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Low speed digital signals for use in coal mines —

Part 3: Specification for message protocols

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Foreword

This Part of BS 6556 has been prepared under the direction of the Mining and Quarrying Requisites Standards Committee.

Control and monitoring activities below ground in coal mines require the transmission of data between items of electrical equipment supplied by different manufacturers. Data can be transmitted in analogue or alternatively digital form. For analogue, BS 5754:1980 "*Specification for electrical analogue and state signals for use in coal mines*" was produced with the purpose of promoting compatibility between transducers, recorders, indicators and data transmission systems of different manufacture and having inputs or outputs, as appropriate, in the form of d.c. voltage analogue signals or signals derived from relay contacts or a mechanical switch. This standard deals with the digital form.

A major disadvantage with control and monitoring systems employing the direct transmission of analogue signals is that since a galvanic connection is necessary between the transmitting and receiving circuits, faults, at different points of the system, particularly to earth, can seriously affect overall performance. The avoidance of such faults, on pit-wide systems, is extremely difficult. The generation of analogue signals within high voltage switchgear, and subsequent transmission for monitoring purposes, also presents difficulty in achieving the required degree of segregation between intrinsically safe and power circuits. A further disadvantage with analogue signals is that the simultaneous transmission of several signals requires either a multicore cable or separate cables.

These disadvantages can be largely overcome if the analogue or state information is transmitted in the form of serially coded digital signals. With such signals complete galvanic isolation between the transmitting and receiving circuits is possible and, within wide limits, only two wires are required for transmission in each direction irrespective of the volume of data.

If full benefit of digital signal data transmission is to be realized it is important that transmission systems of different manufacture conform to a common electrical standard and operate in a uniform manner with identical procedure (or protocol) for handling the data. This standard aims to promote such conformity. It specifies relevant requirements for a low speed digital signal link comprising a master and one or more slaves which interconnects the intrinsically safe circuits of one item of apparatus and the intrinsically safe circuits of other apparatus in such a way that units of different manufacture can be interchangeably coupled at the transmission line terminals.

This standard is published in three Parts as follows:

— *Part 1: Specification for optical coupling;*

— *Part 2: Specification for transformer coupling;*

— *Part 3: Specification for message protocols.*

Parts 1 and 2 of this standard offer alternative methods of achieving galvanic isolation between the intrinsically safe circuits of interconnected apparatus, but the two methods are not compatible.

Part 1 of this standard specifies a 600 bits/s transmission system which employs optical coupling as the means of achieving galvanic isolation. A system will comprise a master and from 1 to 8 slaves connected in point-to-point or multi-drop modes, with two cable conductors being used for each direction of transmission. Transmission from the master to a slave is achieved by the master acting as a switched current source which activates a light emitter at each slave. Transmission from slave to master is achieved by the master acting as both a current source, which is switched at the slave by a light dependent device, and a current monitor which senses the switched current.

Part 2 of this standard specifies a 600 bits/s transmission system which employs transformer coupling as the means of achieving galvanic isolation. A system will comprise a master and from 1 to 15 slaves connected in point-to-point or multi-drop modes. Transmission between master and slaves is achieved by frequency shift keying (FSK) techniques, one pair of cable conductors being used for each direction of transmission.

This Part of this standard defines the message protocols to be used by systems complying with Parts 1 or 2. It does not, however, place any restrictions on the application data contained in transmitted messages, although industry standards may exist to regulate this.

It is envisaged that for high voltage applications optical coupling will be employed due to the relative ease of meeting segregation requirements. The optical system, however, has a limit of 8 slaves and a range of 2 km while the transformer method has a greater range and can handle up to 15 slaves. For intermediate applications either system may be suitable.

In Parts 1 and 2 of this standard slaves are the physical interface between the transmission line and one or more addressable logical slaves specified in Part 3 of this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations. Attention is drawn to the Health and Safety at Work etc. Act 1974, the Mines and Quarries Act 1954, the Regulations made under these Acts, and also any other appropriate statutory requirements or byelaws. These place responsibility for complying with certain specific safety requirements on the manufacturer and the user. The address of the recognized certification authority in the United Kingdom for Group 1 (coal mining) apparatus for intrinsic safety purposes is as follows:

Health and Safety Executive

HSE (M) Certification Support Unit

Harpur Hill, Buxton, Derbyshire SK17 9JN.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 18, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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0 Introduction

0.1 General

Two protocols are covered by this Part of this standard; data only protocol (DOP) and simple asynchronous protocol (SAP).

Both protocols use the same element of transmission which consists of 11 bits as follows (see Figure 1):

a) 1 start bit;

b) 8 data bits (a byte);

c) an even parity bit;

d) a stop bit.

The even parity bit contributes to error checking of the data.

Within each protocol between 1 and 128 bytes of application data, each complete with its start, stop and parity bits, can be transmitted.

0.2 Data only protocol (DOP)

DOP is a very simple protocol limited to point-to-point applications (see Figure 2). Transmissions consist purely of application data. Separate messages are identified by a short gap. Error detection is limited to parity, framing and, in the case of MODEM systems, carrier checks.

0.3 Simple asynchronous protocol (SAP)

0.3.1 *General description of SAP.* SAP is a set of rules which ensures that order is maintained on the data link between the master and its slaves.

The master controls all link activity. There is only one master and from 1 to 15 slaves. The slaves are connected in multi-drop as shown in Figure 3.

The master can send a message to one or all slaves. Slaves may only send messages to the master.

SAP allows the use of four message types as follows:

a)	an application data message	(ADM) (see Figure 4);
b)	a link control message	(LCM) (see Figure 5);
c)	a broadcast message	(BRO) (see Figure 4);
d)	an initialization message	(IM) (see Figure 5).

Each message begins with a start of message byte (SMB) by which it is identified (see Table 1). The second byte is always the address byte (AB) which contains the slave address.

The LCM and IM consist simply of the SMB and AB and are used for link control purposes only.

The ADM and BRO are data messages and contain the application data field (ADF) which may be between 1 and 128 bytes in length. The ADF may exceed this length where byte stuffing is necessary (see **0.3.6**).

0.3.2 *Normal link operation.* A link control message (LCM) is used by the master to poll each active slave in a designated polling sequence.

A slave polled by an LCM may respond by transmitting one of the following:

a) an application data message (ADM) if there is application data to send;

b) an LCM if there is no application data to send;

c) an initialization message (IM) if the slave requires initialization.

Reception of a poll is the only condition which allows a slave to transmit a message. Only one slave is allowed to transmit over the link at any one time.

The master sends application data to a single slave by means of an ADM or to all slaves by means of a broadcast message (BRO).

0.3.3 *Initialization.* Initialization of stations is achieved by the exchange of initialization messages (IM). An IM from the master is a poll that is substituted in the polling sequence in place of an LCM where a slave requires initialization.

0.3.4 *Message loss.* The protocol includes facilities which detect when an application data message (ADM) has been lost. Each ADM to and from each slave is designated as either ODD or EVEN by assigning unique start of message bytes (SMB) to each type (see Table 1).

A master or slave receiving an ADM acknowledges its reception and type (ODD or EVEN) by the use of an acknowledge bit (ACK-BIT) contained in the address byte (AB). The ACK-BIT acts as a toggle which is set and reset only by the reception of a valid in-sequence ADM. Failure of the ACK-BIT to toggle as expected will cause a re-transmission.

To ensure that a datum point is established after initialization, messages before the reception of a valid ADM will have the acknowledge bits (ACK-BITs) equal to one and the first ADM to and from each slave will be EVEN.

0.3.5 *Broadcast message.* A broadcast facility is provided to allow the master to transmit to every slave. An address is reserved for this purpose. This message is received simultaneously by all slaves and is not acknowledged.

0.3.6 *Byte stuffing.* As the codes 80H, 81H, 83H, 85H and 87H are reserved for link control, it is necessary to ensure that these codes are not transmitted when they occur in application data. To prevent this, data having the same code as a reserved code is transmitted as two bytes, a stuff byte (STF), reserved value 80H, and a byte derived by subtracting 80H from the data byte. The receiving station on recognizing 80H adds this to the following byte to restore the original data (see Table 3).

0.3.7 *Message priority and length.* Facilities are provided for assigning higher priority to selected ADMs and BROs. This is achieved by a priority bit contained in the applications data description byte (ADD). The remaining bits in this byte are used to represent the number of bytes in the application data field (ADF).

0.3.8 *Error checking.* Additional to the parity, framing and, in the case of the MODEM system, carrier checks within the transmission element, there are two further checks used within the protocol.

The address byte (AB) contains its own error detection bits so that a slave recognizing its address (or a broadcast) is assured of its validity and can prepare to receive the remainder of the message.

The check field (CF) at the end of each ADM and BRO allows the integrity of data to be checked before it is used. This is a 16 bit cyclic redundancy check.

0.3.9 *Link failure.* Link failures are detected by stations being unable to gain correct responses after re-transmissions.

Slaves considered by the master to have failed are polled at less regular intervals defined by the polling sequence.

0.3.10 *Poll insertion.* To improve link efficiency, a master transmitting an ADM may insert a poll within the ADM. This facility is used when there is no reply outstanding. An ADM may have many polls inserted. Such polls override the normal order of transmission and may appear anywhere in an ADM including immediately following the SMB or an STF or between the two bytes of the CF.

1 Scope

This Part of BS 6556 specifies two message protocols employed with particular low speed digital signals systems for use in coal mines, using either optical coupling (see BS 6556-1) or transformer coupling (see BS 6556-2). Either protocol can be employed in either transmission system.

The protocols require only limited station intelligence for successful implementation. One protocol, known as simple asynchronous protocol, is designed to work in point-to-point or multi-drop configurations. The other protocol, known as data only protocol, will only work in point-to-point configurations.

Protocol for the applications data is not specified by this standard although industry standards will exist to regulate this.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions and abbreviations

2.1 Definitions

For the purposes of this Part of BS 6556 the following definitions apply.

2.1.1
bit

the element of digital information taking the value 1 or 0

2.1.2
bit period

the time taken to transmit a single bit

2.1.3
parity bit

a check bit which is derived from a number of data bits and provides a degree of checking for corruption

2.1.4
byte

a group of 8 bits d_0 to d_7, with d_0 being the least significant bit and d_7 being the most significant bit

2.1.5
byte period

the time taken to transmit a single byte along with its associated start, stop and parity bits

2.1.6
current loop link

a transmission technique complying with BS 6556-1

2.1.7
MODEM

a combined modulator demodulator complying with BS 6556-2

2.1.8
receive line signal detected (RLSD)

an output from a demodulator complying with BS 6556-2

2.1.9
request to send (RTS)

a control input of a modulator complying with BS 6556-2

2.1.10
ready for sending (RFS)

an output from the modulator

2.1.11
point-to-point

a system of operation of a link having only one master and one slave

2.1.12
multi-drop

a system of operation of a link having one master and several slaves

2.1.13
polling

a system where a master requests a response from a slave

2.1.14
contention

a condition where more than one slave attempts to transmit at the same time

2.1.15
message

an application data message (ADM), broadcast message (BRO), link control message (LCM) or initialization message (IM)

2.1.16
even message

an application data message (ADM) commencing with a start of message byte (SMB) equal to start of even ADM/start of broadcast message (BRO)

2.1.17
odd message

an application data message (ADM) commencing with start of message byte (SMB) equal to start of odd ADM

2.1.18
idle

no message is being transmitted

2.1.19
stuffing

a means to prevent reserved values, used for control purposes, occurring in the transmitted data

2.2 Abbreviations

For the purposes of this Part of BS 6556 the following abbreviations apply.

2.2.1 AB. Address byte.

2.2.2 ACK-BIT. Acknowledge bit.

2.2.3 ADD. Application data description byte.

2.2.4 ADF. Application data field.

2.2.5 ADM. Application data message.

2.2.6 BRO. Broadcast message.

2.2.7 CF. Check field.

2.2.8 DOP. Data only protocol.

2.2.9 H. Hexadecimal.

2.2.10 IM. Initialization message.

2.2.11 LCM. Link control message.

2.2.12 LSB. Least significant bit.

2.2.13 MSB. Most significant bit.

2.2.14 SAP. Simple asynchronous protocol.

2.2.15 SCM. Start of LCM.

2.2.16 SIM. Start of IM.

2.2.17 SMB. Start of message byte.

2.2.18 STF. Stuff byte.

2.2.19 STM0. Start of EVEN ADM/start of BRO.

2.2.20 STM1. Start of ODD ADM.

3 Link configurations

3.1 General

Every data link configuration shall have a master and one of the following alternatives.

a) A single slave communicating according to DOP in a unidirectional point-to-point configuration. For bidirectional operation two DOP links shall be used (see Figure 2).

b) 1 to 15 slaves communicating according to SAP in multi-drop configurations (see Figure 3).

3.2 Master station

All transmissions on the link shall go to or come from the master. Only one master shall exist on the link. When using SAP all other stations on the link shall be under the control of the master. When MODEMs are used the master's transmitters shall have request to send (RTS) permanently asserted.

NOTE Clause **9.1** of BS 6556-2:1985 requires the signal RTS to be capable of being switched.

3.3 Slave station

All stations linked to the master shall be slaves. All slave transmissions shall be directed to the master. When MODEMs are used each slave transmitter shall have RTS permanently asserted for DOP and controlled for SAP. On SAP slaves the slave address shall be user configurable.

4 Transmissions

The transmission protocol shall be byte orientated and the element of each transmission shall consist of a single byte (d_0 to d_7) to which an even parity bit shall be applied, plus a start bit and a stop bit. The order in which these bits are transmitted shall be as shown in Figure 1. All bits shall be of equal duration. The time taken to transmit all 11 bits shall be termed the byte period. The start bit shall take the value 0. The stop bit shall take the value 1.

A transmission shall consist of an integral number of bytes each with its start, stop and parity bits. The bytes within a transmission shall be contiguous. Transmission shall be preceded and followed by periods of line idle (see Figure 6). Additionally, where SAP slaves are using MODEMs the line shall be relinquished (see Figure 7).

5 Checks

The receiving circuit shall make the following checks on each incoming transmission.

a) *Parity check.* Each incoming byte shall have its even parity computed. The result shall be compared with the received parity bit. Failure to match shall produce a parity error.

b) *Framing check.* The bit corresponding in time to the stop bit of each received byte shall be checked for the correct value. An incorrect value shall produce a framing error.

c) *Carrier check.* On links using MODEMs the receive line signal detected (RLSD) shall be present throughout the reception of a transmission otherwise a carrier error shall be produced.

6 Data only protocol (DOP)

6.1 General

DOP is a very simple protocol limited to point-to-point applications and shall be used only on the type of link shown in Figure 2.

6.2 Transmission format

A transmission under DOP shall consist of between 1 and 128 bytes of applications data, each byte complete with start, stop and parity bits.

The idle period between transmissions shall be not less than 3 and not greater than 5 byte periods.

6.3 Reception

The receiving station shall recognize an idle condition of 2 or more byte periods as being a gap between transmissions.

A parity, framing and, on links using MODEMs, carrier error detected in a transmission shall cause it to be invalid.

An idle condition of 6 or more byte periods and, in the case of MODEMs, loss of RLSD, shall be used to indicate link failure.

7 Simple asynchronous protocol (SAP)

7.1 Transmission characteristics

7.1.1 *General.* There shall be three types of transmission from a master as follows:

a) a single poll message (LCM or IM);

b) a single message with application data (ADM or BRO);

c) multiple messages comprising a single message with application data (ADM or BRO) and one or more poll messages (LCMs or IMs).

NOTE Polls may precede, follow or be inserted within the ADM or BRO.

Slave transmissions shall consist of a single SAP message.

7.1.2 *Master transmission timings.* The master's transmissions shall be separated by a minimum of 1 byte period of line idle. If the master has another message waiting at the end of a transmission, the next transmission shall begin within 13 bit periods except as specified in **7.4.3**.

7.1.3 *Slave transmission timings.* Slaves on current loop links shall respond as shown in Figure 8. The slave delay time T_1 shall not exceed 1 byte period.

Slaves of the MODEM type shall respond as shown in Figure 9. The slave shall assert its MODEM RTS within the slave delay time T_2. T_2 plus the MODEM turn on time T_3 shall not exceed 2 byte periods. Following the reception of the MODEM signal RFS the slave shall begin the transmission within time T_4, where time T_2 plus time T_4 shall not exceed 1 byte period. On completion of the transmission the slave shall maintain RTS until at least the end of the last stop bit. The slave delay time T_5 plus the worst case of master RLSD turn off delay time T_6 shall not exceed 1 byte period.

NOTE T_3 and T_6 are specified in Part 2 of this standard.

7.1.4 *End of transmission checks.* On current loop links the master shall, before issuing another poll, ensure that a start bit does not follow the end of a slave transmission. If a start bit is present the master shall detect at least 1 byte period of line idle before issuing another poll (see Figure 8).

Where the master detects the absence of a start bit within a slave transmission it shall detect at least one byte period of line idle before issuing another poll.

On links using MODEMs the master shall ensure that RLSD goes OFF following the end of a slave transmission before issuing another poll (see Figure 9).

Where the master detects RLSD OFF within a slave transmission it shall detect at least one byte period of RLSD OFF before issuing another poll.

7.1.5 *Recovery from framing errors.* On detection of a framing error the master shall:

a) on current loop links detect at least one byte of line idle before issuing another poll;

b) on links using MODEMs wait for RLSD to become OFF before issuing another poll.

7.1.6 *Poll time out.* On current loop links the master shall, within two byte periods from the end of a poll, have received the first byte transmitted by the polled slave, otherwise the next poll shall be issued.

On links using MODEMs the master shall, within 2 byte periods from the end of a poll, have detected RLSD ON, otherwise the next poll shall be issued.

7.2 Message types

7.2.1 *General.* SAP protocol shall use four message types as follows:

a) an application data message (ADM);

b) a link control message (LCM);

c) a broadcast message (BRO);

d) an initialization message (IM).

The components of each message type shall be as specified in **7.3**.

7.2.2 *Application data message (ADM).* An ADM shall be used to transmit application data from the master to individual slaves and vice versa.

The ADM shall comprise the following:

a) a start of message byte (SMB);

b) an address byte (AB);

c) an application data description byte (ADD);

d) an application data field (ADF);

e) a check field (CF).

The order of transmission shall be as shown in Figure 4.

7.2.3 *Link control message (LCM).* The LCM shall be used by the master to poll a slave and by any polled slave with no ADM to send.

The LCM shall comprise the following:

a) a start of message byte (SMB);

b) an address byte (AB).

The order of transmission shall be as shown in Figure 5.

7.2.4 *Broadcast message (BRO).* The BRO shall be sent only by the master and shall be used to send application data intended for all slaves.

The BRO shall comprise the following:

a) a start of message byte (SMB);

b) an address byte (AB);

c) an application data description byte (ADD);

d) an application data field (ADF);

e) a check field (CF).

The order of transmission shall be as shown in Figure 4.

7.2.5 *Initialization message (IM).* The IM shall be used by the master and slaves for initialization.

NOTE The IM from a master to a slave is a poll.

The IM shall comprise the following:

a) a start of message byte (SMB);

b) an address byte (AB).

The order of transmission shall be as shown in Figure 5.

7.3 Message components

7.3.1 *Start of message byte (SMB).* The SMB shall be used to identify the start of all messages. The SMB values are reserved and shall be in accordance with those given in Table 1.

Table 1 — Start of message (SMB) codes

SMB	Mnemonic	Code
Start of EVEN ADM and all BRO	STM0	81H
Start of ODD ADM	STM1	83H
Start of LCM	SCM	85H
Start of IM	SIM	87H

7.3.2 *Address byte (AB).* The AB shall be used to identify slaves and carry the ACK-BIT (see Figure 10). There shall be 31 valid AB values in accordance with those given in Table 2. Values 00H shall be used only to identify BROs.

The AB shall comprise the following.

a) The address bits shall comprise bits d_0, d_1, d_2, d_3, of the AB.

In transmissions from the master the address bits shall be the address of the appropriate slave. In transmissions from a slave the address bits shall be the address of the slave.

b) *Acknowledge bit (ACK-B1T).* The ACK-BIT shall comprise bit d_6 and shall have the following uses.

1) In IMs

i) The ACK-BIT shall have the value 1 in an IM from either master or slave when used to request initialization.

ii) The ACK-BIT shall have the value 0 in an IM used to acknowledge reception of a valid initialization request.

2) In ADMs and LCMs

i) The ACK-BIT shall be used to acknowledge the last valid in-sequence ADM received by the station.

ii) If that in-sequence ADM was EVEN the ACK-BIT returned shall have the value 0 until the next in-sequence (ODD) ADM is received.

iii) If that in-sequence ADM was ODD the ACK-BIT returned shall have the value 1 until the next in-sequence (EVEN) ADM is received.

3) In BROs, the ACK-BIT has no function and shall always have the value 0.

c) *Error detection bits*. The error detection bits shall be used for detecting errors in the AB and shall comprise bits d_4, d_5 and d_7.

NOTE Error detection has been incorporated into the AB values given in Table 2.

Table 2 — Valid address bytes

Slave address (Decimal)	Address byte ACK-BIT = 0 (Hexadecimal)	Address byte ACK-BIT = 1 (Hexadecimal)
0 (BRO)	00H	—
1	91H	E1H
2	A2H	D2H
3	33H	43H
4	34H	44H
5	A5H	D5H
6	96H	E6H
7	07H	77H
8	88H	F8H
9	19H	69H
10	2AH	5AH
11	BBH	CBH
12	BCH	CCH
13	2DH	5DH
14	1EH	6EH
15	8FH	FFH

7.3.3 *Application data description byte (ADD).* The ADD shall be used to specify the number of bytes in the ADF and also the message priority (see Figure 11).

The ADD shall comprise the following.

a) *ADF (length).* Bits d_0 to d_6 shall represent in binary the number of bytes in the ADF prior to stuffing. 128 bytes shall be represented by all zeroes.

b) *Priority bit*. Bit d_7 shall be the message priority bit. This bit shall either have the value 0 for normal priority or the value 1 for high priority.

7.3.4 *Application data field (ADF).* The ADF shall comprise from 1 to 128 bytes of application information prior to stuffing.

NOTE The information content of the ADF is not restricted by this standard.

7.3.5 *Check field (CF).* The CF shall be a 2 byte field which is used to verify the accuracy of the ADD and ADF.

The check shall not include start, stop and parity bits and shall be applied to the ADD and ADF.

This check shall be in accordance with that defined in BS 5397 and based on the polynomial $X^{16} + X^{12} + X^5 + 1$ (see Appendix A).

7.3.6 *Byte stuffing.* The following procedure shall be used to ensure that reserved values used for link control do not occur within the content of any ADD, ADF or CF.

a) The transmitting station shall, on recognizing 80H, 81H, 83H, 85H or 87H send the stuff byte (STF) value 80H followed by a byte equal to the data byte minus the 80H byte.

b) The receiving station shall, on recognizing the 80H byte, add the 80H byte to the next ADM byte to restore the original data. If the restored data is not a reserved value this shall be a stuffing error.

The byte stuffing process shall be carried out after calculating the CF at the transmitter and prior to confirming the CF at the receiver.

The required stuffing characters shall be in accordance with those given in Table 3.

NOTE As 80H is the value assigned to the stuff byte it has to be a reserved value.

Table 3 — Stuffing codes

Data byte	Transmitted bytes	
	Sent first	Sent next
80H	80H	00H
81H	80H	01H
83H	80H	03H
85H	80H	05H
87H	80H	07H

7.4 Link operation

7.4.1 *Link start-up procedure.* The link start-up procedure shall be as follows.

a) All configured slaves shall be considered active.

b) The master shall send an IM with ACK-BIT value 1 to the configured slave with the lowest numerical address.

This slave shall reply with an IM, ACK-BIT value 0.

If the IM is received by the master, then to complete the start-up of the slave the master shall poll the slave with an LCM on the next scan. From that point ADM's may be sent to and received from that slave.

If the IM is not received by the master the next poll to that slave shall be an IM with ACK-BIT value 1.

c) Step b) shall be repeated for all other configured slaves in ascending address order.

d) Any slave failing to reply to an IM on three consecutive scans shall be considered failed (see **7.4.4**).

7.4.2 *Slave initialization.* When the master requires to initialize an individual slave it shall perform steps b), c) and d) of **7.4.1** for that slave address. When a slave requires to be initialized it shall wait until polled by the master then shall proceed as follows.

a) If the poll is an IM, ACK-BIT value 1 the slave shall return an IM, ACK-BIT value 0. Reception of this by the master shall complete the initialization procedure.

b) If the poll is an IM, ACK-BIT value 0 or an LCM the slave shall request initialization by sending an IM, ACK-BIT value 1. The next poll to that slave shall be an IM, ACK-BIT value 0 to complete the initialization procedure.

7.4.3 *Normal operation.* The master polls a slave by sending an LCM or IM. Reception of a valid poll shall be the only condition which allows a slave to transmit. The slave shall respond by sending an IM, LCM or an ADM as required.

The master may send an ADM to any initialized slave. The reception of that ADM shall be acknowledged when the slave is next polled. The master shall ensure that ADMs sent to a slave are separated by a poll to the same slave to enable acknowledgement to be made.

Following initialization of a slave:

a) the first ADM transmitted to and from the slave shall be EVEN;

b) the ACK-BIT on all LCMs and ADMs transmitted by the master to the slave shall take the value 1 until a valid ADM is received from that slave;

c) the ACK-BIT on all LCMs and ADMs transmitted by the slave to the master shall take the value 1 until a valid ADM is received by that slave.

To ensure that loss of an ADM can be detected, ADMs shall be designated ODD or EVEN. ADMs from any slave and from the master to any particular slave shall toggle between ODD and EVEN after each correct acknowledgement.

The master shall send BROs as required. The reception of BROs shall not be acknowledged.

Whenever the master has no poll outstanding it shall issue a poll immediately unless an ADM or BRO is being transmitted, in which case, the poll shall be inserted as soon as is practicable between any two bytes of that transmitted message. Where the master is waiting to send an LCM and an ADM to the same slave the ADM shall be started first.

ADMs to a slave which include a poll or polls to that slave shall not be acknowledged until the first poll following the end of that ADM.

Following the poll of a slave the master shall not begin an ADM to that slave until that slave has completed its reply.

7.4.4 *Polling cycle.* The master shall execute continuous polling cycles. Except where interrupted in accordance with **7.4.7**, each polling cycle shall consist of a number of scans. The addresses of slaves in the polling cycle shall be user configurable.

The number of scans shall be equal to the number of failed slaves at the beginning of the cycle. If there are no failed slaves the number of scans shall be one.

Each scan shall consist of polling all active slaves in ascending order and one failed slave.

The failed slave polled on each scan shall be determined by selecting addresses from the failed slaves in ascending order.

Any failed slave that initializes shall be considered active on the next scan.

Slaves identified as failed within a scan shall not be polled again within that polling cycle.

NOTE Specific applications may require the number of slaves on a link to be limited to ensure adequate response times.

7.4.5 *Message priorities.* Messages shall be transmitted and actioned according to the following priority:

a) BRO with priority bit value 1 (highest);

b) ADM with priority bit value 1;

c) BRO with priority bit value 0;

d) ADM with priority bit value 0 (lowest).

Messages of the same type with equal priority shall be handled in “first in”/”first out” order.

The current message shall be completed before a higher priority message may begin.

NOTE Use of the priority bit will be governed by the application.

7.4.6 *Adding slaves to the configuration.* The master may add a slave or slaves to the configuration. Such slave(s) shall be considered active and included in the next scan of the normal polling cycle. The first poll to newly configured slaves shall be an IM with ACK-BIT set to 1. The start-up sequence in **7.4.1**, b) shall apply to the newly configured slaves.

7.4.7 *Removing slaves from the configuration.* The master shall be able to remove a slave or slaves from the configuration as follows.

a) The master shall interrupt the current polling cycle at the end of the current poll.

b) The master shall poll each slave that is to be removed from the configuration, in ascending address order, with an IM with ACK-BIT value 1 and then remove the slave from the current polling cycle and the configuration.

c) The master shall resume the interrupted polling cycle.

7.4.8 *Validation and error handling.* A received LCM shall be valid when all of the following are true:

a) SMB = SCM (85H);

b) AB = the appropriate value given in Table 2 (excluding 00H);

c) No parity, framing or carrier errors are detected.

A received IM shall be valid when all of the following are true:

a) SMB = SIM (87H);

b) AB = the appropriate value given in Table 2 (excluding 00H);

c) No parity, framing or carrier errors are detected.

A received BRO shall be valid when all of the following are true:

a) SMB = STM0 (81H);

b) AB = 00H;

c) The CF indicates no error in the ADD or ADF;

d) No parity, framing, carrier or stuffing errors are detected.

A received LCM, IM or BRO which is not valid shall be ignored.

Reception of an acknowledge initialization when initialization has not been requested shall cause the message to be ignored except as required by **7.4.2**.

Reception by a slave of a second poll before the first has been serviced shall cause the new poll to be ignored.

A received ADM shall be valid when all of the following are true:

a) SMB = STM0 (81H) or STM1 (83H);

b) AB = the appropriate value given in Table 2 (excluding 00H);

c) the CF indicates no error in the ADD or ADF;

d) no parity, framing, carrier or stuffing errors are detected.

A received ADM which is not valid shall not be acknowledged.

NOTE Error handling of ADMs is dependent on which part of the message is in error.

If the SMB or AB are in error the ADM shall be ignored.

If the ADD, ADF or CF are in error the ADF shall be ignored but the acknowledgement gained from the AB shall be accepted.

When an ADM is received its SMB (STM0 or STM1) shall be predetermined by the protocol. The reception of an ADM with an unexpected value of SMB shall cause the message to be ignored.

Following the transmission of an ADM to a slave the next LCM or ADM received from that slave shall acknowledge reception of the ADM transmitted except where acknowledgement is delayed as in **7.4.3**. If not acknowledged then loss of the ADM shall be assumed. When an ADM is lost the next ADM to that slave shall have the same SMB as the last ADM. This shall be termed first re-transmission.

Following the transmission of an ADM from a slave the next LCM or ADM received by that slave shall acknowledge reception of the ADM transmitted. If not acknowledged then loss of the ADM shall be assumed. When an ADM is lost the next ADM from that slave shall have the same SMB as the last ADM. This shall be termed first re-transmission.

If a first re-transmission is not acknowledged a second re-transmission shall be executed. If this does not result in correct acknowledgement then initialization shall be requested.

Reception of an erroneous acknowledgement other than in response to an ADM shall cause the message containing that acknowledgement to be ignored.

7.4.9 *Slave failure.* If a valid reply from an active initialized slave is not received by the master in response to a poll on three consecutive scans then the master shall initialize that slave.

If the master fails to receive an acknowledge initialization from an active slave that requires initialization on three consecutive scans, then the master shall not poll that slave again in the current cycle. The slave shall then be considered failed.

8 Marking

Masters and slaves complying with this Part of this standard shall, in addition to and separate from any marking required by Part 1 or Part 2 of this standard, be marked externally with the number and date of this standard, i.e. BS 6556-3:1985*. Additionally the message protocol used shall be identified either as “SAP” or “DOP”.

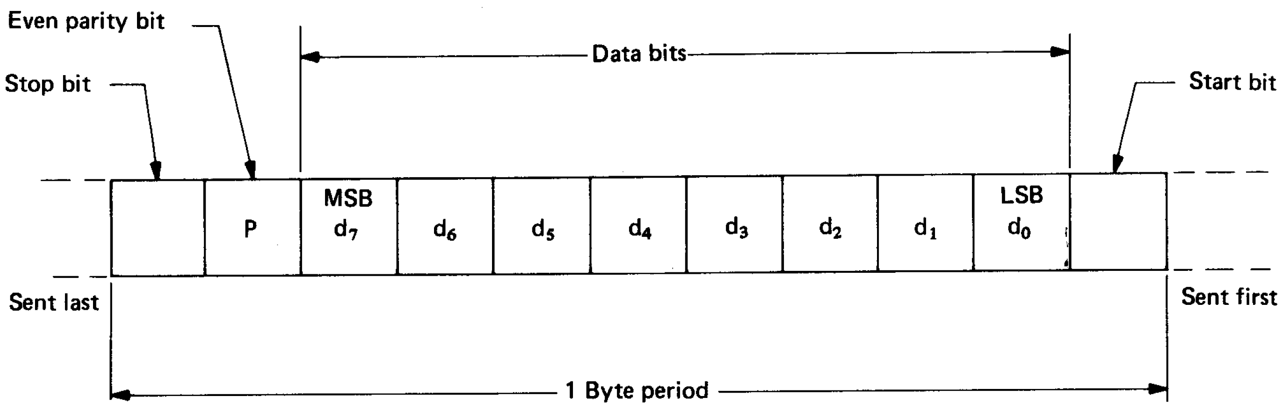


Figure 1 — The components of the byte transmission

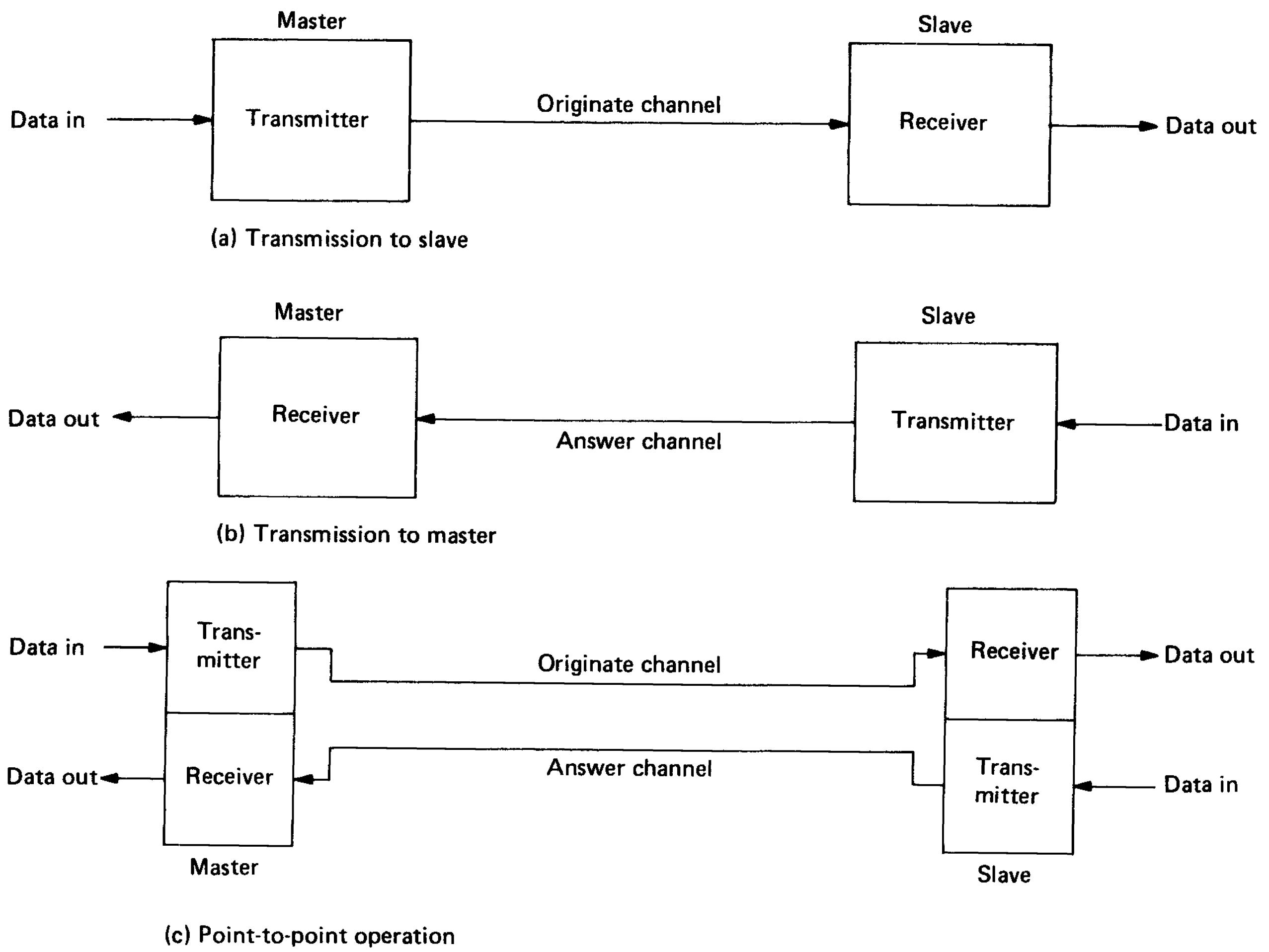
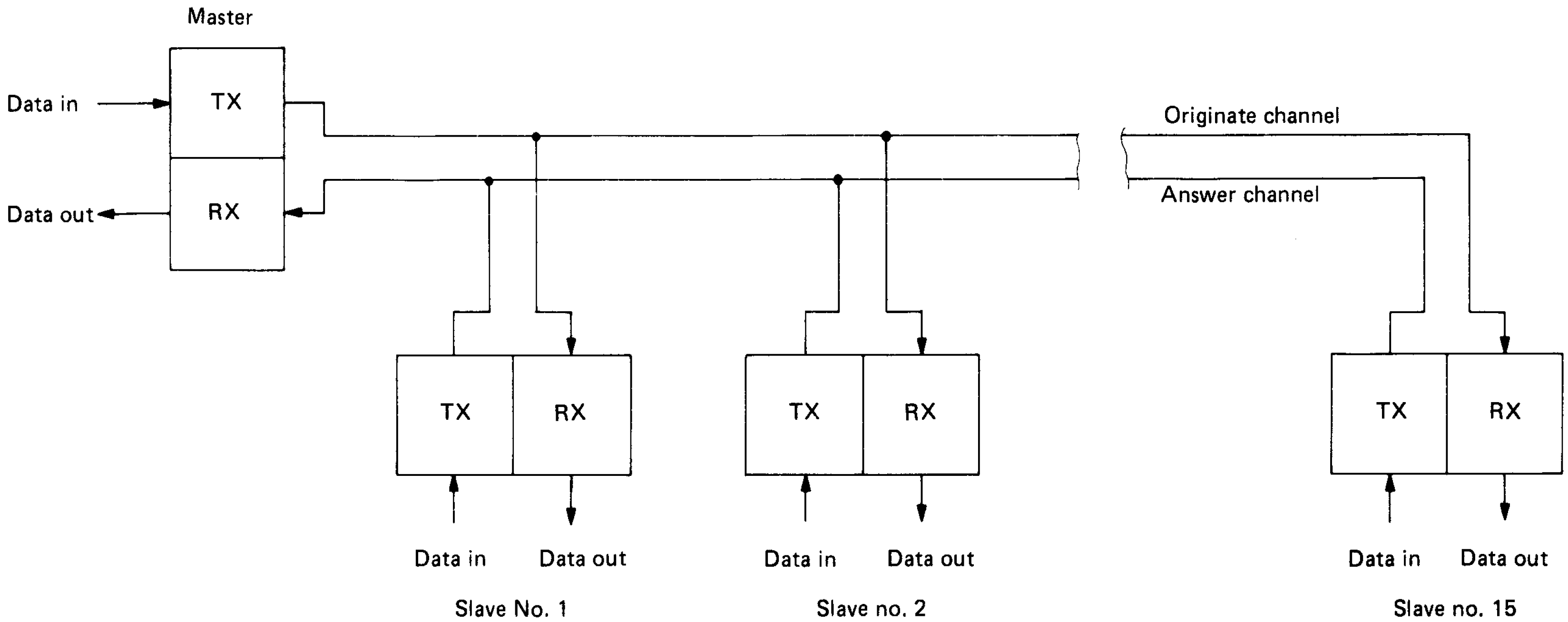


Figure 2 — Operation using DOP



Key:
TX = Transmitter
RX = Receiver

Figure 3 — Operation for 1 to 15 slaves using SAP

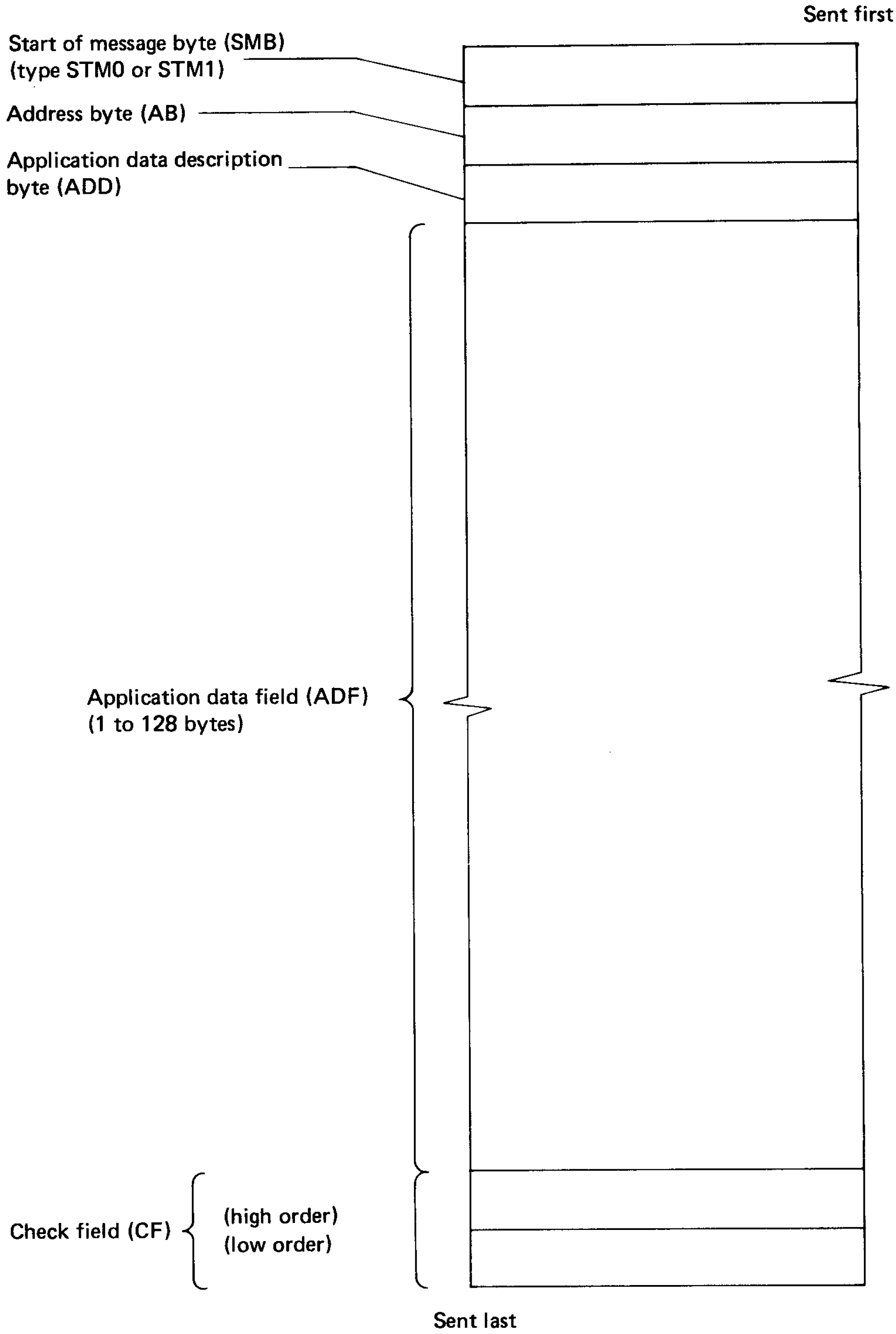


Figure 4 — Application data message (ADM) and broadcast message (BRO) format

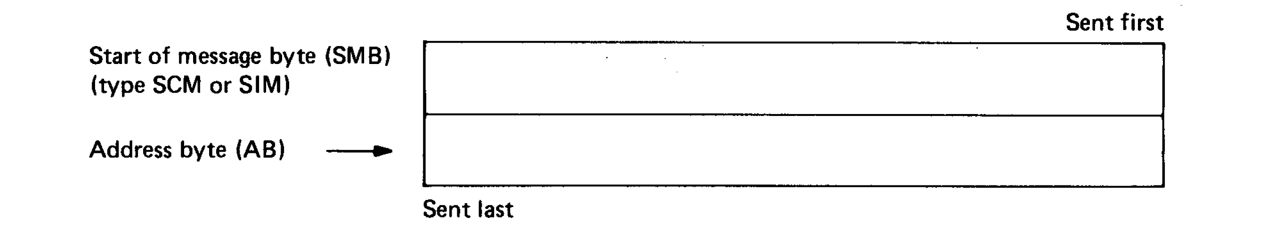


Figure 5 — Link control message (LCM) and initialization message (IM) format

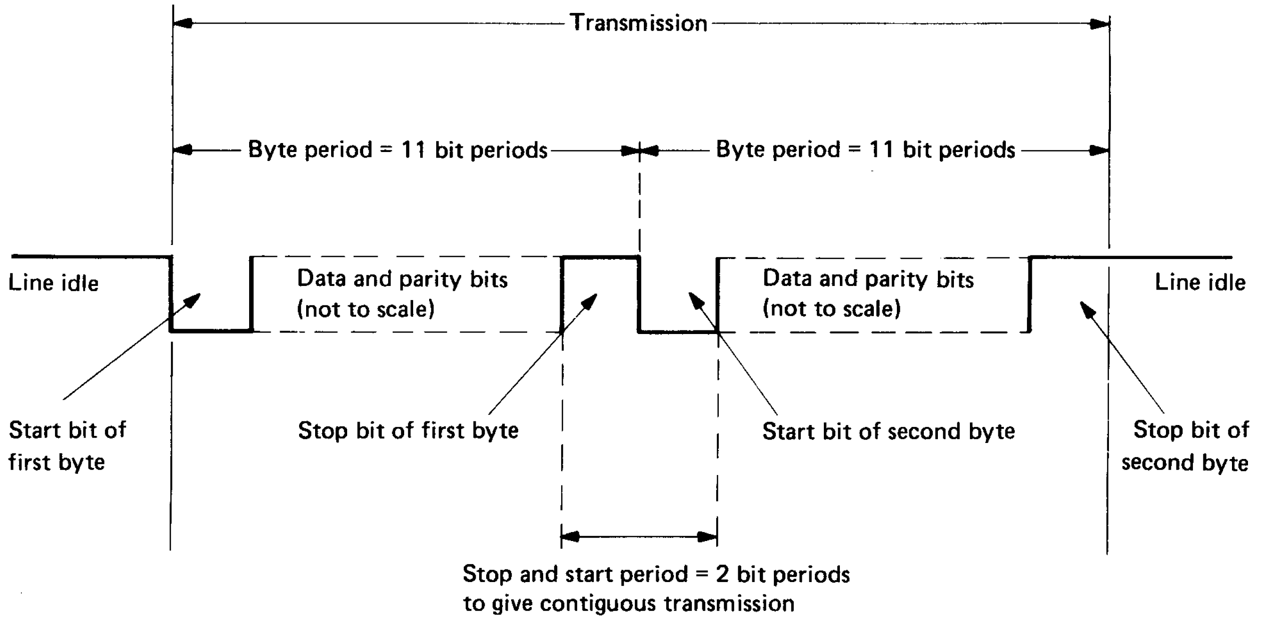


Figure 6 — A 2 byte transmission

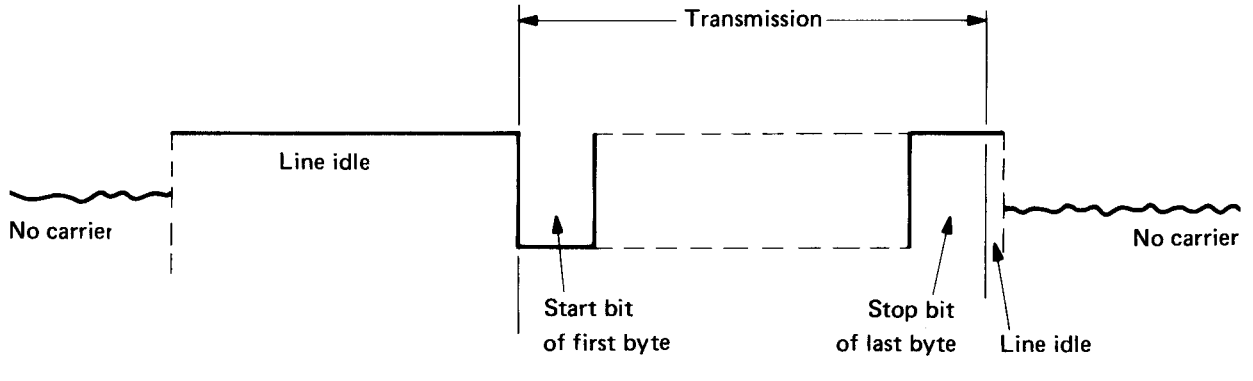


Figure 7 — Transmission envelope from slave with MODEM

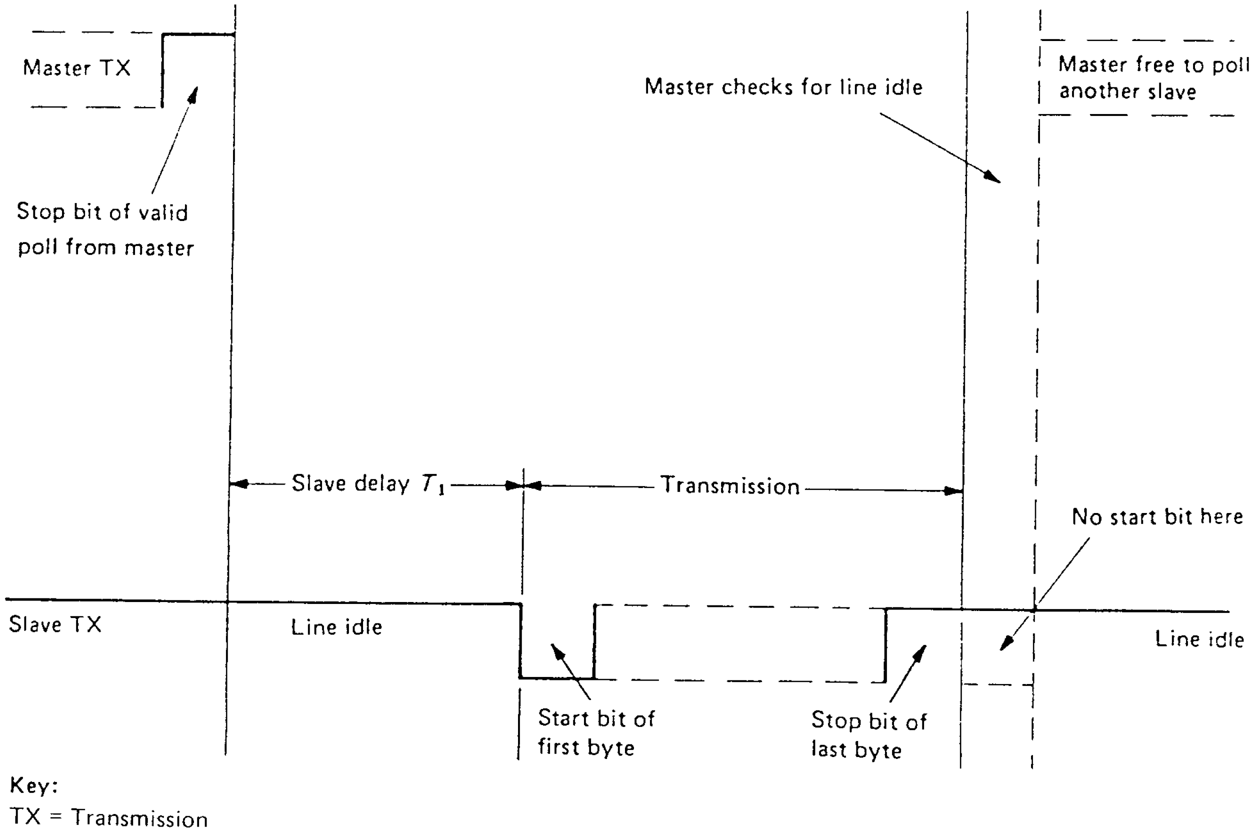
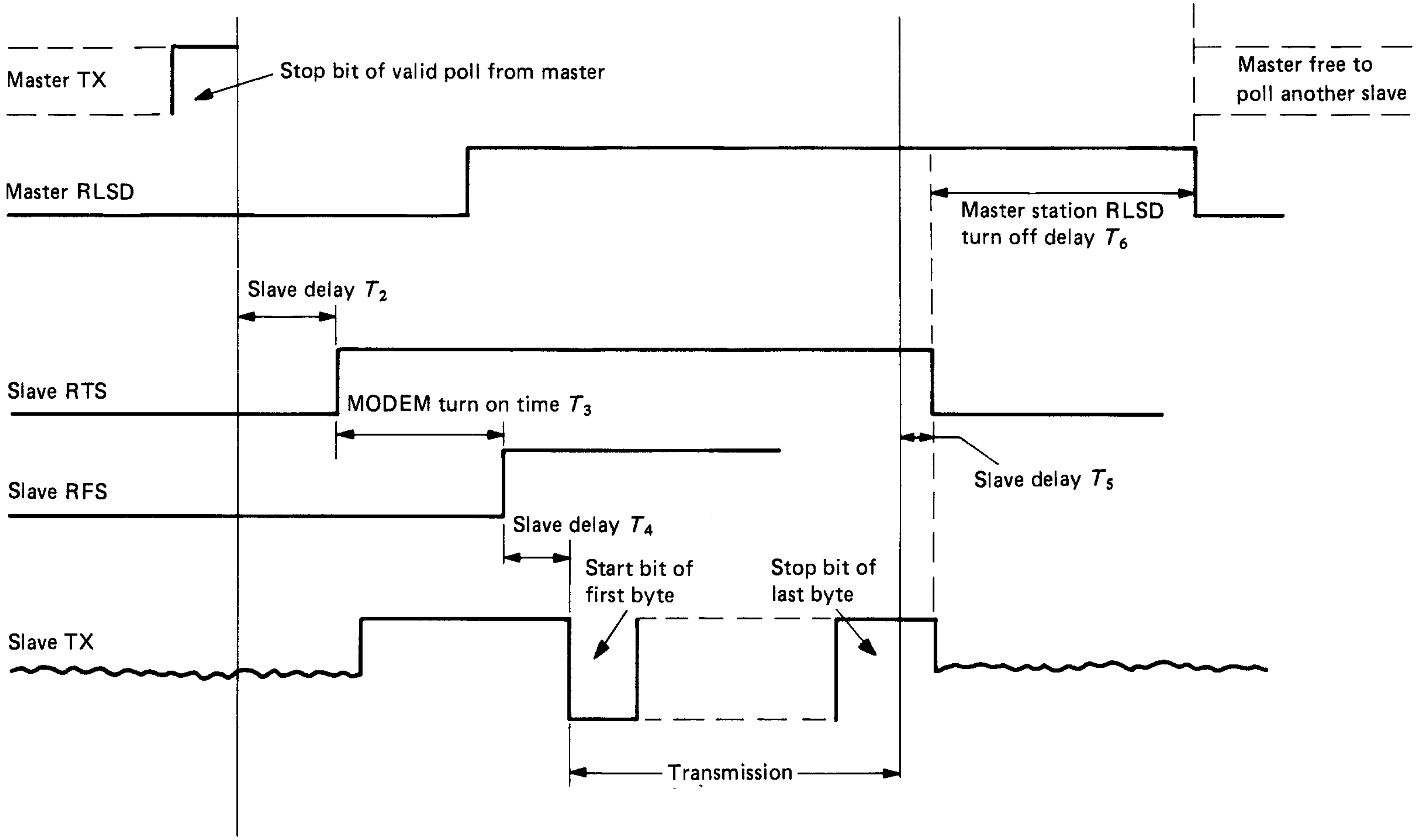


Figure 8 — Slave response to poll (current loop link)



Key:
TX = Transmission at the line terminals

NOTE Modulator an demodulator delays are specified in BS 6556-2.

Figure 9 — Slave response to poll (MODEM link)

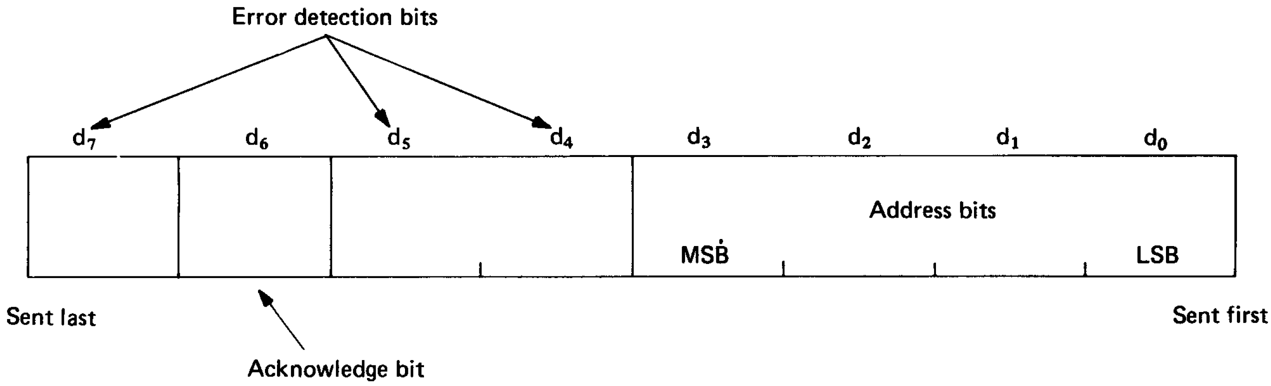


Figure 10 — Composition of message address byte (AB)

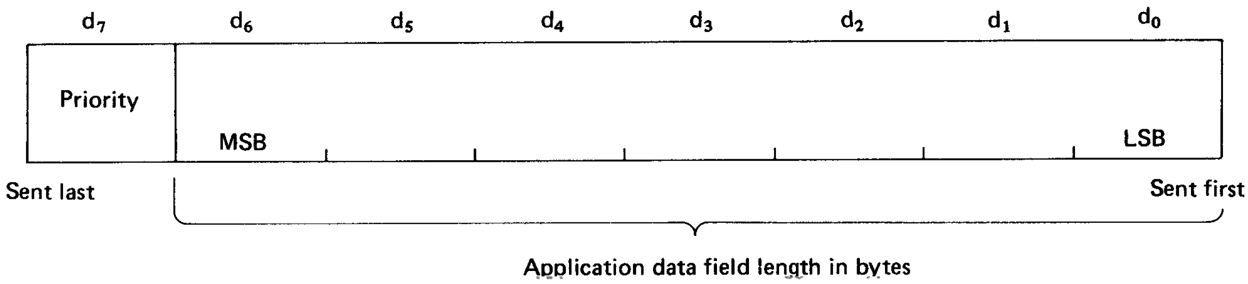


Figure 11 — Composition of application data description byte (ADD)

Appendix A Method for the generation and verification of check field (CF)

A.1 General

The CF used by SAP to confirm the content of the ADD and ADF is based on the polynomial $X^{16} + X^{12} + X^5 + 1$ defined in BS 5397 for use in the high-level data link control protocol. While integrated circuits developed to support that protocol will execute the CF generation and verification directly, it is anticipated that in SAP this function will usually be performed by means of a program within a microprocessor.

This appendix describes a method for generating and verifying SAP CFs that is suitable for implementation on most microprocessors. Typical implementations will require about 50 program memory locations and on execution will process each byte in about 100 µs. The theoretical basis of the algorithm is not included in this appendix.

The algorithm is described as a series of operations on an elementary computer the characteristics of which are described first.

A.2 The elementary computer

The elementary computer consists of three 8-bit memory locations LL (low), LH (high) and LT (temporary) and a register R which has 9 bits (d_0 to d_7 and a carry bit d_c). d_0 is the least significant bit of the register which is conceptually laid out as follows:

left d_c d_7 d_6 d_5 d_4 d_3 d_2 d_1 d_0 right

The instructions supported by the computer are as follows, where the symbol := is used as an abbreviation for "becomes equal to":

a) LOAD — This instruction loads a memory location or the register (bits d_o to d_7) with data. The data may be a byte constant or the contents of another location or register (bits d_0 to d_7) with the contents of the source register or location being unchanged.

b) EXOR — This instruction computes the exclusive OR of each of bits 0 to 7 of R with the corresponding bit in the nominated location. The result of the operation is placed in R.

c) AND — This instruction computes the logical AND of each of the bits 0 to 7 of R with the corresponding bit of a byte constant. The result of the operation is placed in R.

d) SHIFT — This instruction shifts the contents of each bit of R one place to the left with the result that $d_7 := d_6$, $d_6 := d_5$, $d_5 := d_4$, $d_4 := d_3$, $d_3 := d_2$, $d_2 := d_1$, $d_1 := d_0$ and $d_0 := 0$. It is not necessary to define the behaviour of d_c.

e) ROTATE — This instruction shifts each bit of R one place to the right through d_c without data loss with the result that $d_0 := d_1$, $d_1 := d_2$, $d_2 := d_3$, $d_3 := d_4$, $d_4 := d_5$,$d_5 := d_6$, $d_6 := d_7$, $d_7 := d_c$ and $d_c :=$ the value of d_o when the instruction was begun. It should be noted that the contents of d_c are undefined at the start of ROTATE sequences. In the following algorithm this undefined bit is always masked out of the final result with AND instructions.

A.3 The algorithm

A.3.1 *General*

The algorithm consists of the following three parts:

a) initialization;

b) byte processing;

c) termination.

A.3.2 *Initialization*

Carry out the initialization procedure before processing the contents of the ADD and ADF as follows:

a) LOAD LL with FFH;

b) LOAD LH with FFH.

A.3.3 *Byte processing*

The byte processing procedure will be executed $n + 1$ times (on the ADD and ADF bytes in order of transmission) by the check generator to produce the CF and $n + 3$ times (on the ADD, ADF and CF bytes in order of reception) by the check verifier to test the CF where n is the byte count in bits d_0 to d_6 of the ADD and then:

LOAD	R	with next byte to be included in check calculation
LOAD	LT	with LL
EXOR	R	with LH
LOAD	LH	with R
SHIFT		
SHIFT		
SHIFT		
SHIFT		

EXOR	R	with LH
LOAD	LL	with R
LOAD	LH	with LT
ROTATE		
ROTATE		
ROTATE		
ROTATE		
LOAD	LT	with R
ROTATE		
ROTATE		
AND	R	with F8H
EXOR	R	with LH
LOAD	LH	with R
LOAD	R	with LT
AND	R	with 0FH
EXOR	R	with LH
LOAD	LH	with R
LOAD	R	with LT
ROTATE		
AND	R	with 07H
EXOR	R	with LL
LOAD	LL	with R

A.3.4 *Termination*

When the generator has processed all $n + 1$ bytes of the ADD and ADF then:

LOAD	R	with FFH
EXOR	R	with LH
LOAD	LH	with R
LOAD	R	with FFH
EXOR	R	with LL
LOAD	LL	with R

LH and LL will contain the CF. LH should be transmitted first.

When the verifier has processed all $n + 3$ bytes of the ADD, ADF and CF then for error free reception LL should be FOH and LH should be B8H. Any other value indicates an error.

blank

Publications referred to

BS 5397, *High-level data link control procedures.*
BS 5754, *Specification for electrical analogue and state signals for use in coal mines*[1].
BS 6556, *Low speed digital signals for use in coal mines.*
BS 6556-1, *Specification for optical coupling.*
BS 6556-2, *Specification for transformer coupling.*

[1] Referred to in the foreword only.

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