed of 43 Hex}
var
xordbits, count, l_reply: Word;      {16 bit}
bit5, bit7, bit8: Boolean;
begin
l_reply := ($43 +$22) mod 256;
for count := 1 to 16 do
 begin
  if ((l_reply and $20) = $0) then
   bit5 := FALSE
  else
   bit5 := TRUE;
  if ((l_reply and $80) = $0) then
   bit7 := FALSE
  else
   bit7 := TRUE;
  if ((l_reply and $100)= $0) then
   bit8 := FALSE
  else
   bit8 := TRUE;
  if (bit5 xor bit7 xor bit8) then
   xordbits := 1
  else
   xordbits := 0;
  l_reply := l_reply SHL 1;
  l_reply := l_reply + xordbits;
end;{for}
l_reply := l_reply + $5A5A;      {add the password parameter}
password := IntToHex(Loword(l_reply), 4);
end;
```

* * * * * * * *

APPENDIX C – ERROR CODES

C.1 APPLICATION ERROR CODES

Error Number	Description
00	No error
01	Device controller off-line
02	Syntax error in command
03	Length error in command - Application message is too long or too short
04	Data checksum error
05	Text with non ASCII characters
06	Frame too large for sign - The number of characters sent exceeds the number of characters capable of being displayed by the sign in that font; or the length of the graphics frame exceeds the graphics frame capabilities of the sign.
07	Unknown MI Code
08	MI Code not supported by device controller
09	Power is OFF
0A	Undefined device number
0B	Font not supported
0C	Colour not supported
0D	Overlaps/overlays not supported
0E	Dimming level not supported
0F	Frame, message, plan, voice or strategy currently active
10	Facility Switch override
11	Conspicuity device definition not supported by device controller
12	Transition time not supported
13	Frame, message or plan undefined
14	Plan not enabled

Error Number	Description
15	Plan enabled
16	Size mismatch - The number of pixel rows or the number of pixel columns required by the message do not match the respective pixel row/column display capabilities of the sign.
17	Frame too small - The number of characters sent equals 0; or the length of a graphics frame equals 0; or the length of the graphics frame is less than the graphics frame display capabilities of the sign.
18	HAR strategy stopped by master
19	HAR voice or strategy undefined
1A	HAR error in strategy definition
1B	HAR voice data error
1C	HAR voice format not supported by device controller
1D	HAR hardware error
1E	Time expired
1F	Colour depth not supported
20	Incomplete colour frame definition
21	Incorrect password
22	Interlocking reject (invalid settings)
23	Interlocking reject (missing signs)
24	Interlocking not active
25	Interlocking active
26 to 9F	Not allocated
A0 to FF	Reserved (see below)

Error Codes A0 Hex to FF Hex are reserved but unallocated. Manufacturers may request the definition of other errors by contacting RMS. At the discretion of RMS, RMS may agree to the request and provide an error number from the list of reserved error codes.

C.2 CONTROLLER AND DEVICE ERROR CODES

Error Number	Description
00	No error
01	Power failure
02	Communications time-out error (communications failure with host)
03	Memory error
04	Battery failure
05	Internal communications failure
06	Sign lamp failure
07	Sign single-LED failure
08	Sign multi-LED failure
09	Over-temperature alarm (fan failure)
0A	Under-temperature alarm (heater failure)
0B	Conspicuity device failure
0C	Sign luminance controller failure
0D	Controller reset (via watchdog)
0E	Battery low
0F	Powered off by command
10	Facility Switch override
11	Sign display driver failure
12	Sign firmware mismatch
13	Sign lamp pair failure
14	Equipment over-temperature
15	No response from sensor
16	Cut sensor cable
17	Sensor short circuit
18	Sensor dirty lens
19	HAR hardware error

Error Number	Description
1A	HAR radio fault
1B	HAR voice data error
1C	Display time-out error
1D	Backup controller unavailable
1E	Not allocated (used incorrectly by SA TS 5719:2017)
1F	Not allocated (used incorrectly by SA TS 5719:2017)
20	Under local control
21	Main processor communications error
22	Mimic state error
23	Sign moved from set location
24	Cabinet door open
25	Sign tilted
26	Sign orientation changed
27	Battery charger/regulator fault
28	Internal power supply fault
29	Vibration alarm
2A	Operating on secondary power
2B to 9F	Not allocated
A0 to FE	Reserved (see below)
FF	Pre-existing or reoccurring fault exists

NOTE: Refer to Clauses 3.6.3.7 and 3.6.3.29 for use of Error Code FF Hex. Furthermore SA TS 5719 uses this error code to indicate "Undefined fault exists".

Error Codes A0 Hex to FE Hex are reserved but unallocated. Manufacturers may request the definition of other errors by contacting RMS. At the discretion of RMS, RMS may agree to the request and provide an error number from the list of reserved error codes.

Comments:

- All fault occurrences and fault clearances are entered into the Fault Log, in addition to the updating of the corresponding fields in the Status Reply and Extended Status Reply messages (controller and sign error code fields).
- A fault occurrence is deemed to occur when the fault is detected. A fault clearance is deemed to occur when the fault is rectified (automatically or manually). For multiple faults of the one type (i.e.: the same error number), only the first fault shall be logged, and only when all faults of this type are cleared shall a fault clearance be logged.
- For each fault that occurs, when the fault is cleared it shall be entered into the Fault Log. For example, a communications time-out error occurs when there has been no communications with the master for a set time after the link was established. At this time, the fault occurrence is logged. When the link is re-established, the communications time-out error is cleared and it is at this time, the clearance logged.

* * * * * * * *

APPENDIX D – MESSAGE EXAMPLE

To transmit SIGN SET TEXT FRAME with the text 'SLOW DOWN' as stored message 1 in the sign controller with address 02, the data packet is constructed as follows:

<SOH> 00 00 02 <STX> 0A 4A 08 05 03 01 09 53 4C 4F 57 20 44 4F 57 4E C8 B7 BE 44 <ETX>

where:

- N(S) and N(R) are both 00
- 02 is the sign controller address
- 0A is the MI Code
- 4A is the frame ID as it is stored in the sign controller's memory
- 08 is the revision number
- 05 is the code for the font
- 03 is the code for the colour
- 01 is the code for conspicuity devices
- 09 is the length of the text frame
- ASCII 'SLOW DOWN' represented in Hex is 53 4C 4F 57 20 44 4F 57 4E.
- C8B7 is the application message CRC represented in Hex (calculated on 16 bytes).
- BE44 is the CRC of the data packet represented in Hex (calculated on 44 bytes)

The complete transmission would be:

Header	**Application Message**	**End of block**
01 30 30 30 30 30 32 02	30 41 34 41 30 38 30 35 30 33 30 31 30 39 35 33 34 43 34 46 35 37 32 30 34 34 34 46 35 37 34 45 43 38 42 37	42 45 34 34 03

* * * * * * * *

APPENDIX E – ENVIRONMENTAL/WEATHER STATION CRC CALCULATION

The Controller Hardware Checksum in the Environmental/Weather Status Reply (Clause 3.6.3.42) is calculated according to Appendix A - CRC Calculation.

The checksum is calculated across the series of bytes as defined in the Environmental/Weather Threshold Definition (Clause 3.6.3.45) for each and every environmental/weather threshold type, but in the following order:

- Environmental/Weather Parameter Type
- Number of Thresholds
- Threshold Value 1 *(least significant byte)*
- Threshold Value 1 *(most significant byte)*
- Rising/Falling
- Threshold Value 2 *(least significant byte)*
- Threshold Value 2 *(most significant byte)*
- Rising/Falling
- Etc.

NOTE: For calculating the Controller Hardware Checksum in the Environmental/Weather Status Reply (Clause 3.6.3.42), the least significant byte of the threshold value is placed before the most significant byte.

The checksum is calculated in ascending order of environmental/weather parameter types and includes all parameter types. If no thresholds are defined for a parameter type, then the first two bytes as specified above are used for that type, with the second byte, the Number of Thresholds, being zero. Also, when calculating the checksum, the order of the thresholds within each environmental/weather parameter type is the order in which they were sent by the master in the Environmental/Weather Threshold Definition for that particular environmental/weather parameter type.

If the environmental/weather station does not support threshold types, then the value of the checksum in the Environmental/Weather Status Reply (Clause 3.6.3.42) shall be set to zero and is ignored by the master.

The following is an example checksum calculation:

If the two threshold pairs (rising and falling) for 1 Hour Precipitation (i.e. environmental/weather parameter type 34, or 22h) are defined as:

- 03E8h rising *(value (a))*, 0ABEh rising *(value (b))*
- 05DCh falling *(value (c))*, 0000h falling *(value (d))*

and the three threshold pairs for Surface 24 Hour Precipitation (i.e. environmental/weather parameter type 35, or 23h) are defined as:

- 03E8h rising *(value (e))*, 07D0h rising *(value(f))*, 0BB8h rising *(value (g))*
- 09C4h falling *(value (h))*, 05DCh falling *(value (i))*, 0000h falling *(value (j))*

and were sent in the order *values (a), (d), (b), (c),* and *values (e), (j), (f), i), (g), (h)* (all in hex), the application messages for the Threshold Definition would be:

83 22 04 03 E8 00 00 00 01 0A BE 00 05 DC 01

and

83 23 06 03 E8 00 00 00 01 07 D0 00 05 DC 01 0B B8 00 09 C4 01

respectively.

The Controller Hardware Checksum would be calculated on the following series of bytes (assuming all other environmental/weather parameter types have no thresholds):

01 00 0A 00 0B 00 0C 00 0D 00 0E 00 14 00 15 00 1E 00 1F 00 20 00 21 00 **22 04 E8 03 00 00 00 01 BE 0A 00 DC 05 01 23 06 E8 03 00 00 00 01 D0 07 00 DC 05 01 B8 0B 00 C4 09 01** 28 00 29 00 2A 00 2B 00 32 00 33 00 34 00 35 00 3C 00 3D 00 3E 00 3F 00 40 00 42 00

with a resultant checksum of F352h;

However, if the threshold values were sent in the order *values (a), (b), (c), (d),* and *values (e), (f), (g), (h), (i), (j)* (all in hex), the application messages for the Threshold Definition would be:

83 22 04 03 E8 00 0A BE 00 05 DC 01 00 00 01

and

83 23 06 03 E8 00 07 D0 00 0B B8 00 09 C4 01 05 DC 01 00 00 01

respectively.

The Controller Hardware Checksum would be calculated on the following series of bytes:

01 00 0A 00 0B 00 0C 00 0D 00 0E 00 14 00 15 00 1E 00 1F 00 20 00 21 00 **22 04 E8 03 00 BE 0A 00 DC 05 01 00 00 01 23 06 E8 03 00 D0 07 00 B8 0B 00 C4 09 01 DC 05 01 00 00 01** 28 00 29 00 2A 00 2B 00 32 00 33 00 34 00 35 00 3C 00 3D 00 3E 00 3F 00 40 00 42 00

with a resultant checksum of 2158h.

* * * * * * * *