IBM Binary Synchronous Communications (BSC)

In this report:

Note: The subject of this report is a mature standard. No significant developments are anticipated, but Datapro will provide a new report when the topic warrants it.

Datapro Summary

After it announced the System/360 with its associated 270X Transmission Control Unit in 1964, IBM introduced Binary Synchronous Communications (BSC), which provided procedures for controlling data communications between host computers and remote terminals or between host computers. This method of transmitting binary-coded data applies to such terminals as the IBM 2780, 2770, 2922, 3270, etc. BSC accommodates a variety of transmission codes and medium- to high-speed communications equipment. Although originally designed for point-to-point batch transmission, BSC was altered to accommodate a variety of other functions. These alterations have resulted in a number of different BSC versions; the two most popular are 2780 BSC and 3270 BSC. A de facto standard for data communications, BSC is characterized by the requirement that each block transmitted be acknowledged and by its incapability to accommodate full-duplex transmission. BSC has been phased out by IBM in favor of Synchronous Data Link Control (SDLC), but is still widely used.

BSC supports variable block lengths and is well suited to batch data transmission. It functions with devices that transmit EBCDIC, ASCII, or Six-Bit Transcode (SBT) code. Its control procedures work with point-to-point or multipoint leased lines or switched facilities at medium speeds over voice-grade channels or high speeds over wideband channels. BSC works with half-duplex or full-duplex channels but cannot support full-duplex data transmission. A full-duplex line increases the transmission efficiency of BSC operations by allowing faster response. Synchronization is retained in both directions at all times.

In BSC, as in other synchronous transmission techniques, synchronization is achieved by sending specific characters, called a sync (SYN) pattern, at the start of transmission. The receiving station recognizes this pattern, adjusts its timing to conform, and operates in step with the transmitting station. Data is sent as a serial string of binary digits (bits) of one or more eight-bit (one byte) transmission blocks.

BSC Versus SDLC

BSC, a simpler protocol than SDLC, is byte oriented—it transmits data in eight-bit blocks and requires an acknowledgment after each transmitted block. BSC is not totally device independent. Since it is used with several IBM equipment types, a number of versions of BSC exist.

Since SDLC is a device-independent, bit-oriented protocol, various versions are not required for different equipment types. It accommodates true full-duplex, point-to-point or multipoint transmission and can be used with any device using any code. The delay time associated with BSC's acknowledgment requirements is minimized. SDLC permits the transmission of 127 blocks before an acknowledgment is required, making it more suitable for satellite transmission. SDLC requires sufficient memory capacity in the receiving device to store the transmitted blocks before an acknowledgment is received. Both BSC and SDLC use the CRC error-checking technique.

BSC Versus ASCII

ASCII transmission control discipline, sometimes labeled asynchronous protocol or teletypewriter compatible, is used by communications vendors and users in many arbitrary arrangements. As such, the ASCII protocol is a very loosely defined standard that enjoys extreme flexibility at the expense of a common set of control procedures. The IBM BSC protocol is more rigid, even though variations exist due to its device-dependent nature.

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Data Link Definition and Arrangements

A data link consists of the communications lines, data equipment, and modems at each end of a communications channel used for the transmission of data among two or more stations. The terminal equipment constituting a station can vary from a basic send/receive device to a complex control unit with many attached input/output terminals or peripherals. The specific modem at each channel termination point (station) is determined by the type of communications channel and the speed of the equipment at each station.

Physical Arrangement

The data link can be point-to-point or multipoint. Point-to-point connections occur over leased lines or over switched (dial-up) lines. In either connection, the point-to-point link physically connects only two stations.

In a leased-line connection, communication always occurs between the same two stations. In a switched network connection, the data link is disconnected when transmission between the stations is complete. A new data link is set up through manual or automatic dialing procedures for the next transmission to any station connected to the switched network.

Multipoint Arrangement

In a multipoint arrangement, the control station initiates all transmissions by polling or selecting one of the other stations. *Polling* by the control station is an invitation to the subsidiary station to transmit data. Conversely, *station selection* (sometimes referred to as calling) by the control station is a request to transmit data to the addressed subsidiary station.

Through polling and selection, the control station can specify the addressed station and govern the direction of transmission. The control station usually addresses each station, though stations can be skipped under certain conditions. The poll/select sequence can be adjusted for more frequent addressing of some stations to handle differences in traffic volume. While the control station and one of the subsidiary stations are in communication, the other subsidiary stations on that line remain in passive monitoring mode.

The multipoint arrangement enables more than two stations to be connected to a single communications link over nonswitched lines.

Logical Arrangement

The *logical* arrangement of the data link is either a peer-to-peer or a hierarchical relationship. A peer-to-peer relationship occurs between two stations, enabling either station to initiate communications with the other and control the resulting session.

Typically, this is a terminal-to-terminal or program-to-program relationship, but it can also be a CPU-to-CPU relationship. A peer-to-peer relationship requires a point-to-point (leased-line or dial-up) physical connection.

Hierarchical Arrangement

In a hierarchical—or master/slave—relationship, one station is configured with host (master) software and is designated the *control station*; the others are configured with terminal (slave) logic and are designated the *subsidiary* or *tributary stations*. The control station does all the polling and addressing of subsidiary stations; the roles are not interchangeable.

Hierarchical arrangements can occur over point-to-point or multipoint connections. In a point-to-point, leased-line arrangement, the control station responds to a program request by automatically activating the preestablished connection to the subsidiary station that is always in a receive-ready state.

In a point-to-point, dial-up arrangement, the control station automatically dials the call to the subsidiary station or, in the absence of auto call capability, the call can be dialed manually. At the receiving end, the call can be answered automatically or manually.

Transmission Elements

Codes

BSC is usually associated with IBM's EBCDIC and Six-Bit Transcode. ASCII-coded data can, however, also be accommodated within BSC. EBCDIC has 256 code assignment positions, SBT has 64 assignment positions, and ASCII has 128 assignment positions. Most of the control characters of the ASCII code are identical to the control codes of BSC. Figure 1 illustrates the character assignments of these three codes.

Control Characters

BSC defines a set of control characters and procedures that determine how these controls should be used and the specific functions that result.

- **Synchronous Idle (SYN)** establishes and maintains synchronization; it can also serve as time-fill in the absence of data or other control characters. A *character-phase sync pattern* is two SYNs and begins each transmission.
- **Start of Heading (SOH)** precedes a block of heading characters. A *heading* consists of information such as priority or routing, used to process the text portion of the message.
- **Start of Text (STX)** precedes a block of text characters and terminates a heading.
- **End of Transmission Block (ETB)** indicates the end of a block of characters begun with SOH or STX. ETB requires a reply indicating the status of the receiving station.
- **End of Intermediate Transmission Block (ITB)** divides a message for error checking without reversing the direction of the transmission. All BSC stations must be capable of receiving the ITB character; the capability to transmit ITB is optional.
- **End of Text (ETX)** terminates a block of characters. ETX requires a reply indicating the status of the receiving station.
- **End of Transmission (EOT)** signals the end of a message and resets all stations on the line. EOT is also used as a response to a poll, when the polled station has nothing to transmit, and as an abort signal, to indicate a system malfunction or condition that would prevent transmission.
- **Enquiry (ENQ)** obtains a repeat transmission or bids for the line when transmitting point-to-point; also indicates the end of a poll or selection sequence. In a switched network operation, the calling station transmits ENQ ("Who are you?") to request the identification of the station being called.
- **Affirmative Acknowledgment (ACK 0/ACK 1)**, in proper character sequence, indicates that the preceding block was accepted without error and that the receiving station is ready to accept the next block. (ACK 0 is also the positive response to the multipoint selection or point-to-point line bid.)
- **Data Link Escape (DLE)** provides supplementary line control characters, such as WACK, ACK, and transparent mode control characters.
- **Wait-before-Transmit Positive Acknowledgment (WACK)** permits a "temporarily not ready to receive" message to be sent from the receiving to the transmitting station. It is a positive acknowledgment to the received data block or selection. WACK is actually a two-character control sequence composed of DLE followed by a second designated character that varies with the code.

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Figure 1.
Hexadecimal Representation of Character Codes

ASCII Character Assignments

Character	Hex
A	41
B	42
C	43
D	44
E	45
F	46
G	47
H	48
I	49
J	4A
K	4B
L	4C
M	4D
N	4E
O	4F
P	50
Q	51
R	52
S	53
T	54
U	55
V	56
X	58
Y	59
Z	5A
a	61
b	62
c	63
d	64
e	65
f	66
g	67
h	68
i	69
j	6A
k	6B
l	6C
m	6D
n	6E
o	6F
p	70
q	71
r	72
s	73
t	74
u	75
v	76
w	77
x	78
y	79
z	7A
0	30
1	31
2	32
3	33
4	34
5	35
6	36
7	37
8	38
9	39
Space	20
!	21

Character	Hex
"	22
#	23
$	24
%	25
&	26
'	27
(	28
)	29
*	2A
+	2B
,	2C
-	2D
.	2E
/	2F
:	3A
;	3B
,	3C
=	3D
>	3E
?	3F
@	40
[	5B
\	5C
]	5D
	5E
	5F
\	60
{	7B
|	7C
}	7D
~	7E
BEL	07
BS	08
CAN	18
CR	0D
DC1	11
DC2	12
DC3	13
DC4	14
DEL	7F
DLE	10
EM	19
ENQ	05
EOT	04
ESC	1B
ETB	17
ETX	03
FF	0C
FS	1C
GS	1D
HT	09
LF	0A
NAK	15
NUL	00
RS	1E
S1	0F
S0	0E
SOH	01
STX	02
SUB	1A
SYN	16
US	1F
VT	0B

EBCDIC Character Assignments (as defined for the IBM 3270*)

Character	Hex
A	C1
B	C2
C	C3
D	C4
E	C5
F	C6
G	C7
H	C8
I	C9
J	D1
K	D2
L	D3
M	D4
N	D5
O	D6
P	D7
Q	D8
R	D9
S	E2
T	E3
U	E4
V	E5
W	E6
X	E7
Y	E8
Z	E9
a	81
b	82
c	83
d	84
e	85
f	86
g	87
h	88
i	89
j	91
k	92
l	93
m	94
n	95
o	96
p	97
q	98
r	99
s	A2
t	A3
u	A4
v	A5
w	A6
x	A7
y	A8
z	A9
0	F0
1	F1
2	F2
3	F3
4	F4
5	F5
6	F6
7	F7
8	F8
9	F9
&	50
/	61

Character	Hex
$	5B
¢	4A
!	5A
	6A
:	7A
#	7B
,	6B
	4B
<	4C
*	5C
%	6C
@	7C
(	4D
)	5D
—	6D
'	7D
+	4E
;	5E
>	6E
=	7E
|	4F
	5F
?	6F
"	7F
SBA	11
EUA	12
IC	13
RA	3C
DLE	10
EM	19
ENQ	2D
ETB	26
EOT	37
ESC	27
ETX	03
FF	0C
PT	05
DUP	1C
SF	1D
FM	1E
ITB	1F
NAK	3D
NL	15
NUL	00
ESC	27
SOH	01
Space	40
STX	02
SUB	3F
SYN	32

Six-Bit Transcode Character Assignments

Character	Hex
A	01
B	02
C	03
D	04
E	05
F	06
G	07
H	08
I	09
J	11
K	12
L	13
M	14
N	15
O	16
P	17
Q	18
R	19
S	22
T	23
U	24
V	25
W	26
X	27
Y	28
Z	29
0	30
1	31
2	32
3	33
4	34
5	35
6	36
7	37
8	38
9	39
Space	1A
.	0B
,	2B
$	1B
#	3B
<	0C
*	1C
/	21
%	2C
@	3C
-	20
&	10
BEL	0D
DEL	3F
DLE	1F
EM	3E
ENQ	2D
EOT	1E
ESC	2A
ETB	0F
ETX	2E
HT	2F
NAK	3D
SOH	00
STX	0A
SUB	0E
SYN	3A
US	1D

****Other terminals will have functions defined for them which do not appear here; e.g., hex 04 for the IBM 2780 is PF. Similarly, other terminals may have different names for functions defined here; e.g., hex 05 for the 2780 is HT.***

This figure presents the ASCII, EBCDIC, and Six-Bit Transcode Character Assignments.

- **Negative Acknowledgment (NAK)** indicates that the previously received block was in error and the station is ready for retransmission or that the receiving station is not ready to respond to a station selection or line bid.

- **Reverse Interrupt (RVI)**, transmitted by a receiving station, is a request to interrupt the current transmission to accommodate a higher-priority message. In a multipoint operation, RVI is actually a two-character control sequence composed of DLE

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Table 1. BSC Control Sequences for Point-to-Point Transmission

Action	Character Sequences	
Transmission initiated	SYN . . . SYN ENQ FF	SYN . . . SYN ACK 0 FF
Transmit data block 1	SYN . . . SYN STX Text . . . ETB BCC FF	SYN . . . SYN ACK 1 FF
Transmit data block 2	SYN . . . SYN STX Text . . . ETB BCC FF	SYN . . . SYN NAK FF
Retransmit data block 2	SYN . . . SYN STX Text . . . ETB BCC FF	SYN . . . SYN ACK 0 FF
Transmit data block 3	SYN . . . SYN STX Text . . . ETB BCC FF	SYN . . . SYN ACK 1 FF
End transmission	SYN . . . SYN EOT FF	—
Idle	—	—

Notes:
Hex FF (all binary ones) is a trailing pad for transmissions.
ACK 0 and ACK 1 are used alternately to indicate affirmative acknowledgment of every data block.

followed by a second designated character that varies with the code in use. In a multipoint operation, this character is transmitted by the control station (acting as a receiving station) to communicate with another station on the line. RVI is treated as a positive acknowledgment by the sending station, and it responds by emptying its buffers. Receiving RVI is mandatory for all BSC stations; transmitting RVI is optional.

- **Temporary Text Delay (TTD)** is used by the sending station to hold the line when it is not ready to transmit. It is normally sent after approximately two seconds if the next block of information is not ready to be sent in that time. When transmitted, TTD is actually a two-character control sequence comprised of STX ENQ. The receiving station responds to this character sequence with a NAK, and the sending station can repeat the TTD one or more times.
- **Disconnect Sequence for a Switched Line (DLE EOT)** indicates that the transmitter is going "on hook" and can be sent by the called or calling station. It is usually sent when all message exchanges are complete.

Basic Operation of the Data Link

The major purpose of BSC is to ensure the orderly transfer of data from one station to another via an established set of procedures based on data link control characters, which delimit parts of each message and control transmission. The message, carried as binary-coded characters, can be transmitted as a single block or as a number of blocks. For each block transmitted, short control character sequences are required from the receiving station before the next block can be sent.

BSC protocol requires checking each transmission block as it is received and responding with an acknowledgment that indicates correct/accepted or incorrect/rejected. When a block is rejected, the transmitting station must resend the block. Block-by-block acknowledgment ensures the proper reception of data; however, the time consumed by individual block arrangements reduces efficiency. Occasional transmission errors can occur during retransmission.

A corollary technique is incorporated into the BSC discipline. As each block is sent and accepted, the positive acknowledgment is alternated, through the use of acknowledgment zero (ACK 0) and acknowledgment one (ACK 1), successively. Hence, the transmitting station can detect missing blocks.

Block Element

The block consists of data immediately preceded by a STX character and, when the complete message (text) is contained in a single block, is followed by an ETX character. The block is preceded by at least two SYN characters. In practice, the possibility of the loss of the first SYN character is avoided by transmitting more than two SYN characters. The transmitting station also calculates a Block Check Character (BCC) and appends this check immediately following the ETX control character, comparing it to the received Block Check in order to respond with a positive (ACK) or negative (NAK) acknowledgment. The acknowledgment is returned to the sending station as a block preceded by synchronization characters. The data may be lengthy enough to warrant its segmentation into more than one block.

Block transmission in BSC starts when the sending station acquires an available line by sending the ENQ control character and receiving a ready response (ACK 0) from the receiving station. Transmission is ended by transmitting the EOT, which causes the line to be placed in an idle (available) state. See Table 1.

To ensure reception of the first and last characters, a BSC station adds a *padding character* before and after each transmission. The lead padding character is usually an additional SYN character; the end padding character must be all binary ones (hexadecimal FF).

The *station address* is included in BSC multipoint communications. Before incoming traffic is accepted by the control station, it polls the subsidiary station by means of a unique station address. Subsidiary stations are polled sequentially by the control station in a sequence called a poll train. Similarly, the control station manages outgoing traffic by selecting each station in turn. The polling or selection sequence defines the specific device component or one of several attached devices of a clustered station.

The control station initiates multipoint control mode by transmitting a control character sequence beginning with EOT and ending with ENQ. The station address and the device element, if applicable, are included between the EOT and ENQ controls. Commands recognized by intelligent terminals can also be accommodated in the polling or selection sequence. A basic BSC polling sequence is shown in Table 2. A simple selection sequence is shown in Table 3.

Error Checking

BSC incorporates several techniques, depending on transmission code and station equipment, to check the accuracy of received data. With EBCDIC and SBT code, **Cyclical Redundancy Checking (CRC)** is employed—CRC-12 with SBT and CRC-16 with EBCDIC to constitute the Block Check Character (BCC). The BCC, though functionally one sequence, is composed of two 6-bit characters in SBT and two 8-bit characters in EBCDIC.

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Table 2. BSC Polling Sequences for Multipoint Transmission

Action	Character Sequences		
	Control Station	Station A	Station B
Poll A; no data	EOT A1 ENQ	EOT	—
Poll B; B sends	EOT B1 ENQ	—	STX Text . . . ETX BCC
	ACK 1	—	—
Poll A; A sends	EOT A1 ENQ	STX Text . . . ETB BCC	—
	ACK 1	STX Text . . . ETB BCC	—
	ACK 0	—	—
Poll B; B sends	EOT B2 ENQ	—	STX Text . . . ETX BCC
	ACK 1	—	—

Note:
SYN and Padding characters are not shown to simplify the illustration.

CRC is calculated by the sending and the receiving station by cyclically summing bits of the message as a binary accumulation and dividing this value by a prime number. The remainder is kept as the BCC. Because of the notation used to design and explain cyclic checking, the process is frequently referred to as polynomial checking.

With ASCII, **Vertical Redundancy Checking (VRC)** verifies each character as it is received, and the entire block is checked by **Longitudinal Redundancy Checking (LRC)**. The LRC character is calculated by the transmitting station and inserted at the end of the transmission block as the BCC, which immediately follows an ETB, ETX, or ITB character. LRC accumulation is reset by the next STX character. Following an ITB BCC, the accumulation is reset and starts again with the next received STX. VRC is also called *character parity checking*; LRC is also called *lateral parity checking*.

Supplementary Controls

Transparent Text Mode

Coded characters can be transmitted under BSC in nontransparent or transparent mode. In *nontransparent mode*, all characters are examined as received by the receiving station, and control characters can be acted upon immediately, even when interspersed with data characters. In *transparent text mode*, all text (data transmitted between STX and ETB or ETX) is treated solely as bit patterns, and recognition of control characters transmitted as a part of the text is suspended.

Transparent text mode supports greater versatility in the range of coded data that can be accommodated in the text positions of the transmission block. It is particularly useful for transmitting binary data, machine language programs, packed decimal data, and fixed- or floating-point arithmetic values.

Data Link Escape (DLE) is the first character of the two-character control sequence that controls transparent text mode operations. The second control character must be preceded by DLE for it to be recognized and acted upon as a control function in the transparent mode. Transmission of DLE as a data bit pattern is handled by preceding it with another DLE.

The boundaries of transparent text are determined by DLE STX, DLE ITB or DLE ETB, and DLE ETX sequences, which initiate and terminate the transparent mode. The length of a transparent transmission block can vary with each transmission.

Limited Conversational Mode

Heading or text data can be transmitted as a reply to a complete transmission block. It is sent as an affirmative reply to a block of text that has ended with either ETX or DLE ETX. It cannot follow a heading block or blocks of text ended with ETB. Conversational replies are transmitted as transmission blocks that must begin with SOH, STX, or DLE STX. A station receiving a conversational transmission block cannot respond with another conversational transmission block.

Other Controls

The format of BSC also enables the text block to be preceded with heading information to accommodate functions such as routing, priority indication, and program-related indicators. The SOH character begins the text block. End of heading information is delimited by the STX character. In this format, the SOH begins the BCC accumulation.

Transmission can be delayed by the transmitting station without relinquishing control of the line by transmitting the TTD sequence in place of the next transmission block. The sequence must be sent within two seconds after the last ACK has been received. The TTD can be repeated after each ACK response, but it must always be issued within two seconds of the last received response.

Transmission can be delayed by the receiving station by returning another positive acknowledgment control character, WACK. It can be sent as a response to a transmission block, a selection sequence, or a line bid (in point-to-point line contention). The normal response to WACK is an ENQ, but EOT can be used.

A transmitting station can be alerted to relinquish the line after sending the last transmission block by responding with a Reverse Interrupt acknowledgment. The RVI can be returned as a response to any block but is acted on only after the current transmission ends with the reception of the last block.

In switched connections, transmission is ended by sending the DLE EOT control sequence, which causes the receiving end of a switched connection to disconnect. It can be transmitted by the calling or the called station.

Leading Graphics

From one to seven graphics characters preceding an ACK or NAK can be sent in response to a block of data. All BSC stations must be capable of receiving leading graphics characters and recognizing control sequences regardless of the presence of graphics characters.

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Table 3. BSC Selection Sequences for Multipoint Transmission

Action	Character Sequences		
	Control Station	Station A	Station B
Select A; send to A	EOT A2 ENQ	ACK 0	—
	STX Text . . . ETX BCC	ACK 1	—
Select B; B not available	EOT B1 ENQ	—	NAK
Select A; send to A	EOT A2 ENQ	ACK 0	—
	STX Text . . . ETX BCC	ACK 1	—
Select B; send to B	EOT B1 ENQ	—	ACK 0
	STX Text . . . ETX BCC	—	ACK 1

Note:
SYN and Padding characters are not shown to simplify the illustration.

Switched Network Operation

Dial-up connections can be set manually or automatically through a switched network for point-to-point connections. Stations in the switched network must first determine line assurance. Stations can request station identification as an option; normal BSC procedures are otherwise followed. When both stations have completed transmissions, a disconnect control sequence is sent.

The calling station transmits ENQ or ID ENQ, and the called station responds with ID ACK 0. The ID must be at least 2, but no more than 15, characters in length. All BSC stations must transmit ID characters on the switched network. The ENQ request can also be answered with WACK or NAK. ID sequences can precede ENQ, NAK, or ACK 0, but never WACK. Following the exchange, any of the following sequences can be used to begin transmission:

- EOT—Calling station establishes control mode.
- SOH—Initiates header block transmission.
- STX—Initiates text block transmission.
- DLE STX—Initiates transparent text transmission.

Calls between stations can be ended by time-outs or by transmitting DLE EOT.

Time-Outs

Time-outs prevent indefinite data link tie-ups from invalid sequences, missing sequences, or missed line turnaround signals by providing a fixed time for an operation to occur.

Transmit Time-Outs occur at one-second intervals and establish the rate at which sync idle characters are inserted automatically into text or heading data. Two SYN characters are inserted in nontransparent mode; the DLE SYN sequence is inserted in transparent mode. When business machine clocking is used, DLE SYN is required at least every 84 characters; at least 54 characters must occur between DLE SYNs. If SYN characters are transmitted consecutively for more than three seconds, a time-out will occur.

Receive Time-Out is a three-second time-out that limits waiting time for a response. It allows for the checking of the line for sync idle characters that restart the time-out when detected. Receive time-out is restarted each time an EOT, ENQ, ACK, NAK, or WACK is recognized while a station is in control.

Disconnect Time-Out occurs on data links over switched facilities. It is a 20-second time-out to prevent a station from holding a connection for long periods of inactivity. After 20 seconds of inactivity, the station will disconnect.

Continue Time-Out is activated on stations whose device speeds affect buffer availability, causing delays in transmission. This two-second time-out is related to the use of TTDs or WACKs to control station operation delays. TTD is sent within two seconds of the acknowledgment of the last block to accommodate stations that cannot send the next transmission block before that time. A receiving station that cannot receive within the two-second time-out must transmit WACK to prevent the transmitting station from timing out the reply.

BSC Equipment Mixing Rules

The following rules apply to all station equipment on the same multipoint or switched point-to-point communications facility.

- Stations must have the same type of modems, and each modem must have the same features.
- The clocking method must be the same for all stations, and the bit rate must be the same for all devices.
- Stations must use the same data code.
- Full- or half-duplex mode must be used with all devices on the line.
- When terminal identification is used on the switched network, all stations using the same termination (phone number) at the central computer may use different identification sequences.
- The control station in a multipoint network must use the same number of characters for each address in the common polling list. Terminals with different length addresses must extend the shorter addresses to the size of the largest address by inserting leading SYN characters in the polling list. ■

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IBM
Binary Synchronous Communications (BSC)

In this report:

Note: The subject of this report is considered as a mature standard. No significant developments are anticipated, but because of its importance in the industry, coverage is being continued.

Synopsis
Binary Synchronous Communications (BSC) defines a set of rules for the synchronous transmission of binary-coded data. It accommodates a variety of transmission codes and medium- to high-speed communications equipment. BSC, a de facto standard for data communications, is characterized by the requirement that each block transmitted be acknowledged and by its incapability to accommodate full-duplex transmission.

Highlights

Following the announcement of the IBM System/360 with its associated 270X Transmission Control Unit in 1964, IBM introduced Binary Synchronous Communications (BSC), which provided procedures for the control of data communications between host computers and remote terminals or between host computers. This method of transmission of binary-coded data applies to such terminals as the IBM 2780, 2770, 2922, 3270, etc. BSC is the most widely adopted protocol for high-speed data transmission. Although BSC was originally designed for point-to-point batch transmission, it has been altered to accommodate a variety of other functions. These alterations have resulted in a number of different versions of BSC; the two most popular are 2780 BSC and 3270 BSC.

BSC is being phased out by IBM in favor of Synchronous Data Link Control (SDLC). BSC will continue to exist, however, because of the many independent terminal products that emulate the IBM 3780 terminals and IBM 3270 BSC terminal clusters; nearly every major minicomputer product line includes emulation software for one or both of these types of BSC transmission.

Analysis

BSC supports variable block lengths and is well suited to batch data transmission. It functions with devices that transmit EBCDIC, ASCII, or Six-Bit Transcode (SBT) code. Its control procedures work with point-to-point or multipoint leased lines or switched facilities at medium speeds over voice grade channels or high speeds over wideband channels. BSC works with half-duplex or full-duplex channels but cannot support full-duplex data transmission. A full-duplex line increases the transmission efficiency of BSC operations by allowing faster response. Synchronization is retained in both directions at all times.

In BSC, as in other synchronous transmission techniques, synchronization is achieved by sending specific characters, called a sync (SYN) pattern, at the start of transmission. The receiving station recognizes this pattern, adjusts its timing to conform, and operates in step with the transmitting station. Data is sent as a serial string of binary digits (bits) of one or more eight-bit (one byte) transmission blocks.

BSC vs SDLC

BSC, a simpler protocol than SDLC, is byte oriented—it transmits data in eight-bit blocks and requires an acknowledgment after each transmitted block. BSC is not totally device independent. Since it is used with several IBM equipment types, a number of versions of BSC exist.

Since SDLC is a device-independent, bit-oriented protocol, various versions are not required for different equipment types. It accommodates true full-duplex, point-to-point or multipoint transmission and can be used with any device using any code.

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The delay time associated with BSC's acknowledgment requirements is minimized. SDLC permits the transmission of 127 blocks before an acknowledgment is required, making it more suitable for satellite transmission. SDLC requires sufficient memory capacity in the receiving device to store the transmitted blocks before an acknowledgment is received. Both BSC and SDLC use the CRC error-checking technique.

BSC vs ASCII

ASCII transmission control discipline, sometimes labeled asynchronous protocol or teletypewriter compatible, is used by communications vendors and users in many arbitrary arrangements. As such, the ASCII protocol is a very loosely defined standard that enjoys extreme flexibility at the expense of a common set of control procedures. The IBM BSC protocol is more rigid, even though variations exist due to its device-dependent nature.

Data Link Definition and Arrangements

A data link consists of the communications lines, data equipment, and modems at each end of a communications channel used for the transmission of data among two or more stations. The terminal equipment constituting a station can vary from a basic send/receive device to a complex control unit with many attached input/output terminals or peripherals. The specific modem at each channel termination point (station) is determined by the type of communications channel and the speed of the equipment at each station.

Physical Arrangement

The data link can be point-to-point or multipoint. Point-to-point connections occur over leased lines or over switched (dial-up) lines. In either connection, the point-to-point link physically connects only two stations.

In a leased-line connection, communication always occurs between the same two stations. In a switched network connection, the data link is disconnected when transmission between the stations is complete. A new data link is set up through manual or automatic dialing procedures for the next transmission to any station connected to the switched network.

Multipoint Arrangement

In a multipoint arrangement, the control station initiates all transmissions by polling or selecting one of the other stations. *Polling* by the control station is an invitation to the subsidiary station to transmit data. Conversely, *station selection* (sometimes referred to as calling) by the control station is a request to transmit data to the addressed subsidiary station.

Through polling and selection, the control station can specify the addressed station and govern the direction of transmission. The control station usually addresses each station, though stations can be skipped under certain conditions. The poll/select sequence can be adjusted for more frequent addressing of some stations to handle differences in traffic volume. While the control station and one of the subsidiary stations are in communication, the other subsidiary stations on that line remain in passive monitoring mode.

The multipoint arrangement enables more than two stations to be connected to a single communications link over nonswitched lines.

Logical Arrangement

The *logical* arrangement of the data link is either a peer-to-peer or a hierarchical relationship. A peer-to-peer relationship occurs between two stations, enabling either station to initiate communications with the other and control the resulting session.

Typically, this is a terminal-to-terminal or program-to-program relationship, but it can also be a CPU-to-CPU relationship. A peer-to-peer relationship requires a point-to-point (leased-line or dial-up) physical connection.

Hierarchical Arrangement

In a hierarchical—or master/slave—relationship, one station is configured with host (master) software and is designated the *control station*; the others are configured with terminal (slave) logic and are designated the *subsidiary* or *tributary stations*. The control station does all the polling and addressing of subsidiary stations; the roles are not interchangeable.

Hierarchical arrangements can occur over point-to-point or multipoint connections. In a point-to-point, leased-line arrangement, the control station responds to a program request by automatically activating the preestablished connection to the subsidiary station that is always in a receive-ready state.

In a point-to-point, dial-up arrangement, the control station automatically dials the call to the subsidiary station or, in the absence of auto call capability, the call can be dialed manually. At the receiving end, the call can be answered automatically or manually.

Transmission Elements

Codes

BSC is usually associated with IBM's EBCDIC and Six-Bit Transcode (SBT). ASCII-coded data can, however, also be accommodated within BSC. EBCDIC has 256 code assignment positions, SBT has 64 assignment positions, and ASCII has 128 assignment positions. Most of the control characters of the ASCII code are identical to the control codes of BSC. Figure 1 illustrates the character assignments of these three codes.

Control Characters

BSC defines a set of control characters and procedures that determine how these controls should be used and the specific functions that result.

- **Synchronous Idle (SYN)** establishes and maintains synchronization; it can also serve as time-fill in the absence of data or other control characters. A *character-phase sync pattern* is two SYNs and begins each transmission.
- **Start of Heading (SOH)** precedes a block of heading characters. A *heading* consists of information such as priority or routing, used to process the text portion of the message.
- **Start of Text (STX)** precedes a block of text characters and terminates a heading.
- **End of Transmission Block (ETB)** indicates the end of a block of characters begun with SOH or STX. ETB requires a reply indicating the status of the receiving station.

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Figure 1.
Hexadecimal Representation of Character Codes

ASCII Character Assignments

Character	Hex
A	41
B	42
C	43
D	44
E	45
F	46
G	47
H	48
I	49
J	4A
K	4B
L	4C
M	4D
N	4E
O	4F
P	50
Q	51
R	52
S	53
T	54
U	55
V	56
X	58
Y	59
Z	5A
a	61
b	62
c	63
d	64
e	65
f	66
g	67
h	68
i	69
j	6A
k	6B
l	6C
m	6D
n	6E
o	6F
p	70
q	71
r	72
s	73
t	74
u	75
v	76
w	77
x	78
y	79
z	7A
0	30
1	31
2	32
3	33
4	34
5	35
6	36
7	37
8	38
9	39
Space	20
!	21

Character	Hex
"	22
#	23
$	24
%	25
&	26
'	27
(	28
)	29
*	2A
+	2B
,	2C
-	2D
.	2E
/	2F
:	3A
;	3B
<	3C
=	3D
>	3E
?	3F
@	40
[	5B
\	5C
]	5D
	5E
	5F
\	60
{	7B
|	7C
}	7D
~	7E
BEL	07
BS	08
CAN	18
CR	0D
DC1	11
DC2	12
DC3	13
DC4	14
DEL	7F
DLE	10
EM	19
ENQ	05
EOT	04
ESC	1B
ETB	17
ETX	03
FF	0C
FS	1C
GS	1D
HT	09
LF	0A
NAK	15
NUL	00
RS	1E
S1	0F
SO	0E
SOH	01
STX	02
SUB	1A
SYN	16
US	1F
VT	0B

EBCDIC Character Assignments (as defined for the IBM 3270*)

Character	Hex
A	C1
B	C2
C	C3
D	C4
E	C5
F	C6
G	C7
H	C8
I	C9
J	D1
K	D2
L	D3
M	D4
N	D5
O	D6
P	D7
Q	D8
R	D9
S	E2
T	E3
U	E4
V	E5
W	E6
X	E7
Y	E8
Z	E9
a	81
b	82
c	83
d	84
e	85
f	86
g	87
h	88
i	89
j	91
k	92
l	93
m	94
n	95
o	96
p	97
q	98
r	99
s	A2
t	A3
u	A4
v	A5
w	A6
x	A7
y	A8
z	A9
0	F0
1	F1
2	F2
3	F3
4	F4
5	F5
6	F6
7	F7
8	F8
9	F9
&	50
/	61

Character	Hex
$	5B
¢	4A
!	5A
	6A
:	7A
#	7B
,	6B
	4B
<	4C
*	5C
%	6C
@	7C
(	4D
)	5D
—	6D
'	7D
+	4E
;	5E
>	6E
=	7E
|	4F
	5F
?	6F
"	7F
SBA	11
EUA	12
IC	13
RA	3C
DLE	10
EM	19
ENQ	2D
ETB	26
EOT	37
ESC	27
ETX	03
FF	0C
PT	05
DUP	1C
SF	1D
FM	1E
ITB	1F
NAK	3D
NL	15
NUL	00
ESC	27
SOH	01
Space	40
STX	02
SUB	3F
SYN	32

Six-Bit Transcode Character Assignments

Character	Hex
A	01
B	02
C	03
D	04
E	05
F	06
G	07
H	08
I	09
J	11
K	12
L	13
M	14
N	15
O	16
P	17
Q	18
R	19
S	22
T	23
U	24
V	25
W	26
X	27
Y	28
Z	29
0	30
1	31
2	32
3	33
4	34
5	35
6	36
7	37
8	38
9	39
Space	1A
.	0B
,	2B
$	1B
#	3B
<	0C
*	1C
/	21
%	2C
@	3C
-	20
&	10
BEL	0D
DEL	3F
DLE	1F
EM	3E
ENQ	2D
EOT	1E
ESC	2A
ETB	0F
ETX	2E
HT	2F
NAK	3D
SOH	00
STX	0A
SUB	0E
SYN	3A
US	1D

***Other terminals will have functions defined for them which do not appear here; e.g., hex 04 for the IBM 2780 is PF. Similarly, other terminals may have different names for functions defined here; e.g., hex 05 for the 2780 is HT.**

This figure presents the ASCII, EBCDIC, and Six-Bit Transcode Character Assignments.

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- **End of Intermediate Transmission Block (ITB)** divides a message for error checking without reversing the direction of the transmission. All BSC stations must be capable of receiving the ITB character; the capability to transmit ITB is optional.
- **End of Text (ETX)** terminates a block of characters. ETX requires a reply indicating the status of the receiving station.
- **End of Transmission (EOT)** signals the end of a message and resets all stations on the line. EOT is also used as a response to a poll, when the polled station has nothing to transmit, and as an abort signal, to indicate a system malfunction or condition that would prevent transmission.
- **Enquiry (ENQ)** obtains a repeat transmission or bids for the line when transmitting point-to-point; also indicates the end of a poll or selection sequence. In a switched network operation, the calling station transmits ENQ ("Who are you?") to request the identification of the station being called.
- **Affirmative Acknowledgment (ACK 0/ACK 1)**, in proper character sequence, indicates that the preceding block was accepted without error and that the receiving station is ready to accept the next block. (ACK 0 is also the positive response to the multipoint selection or point-to-point line bid.)
- **Data Link Escape (DLE)** provides supplementary line control characters, such as WACK, ACK, and transparent mode control characters.
- **Wait-before-Transmit Positive Acknowledgment (WACK)** permits a "temporarily not ready to receive" message to be sent from the receiving to the transmitting station. It is a positive acknowledgment to the received data block or selection. WACK is actually a two-character control sequence composed of DLE followed by a second designated character that varies with the code.
- **Negative Acknowledgment (NAK)** indicates that the previously received block was in error and the station is ready for retransmission or that the receiving station is not ready to respond to a station selection or line bid.
- **Reverse Interrupt (RVI)**, transmitted by a receiving station, is a request to interrupt the current transmission to accommodate a higher priority message. In a multipoint operation, RVI is actually a two-character control sequence composed of DLE followed by a second designated character that varies with the code in use. In a multipoint operation, this character is transmitted by the control station (acting as a receiving station) to communicate with another station on the line. RVI is treated as a positive acknowledgment by the sending station, and it responds by emptying its buffers. Receiving RVI is mandatory for all BSC stations; transmitting RVI is optional.
- **Temporary Text Delay (TTD)** is used by the sending station to hold the line when it is not ready to transmit. It is normally sent after approximately two seconds if the next block of information is not ready to be sent in that time. When transmitted, TTD is actually a two-character control sequence comprised of STX ENQ. The receiving station responds to this character sequence with a NAK, and the sending station can repeat the TTD one or more times.
- **Disconnect Sequence for a Switched Line (DLE EOT)** indicates that the transmitter is going "on hook" and can be sent by the called or calling station. It is usually sent when all message exchanges are complete.

Basic Operation of the Data Link

The major purpose of BSC is to ensure the orderly transfer of data from one station to another via an established set of procedures based on data link control characters, which delimit parts of each message and control transmission. The message, carried as binary-coded characters, can be transmitted as a single block or as a number of blocks. For each block transmitted, short control character sequences are required from the receiving station before the next block can be sent.

BSC protocol requires checking each transmission block as it is received and responding with an acknowledgment that indicates correct/accepted or incorrect/rejected. When a block is rejected, the transmitting station must resend the block. Block-by-block acknowledgment ensures the proper reception of data; however, the time consumed by individual block arrangements reduces efficiency. Occasional transmission errors can occur during retransmission.

A corollary technique is incorporated into the BSC discipline. As each block is sent and accepted, the positive acknowledgment is alternated, through the use of acknowledgment zero (ACK 0) and acknowledgment one (ACK 1), successively. Hence, the transmitting station can detect missing blocks.

Table 1. BSC Control Sequences for Point-to-Point Transmission

Action	Character Sequences	
Transmission initiated	SYN . . . SYN ENQ FF	SYN . . . SYN ACK 0 FF
Transmit data block 1	SYN . . . SYN STX text . . . ETB BCC FF	SYN . . . SYN ACK 1 FF
Transmit data block 2	SYN . . . SYN STX text . . . ETB BCC FF	SYN . . . SYN NAK FF
Retransmit data block 2	SYN . . . SYN STXtext . . . ETB BCC FF	SYN . . . SYN ACK 0 FF
Transmit data block 3	SYN . . . SYN STXtext . . . ETB BCC FF	SYN . . . SYN ACK 1 FF
End transmission	SYN . . . SYN EOT FF	—
Idle	—	—

Notes:
Hex FF (all binary ones) is a trailing pad for transmissions.
ACK 0 and ACK 1 are used alternately to indicate affirmative acknowledgment of every data block.

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Table 2. BSC Polling Sequences for Multipoint Transmission

Action	Character Sequences		
	Control Station	Station A	Station B
Poll A; no data	EOT A1 ENQ	EOT	—
Poll B; B sends	EOT B1 ENQ	—	STX Text . . . ETX BCC
	ACK 1	—	—
Poll A; A sends	EOT A1 ENQ	STX Text . . . ETB BCC	—
	ACK 1	STX Text . . . ETB BCC	—
	ACK 0	—	—
Poll B; B sends	EOT B2 ENQ	—	STX Text . . . ETX BCC
	ACK 1	—	—

Note:
SYN and Padding characters are not shown to simplify the illustration.

Block Element

The block consists of data immediately preceded by a Start of Text (STX) character and, when the complete message (text) is contained in a single block, is followed by an End of Text (ETX) character. The block is preceded by at least two synchronization (SYN) characters. In practice, the possibility of the loss of the first SYN character is avoided by transmitting more than two SYN characters. The transmitting station also calculates a Block Check Character (BCC) and appends this check immediately following the ETX control character, comparing it to the received Block Check in order to respond with a positive (ACK) or negative (NAK) acknowledgment. The acknowledgment is returned to the sending station as a block preceded by synchronization characters. The data may be lengthy enough to warrant its segmentation into more than one block.

Block transmission in BSC starts when the sending station acquires an available line by sending the enquiry (ENQ) control character and receiving a ready response (ACK 0) from the receiving station. Transmission is ended by transmitting the End of Transmission character (EOT), which causes the line to be placed in an idle (available) state. See Table 1.

To ensure reception of the first and last characters, a BSC station adds a *padding character* before and after each transmission. The lead padding character is usually an additional SYN character; the end padding character must be all binary ones (hexadecimal FF).

The *station address* is included in BSC multipoint communications. Before incoming traffic is accepted by the control station, it polls the subsidiary station by means of a unique station address. Subsidiary stations are polled sequentially by the control station in a sequence called a poll train. Similarly, the control station manages outgoing traffic by selecting each station in turn. The polling or selection sequence defines the specific device component or one of several attached devices of a clustered station.

The control station initiates multipoint control mode by transmitting a control character sequence beginning with EOT and ending with ENQ. The station address and the device element, if applicable, are included between the EOT and ENQ controls. Commands recognized by intelligent terminals can also be accommodated in the polling or selection sequence. A basic BSC polling sequence is shown in Table 2. A simple selection sequence is shown in Table 3.

Error Checking

BSC incorporates several techniques, depending on transmission code and station equipment, to check the accuracy of received data. With EBCDIC and SBT code, **Cyclical Redundancy Checking (CRC)** is employed—CRC-12 with SBT and CRC-16 with EBCDIC to constitute the Block Check Character (BCC). The BCC, though functionally one sequence, is composed of two 6-bit characters in SBT and two 8-bit characters in EBCDIC. CRC is calculated by the sending and the receiving station by cyclically summing bits of the message as a binary accumulation and dividing this value by a prime number. The remainder is kept as the BCC. Because of the notation used to design and explain cyclic checking, the process is frequently referred to as polynomial checking.

With ASCII, **Vertical Redundancy Checking (VRC)** verifies each character as it is received, and the entire block is checked by **Longitudinal Redundancy Checking (LRC).** The LRC character is calculated by the transmitting station and inserted at the end of the transmission block as the BCC, which immediately follows an ETB, ETX, or ITB character. LRC accumulation is reset by the next STX character. Following an ITB BCC, the accumulation is reset and starts again with the next received STX. VRC is also called *character parity checking*; LRC is also called *lateral parity checking.*

Supplementary Controls

Transparent Text Mode

Coded characters can be transmitted under BSC in nontransparent or transparent mode. In *nontransparent mode*, all characters are examined as received by the receiving station, and control characters can be acted upon immediately, even when interspersed with data characters. In *transparent text mode*, all text (data transmitted between STX and ETB or ETX) is treated solely as bit patterns, and recognition of control characters transmitted as a part of the text is suspended.

Transparent text mode supports greater versatility in the range of coded data that can be accommodated in the text positions of the transmission block. It is particularly useful for transmitting binary data, machine language programs, packed decimal data, and fixed- or floating-point arithmetic values.

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Table 3. BSC Selection Sequences for Multipoint Transmission

Action	Character Sequences		
	Control Station	Station A	Station B
Select A; send to A	EOT A2 ENQ	ACK 0	—
	STX Text . . . ETX BCC	ACK 1	—
Select B; B not available	EOT B1 ENQ	—	NAK
Select A; send to A	EOT A2 ENQ	ACK 0	—
	STX Text . . . ETX BCC	ACK 1	—
Select B; send to B	EOT B1 ENQ	—	ACK 0
	STX Text . . . ETX BCC	—	ACK 1

Note:
SYN and Padding characters are not shown to simplify the illustration.

Data Link Escape (DLE) is the first character of the two-character control sequence that controls transparent text mode operations. The second control character must be preceded by DLE for it to be recognized and acted upon as a control function in the transparent mode. Transmission of DLE as a data bit pattern is handled by preceding it with another DLE.

The boundaries of transparent text are determined by DLE STX, DLE ITB or DLE ETB, and DLE ETX sequences, which initiate and terminate the transparent mode. The length of a transparent transmission block can vary with each transmission.

Limited Conversational Mode

Heading or text data can be transmitted as a reply to a complete transmission block. It is sent as an affirmative reply to a block of text that has ended with either ETX or DLE ETX. It cannot follow a heading block or blocks of text ended with ETB. Conversational replies are transmitted as transmission blocks that must begin with SOH, STX, or DLE STX. A station receiving a conversational transmission block cannot respond with another conversational transmission block.

Other Controls

The format of BSC also enables the text block to be preceded with heading information to accommodate functions such as routing, priority indication, and program-related indicators. The Start of Header (SOH) character begins the text block. End of heading information is delimited by the STX character. In this format, the SOH begins the BCC accumulation.

Transmission can be delayed by the transmitting station without relinquishing control of the line by transmitting the TTD sequence in place of the next transmission block. The sequence must be sent within two seconds after the last ACK has been received. The TTD can be repeated after each ACK response, but it must always be issued within two seconds of the last received response.

Transmission can be delayed by the receiving station by returning another positive acknowledgment control character, WACK. It can be sent as a response to a transmission block, a selection sequence, or a line bid (in point-to-point line contention). The normal response to WACK is an ENQ, but EOT can be used.

A transmitting station can be alerted to relinquish the line after sending the last transmission block by responding with a Reverse Interrupt (RVI) acknowledgment. The RVI can be returned as a response to any block but is acted on only after the current transmission ends with the reception of the last block.

In switched connections, transmission is ended by sending the DLE EOT control sequence, which causes the receiving end of a switched connection to disconnect. It can be transmitted by the calling or the called station.

Leading Graphics

From one to seven graphics characters preceding an ACK or NAK can be sent in response to a block of data. All BSC stations must be capable of receiving leading graphics characters and recognizing control sequences regardless of the presence of graphics characters.

Switched Network Operation

Dial-up connections can be set manually or automatically through a switched network for point-to-point connections. Stations in the switched network must first determine line assurance. Stations can request station identification as an option; normal BSC procedures are otherwise followed. When both stations have completed transmissions, a disconnect control sequence is sent.

The calling station transmits ENQ or ID ENQ, and the called station responds with ID ACK 0. The ID must be at least 2, but no more than 15, characters in length. All BSC stations must transmit ID characters on the switched network. The ENQ request can also be answered with WACK or NAK. ID sequences can precede ENQ, NAK, or ACK 0, but never WACK. Following the exchange, any of the following sequences can be used to begin transmission:

- EOT—Calling station establishes control mode.
- SOH—Initiates header block transmission.
- STX—Initiates text block transmission.
- DLE STX—Initiates transparent text transmission.

Calls between stations can be ended by time-outs or by transmitting DLE EOT.

Time-Outs

Time-outs prevent indefinite data link tie-ups from invalid sequences, missing sequences, or missed line turnaround signals by providing a fixed time for an operation to occur.

Transmit Time-Outs occur at one-second intervals and establish the rate at which sync idle characters are inserted

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automatically into text or heading data. Two SYN characters are inserted in nontransparent mode; the DLE SYN sequence is inserted in transparent mode. When business machine clocking is used, DLE SYN is required at least every 84 characters; at least 54 characters must occur between DLE SYNs. If SYN characters are transmitted consecutively for more than three seconds, a time-out will occur.

Receive Time-Out is a three-second time-out that limits waiting time for a response. It allows for the checking of the line for sync idle characters that restart the time-out when detected. Receive time-out is restarted each time an EOT, ENQ, ACK, NAK, or WACK is recognized while a station is in control.

Disconnect Time-Out occurs on data links over switched facilities. It is a 20-second time-out to prevent a station from holding a connection for long periods of inactivity. After 20 seconds of inactivity, the station will disconnect.

Continue Time-Out is activated on stations whose device speeds affect buffer availability, causing delays in transmission. This two-second time-out is related to the use of TTDs or WACKs to control station operation delays. TTD is sent within two seconds of the acknowledgment of the last block to accommodate stations that cannot send the next transmission block before that time. A receiving station that cannot receive within the two-second time-out must transmit WACK to prevent the transmitting station from timing out the reply.

BSC Equipment Mixing Rules

The following rules apply to all station equipment on the same multipoint or switched point-to-point communications facility.

- Stations must have the same type of modems, and each modem must have the same features.
- The clocking method must be the same for all stations, and the bit rate must be the same for all devices.
- Stations must use the same data code.
- Full- or half-duplex mode must be used with all devices on the line.
- When terminal identification is used on the switched network, all stations using the same termination (phone number) at the central computer may use different identification sequences.
- The control station in a multipoint network must use the same number of characters for each address in the common polling list. Terminals with different length addresses must extend the shorter addresses to the size of the largest address by inserting leading SYN characters in the polling list. ■

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IBM Binary Synchronous Communications (BSC)

[redacted]

In this report:

Synopsis

Editor's Note
Binary Synchronous Communications (BSC) defines a set of rules for the synchronous transmission of binary-coded data. It accommodates a variety of transmission codes and medium-to-high speed communications equipment. BSC, a de facto standard for data communications, is characterized by the requirement that each block transmitted be acknowledged and by its inability to accommodate full-duplex transmission.

Report Highlights
Following the announcement of the IBM System 360 with its associated 270X Transmission Control Unit in 1964, IBM introduced Binary Synchronous Communications (BSC), which provided procedures for the control of data communications between host computers and remote terminals or between host computers. This method of transmission of binary-coded data applies to such terminals as the IBM 2780, 2770, 2922, 3270, etc. BSC is the most widely adopted protocol for high-speed data transmission. Although BSC was originally designed for point-to-point batch transmission, it has been altered to accommodate a variety of other functions. These alterations have resulted in a number of different versions of BSC; the two most popular are 2780 BSC and 3270 BSC.

BSC is being phased out by IBM in favor of Synchronous Data Link Control (SDLC). BSC will continue to exist, however, because of the many independent terminal products that emulate the IBM 3780 terminals and IBM 3270 BSC terminal clusters; nearly every major minicomputer product line includes emulation software for one or both of these types of BSC transmission.

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Analysis

BSC permits the use of variable block lengths and is particularly well suited to batch data transmission. It can be used with devices that transmit EBCDIC, ASCII, or Six-Bit Transcode (SBT) code. Its control procedures can be employed with point-to-point or multipoint leased lines or switched facilities operating at medium speeds over voice grade channels or high speeds over wideband channels. BSC can be used with half-duplex or full-duplex channels but cannot support full-duplex data transmission. The use of a full-duplex line increases the transmission efficiency of BSC operations by allowing faster response. Synchronization is retained in both directions at all times.

In BSC, as in other synchronous transmission techniques, synchronization is achieved by sending specific characters, called a sync (SYN) pattern, at the start of transmission. The receiving station recognizes this pattern, adjusts its timing to conform, and operates in step with the transmitting station. Data is sent as a serial string of binary digits (bits) composed of one or more eight-bit (one byte) transmission blocks.

BSC vs. SDLC

BSC, a simpler protocol than SDLC, is byte oriented—it transmits data in eight-bit blocks and requires an acknowledgment after each transmitted block. BSC is not totally device independent; because it is used with several IBM equipment types, a number of versions of BSC exist.

SDLC, on the other hand, is a device-independent, bit-oriented protocol; therefore, the need for various versions for different equipment types has been eliminated. It accommodates true full-duplex, point-to-point or multipoint transmission and can be used with any device using any code. The delay time associated with BSC's acknowledgment requirements is minimized. SDLC permits the transmission of 127 blocks before an acknowledgment is required, making it more suitable for satellite transmission. SDLC requires sufficient memory capacity in the receiving device to store the transmitted blocks before an acknowledgment is received. Both BSC and SDLC use the CRC error-checking technique.

BSC vs. ASCII

ASCII transmission control discipline, sometimes labeled "asynchronous protocol" or "Teletypewriter compatible," is employed by communications vendors and users in many arbitrary arrangements. As such, the ASCII protocol is a very loosely defined standard that enjoys extreme flexibility at the expense of a common set of control procedures. The IBM BSC protocol is more rigid, even though variations exist due to its device-dependent nature.

Data Link Definition and Arrangements

A data link consists of the communications lines, data equipment, and modems at each end of a communications channel used for the transmission of data among two or more stations. The terminal equipment constituting a station can vary from a basic send/receive device to a complex control unit with many attached input/output terminals or peripherals. The specific modem used at each channel termination point (station) is determined by the type of communications channel and the speed of the equipment at each station.

Physical Arrangement

The *physical* arrangement of the data link can be either point to point or multipoint. Point-to-point connections can be established over leased lines or over switched (dial-up) communications lines. With either connection, the point-to-point link physically connects only two stations.

With a leased-line connection, communication is always between the same two stations. With a switched network connection, the data link is disconnected when transmission between the stations is complete; a new data link is set up through manual or automatic dialing procedures for the next transmission to any station connected to the switched network.

Multipoint Arrangement

In a multipoint arrangement, the control station initiates all transmissions by polling or selecting one of the other stations. *Polling* by the control station is an invitation to the subsidiary station to

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transmit data (inbound transmission). Conversely, *station selection* (sometimes referred to as calling) by the control station is a request to transmit data to the addressed subsidiary station (outbound transmission).

Through polling and selection procedures, the control station can specify the addressed station and govern the direction of transmission over the line. The control station usually addresses each station in turn, though stations can be skipped under certain conditions. The poll/select sequence can be adjusted to provide more frequent addressing of some stations to handle differences in traffic volume among the stations. While the control station and one of the subsidiary stations are in communication, the other subsidiary stations on that line remain in passive monitoring mode.

The multipoint arrangement is similar to a party line, in that it permits more than two stations to be connected to a single communications link. Multipoint connections are established over nonswitched lines.

Logical Arrangement

The *logical* arrangement of the data link is either a peer-to-peer or a hierarchical relationship. A peer-to-peer relationship is established between two stations in which either station can initiate communications with the other and control the resulting session.

Typically, this is a terminal-to-terminal or program-to-program relationship, but it can also be a CPU-to-CPU relationship. For example, IBM 3780 requires that each station be configured with a 3780 communications package, which results in a symmetrical relationship. A peer-to-peer relationship requires a point-to-point (leased line or dial-up) physical connection.

Hierarchical Arrangement

In a hierarchical—or master/slave—relationship, one station is configured with host (master) software and is designated the *control station*; the others are configured with terminal (slave) logic and are designated the *subsidiary* or *tributary stations.* The control station does all the polling and addressing of subsidiary stations; the roles are not interchangeable.

Hierarchical arrangements may be established over point-to-point or multipoint physical connections. In a point-to-point, leased-line arrangement, the control station responds to a program request by automatically activating the preestablished connection to the subsidiary station that is always in a receive-ready state.

In a point-to-point, dial-up arrangement, the control station automatically dials the call to the subsidiary station or, in the absence of auto call capability, the call may be dialed manually. At the receiving end, the call may be answered either automatically or manually. An example of a point-to-point hierarchical relationship is IBM HASP communications, which requires a master with a host communications spooling system or RTAM protocol, and a slave with the HASP workstation software.

Transmission Elements

Codes

BSC is usually associated with IBM's EBCDIC and Six-Bit Transcode (SBT). ASCII-coded data can, however, also be accommodated within BSC. EBCDIC has 256 code assignment positions, SBT has 64 assignment positions, and ASCII has 128 assignment positions. Most of the control characters of the ASCII code are identical to the control codes used within BSC. Figure 1 illustrates the character assignments of these three codes.

Control Characters

BSC defines a set of control characters and procedures that determine how these controls should be used and what specific functions can be accomplished. A list of these control characters and their functions follows (see Table 4 for hexadecimal representations).

- **Synchronous Idle (SYN)** establishes and maintains synchronization; it is also used as time-fill in the absence of data or other control characters. A *character-phase sync pattern* is two SYNs and begins each transmission.
- **Start of Heading (SOH)** precedes a block of heading characters. A *heading* consists of information such as priority, routing, etc., used to process the text portion of the message.
- **Start of Text (STX)** precedes a block of text characters and terminates a heading.

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Figure 1.
Hexadecimal Representation of Character Codes

ASCII Character Assignments

Character	Hex
A	41
B	42
C	43
D	44
E	45
F	46
G	47
H	48
I	49
J	4A
K	4B
L	4C
M	4D
N	4E
O	4F
P	50
Q	51
R	52
S	53
T	54
U	55
V	56
X	58
Y	59
Z	5A
a	61
b	62
c	63
d	64
e	65
f	66
g	67
h	68
i	69
j	6A
k	6B
l	6C
m	6D
n	6E
o	6F
p	70
q	71
r	72
s	73
t	74
u	75
v	76
w	77
x	78
y	79
z	7A
0	30
1	31
2	32
3	33
4	34
5	35
6	36
7	37
8	38
9	39
Space	20
!	21

Character	Hex
"	22
#	23
$	24
%	25
&	26
'	27
(	28
)	29
*	2A
+	2B
,	2C
-	2D
.	2E
/	2F
:	3A
;	3B
<	3C
=	3D
>	3E
?	3F
@	40
[	5B
\	5C
]	5D
	5E
	5F
\	60
{	7B
|	7C
}	7D
~	7E
BEL	07
BS	08
CAN	18
CR	0D
DC1	11
DC2	12
DC3	13
DC4	14
DEL	7F
DLE	10
EM	19
ENQ	05
EOT	04
ESC	1B
ETB	17
ETX	03
FF	0C
FS	1C
GS	1D
HT	09
LF	0A
NAK	15
NUL	00
RS	1E
S1	0F
SO	0E
SOH	01
STX	02
SUB	1A
SYN	16
US	1F
VT	0B

EBCDIC Character Assignments (as defined for the IBM 3270*)

Character	Hex
A	C1
B	C2
C	C3
D	C4
E	C5
F	C6
G	C7
H	C8
I	C9
J	D1
K	D2
L	D3
M	D4
N	D5
O	D6
P	D7
Q	D8
R	D9
S	E2
T	E3
U	E4
V	E5
W	E6
X	E7
Y	E8
Z	E9
a	81
b	82
c	83
d	84
e	85
f	86
g	87
h	88
i	89
j	91
k	92
l	93
m	94
n	95
o	96
p	97
q	98
r	99
s	A2
t	A3
u	A4
v	A5
w	A6
x	A7
y	A8
z	A9
0	F0
1	F1
2	F2
3	F3
4	F4
5	F5
6	F6
7	F7
8	F8
9	F9
&	50
/	61

Character	Hex
$	5B
¢	4A
!	5A
	6A
:	7A
#	7B
,	6B
	4B
<	4C
*	5C
%	6C
@	7C
(	4D
)	5D
—	6D
'	7D
+	4E
;	5E
>	6E
=	7E
|	4F
	5F
?	6F
"	7F
SBA	11
EUA	12
IC	13
RA	3C
DLE	10
EM	19
ENQ	2D
ETB	26
EOT	37
ESC	27
ETX	03
FF	0C
PT	05
DUP	1C
SF	1D
FM	1E
ITB	1F
NAK	3D
NL	15
NUL	00
ESC	27
SOH	01
Space	40
STX	02
SUB	3F
SYN	32

Six-Bit Transcode Character Assignments

Character	Hex
A	01
B	02
C	03
D	04
E	05
F	06
G	07
H	08
I	09
J	11
K	12
L	13
M	14
N	15
O	16
P	17
Q	18
R	19
S	22
T	23
U	24
V	25
W	26
X	27
Y	28
Z	29
0	30
1	31
2	32
3	33
4	34
5	35
6	36
7	37
8	38
9	39
Space	1A
.	0B
,	2B
$	1B
#	3B
<	0C
*	1C
/	21
%	2C
@	3C
-	20
&	10
BEL	0D
DEL	3F
DLE	1F
EM	3E
ENQ	2D
EOT	1E
ESC	2A
ETB	0F
ETX	2E
HT	2F
NAK	3D
SOH	00
STX	0A
SUB	0E
SYN	3A
US	1D

****Other terminals will have functions defined for them which do not appear here; e.g., hex 04 for the IBM 2780 is PF. Similarly, other terminals may have different names for functions defined here; e.g., hex 05 for the 2780 is HT.***

This figure presents the ASCII, EBCDIC, and Six-Bit Transcode Character Assignments.

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- **End of Transmission Block (ETB)** indicates the end of a block of characters begun with either SOH or STX. ETB requires a reply indicating the status of the receiving station.
- **End of Intermediate Transmission Block (ITB)** divides a message for error checking without reversing the direction of the transmission. All BSC stations must have the capability to receive the ITB character; the capability to transmit ITB is optional.
- **End of Text (ETX)** terminates a block of characters. ETX requires a reply indicating the status of the receiving station.
- **End of Transmission (EOT)** signals the end of a message and resets all stations on the line. EOT is also used as a response to a poll, when the polled station has nothing to transmit, and as an abort signal, to indicate a system malfunction or condition that would prevent transmission.
- **Enquiry (ENQ)** obtains a repeat transmission or bids for the line when transmitting point to point. It also indicates the end of a poll or selection sequence. In a switched network operation, the calling station transmits ENQ ("Who are you?") to request the identification of the station being called.
- **Affirmative Acknowledgment (ACK 0/ACK 1),** in proper character sequence, indicates that the preceding block was accepted without error and that the receiving station is ready to accept the next block. (ACK 0 is also used as the positive response to the multipoint selection or point-to-point line bid.)
- **Data Link Escape (DLE)** provides supplementary line control characters, such as WACK, ACK, and transparent mode control characters. (See the Transparent Mode section for further explanation.)
- **Wait-before-Transmit Positive Acknowledgment (WACK)** permits a "temporarily not ready to receive" message to be sent from the receiving to the transmitting station. It is a positive acknowledgment to the received data block or selection. WACK is actually a two-character control sequence composed of DLE followed by a second designated character that varies with the code being used (EBCDIC, SBT, or ASCII) (see Table 4). The capability to receive WACK is mandatory; the capability to transmit is optional.
- **Negative Acknowledgment (NAK)** indicates either that the previously received block was in error and the station is ready for retransmission or that the receiving station is not ready to respond to a station selection or line bid.
- **Reverse Interrupt (RVI)**, transmitted by a receiving station, is a request to interrupt the current transmission to accommodate a higher priority message. With a multipoint operation, RVI is actually a two-character control sequence composed of DLE followed by a second designated character that varies with the code being used (EBCDIC, SBT, or ASCII) (see Table 4). In a multipoint operation, this character is transmitted by the control station (acting as a receiving station) because it wishes to communicate with another station on the line. RVI is treated as a positive acknowledgment by the sending station, and it responds by emptying its buffers. The capability to receive RVI is mandatory for all BSC stations; the capability to transmit RVI is optional.
- **Temporary Text Delay (TTD)** is used by the sending station when it wishes to hold the line but it is not ready to transmit. It is normally sent after approximately two seconds if the next block of information is not ready to be sent in that time. When transmitted, TTD is actually a two-character control sequence comprised of STX ENQ. The receiving station responds to this character sequence with a NAK, and the sending station may repeat the TTD one or more times.
- **Disconnect Sequence for a Switched Line (DLE EOT)** indicates that the transmitter is going "on hook" and can be sent by either the called or calling station. It is usually sent when all message exchanges are complete.

Basic Operation of the Data Link

The major purpose of BSC is to ensure the orderly transfer of data from one station to another using an established set of procedures based on data link control characters. Data link control characters

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delimit parts of each message and control transmission. The message, carried as binary-coded characters, can be transmitted as a single block or as a number of blocks. For each block transmitted, short control character sequences are required from the receiving station before the next block can be sent.

An important principle of the BSC protocol is the requirement for checking each transmission block as it is received and to respond with an acknowledgment that indicates that it is correct/accepted or incorrect/rejected. When a block is rejected, the transmitting station must resend the block. The principle of block-by-block acknowledgment ensures the proper reception of data; however, the time consumed by individual block arrangements reduces transmission efficiency. Occasional transmission errors could occur during the retransmission procedures.

A corollary technique is incorporated in the BSC discipline. As each block is sent and accepted, the positive acknowledgment is alternated, by using acknowledgment zero (ACK 0) and acknowledgment one (ACK 1), successively. Hence, the transmitting station can detect missing blocks.

Block Element

The block is the basic data element in BSC. It consists of data immediately preceded by a Start of Text (STX) character and, when the complete message (text) is contained in a single block, it is followed by an End of Text (ETX) character. The block is preceded by at least two synchronization (SYN) characters. In practice, the possibility of the loss of the first SYN character is typically guarded against by transmitting more than two SYN characters. The transmitting station also calculates a Block Check Character (BCC) and appends this check immediately following the ETX control character and compares it to the received Block Check in order to respond with a positive (ACK) or negative (NAK) acknowledgment. The acknowledgment is returned to the sending station as a block preceded by synchronization characters.

The data (text) may be lengthy enough to warrant its segmentation into more than one block. The probability of transmission errors rises when the block is longer and transmission speed is faster. Consequently, the frequency of retransmission would increase and efficiency would decrease. At some optimum point, the retransmission loss offsets the loss of efficiency due to added control sequence exchanges (ACK/NAK). Therefore, multiple block transmission is common. In this case, only the last block of text is followed by ETX. The first and other blocks end each block of text with End of Transmission Block (ETB) or Intermediate Transmission Block (ITB) control characters. The ITB can be used to check parts of text separately within a block, without requiring a response. Both ETB and ITB are followed by a Block Check Character.

Block transmission in BSC starts when the sending station acquires an available line. This is accomplished by sending the enquiry (ENQ) control character and receiving a ready response (ACK 0) from the receiving station. Transmission is ended by transmitting the End of Transmission character (EOT), which causes the line to be placed

Table 1. BSC Control Sequences for Point-to-Point Transmission

Action	Character Sequences	
Transmission initiated	SYN...SYN ENQ FF	SYN...SYN ACK 0 FF
Transmit data block 1	SYN...SYN STX text...ETB BCC FF	SYN...SYN ACK 1 FF
Transmit data block 2	SYN...SYN STX text...ETB BCC FF	SYN...SYN NAK FF
Retransmit data block 2	SYN...SYN STXtext...ETB BCC FF	SYN...SYN ACK 0 FF
Transmit data block 3	SYN...SYN STXtext...ETB BCC FF	SYN...SYN ACK 1 FF
End transmission	SYN...SYN EOT FF	—
Idle	—	—

Notes:
Hex FF (all binary ones) is a trailing pad for transmissions.
ACK 0 and ACK 1 are used alternately to indicate affirmative acknowledgment of every data block.

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in an idle (available) state. An illustration of basic BSC transmission sequences is shown in Table 1.

To ensure reception of the first and last characters of a transmission, a BSC station adds a *padding character* before and after each transmission. The lead padding character is usually an additional SYN character; the end padding character must be all binary ones (hexadecimal FF).

The *station address* is included to accomplish BSC multipoint communications. Before incoming traffic is accepted by the control station, it polls the subsidiary station by means of a unique station address. Subsidiary stations are polled sequentially by the control station (the sequence is called a "poll train"). In a similar manner the control station manages outgoing traffic by selecting each station in turn. The polling or selection sequence transmitted defines the specific device component (such as a card reader, punch, or printer) or one of several attached devices (such as CRT #1) of a clustered station.

The control station initiates multipoint control mode by transmitting a control character sequence beginning with EOT and ending with ENQ. The station address and the device element, if applicable, are included between the EOT and ENQ controls. Commands recognized by "intelligent" terminals can also be accommodated in the polling or selection sequence. A basic BSC polling sequence is shown in Table 2. A simple selection sequence is illustrated in Table 3.

Error Checking

BSC incorporates several techniques, depending on the transmission code and the type of station equipment used, to check the accuracy of received data. These checking methods are directly related to the codes used. With EBCDIC and SBT code, **Cyclical Redundancy Checking (CRC)** is employed. CRC-12 is used with SBT and CRC-16 with EBCDIC to constitute the Block Check Character (BCC). The BCC, though functionally one sequence, is composed of two six-bit characters in SBT and two eight-bit characters in EBCDIC. CRC is calculated by both the sending and the receiving station by cyclically summing bits of the message as a binary accumulation and dividing this value by a prime number. The remainder is kept as the BCC. Because of the notation used to design and explain cyclic checking, it is frequently referred to as polynomial checking.

With ASCII, **Vertical Redundancy Checking (VRC)** verifies each character as it is received, and the entire block is checked by **Longitudinal Redundancy Checking (LRC)**. The LRC character is calculated by the transmitting station and inserted at

Table 2. BSC Polling Sequences for Multipoint Transmission

Action	Character Sequences		
	Control Station	Station A	Station B
Poll A; no data	EOT A1 ENQ	EOT	—
Poll B; B sends	EOT B1 ENQ	—	STX Text...ETX BCC
	ACK 1	—	—
Poll A; A sends	EOT A1 ENQ	STX Text...ETB BCC	—
	ACK 1	STX Text...ETB BCC	—
	ACK 0	—	—
Poll B; B sends	EOT B2 ENQ	—	STX Text...ETX BCC
	ACK 1	—	—

Note:
SYN and Padding characters are not shown to simplify the illustration.

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Table 3. BSC Selection Sequences for Multipoint Transmission

Action	Character Sequences		
	Control Station	Station A	Station B
Select A; send to A	EOT A2 ENQ	ACK 0	—
	STX Text...ETX BCC	ACK 1	—
Select B; B not available	EOT B1 ENQ	—	NAK
Select A; send to A	EOT A2 ENQ	ACK 0	—
	STX Text...ETX BCC	ACK 1	—
Select B; send to B	EOT B1 ENQ	—	ACK 0
	STX Text...ETX BCC	—	ACK 1

Note:
SYN and Padding characters are not shown to simplify the illustration.

the end of the transmission block as the BCC, which immediately follows an ETB, ETX, or ITB character. LRC accumulation is reset by the next STX character. Following an ITB BCC, the accumulation is reset and starts again with the next received STX. VRC is also called *character parity checking*; LRC is also called *lateral parity checking.*

Supplementary Controls

Transparent Text Mode

Coded characters may be transmitted under BSC operation in nontransparent or transparent mode. In *nontransparent mode*, all characters are examined as received by the receiving station, and control characters can be acted upon immediately, even when interspersed with data characters.

In *transparent text mode*, all text, that is data transmitted between STX and ETB or ETX, is treated solely as bit patterns, and recognition of control characters transmitted as a part of the text is suspended.

Transparent text mode permits greater versatility in the range of coded data that can be accommodated in the text positions of the transmission block. It is particularly useful for transmitting binary data, machine language programs, packed decimal data, and fixed- or floating-point arithmetic values.

Data Link Escape (DLE) is the first character of the two-character control sequence that controls transparent text mode operations. The second control character must be preceded by DLE for it to be recognized as a control function in the transparent mode and to be acted upon. Transmission of DLE as a data bit pattern is handled by preceding it with another DLE. The following sequences are used for transparent mode functions:

DLE STX	Initiates transparent text mode.
DLE ETB or DLE ETX	Terminates transparent text mode, returns to nontransparent mode, and calls for an acknowledgment.
DLE ITB	Terminates transparent text mode, returns to transparent mode, but does not call for an acknowledgment.
DLE ENQ	Signals that this block is to be disregarded; returns to transparent mode.
DLE SYN	May be used to maintain synchronization or as a time-fill sequence.
DLE DLE	Used to allow DLE as a data character within transparent text. First DLE is discarded.

The boundaries of transparent text are determined by the DLE STX, the DLE ITB or DLE ETB, and DLE ETX sequences. These sequences initiate and terminate the transparent mode. The length of a transparent transmission block can vary with each transmission.

Limited Conversational Mode

Heading or text data may be transmitted as a reply to a complete transmission block. It is sent as an affirmative reply to a block of text that has ended with either ETX or DLE ETX. It may not follow a heading block or blocks of text ended with ETB.

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Conversational replies are transmitted as transmission blocks that must begin with SOH, STX, or DLE STX. A station that receives a conversational transmission block may not respond with another conversational transmission block.

Other Controls

The transmission format of BSC also permits the text block to be preceded with heading information to accommodate functions such as routing, priority indication, and program-related indicators. The Start of Header (SOH) character begins the text block. End of heading information is delimited by the STX character. In this format, the SOH begins the BCC accumulation.

Transmission can be delayed by the transmitting station without relinquishing control of the line by transmitting the TTD sequence in place of the next transmission block. The sequence must be sent within two seconds after the last ACK has been received. The TTD may be repeated after each ACK response, but it must always be issued within two seconds of the last received response.

Transmission can be delayed by the receiving station by returning another positive acknowledgment control character, WACK. It can be sent as a response to a transmission block, a selection sequence, or a line bid (in point-to-point line contention). The normal response to WACK is an ENQ, but EOT may be used. When ENQ is received, the receiving station may continue to respond with WACK until it is ready to receive.

A transmitting station can be alerted to relinquish the line after sending the last transmission block by responding with a Reverse Interrupt (RVI) acknowledgment. The RVI may be returned as a response to any block but is acted on only after the current transmission ends with the reception of the last block.

With switched connections, transmission is ended by sending the DLE EOT control sequence. This control sequence causes the receiving end of a switched connection to disconnect. It may be transmitted by either the calling or the called station.

Leading Graphics

From one to seven graphics characters preceding an ACK or NAK may be sent in response to a block of data. All BSC stations must be capable of receiving leading graphics characters and recognizing control sequences regardless of the presence of graphics characters. The functional significance of these characters and the ability to transmit them is determined by station specifications.

Table 4. Hexadecimal Representation of Control Character Bit Patterns

Control Character	ASCII	EBCDIC	*SBT
SYN	16	32	3A
SOH	01	01	00
STX	02	02	0A
ETB	17	26	0F
ITB	1F	1F	1D
ETX	2E	03	2E
EOT	04	37	1E
ENQ	05	2D	2D
DLE	10	10	1F
ACK/0	10/30	10/70	1F/20
ACK/1	10/31	10/61	1F/23
NAK	15	3D	3D
WACK	10/30	10/6B	1F/26
RVI	10/3C	10/7C	10/02
TTD	02/05	02/2D	0A/2D

**SBT is represented in hex with first two bits of the first character taken as "00"; only six bits are transmitted.*

Switched Network Operation

Dial-up connections can be established either manually or automatically through a switched network for point-to-point connections. Stations using the switched network must first determine line assurance (a signal between data sets). Stations may request station identification as an option; normal BSC procedures are otherwise followed. When both stations have completed transmissions, a disconnect control sequence is sent.

The calling station transmits ENQ or ID ENQ, and the called station responds with ID ACK 0. The ID must be at least 2, but no more than 15 characters in length. All BSC stations must be capable to transmitting ID characters for operation on the switched network. The ENQ request can also be answered with either WACK or NAK. ID sequences may precede ENQ, NAK, or ACK 0 but are never permitted to precede WACK. Following the exchange (calling station bids ENQ, receives ACK 0 reply), any of the following sequences may be used to begin transmission:

- EOT—Calling station establishes control mode.

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- SOH—Initiates header block transmission.
- STX—Initiates text block transmission.
- DLE STX—Initiates transparent text transmission.

Calls between stations can be terminated by time-outs or by transmitting DLE EOT.

Time-Outs

Time-outs prevent indefinite data link tie-ups caused by invalid sequences, missing sequences, or missed line turnaround signals by providing a fixed time in which a specific operation may occur.

Four time-out functions are provided:

Transmit Time-Outs occur at one-second intervals and establish the rate at which sync idle characters are inserted automatically into text or heading data. Two SYN characters are inserted in nontransparent mode; the DLE SYN sequence is inserted in transparent mode. When business machine clocking is used, DLE SYN is required at least every 84 characters; at least 54 characters must occur between DLE SYNs. "Sync idles" have no effect on the transmission format. If SYN characters are transmitted consecutively for more than three seconds, a time-out will occur.

The **Receive Time-Out** is a three-second time-out used to limit waiting time for a response. It allows for the checking of the line for sync idle characters that restart the time-out when detected. The receive time-out is restarted each time an EOT, ENQ, ACK, NAK, or WACK is recognized while a station is in control.

The **Disconnect Time-Out** is used on data links established over switched facilities. It is a 20-second time-out used to prevent a station from holding a connection for long periods of inactivity. After 20 seconds of inactivity, the station will disconnect.

The **Continue Time-Out** is used with stations whose device speeds affect buffer availability, causing delays in transmission. This two-second time-out is related to the use of TTDs or WACKs to control station operation delays. TTD is sent within two seconds of the acknowledgment of the last block to accommodate stations not capable of sending the next transmission block before that time. A receiving station that cannot receive within the two-second time-out must transmit WACK to prevent the transmitting station from timing out the expected reply.

BSC Equipment Mixing Rules

The following rules apply to all station equipment on the same multipoint or switched point-to-point communications facility.

- Stations must have the same type of modems, and each modem must have the same features.
- The method of clocking must be the same for all stations, and the bit rate must be the same for all devices.
- Stations must use the same data code.
- Either full- or half-duplex mode must be used with all devices on the line.
- When terminal identification is used on the switched network, all stations using the same termination (phone number) at the central computer may use different identification sequences.
- The control station in a multipoint network must use the same number of characters for each address in the common polling list. Terminals that have different length addresses must extend the shorter addresses to the size of the largest address by inserting leading SYN characters in the polling list. ■

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