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SURFACE VEHICLE INFORMATION REPORT

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Survey of Known Protocols

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1. ***Scope***—This SAE Information Report is a summary comparison of existing protocols found in manufacturing, automotive, aviation, military, and computer applications which provide background or may be applicable for Class C application (see Figure 1). The intent of this report is to present a summary of each protocol, not an evaluation. This is not intended to be a comprehensive review of all applicable protocols. The form for evaluation of a protocol exists in this paper and new protocols can be submitted on this form to the committee for consideration in future revisions of this report.

This report contains a table which provides a side-by-side comparison of each protocol considered. The subsequent section provides a more detailed examination of the protocol attributes. Many of the protocols do not specify a method for one or more of the criteria. In these circumstances 'user defined' or 'not specified' will appear under the heading.

Certain protocol specifics or details are omitted for the sake of brevity. Every attempt is made to provide the interested reader with the necessary references for further research.

1.1 Background—Three classes of vehicle communications have been identified by the SAE Vehicle Networking Subcommittee. These classes are defined as follows:

a. Class A: A potential multiplex system usage whereby vehicle wiring is reduced by the transmission and reception of multiple signals over the same signal bus between nodes that would have been accomplished by individual wires in a conventionally wired vehicle (i.e., low-speed body wiring and control functions, for example, control of exterior lamps).
b. Class B: A potential multiplex system usage whereby data is transferred between nodes to eliminate redundant sensors and other system elements (i.e., data communications, for example, sharing of vehicle parametric data).
c. Class C: A potential multiplex system usage whereby high data rate signals typically associated with real-time control systems, such as engine controls and anti-skid brakes, are sent over the signal bus to facilitate distributed control and to further reduce vehicle wiring (i.e., high-speed real-time control, for example, distributed engine control).

These three classes describe the various applications of communication that are anticipated to exist within a vehicle. Each class is intended to be able to support the lower level Class applications. That is, Class A systems are designed for basic low level switch multiplexing. Class B introduces the aspect of parametric data sharing while still providing for Class A applications. Class C introduces the aspect of real-time control but still allows Class B and Class A tasks to be performed. Issues such as cost, reliability, and bus bandwidth will determine which link or combination of links are most appropriate for a given application.

For definition of other terms used in this report, please refer to SAE J1213.

	Aircraft MIL STD 1553	ABUS	AUTOLAN	CAN	DDB	ETHERNET	HDLC/ SDLC	J1850	JIAWG	MINI-MAP	TOKEN RING	TOKEN SLOT DEVICE	VAN
AFFILIATION	Military Standard	VW	General Instrument	Proposed ISO Bosch	Philips	IEEE 802.3	ISO(HSLC) IBM(SDLC)	SAE J1850	SAE	IEEE	IEEE 802.5	GM	Proposed ISO
APPLICATION	Aircraft Network (fighter...)	Auto In-Vehicle	Auto In-Vehicle	Auto In-Vehicle	Audio/ Video	Lab and Business	Industrial	Auto In-Vehicle	Avionics	Factory Communications	Computer	Auto In-Vehicle	Auto In-Vehicle
TRANSMISSION MEDIA	Shielded TW.Pair Fiber Optic	Single Wire	Twisted Pair	Twisted Pair Fiber Optic	Twisted Pair	"Thick" Coaxial Cable		Single Wire Twisted Pair	Fiber Optics	Twisted Pair,Coax Fiber Optics	Dual Twisted Pair	Twisted Pair Fiber Optics	Twisted Pair
BIT ENCODING	Manchester II Biphase	NRZ	Alternate Pulse Inversion	NRZ With Bit Stuffing	PWM	Manchester	NRZ With Inversion And Zero Bit Inserts	VPW PWM	Manchester	Phase Shift Keying (PCFSK, AMPSK)	Manchester	NRZ With Bit Stuffing	Manchester
MEDIA ACCESS	Master/ Slave or Token	Contention	Master/ Slave	Contention	Contention	Contention	Master/ Slave	Contention	Token Passing	Token Passing	Token	Token Slot	Contention
ERROR DETECTION	Parity	Bit Only	CRC	CRC	Parity	CRC	CRC	Optional CRC	CRC	Optional CRC	CRC	CRC	CRC
DATA FIELD LENGTH	2 Bytes Minimum	2 Bytes	2 Bytes	0-8 Bytes	2-128 Bytes	46-1500 Bytes	Any Number of Bytes	0-8 Bytes	32-65536 Bytes	2-256 Bytes	1-4 K Bytes	0-256 Bytes	0-8 Bytes
IN-MESSAGE ACK				Yes				Yes				Yes	
MAXIMUM BIT RATE	1 Mb/S	500 Kb/S	4 Mb/S	1 Mb/S	100 Kb/S	10 Mb/S	375 Kb/S 2.4 Mb/S	10 Kb/S 40 Kb/S	50 Mb/S	5,10,20 Mb/S	4 Mb/S 16 Mb/S	2 Mb/S	User Definable
MAXIMUM BUS LENGTH	Not Specified	Not Specified Typical 30 m	>40 m	Not Specified Typical >40 m	150 m	500 m		40 m	>40 m	>400 m	1500 m	Not Specified Typical 30 m	30 m
MAXIMUM NUMBER OF NODES	Not Specfied	Not Specified Typical 32	127	Not Specified Typical >16	50	1024		Not Specified	128	100	256	32 (Transmit Capability)	16
HARDWARE AVAILABLE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No

FIGURE 1—PROTOCOL DESCRIPTION

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

a. Aircraft Internal Time Division Command / Response Multiplex Data Bus (MIL-STD-1553): "MIL-STD-1553B Designer's Guide" published by ILC Data Device Corporation.

b. Automotive Bit-serial Universal-interface System (ABUS):

1. ABUS presentation by Volkswagen to SAE Class C Task Force 8/89.
2. Press Information and data sheet by Telefunken Electronic 8/88.

c. Auto Local Area Network (AutoLAN):

1. John D. H. Harris, Nigel M. Bailey "General Instrument AUTOLAN - A High Speed Multiplexing System for Automotive Body Wiring Systems" SAE 890541
2. "AUTOLAN CONTROLLER IC 616759 DRAFT 05-04-89"

d. Class B Data Communication Network Interface (SAE J1850): Recommended Practice J1850, Revised 9/19/88.

e. Controller Area Network (CAN):

1. Intel 1989 Automotive Handbook
2. SAE Information Report J1583

f. Digital Data Bus (D2B): Philips Single-Chip 8-Bit Microcontroller User's Guide

g. Ethernet (IEEE 802.3):

1. IEEE 802.3 Summary by M.R. Stepper of the SAE Truck and Bus Control and Communications Subcommittee
2. Intel 1989 Microcommunications Handbook
3. Intel Local Area Networking (LAN) Tutorial

h. Joint Integrated Avionics Working Group (JIAWG):

1. James H. Nelson, Larry T. Shafer, Daryle B. Hamlin, James J. Herrmann "A Candidate for Linear Token-Passing, High-Speed Data Bus Systems" SAE 872494
2. Draft "Standard Joint Integrated Avionics Working Group Linear Token Passing Multiplex Data Bus Protocol" DOCUMENT J88 - M5
3. "Linear Token Passing Multiplex Data Bus Standard" Unisys Document 7340679

i. Mini-Manufacturing Automation Protocol (Mini-MAP):

1. "MiniMAP/MAP Controller/Carrierband Modem Interface" Motorola Inc. Rev. 1
2. "MicroMAP1-7 Manufacturing Automation Protocol Software" Motorola Inc. Rev.1
3. "IEEE 802.4 Token Bus"

j. Synchronous Data Link Control/High-Level Data Link Control (SDLC/HDLC):

1. Microcommunications Handbook, Intel, 1988
2. Microprocessor, Microcontroller and Peripheral Data Volume II, Motorola, 1988

k. Token Ring (IEEE 802.5):

1. ANSI/IEEE std 802.5-1985, Token Ring Access Method
2. ANSI/IEEE std 802.5-1985, Logical Link Control

l. Token Slot Protocol: SAE Information Report J2106 "Token Slot Network for Automotive Control"
m. Vehicle Area Network: VAN Specification, Version 1.2, ISO/TC22/SC3/WG1

3. ***Definitions***—The descriptions of the protocol subsections follow. These descriptions appear in the order in which they are discussed for each protocol.

3.1 **Intent of Protocol Subsections**—The following describes the intent of the various subsections of the protocol characteristics.

3.2 **Application/Affiliation**—The application section briefly identifies the applications for which the protocol was designed to serve (e.g., military, aircraft, industrial, land vehicles, trucks). The affiliation section identifies the organization(s) that originally developed or specified the protocol or which now endorse the protocol.

3.3 **Transmission Media**—The transmission media section describes the physical medium generally associated or required by the given protocol (e.g., single wire, dual (parallel) wire, twisted pair, twisted pair with shield, dual twisted pair, fiber optics).

3.4 **Physical Interface**—This section describes the basic circuitry used to connect the nodes to the network. In some cases the schematic of a typical interface may be shown. In others, a reference to a generally known interface technique may be made. This section may also include additional data about aspects of the interface not readily shown. An example would be that receiver nodes synchronize to the signal from a transmitting node, or that receiver nodes adjust their receiver clock to the received data signal.

3.5 **Bit Encoding**—The bit encoding section describes the way in which the logical bits, 1's and 0's, are translated into signals on the transmission medium by the physical interface (e.g., NRZ, PWM, MANCHESTER).

3.6 **Network Access**—The network access section describes the method used to award the communication network to one of the nodes for the transmission of a message (e.g., master slave, token passing, CSMA/CD).

3.7 **Message Format**—The message format section describes the fields that make up the basic message(s) used in the protocol. This includes the order, name, and size of the fields.

3.8 **Handshaking**—The handshaking section describes the interaction of nodes within a network in order to effect a transfer of data. This may include such things as negative and positive acknowledgement, and in-message acknowledgement.

3.9 **Error Detection Management**—The error detection management section describes the types of errors the protocol detects and recovery techniques it uses (e.g., wrong message length, CRC).

3.10 **Fault Tolerance**—The fault tolerance section describes the ability of the protocol to continue operation, possibly at a degraded level, when various parts of the physical layer or medium of the network on which the protocol is operating fails (e.g., node connections are broken, bus wires are opened, bus wires are shorted to ground or to vehicle battery voltage).

3.11 **Data Rate**—The data rate section identifies the maximum data rate supported by the protocol.

3.12 **Framing Overhead**—The framing overhead section briefly shows the amount of non-data overhead (i.e., framing overhead) associated with the given protocol. If possible the calculation of overhead is shown. Because some protocols offer significantly different message formats and/or message sizes several overhead calculations may be necessary to give an accurate picture of the range of the protocol's overhead requirements.

3.13 **Latency**—The latency section describes the factors that affect the delay between the availability of a message to be transmitted and the beginning of the reception of that message by the intended receiver.

3.14 Power Reduction Mode—The power reduction section has general information about any modes of operation that require less power than normal operation. As a minimum, this section identifies the lower power level(s). It also includes a brief description of the criteria used in transitioning to the lower power mode(s) and to return to normal power mode. Some of this information may be device version specific and will be so identified.

3.15 Selected References—The selected references section identifies the source of the information used to create the summary of a given protocol (e.g., manuals, standards, presentations).

3.16 Contributors—The contributors section recognizes the person(s) who supplied information on the particular protocol and/or who reviewed the information.

4. Protocol Technical Summary

4.1 Aircraft Internal Time Division Command/Response Multiplex Data Bus (MIL-STD-1553)

4.1.1 APPLICATION/AFFILIATION—Military standard (presently in Revision B). Used in aircraft (fighter jet, other) and tank networks. One of the basic tools used by the Department of Defense for integration of weapon systems. In the future, it is intended to be used to integrate flight controls, to integrate propulsion controls, and to store management subsystems.

4.1.2 TRANSMISSION MEDIA—Standard defines specific characteristics for a twisted pair shielded cable. Other media may be used. A related protocol, MIL-STD-1773, supports fiber optics. A summary of Data Bus and Coupling Requirements may be found in Table 1.

TABLE 1—SUMMARY OF DATA BUS AND COUPLING REQUIREMENTS

Parameter	MIL-STD-1553B
Transmission line	
Cable type	Twisted-shielded pair
Capacitance (wire to wire)	30 pf/ft, maximum
Twist	Four per foot (0.33/in), minimum
Characteristic impedance (Z_0)	70 to 85 Ω at 1.0 MHz, maximum
Attenuation	1.5 dB/100 ft at 1.0 MHz, maximum
Length of main bus	Not specified
Termination	Two ends terminated in resistors equal to $Z_{(0)}$ ± 2%
Shielding	75% coverage minimum
Cable coupling	
Stub definition	Short stub < 1 ft Long stub > 1 to 20 ft (may be exceeded)
Coupler requirement	Direct coupled - short stub; transformer coupled - long stub (ref. Figure 1-1.7)
Coupler transformer	
Turns ratio	1:1.41
Input Impedance	3000 Ω, minimum (75 kHz to 1.0 MHz)
Droop	20% maximum (250 kHz)
Overshoot and ringing	± 1.0 V peak (250 kHz square wave with 100 ns maximum rise and fall time)
Common mode rejection	45.0 dB at 1.0 MHz
Fault protection	Resistor in series with each connector equal to (0.75 Z_0) ± 2.0% Ω
Stub voltage	1.0 V to 14.0 V p-p, 1-1, minimum signal voltage (transformer coupled); 1.4 V to 20.0 V, p-p, 1-1, minimum signal voltage (direct coupled)

4.1.3 PHYSICAL INTERFACE—Direct coupling and transformer coupling based on length of connected stub.

4.1.4 BIT ENCODING—Valid Manchester II biphase encoding. Zero crossing deviation of ±23 ns and rise and fall time of greater than or equal to 100 ns specified. 1-1/2 bits positive volts, 1-1/2 bits negative volts for Command and Status Words, the opposite for Data Word. Valid Manchester II for bits other than the word sync.

4.1.5 NETWORK ACCESS—In the "stationary master bus control system," MIL-STD-1553 operates as Master/Slave with respect to the bus controller and the remote terminal. The bus controller is in control of all communication and it is the sole device allowed to transmit command words. All messages are initiated by the bus controller using command word(s). The network implements "Internal Time Division Command/Response" to control access between the bus controller and the remote terminals.

In the "non-stationary master bus control system," multiple bus controllers may (one at a time) control the single data bus system. The protocol provides a method for issuing a bus controller offer, allowing a potential bus controller to accept or reject control via a bit in the returning status word. Two methods have been used: time based and round robin.

4.1.6 MESSAGE FORMAT—There are 10 message types (see Figure 2). The 10 message types may be broken into 2 groups -"information transfer formats" and "broadcast information transfer formats."

Each message consists of 3 primary sections or "words." They are the "Command Word," the "Data Word," and the "Status Word" (see Figure 3).

4.1.7 HANDSHAKING—Message acknowledgement is provided by the "Status Word." For a single receiver, the structure is shown in Figure 3. The broadcast message format requires the receiving remote terminals to suppress their status responses. Therefore, to analyze the status word after a broadcast message has occurred requires a mode code message to a unique terminal to be sent (and the message must be transmitted before any other transmission to that unique terminal).

All accesses to the bus are controlled through the bus controller. For transmissions to a specific remote terminal, the remote terminal address is used. For broadcast messages, the bus controller transmits commands using a remote terminal address of "31 hex."

Acknowledgement is provided by the command/response philosophy, which requires that all error-free messages received by a remote terminal be followed by the transmission of a remote terminal status word.

4.1.8 ERROR DETECTION MANAGEMENT—The message error bit is the only required status bit and it is used to identify messages which do not pass the word or message validation tests. This bit is set if a message fails to pass the tests and the status word is suppressed (i.e., not transmitted). All messages that are not error-free will not have a responding status word—allowing the bus controller to time-out on the no status response, alerting the bus controller of a failure condition. Parity is used at the end of each word. Odd parity is established for all words based on the 16 bits of data plus parity.

a. The word validation includes:

1. word begins with a valid sync field
2. bits are a valid Manchester II code
3. word parity is odd

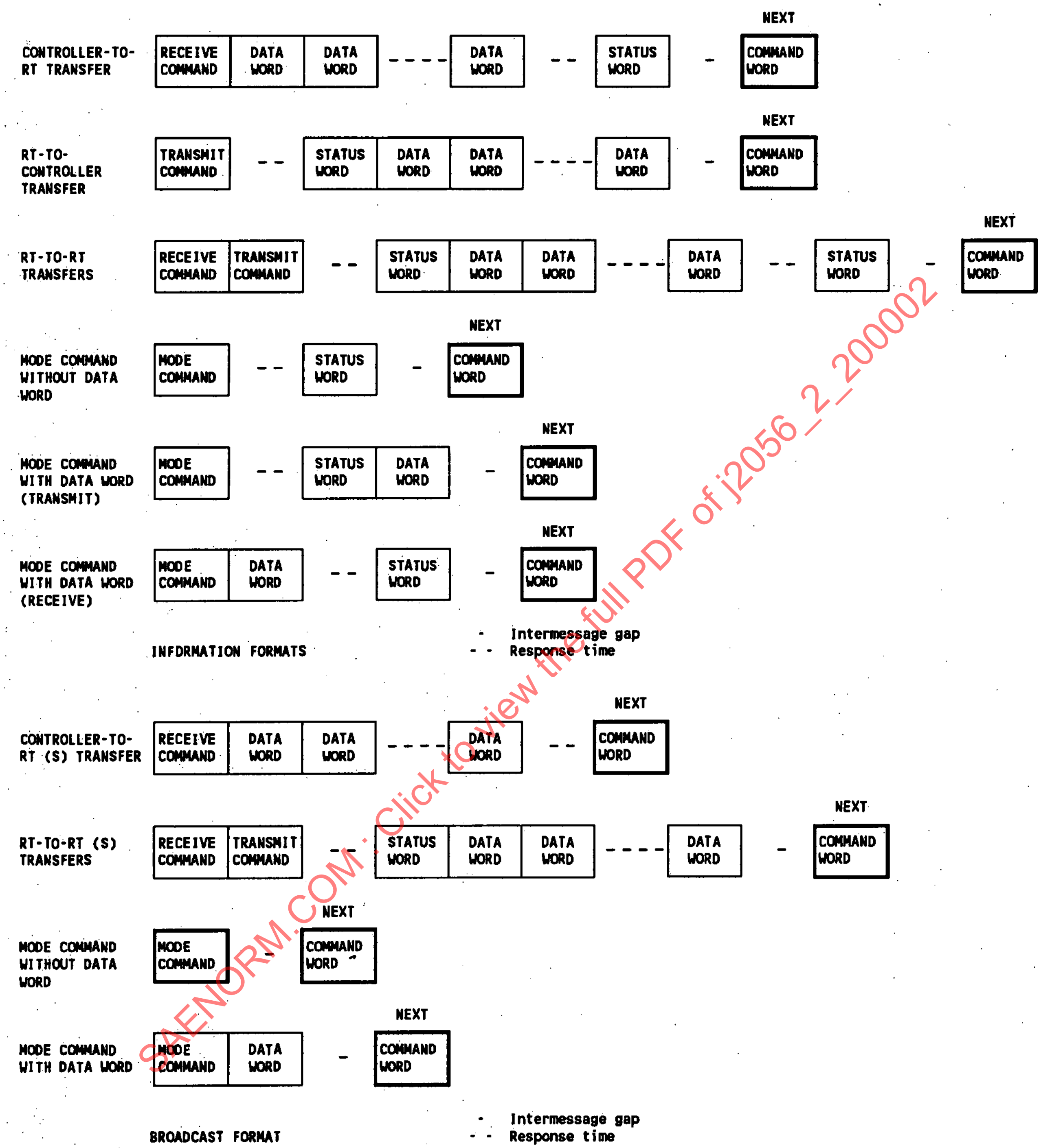


FIGURE 2—TRANSFER FORMATS

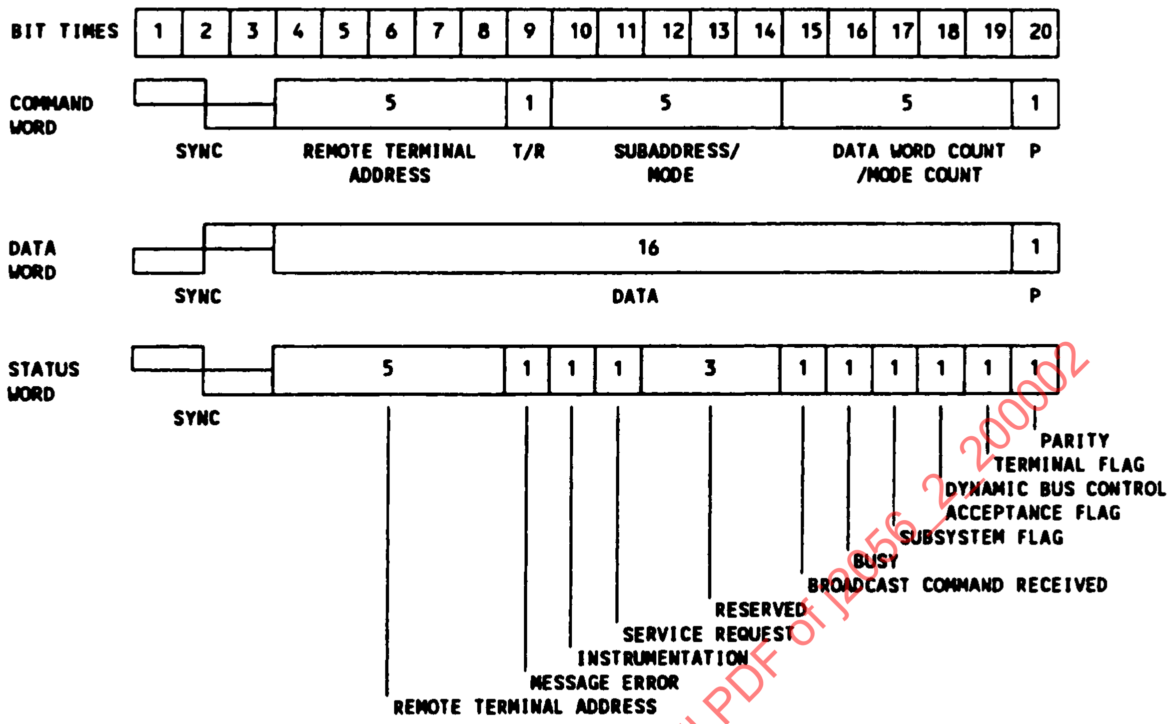


FIGURE 3—THREE PRIMARY SECTIONS OR WORDS

b. The message validation includes—The message is contiguous. This is taken to mean within words (Command, Data, Status). The bus controller shall provide a minimum gap time of 4.0 µs between messages, and the remote terminal will respond within a maximum response time (i.e., the remote terminal shall respond to a valid command word within the time period of 4.0 to 12.0 µs).
c. Additional errors identified are:

1. Message error
2. Busy
3. Subsystem flag
4. Terminal flag
5. Parity error (incorrect odd parity)
6. Improper sync
7. Invalid Manchester
8. Improper number of data bits and parity
9. Discontinuity of data words
10. No status word response

4.1.9 FAULT TOLERANCE—Not specified.

4.1.10 DATA RATE—Maximum specified bit rate is 1 Mb/s.

4.1.11 FRAMING OVERHEAD—Message length (see Figures 2 and 3) appears to be at least 60 bits in addition to the time between Control, Data, and Status Words (which allows 4 to 12 µs). Data Words allow 16 bits each and multiple Data Words may be used within a message. Each Data Word is 20 bits. Using the formula: OVERHEAD/MESSAGE = FRAMING / (FRAMING + DATA) approximate framing overhead per message calculated is 60/(60+40)=60%.

4.1.12 LATENCY—The total length for the frame is network latency which is dependent on several system factors. Framing overhead constants are included in Table 2.

TABLE 2—FRAMING OVERHEAD CONSTANTS

Constants	Bits
Command word	20
Status word	20
Response time	2-10
Intermessage gap	2-30
Mode codes without data words	20
Mode codes with data words	40
Data words	20
Non-stationary master bus controller passing	48 min

Stationary versus non-stationary bus controller systems may see different latency results.

The bus access method used may be either Master/Slave or a form of Token. In either case there are latency factors to be considered. In a master/slave system all communication goes through the master, effectively doubling overhead and/or latency. In a token system, latency is dependent in part on the number of nodes and the additional message traffic required for non-stationary master controller passing. Additionally, if the token is "lost" or nodes drop from the network, additional overhead is required for reconstructing the token ownership and/or the token passing path. Systems may be optimized through the construction of multiple paths for the token, i.e., a “fast loop” for high-priority nodes followed, by a “slow” loop which includes all nodes, followed by another “fast” loop for high-priority nodes again.

4.1.13 POWER REDUCTION MODE—Not specified.

4.2 Automotive Bit-Serial Universal-Interface System (ABUS)

4.2.1 APPLICATION/AFFILIATION—Designed for automotive applications by Volkswagen AG.

4.2.2 TRANSMISSION MEDIA—Not specified. Single wire suggested.

4.2.3 PHYSICAL INTERFACE—Not specified.

4.2.4 BIT ENCODING—NRZ with eight samples / bit, which means each sample is 1/8 the length of the bit. A valid bit has to have either four or six samples the same (see Figure 4). The requirement of either four or six required common samples is user selectable.

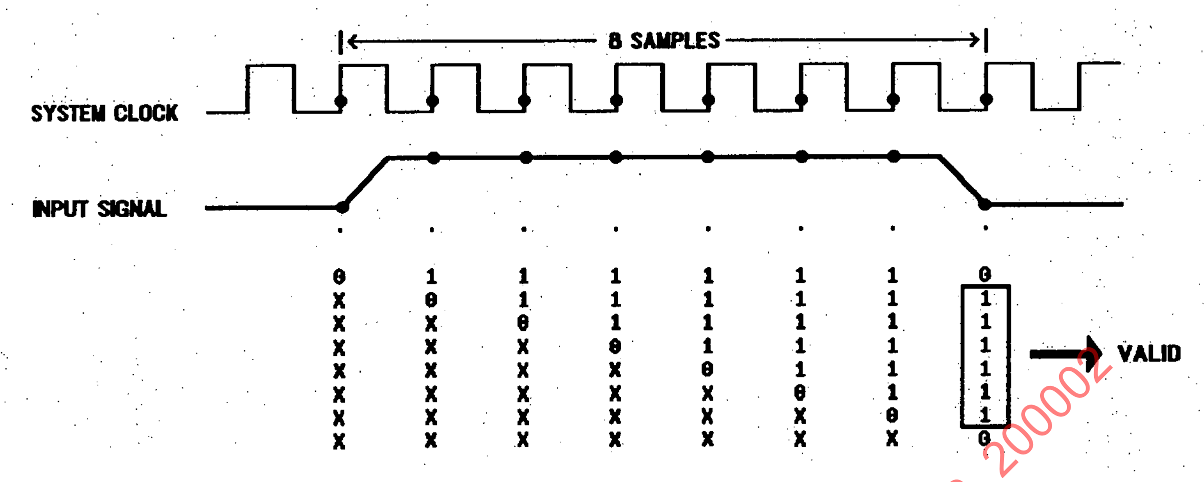


FIGURE 4—NRZ WITH EIGHT SAMPLES / BIT

4.2.5 Network Access—Contention using nondestructive bitwise arbitration. Arbitration occurs through the end of the identifier field.

4.2.6 Message Format—Message length is constant and consists of 1 start bit, 1 bit (NC/DAT) indicating whether it is a data message or a command message, an 11-bit identifier, 16 bits of data, and 2 stop bits (STP0, STP1). Further detail is provided in Figure 5. Two different types of messages are possible, the data message and the command message. Command messages may be used to insure that a following command will not be accepted on the bus until the receiver has read the command. The ABUS IC can be programmed in a way that every following command will not be accepted on the bus until the Master Controller Unit has read the command received last. In this case, no commands are lost.

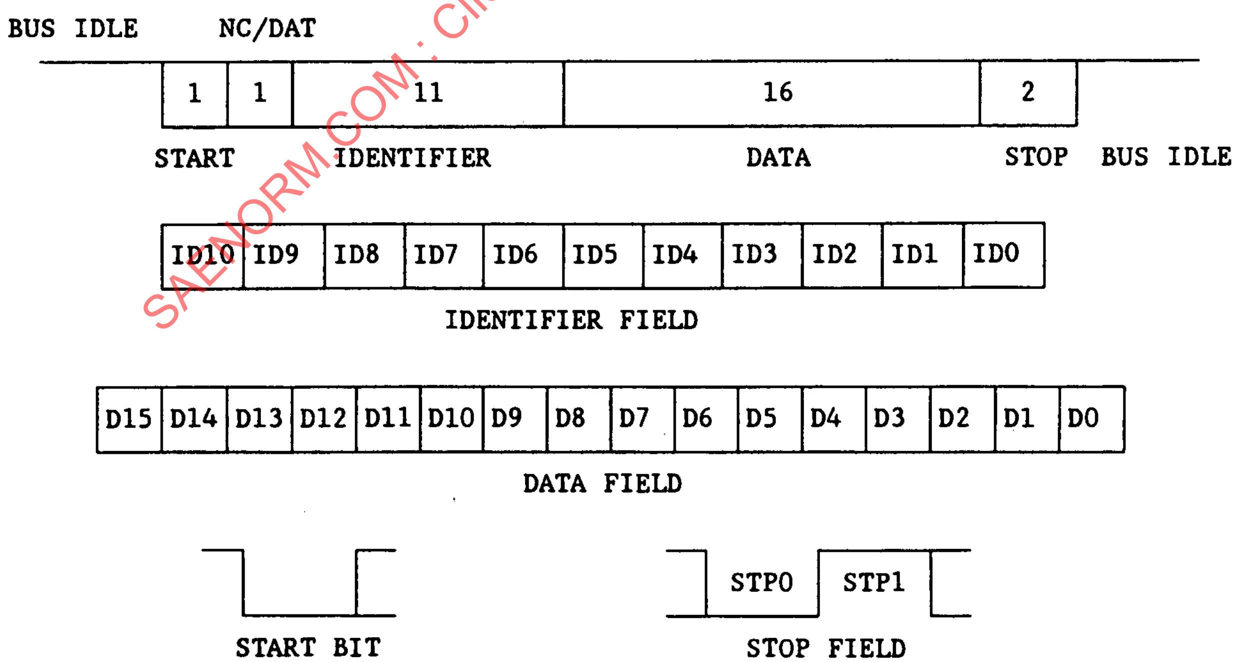


FIGURE 5—MESSAGE FORMAT

4.2.7 HANDSHAKING—Negative acknowledgement by receiver after error is detected. Any receiving device that notices a protocol error notifies all other bus members by pulling down the STP1 bit. If the STP1 bit is low, the message is regarded as invalid by all members. There is no required or dedicated positive acknowledgement.

4.2.8 ERROR DETECTION MANAGEMENT—The transmitter and receiver monitor the bus for errors. The transmitter reads its own message back from the bus and compares it with the message that it intended to send. The receiver detects code errors by sampling the bus and by comparing the samples. Four different types of errors are monitored:

a. Start-bit Error—it has not been possible to generate a start bit at the beginning of the transmission process.
b. Transmit Error—during transmission the value read back was not equal to the value sent out Y times consecutively between the arbitration and STP1 bit.
c. Receive Error—during reception an error has been detected X times consecutively prior to the STP1 bit.
d. Short Circuit—no logical "1" has been read for a period of 256 clock pulses after a high to low transition.

NOTE—X and Y are programmable values (to 8, 16, and 32). In the present implementation these error occurrences are stored in a status register and cause an interrupt. Before they are recognized as an error, the sender tries to send a message for 8 to 32 times.

4.2.9 FAULT TOLERANCE—Not specified.

4.2.10 DATA RATE—Maximum specified bit rate = 500 Kb/s.

4.2.11 FRAMING OVERHEAD—The message length is 31 bits, 16 of these are data. To transmit 4 bytes of data, 2 messages must be sent. Using Equation 1:

$$\text{OVERHEAD/MESSAGE} = \text{FRAMING/(FRAMING + DATA)} \quad \text{(Eq. 1)}$$

Approximate framing overhead/message calculated is: (15+15)/((15+16)+(15+16))=48%.

4.2.12 LATENCY—The ABUS protocol uses nondestructive bitwise arbitration in contention to determine bus access. In the case of two or more nodes beginning transmission simultaneously, the message with the highest priority will win the arbitration and continue transmission. As a result, the maximum latency for the highest priority message is the number of bits in the maximum length message multiplied by the time per bit. A 31-bit message will require 64 ms at 500 Kb/s. Lower priority messages may encounter additional delay in the event that they lose arbitration. Their latency may be determined based on a statistical analysis of the system (bus load, priority, other).

4.2.13 POWER REDUCTION MODE—The power consumption of the ABUS IC can be reduced by using the sleep mode. In this mode, the oscillator is turned off and the power consumption is reduced to 10 to 100 µA. The sleep mode is initiated by the host microprocessor. The IC will wake up either by a reset or by bus activity, but will go through a reset in either case. After the reset it will take about 50 ms for the oscillator to work properly, e.g., the first message works as an "alarm clock"—which implies it is not received completely.

4.3 Auto Local Area Network (AutoLAN)

4.3.1 APPLICATION/AFFILIATION—General Instrument's Transportation Electronics Division designed AutoLAN for transportation applications.

4.3.2 TRANSMISSION MEDIA—The transmission media is a dual twisted pair. One pair carries data and idle bits from the Master to all Slaves. The second pair carries data from the Slaves to the Master.

4.3.3 PHYSICAL INTERFACE—The Physical Interface utilizes a custom 68 pin PLCC package operating at 5 V (±0.5 V).

4.3.4 BIT ENCODING—Alternate Pulse Inversion which is a combination of Pulse Width Modulation and Pulse Inversion. Pulse Width Modulation was not used solely because a varying DC component (in the resulting signal) would not work with a transformer coupled system. See Figure 6.

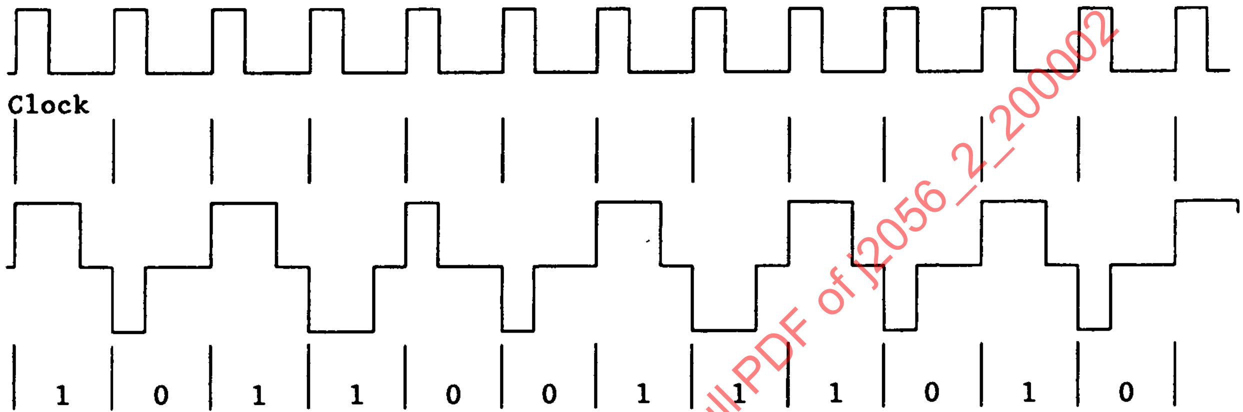


FIGURE 6—ALTERNATE PULSE INVERSION BIPOLAR DATA

4.3.5 MEDIA ACCESS—MASTER/SLAVE

4.3.6 MESSAGE FORMAT—See Figure 7. All messages have the same format.

START (1)	POLL/COMMAND (1)	ADDR (7)	DATA (16)	CRC (7)	STOP (1)

START : Unique signal
P/C : Message Type, Poll or Command
ADDR : Global or Node address
DATA : Input or Output Data, 16 inputs / 16 outputs
CRC : Cyclic Redundancy Check
STOP : Unique signal

FIGURE 7—MESSAGE FORMAT

4.3.7 HANDSHAKING—A Poll Request from the Master is transmitted to each Slave. The addressed Slave sends a Poll Reply which is the Slave's input status. From the Poll Reply, if the input status of the Slave has changed, the Master Polls the Slave and Broadcasts the information to all the Slaves in a Command Message (using a Global Address). All the Slaves read the Broadcast Message and determine what action, if any, should be taken. A Command Message does not require any acknowledgement from the Slaves.

4.3.8 ERROR DETECTION MANAGEMENT—If a Poll Request fails Framing, CRC, or Address Match, the message will be ignored. If a Poll Request message was received and the Poll Reply message failed the Framing, CRC, or Address Match test, the Master will generate a NACK interrupt to its processor.

4.3.9 FAULT TOLERANCE—If a transmission line is cut, all slaves beyond the cut are not accessible by the Master.

4.3.10 FRAMING OVERHEAD/LATENCY—Bit rates of up to 4 Mbps.

Dependent on the time it takes the Master to finally poll the particular slave; then, the time for the slave to reply with its status which, if changed since last poll, will be broadcasted to other slaves. See Table 3.

TABLE 3—FRAMING CONSTANTS

Constants	Bits
Start bit	1
Message Type	1
Global/Node address	7
Data	16
Cyclic Redundancy Check	7
Stop bit	1
Message length is 33 bits. Data Words allow 16 bits. So 16 data bits / 33 bits = 48%.	

4.3.11 POWER REDUCTION MODE—When Slaves stop receiving clock pulses from the Master, Slaves enter Rest Mode with all output circuits maintained. If the Master completely powers down (no DC current to Slaves), all Slaves enter Sleep Mode with less than 100 µs current draw per node.

4.3.12 CONTRIBUTORS

a. Abe Jacobs, General Instruments, El Paso
b. Whit Leverett, General Instruments, El Paso
c. Mike Thomas, General Instruments, Farmington Hills, Michigan

4.4 Class B Data Communication Network Interface (SAE J1850)

4.4.1 APPLICATION/AFFILIATION—The Society of Automotive Engineers (SAE) developed a vehicle data network for communications. A new revision (August 1991) of SAE J1850 has recently been approved by SAE for publication.

4.4.2 TRANSMISSION MEDIA—Three physical layer approaches have been defined: single wire voltage drive, dual wire voltage drive, and balanced current drive. For each of these approaches a different transmission media is specified. The medium for single wire is a single random lay wire. The medium for dual wire and balanced current drive is either a twisted or parallel wire pair.

4.4.3 PHYSICAL INTERFACE—A composite circuit diagram for the receiver/transmitter represents all three bus interfaces. This diagram is shown in Table 3.

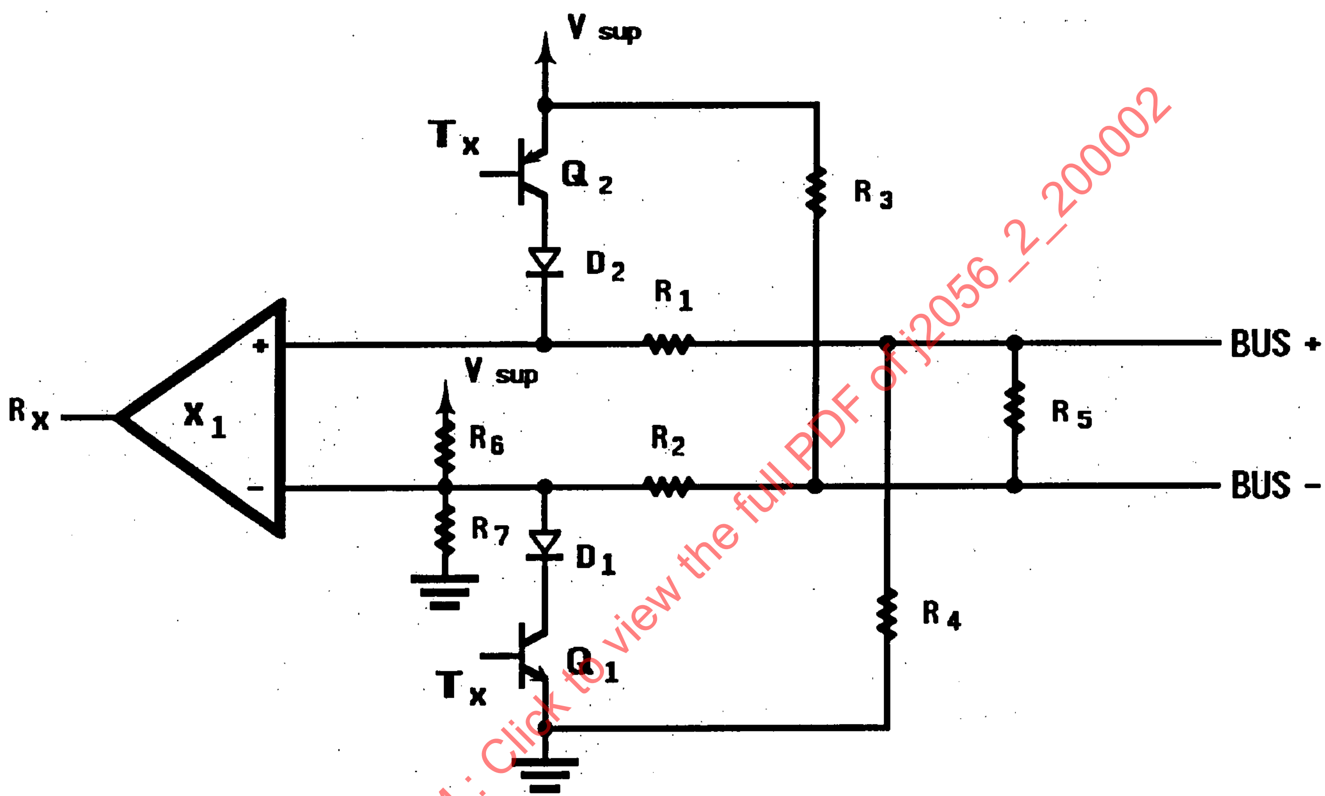


FIGURE 8—DIAGRAM OF SAE J1850 PHYSICAL INTERFACE

4.4.4 BIT ENCODING—Pulse Width Modulation. A "1" bit and "0" bit are shown in Figure 9. All bits are encoded in this manner except for a few unique symbols differentiated by the pulse timing. Some of the symbols include Start of Frame (SOF), End of Data (EOD), and End of Frame (EOF.) See Figure 9 for bit representations.

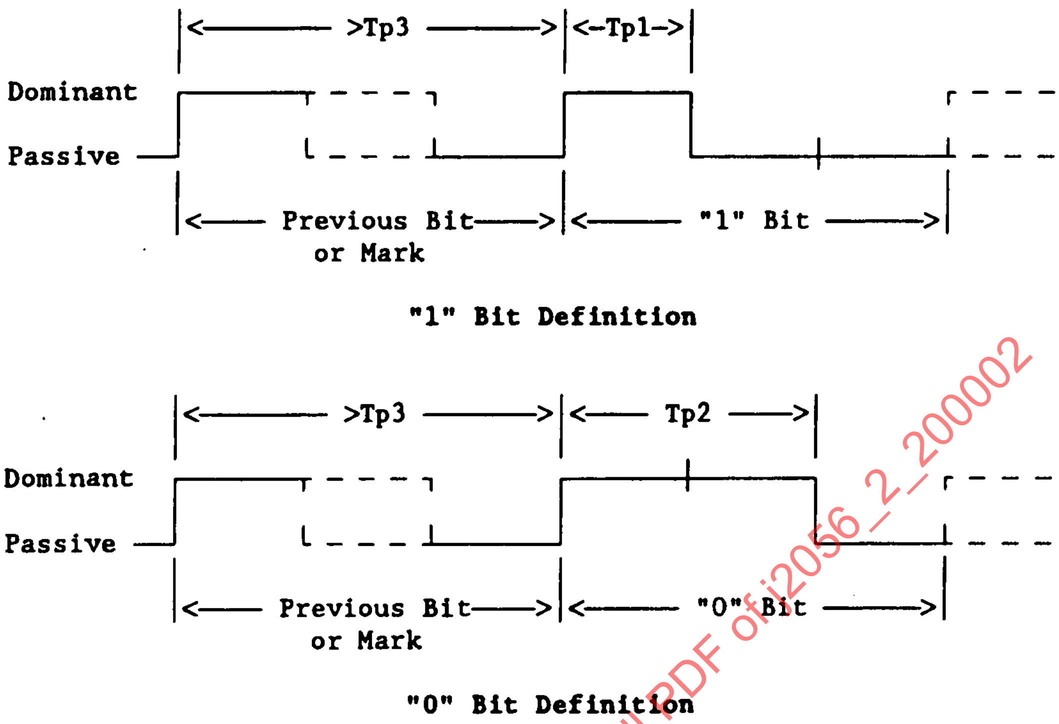


FIGURE 9—SAE J1850 BIT REPRESENTATION

4.4.5 NETWORK ACCESS—Nondestructive prioritized bitwise arbitration.

4.4.6 MESSAGE FORMAT—The maximum length for a message frame is 101 bit times. The error detection byte is included in the data field at the discretion of the designer. Another possible use of the data field could be a message/address identifier. The response byte is explained more fully in 4.4.7. Interframe spacing is nominally 2 bit times. The message frame is shown in Figure 10.

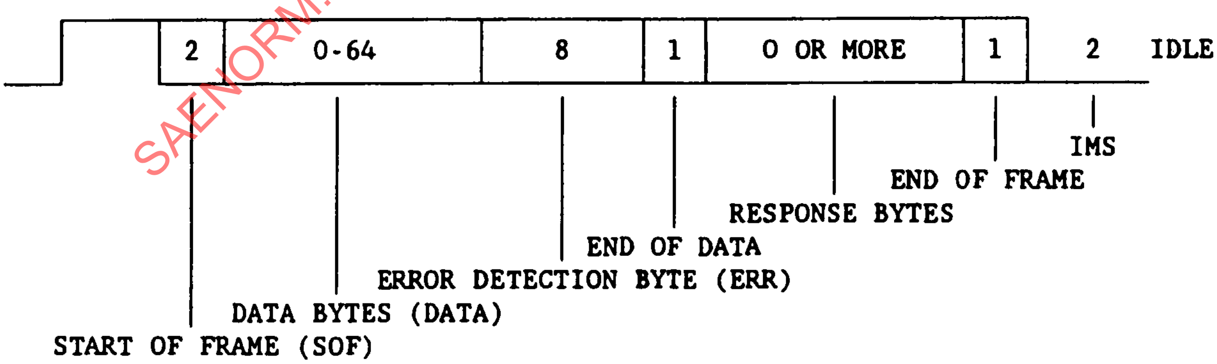


FIGURE 10—SAE J1850 MESSAGE FRAME

4.4.7 HANDSHAKING—Acknowledgement is provided in the message frame using the response bytes. The response byte appears after the EOD. If an acknowledgement is not expected, a response byte will not be sent, and the bus will remain in the passive state signifying an EOF. If the "In-Message Acknowledge/ Response" feature is active, then the response byte is an 8-bit acknowledge identifier, or one or more response bytes followed by an ERR byte. One or more nodes may attempt to respond to the requesting node and arbitration will occur during the response time period.

4.4.8 ERROR DETECTION MANAGEMENT—Includes detection of bus out-of-range, invalid bit value, and invalid message structure. An invalid bit or an invalid message will cause the receive process to be terminated until the next SOF. The in-message Error Detection field (ERR) uses an 8-bit CRC based on the polynomial: $x^8 + x^4 + x^3 + x^2 + 1$.

4.4.9 FAULT TOLERANCE—Continued network operation when a node loses power, bus short to ground, bus short to battery, transceiver failure, loss of connection to network is optional.

4.4.10 DATA RATE—The bit rates specified are 10 Kb/s and 40 Kb/s.

4.4.11 FRAMING OVERHEAD—The total length for the frame is 101 bit times. For the overhead calculation add 2 bits for IMS. The total length for the calculation becomes 103. The total allowed data is 80 bits (assume one byte for address/message identifier). The percentage of overhead is therefore 23/(88 + 23)=27.2%.

4.4.12 LATENCY—In a nondestructive bitwise arbitration scheme, the highest priority message/address will gain access to the bus. In a message priority scheme, a node will experience varying amounts of latency based on the average priority of messages to be transmitted. A node in an address priority system will experience a delay proportional to the priority level of its address and the activity on the bus. Example, a low priority node will experience higher than average latency during periods of high bus loading.

4.4.13 POWER REDUCTION MODE—A node should enter a "sleep state" if the bus is idle for more than 500 ms. "Wake-up" occurs with any activity on the bus.

4.5 Controller Area Network (CAN)

4.5.1 APPLICATION/AFFILIATION—Both Standard (S) and Extended (E) message format is intended for automotive in-vehicle applications. A draft standard within ISO. Published within SAE via Information Report SAE J1583.

4.5.2 TRANSMISSION MEDIA—Not specified. Most of the announced production-intent systems use a wire shielded or unshielded bus. Fiber optic systems using CAN have been demonstrated.

4.5.3 PHYSICAL INTERFACE—User defined. One specific implementation is defined in Bosch presentations and documents to ISO.

4.5.4 BIT ENCODING—NRZ (Non-Return to Zero) with bit stuffing (see Figure 11). Logic level is constant for entire bit field (i.e., either 1 or 0) and bit of opposite state is inserted into bit stream by transmitter if 5 contiguous bits of the same state are seen. Receivers remove the inserted bit from the bit stream resulting with the original data stream. Implementations are programmable to allow either 3 or 1 samples per bit and specify the location of samples within a bit.

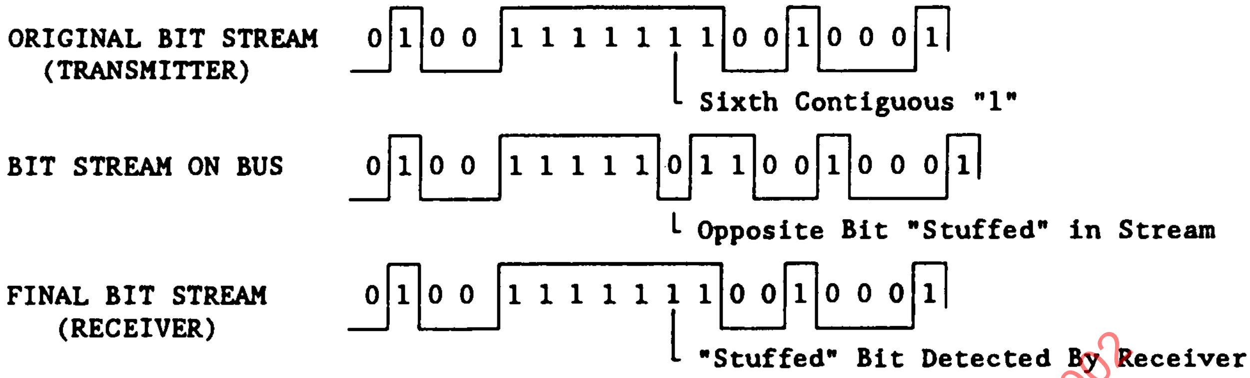


FIGURE 11—NRZ BIT "STUFFING"

4.5.5 NETWORK ACCESS—Contention using nondestructive bitwise arbitration. Any node may transmit if the bus is idle. In the case of simultaneous transmissions, arbitration is resolved through the value in the identifier field. The message priority is defined in the identifier. Each message has a unique identifier, and as a result a unique priority. These identifiers/priorities are defined by the user (system designer).

4.5.6 MESSAGE FORMAT—Primarily 3 message types:

a. Data Frame (see Figure 12)
b. Remote Frame (see Figure 13)
c. Error Frame (see Figure 14)
d. Overload Frame (used in events where individual node has not had complete time to store message, see Figure 15)

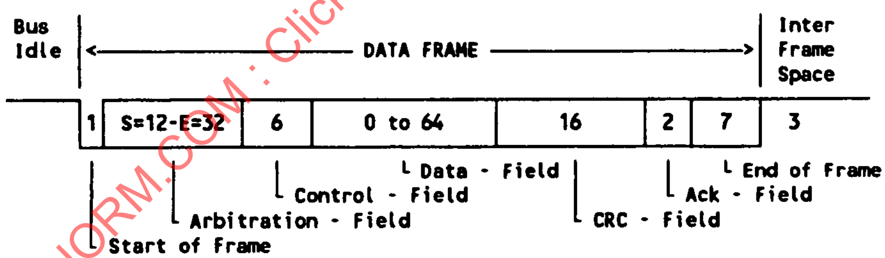


FIGURE 12—DATA FRAME

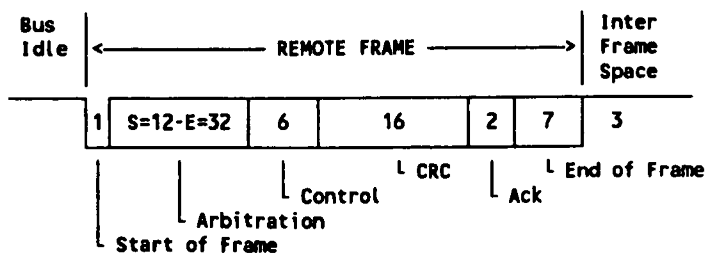


FIGURE 13—REMOTE FRAME

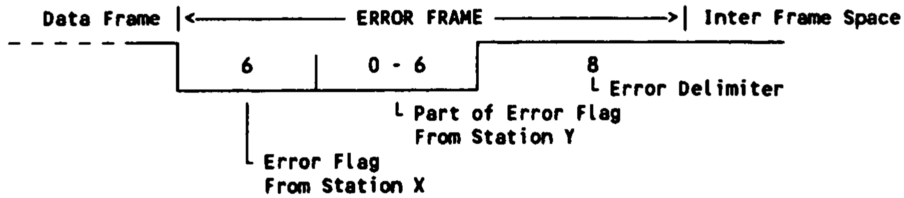


FIGURE 14—ERROR FRAME

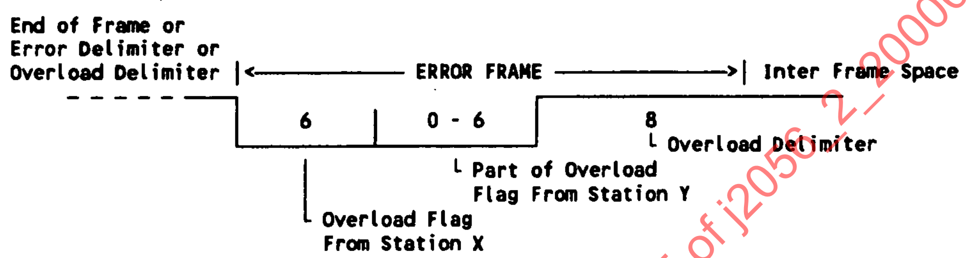


FIGURE 15—OVERLOAD FRAME

4.5.7 HANDSHAKING—Handshaking is provided within the message via either positive or negative acknowledgement. Positive acknowledgement is provided by a dedicated 2-bit field (1 bit for acknowledgement, 1 bit for delimiter) in the message frame. All nontransmitting nodes will confirm uncorrupted message reception by transmitting a "dominant" bit in this dedicated field. As a result, the transmitting node receives confirmation that the message was received uncorrupted and does not have independent acknowledgements from individual nodes. Negative acknowledgement is provided through the Error Frame (see Figure 15 for additional detail).

4.5.8 ERROR DETECTION MANAGEMENT—All nodes monitor all messages. If an error is detected within a message then the node(s) detecting that error destroys that message by transmitting an error frame. The result of this error frame is that all nodes (including the transmitting node) know that an error has been detected within the present message. The transmitter will retransmit the message at its next opportunity (through normal bus access arbitration). Error checking is provided on CRC, message length (message length is specified in the control field), message format, and bit level and timing.

4.5.9 FAULT TOLERANCE—Protocol is intended to be orthogonal, i.e., all nodes address faults in the same manner. Fault confinement is provided by each node constantly monitoring its performance with regard to successful and unsuccessful message transactions. Each node will act on its own bus status based on its individual history. As a result, graceful degradation allows a node transmitter to disconnect itself from the bus. If the bus media is severed or shorted, the ability to continue communications is dependent upon the condition and the physical interface used.

4.5.10 DATA RATE—Bit rate of up to 1 Mbits/s.

4.5.11 FRAMING OVERHEAD—Maximum message length (maximum time between messages) is 111 bit times for Standard Format and 131 bit times for Extended Format, i.e., 111 and 131 µs at 1 Mb/s. For the highest priority message, if a message has just begun and the message in question is queued up the latency will be 111/131 µs, and 222/262 µs maximum until its transmission is complete.

Maximum time between messages with four bytes data is 79 bits for Standard Format and 99 bits for Extended Format (please note: this includes Interframe Space). For a message transmitting 4 bytes of data, using the formula: OVERHEAD/MESSAGE = FRAMING / (FRAMING + DATA) the approximate framing overhead/message calculated for Standard Format is: 47/(47+32)=59%. For 8 data bytes the approximate framing overhead/message calculated is 47/(47+64)=42%. For Extended Format is 67/(67+32)=68% and 67/(67+64)=51%, respectively, (does not include Bit Stuffing).

4.5.12 LATENCY—The CAN protocol uses nondestructive bitwise arbitration in contention to determine bus access. In the case of two or more nodes beginning transmission simultaneously, the message with the highest priority will win the arbitration and continue transmission. As a result, the maximum latency for the highest priority message is the number of bits in the maximum length message multiplied by the time per bit (in other words 111 bits times or 111 µs at 1 Mbit/s for Standard Format and 131 bits times or 131 µs at 1 Mbit/s for Extended Format). Lower priority messages may encounter additional delay in the event that they lose arbitration. Their latency may be determined based on a statistical analysis of the system (bus load, priority, other).

4.5.13 POWER REDUCTION MODE—Not specified.

4.6 Digital Data Bus (D2B)

4.6.1 APPLICATION/AFFILIATION—Digital Data Bus is a product of Philips for use in Audio/Video communications, computer peripherals and automotive.

4.6.2 TRANSMISSION MEDIA—Twisted pair.

4.6.3 PHYSICAL INTERFACE—Differential floating pair. See Figure 16.

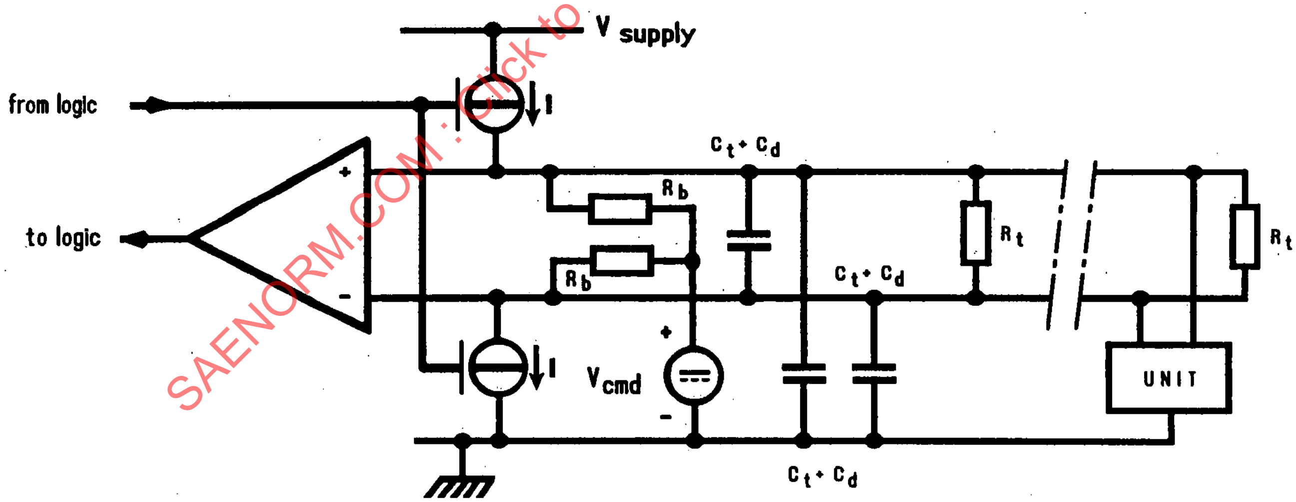


FIGURE 16—D2B PHYSICAL INTERFACE

4.6.4 BIT ENCODING—Pulse Width Modulation (PWM). The general bit format is comprised of four sections:

a. The preparation period
b. The sync period
c. The data period
d. The stop period

The duration of the periods and the bit is dependent on the speed of the bus and the type of the bit. The speed of the bus is determined during contention. Low speed is dominant. There are three speeds possible. The general bit format is shown in Figure 17.

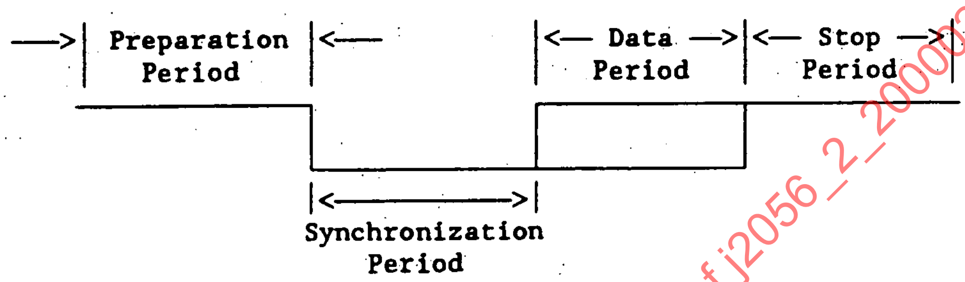


FIGURE 17—PULSE WIDTH MODULATION BIT FORMAT

4.6.5 NETWORK ACCESS—Access is achieved by contention using nondestructive prioritized bitwise arbitration. Competing nodes arbitrate first on the mode in which the node will operate (3-bit field), where low mode is dominant, then all nodes in a common mode arbitrate based on the unique address bits of the competing masters. Low address is dominant. The mode designates the speed at which the bus will operate during the message transfer. A unit may use the bus for one time slot. The amount of data transferred in the time slot depends on the speed mode determined during arbitration.

4.6.6 MESSAGE FORMAT—The message frame consists of 6 fields. A parity bit follows the master, slave, control, and data fields. An acknowledge bit follows the slave field, control field, and the data field. An end-of-data bit follows each data byte. The total length of the frame is 47 bits. See Figure 18 for the frame.

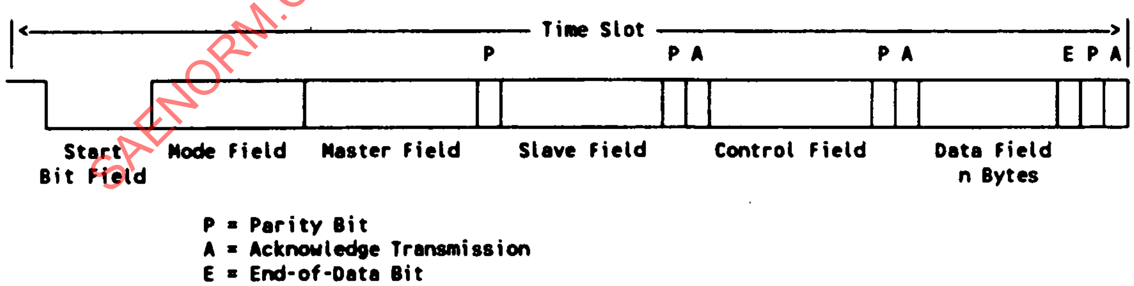


FIGURE 18—SIX FIELD MESSAGE FORMAT

4.6.7 HANDSHAKING—Handshaking is accomplished with positive acknowledgement in the transfer message. No reply from the slave is interpreted as a negative acknowledgement. The master can retry the message provided time remains in the slot. During every transfer there are three different acknowledge bits:

a. After the slave address
b. After the control bits
c. After each data byte

A master has the ability to lock a slave node to its address having the effect of disabling the node from communicating with any other master on the network. This is done when a data transfer exceeds the time slot and the master must arbitrate again for the bus to complete the data transfer.

4.6.8 ERROR DETECTION MANAGEMENT—Error checking is performed through odd parity on the slave address, control field, and after each data byte. The acknowledge bit in the transfer message will not be transmitted by the addressed slave if there is a parity error, the speed mode is too high, timing error, slave locked to another master, or the receive buffer is full.

4.6.9 FAULT TOLERANCE—Fault tolerance for nodes is not specified.

4.6.10 DATA RATE—The maximum bit rate is 1 Mb/s. Three different transmission speeds are allowed.

4.6.11 FRAMING OVERHEAD—The total frame size is 34 bits including Inter Frame Separation. In speed mode 1, 32 data bytes can be transferred from master to slave. Therefore the percentage of overhead is 34/34+256 =11.7%.

4.6.12 LATENCY—D2B allows for three different speed modes for transmission and arbitrates on the address of the competing nodes once in a speed mode. Therefore a low priority node may experience high latency times vs. the average. Latency is also affected by the ability of a master to lock a slave node; a locked node will not respond to any messages, and in certain situations this could degrade the overall performance of the system.

4.6.13 POWER REDUCTION MODES—Power reduction modes are available for the bus controllers.

4.7 Ethernet (IEEE 802.3)

4.7.1 APPLICATION/AFFILIATION—Ethernet is specified by IEEE 802.3. While not restricted to specific applications, Ethernet was developed as a laboratory network. Additionally it is used in CAE/CAD workstation clusters, office or business type network or low-cost PC environments. Ethernet falls into the 10BASE5 category which shows the characteristics of 10 Mb/s, baseband, and segments up to 500 m. Other protocols or implementations falling within the IEEE 802.3 specification include Cheapernet, Thinnet, Thinwire ENET, and Starlan. This summary will focus on Ethernet.

4.7.2 TRANSMISSION MEDIA—"Thick" coaxial cable defined as a 0.4-in, heavily shielded, 50-Ω coaxial cable which extends in segments of up to 500 m with passive terminators at either end.

4.7.3 PHYSICAL INTERFACE—Nodes are connected to the segment with a cable tap, a transceiver, and a shielded, twisted pair transceiver cable which can extend up to 50 m. The transceiver is isolated from the main cable by use of AC/DC converters and pulse transformers or optoisolators. Three signals—transmit, receive, and collision presence—are carried between the transceiver and the node.

4.7.4 BIT ENCODING—Baseband signalling and Manchester phase encoding at a 10 Mb/s rate.

4.7.5 NETWORK ACCESS—CSMA/CD (Carrier Sense Multiple Access / Collision Detect) is the medium access method. Each transmitting node that detects a collision (by sensing an abnormal voltage level on the cable) sends a short "jamming" signal to ensure collision detection by the entire network. The period that each station must wait after detecting a collision before attempting to transmit again is governed by a truncated binary exponential backoff algorithm, which specifies a random waiting time. The random time is chosen from a window whose size is a binary multiple of the round-trip propagation delay time of the network, called the slot time. The window size increases by a power of two after each collision until the tenth collision, after which it remains the same. Each transmission attempt is allowed a maximum 16 collisions before the higher layers are signalled that the message is undeliverable.

4.7.6 MESSAGE FORMAT—An Ethernet frame is made up of seven fields (see Figure 19). The first field is a 56-bit preamble used for hardware synchronization. This field is followed by an 8-bit start-of-frame delimiter field, two 6-byte address fields for destination and source addresses, and a 2-byte length field indicating the actual length of the data. This is followed by the data or information field, which must be a minimum 46 bytes and a maximum 1500 bytes. The last field is a 32-bit frame check sequence, which contains the cyclic redundancy check (CRC) for the frame.

7 BYTES	1 BYTE	6 BYTES	6 BYTES	2 BYTES	46-1500 BYTES	4 BYTES	
Preamble	Start Frame Delimiter	Dest Addr	Source Addr	Length Field	Data Field	Frame Check Sequence	End Frame Delimiter

FIGURE 19—SEVEN FIELD MESSAGE FORMAT

4.7.7 HANDSHAKING—Not specified.

4.7.8 ERROR DETECTION MANAGEMENT—Information reported on transmitted message events includes:

a. Transmission successful
b. Transmission unsuccessful due to lost Carrier Sense
c. Transmission unsuccessful due to lost Clear-to-Send
d. Transmission unsuccessful due to DMA underrun because the system bus did not keep up with the transmission
e. Transmission unsuccessful due to number of collisions exceeding the maximum allowed.

Information reported on incoming message events includes:

a. CRC error due to incorrect CRC in a well-aligned frame
b. Alignment error due to incorrect CRC in a misaligned frame
c. Frame too short—The frame is shorter than the configured value for minimum frame length
d. Overrun since the frame was not completely placed in memory because the system bus did not keep up with incoming data
e. Out of buffers, i.e., no memory resources to store the frame, so part of the frame was discarded

4.7.9 FAULT TOLERANCE—Specific implementations may provide a set of network-wide diagnostics that can serve as the basis for a network management entity. The primary reference used for the following information is the Intel 82586. Networked activity information provided includes number of collision and deferred transmissions. Statistics information includes number of CRC errors, alignment errors, no-resources (correct frames lost due to lack of memory resources) and overrun errors (number of frame sequences lost due to DMA overrun).

Additional diagnostics are provided by the external and internal loopback modes where the node can be configured to verify the transceivers collision detection circuitry, the transmit circuitry, the receive circuitry, internal memory, and the exponential backoff random number generator internal to the device.

4.7.10 DATA RATE—Bit rate of 10 Mb/s.

4.7.11 FRAMING OVERHEAD—Overhead is approximately 24 bytes (though some of the fields are specified in bit lengths). The data field is 46 bytes minimum to 1500 bytes maximum. Using the formula: OVERHEAD/MESSAGE = FRAMING / (FRAMING + DATA) the approximate worst case overhead calculated is 192 bits/(192 bits+368 bits)=34%. The approximate best case calculated is 192/(192+12000)=2%. Although a message with only 4 bytes of data is not allowed, its overhead would be 192/(192+32)=86%.

4.7.12 LATENCY—Ethernet is a nondeterministic contention protocol. Since collisions are resolved through a back-off scheme, latency may be significant for very low priority messages relative to a nondestructive bitwise arbitration protocol. Latency may be determined based on a statistical analysis of the system (bus load, priority, other).

4.7.13 POWER REDUCTION MODE—Not specified.

4.8 Joint Integrated Avionics Working Group (JIAWG)

4.8.1 APPLICATION/AFFILIATION—The High Speed Data Bus protocol was used in a demonstration project and will be succeeded by a protocol developed by the Joint Integrated Avionics working group (JIAWG). This protocol may be the next generation MIL-STD-1553. This survey encompasses the protocol information which the JIAWG has defined. The current applications for this protocol are military avionics, particularly the ATF, ATA, and LHX programs.

4.8.2 TRANSMISSION MEDIA—Fiber optics.

4.8.3 PHYSICAL INTERFACE—Requirements for the Physical Layer are defined in 'The Linear Token Passing Multiplex Bus Protocol (J88-M5).'

4.8.4 BIT ENCODING—The encoding format is Manchester II biphase level. A logic one is transmitted as a unipolar coded signal 1/0. A logic zero is transmitted as a unipolar coded signal 0/1.

4.8.5 NETWORK ACCESS—Token passing.

4.8.6 MESSAGE FORMAT—There is no interframe gap between frames generated from the same station for a given possession of the token. When multiple frames are transmitted for a given possession of the token, only the first frame shall be preceded by a preamble. Refer to Figures 20, 21, and 22.

A node will transmit a claim token frame immediately after the 'Bus Activity Timer' times out.

SD (4)	0 (1)	TDA (7)	TFCS (8)	ED (4)

SD : Start Delimiter - Identifies the start of message.

TDA : Token Destination Address - Specifies Physical Address of where Token is being sent.

TFCS : Token Frame Check Sequence - Checks for bit errors within each token frame.

ED : End Delimiter - Identifies the end of message.

FIGURE 20—CLAIM TOKEN FRAME

SD (4)	FC (8)	0 (1)	SA (7)	FW (1024)	ED (4)

SD : Start Delimiter - Identifies the start of message.

FC : Frame Control - Identifies Frame Type and Priority.

SA : Source Address - Identifies the physical address of node sending the message.

FW : Fill Words

ED : End Delimiter - Identifies the end of message.

FIGURE 21—CLAIM TOKEN FRAME

SD (4)	FC (8)	0 (1)	SA (7)	MDA (15)	WC (16)	INFO (16-65536)	MFCS (16)	ED (4)

SD : Start Delimiter - Identifies the start of message.

FC : Frame Control - Identifies Frame Type and Priority.

SA : Source Address - Physical address of node sending the message.

MDA : Message Destination Address - Identifies a Physical or Logical Address of where message is being sent.

WC : Word Count - Specifies the number of 16-bit fields in the INFO field.

INFO : Information - Contains 1 to 4096 words of message data.

MFCS : Message Frame Check Sequence - Checks for bit errors within each message frame.

ED : End Delimiter - Identifies the end of message.

FIGURE 22—MESSAGE FRAME

4.8.7 HANDSHAKING—A message may be received by all nodes or any subset of nodes except the transmitting node. Nodes accept messages based on physical addressing, logical addressing, or broadcast addressing.

4.8.8 FAULT TOLERANCE—The bus is dual redundant (each node has two transmitters and two receivers). When a station transmits a message, it goes onto both redundant buses at the same time. The receiving node(s) only takes the message off of one bus, until there is an error, and then it switches to the other bus. If both buses are bad in the same place in the data, the message is discarded.

When a node failure occurs, the reconfiguration will occur when the failed station's predecessor in the logical ring attempts to pass the token to it. After two unsuccessful attempts, the node will pass the token to the failed node's successor.

If a node fails while possessing the token, the network will reinitialize itself due to no activity on network.

4.8.9 DATA RATE—Bit rate of up to 50 Mbps.

4.8.10 FRAMING OVERHEAD—Maximum message length is 65608 bit times.

Maximum time between message with four bytes data is 104 bits.

Framing / Framing + Data

$$2-\text{word Data Message} = \frac{72\text{ bits overhead}}{104\text{ overall bits}} = 70\% \quad \text{(Eq. 2)}$$

$$256-\text{word Data Message} = \frac{72\text{ bits overhead}}{4168\text{ overall bits}} = 2\% \quad \text{(Eq. 3)}$$

$$4096-\text{word Data Message} = \frac{72\text{ bits overhead}}{65608\text{ overall bits}} = 0.1\% \quad \text{(Eq. 4)}$$

4.8.11 POWER REDUCTION MODE—Not specified.

4.8.12 CONTRIBUTORS—James H. Nelson, Northrop Aircraft Division, Hawthorne, California

4.9 Mini-Manufacturing Automation Protocol (Mini-MAP)

4.9.1 APPLICATION/AFFILIATION—Mini-MAP was designed for Factory Floor applications, specifically automation. The three ISO layer Mini-MAP carrierband has an IEEE 802.4 Standard Interface.

4.9.2 TRANSMISSION MEDIA—The transmission media is unshielded twisted pair (broadband), shielded twisted pair, coaxial cable, or fiber optics.

4.9.3 PHYSICAL INTERFACE—The Physical Interface for a mini-MAP network is product specific. The Physical Layer restrictions are described in IEEE 802.4 (1989 Chapters 12,13).

4.9.4 BIT ENCODING—5 Mbps carrierband:

a. 5 MHz represents zero's
b. 10 MHz represents one's

4.9.5 NETWORK ACCESS—Token passing. Refer to Figure 23.

SD (8)	DA (16)	SA (16)	MAC (8 - 65776)	FCS (32)	ED (8)

SD (Start Delimiter)	:	Indicates Start of Message
DA (Destination Address)	:	Specifies address of where token is being passed
SA (Source Address)	:	Specifies transmitter address
MAC (Media Access Control)	:	Contains LLC (Logical Link Control) which holds the Function Code. Contains message data (if appropriate) Contains control code (i.e., acknowledgement message, a read command, a write command)
FCS (Frame Control Sequence)	:	Code for passing Token
ED (End Delimiter)	:	Indicates End of Message

FIGURE 23—MESSAGE FORMAT

4.9.6 HANDSHAKING—Acknowledgements are optional. An acknowledgement will be placed in the Media Access Control Field of a new frame.

4.9.7 ERROR DETECTION MANAGEMENT—If a node fails to receive or pass the token, that node will be patched out of the network. If a node fails while possessing the token, the network will reset itself to recover the token.

4.9.8 FAULT TOLERANCE—A network is protected by the ratio of taps. A node can be removed from the network without affecting the operation of the other nodes.

4.9.9 DATA RATE—Bit rate of up to 20 Mbps.

4.9.10 FRAMING OVERHEAD—Maximum message length is 65856 bit times.

4.9.11 LATENCY—The latency a node encounters when needing to get on the bus depends on the time it takes for the Token to get passed to the node.

4.9.12 POWER REDUCTION MODE—Not specified.

4.9.13 CONTRIBUTORS

a. Robert Yee, Ford Motor Company, Dearborn, Michigan
b. Robert Crowder, Ship Star Associates, Newark, Delaware
c. Keith McNab, Industrial Technology Institute, Ann Arbor, Michigan

4.10 Synchronous Data Link Control/High-Level Data Link Control (SDLC/HDLC)

4.10.1 APPLICATION/AFFILIATION—SDLC was originally designed for computer-to-computer and computer-to-terminal applications by IBM. HDLC is a standard communication link protocol established by International Standards Organization (ISO).

4.10.2 TRANSMISSION MEDIA—Not specified. (SDLC/HDLC is a data link layer protocol only.)

4.10.3 PHYSICAL MEDIA—Not specified. (SDLC/HDLC is a data link layer protocol only.)

4.10.4 BIT ENCODING—NRZ and NRZI (NRZ Inverted). NRZI is used to ensure that within a frame, data transitions will occur at least every five bit times.

Zero insertion and deletion is performed automatically. A binary "0" is inserted by the transmitter after any succession of five "1's" within a frame. The receiver deletes the binary "0" that follows any five continuous "1's" within a frame.

4.10.5 NETWORK ACCESS—Not specified. (SDLC/HDLC is a data link layer protocol only.)

4.10.6 MESSAGE FORMAT—Transmit and receive data are contained in a format called a frame. All frames start with an opening flag and end with a closing flag. Between the opening flag and closing flag, a frame contains an address field, a control field, an optional information field and a frame check sequence field.

The fields that make up a frame and their sizes are shown in Figure 24.

The flag is a unique binary pattern (01111110). It provides the frame boundary and a reference for the position of each field of the frame. Optionally two successive frames can share one flag as the closing flag of one frame and the opening flag for the next frame. The receiver searches for a flag on a bit by bit basis and recognizes a flag at any time. The receiver establishes the frame synchronization with every flag. The flags mark the frame boundary and reference for each field.

The 8 bits following the opening flag are the address field. The address field can be extended if selected as an option. The 8 bits following the address field are the control field. The control field can be extended if selected as an option. The information field follows the control field and precedes the Frame Check Sequence field (FCS). The information field contains the "data" to be transferred, if any, but is not always contained in every frame. The information field will continue until it is terminated by the 16 bit FCS and the closing flag. The information field may be subdivided into 5, 6, 7, or 8 bit words. The 16 bits preceding the closing flag form the Frame Check Sequence field. The FCS is a cyclic redundancy check character.

FLAG	address	control	information	FCS	FLAG
8	X * 8	Y * 8	Z * WS	16	8

where:

FLAG = <01111110>

FCS = a 16 bit CRC

WS = word size (5, 6, 7 or 8 bits)

X = number of bytes in the address field

Y = number of bytes in the control field

Z = number of words (see WS above)

FIGURE 24—MESSAGE FRAME FORMAT

4.10.7 HANDSHAKING—The SDLC/HDLC protocol allows the user to select between full duplex, half duplex, synchronous, asychronous, point to point, and loop communication modes.

In loop mode, a master station sends messages which all slave stations relay from one to another, until the message is received back by the master. Any slave station finding its address in the message receives the frame.

4.10.8 ERROR DETECTION MANAGEMENT—The following errors are identified: FCS (i.e., CRC) errors, more than six '1' bits consecutively, and minimum frame size errors are detected when receiving.

4.10.9 FAULT TOLERANCE—Not specified.

4.10.10 DATA RATE—Data rates are not specified for SDLC/HDLC as it is only a data link layer protocol.

4.10.11 FRAMING OVERHEAD—There are a minimum of six (6) bytes of overhead in every message. The length of the information field has no specified maximum. The actual sizes of the address field, control field, and the information field for a given SDLC/HDLC network implementation determines the amount of framing.

4.10.12 LATENCY—The network topology (e.g., point to point, loop, master/slave, full duplex, half duplex), network size and message sizes determines message latency.

4.10.13 POWER REDUCTION MODE—Not specified.

4.11 Token Ring (IEEE 802.5)

4.11.1 APPLICATION/AFFILIATION—Token Ring is specified in IEEE standard 802.5. The protocol was created, "for the purpose of compatible interconnection of data processing equipment."(1)

4.11.2 TRANSMISSION MEDIA—Shielded twisted pair is the media of choice but the specification allows for the use of coaxial cable and optical fiber.

4.11.3 PHYSICAL INTERFACE—The node is connected to the trunk cable that serves as the ring through two balanced twisted pair cables to a trunk coupling unit (TCU). Insertion into the ring is achieved by a "phantom circuit technique." The node impresses a DC voltage on the cables that connect it to the TCU. This DC voltage is transparent to the passage of signals on the ring and allows the TCU to insert the node onto the ring. This connection technique provides for node detection of open circuits, shorts, and node self-test. Refer to Figure 25 for more details.

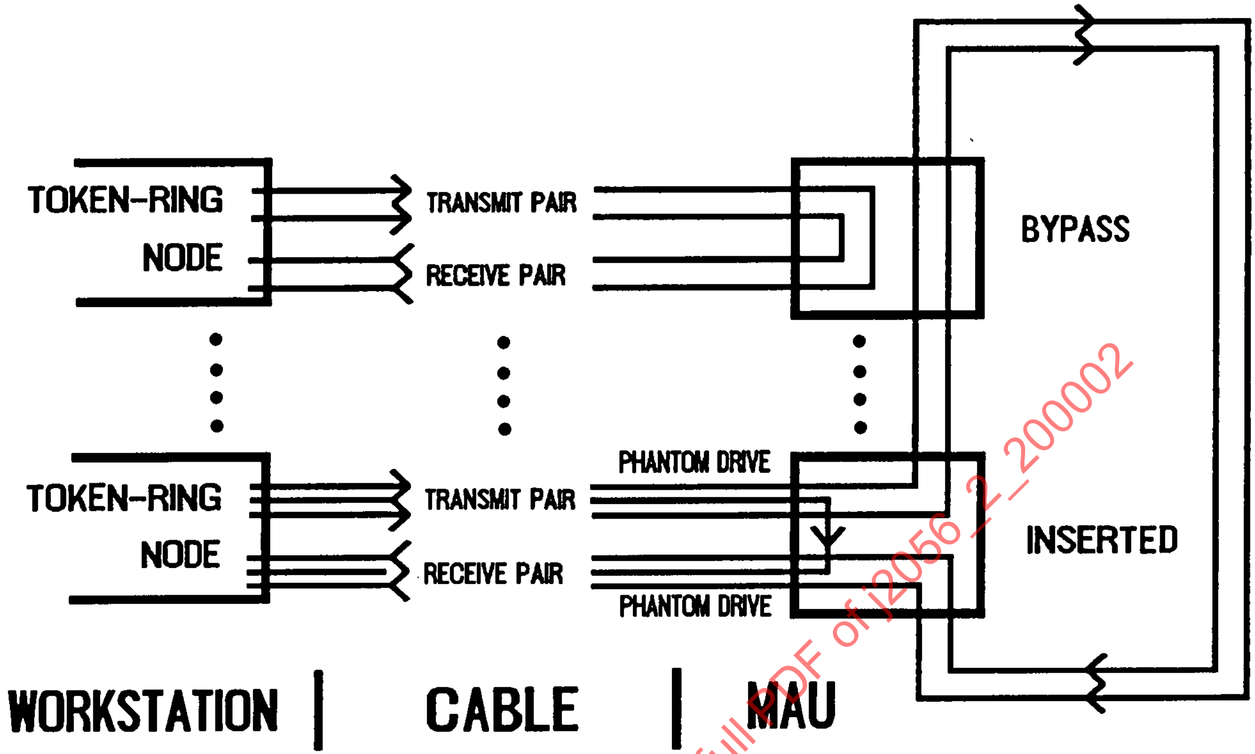


FIGURE 25—TOKEN RING PHYSICAL INTERFACE

4.11.4 Bit Encoding—Coding is accomplished with differential Manchester-type.

It includes 4 symbols:

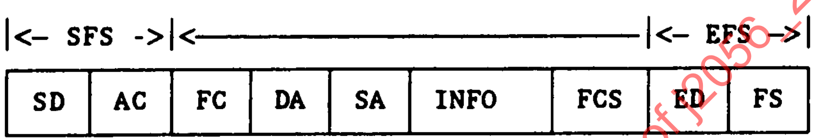
a. Binary zero (0)
b. Binary one (1)
c. Non-data-J (J)
d. Non-data-K (K)

4.11.5 Network Access—Any node may gain access by capturing the "token" that circulates the ring. The token consists of a 24-bit frame with unique signals that characterize the frame as a token. The token will have a priority assigned. A node may use the token only if its message is of equal or greater priority. Priorities are common for all nodes on the ring. Upon receiving the token, a node will transform it to a start-of-frame sequence by changing the token bit. A token holding timer controls the amount of time a node can use the token. When a node is not active, it will receive and retransmit each bit that is on the bus.

4.11.6 MESSAGE FORMAT—The token consists of three 8-bit fields. See Figure 26. The frame can range from 13 bytes (no information or data) to 21 bytes with the information field limited only by the maximum frame time. The maximum frame time is set for each ring. See Figure 27 for the frame. The configuration of the starting delimiter (SD), access control (AC), and frame control (FC) are shown in more detail in Figure 28.

SD - Starting Delimiter (1 octet)
AC - Access Control (1 octet)
ED - Ending Delimiter (1 octet)

FIGURE 26—TOKEN THREE FIELD FORMAT



SFS - Start-of-Frame Sequence
SD - Starting Delimiter (octet)
AC - Access Control (1 octet)
FC - Frame Control (1 octet)
DA - Destination Address (2 or 6 octets)
SA - Source Address (2 or 6 octets)

INFO - Information (0 or more octets)
FSC - Frame-Check Sequence (4 octets)
EFS - End-of-Frame Sequence
ED - Ending Delimiter (1 octet)
FS - Frame Status (1 octet)

FIGURE 27—FRAME DEFINITION

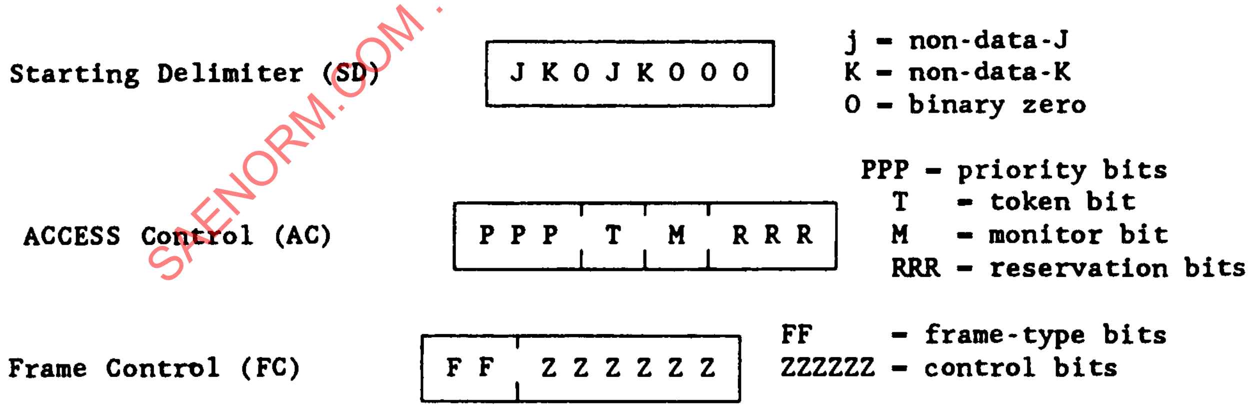


FIGURE 28—FRAME CONFIGURATION

4.11.7 HANDSHAKING—A transmitting node will append information to the token (the token becomes part of the frame) and send. A node(s), upon recognition of its address or a broadcast address, will copy the information into its receiving buffer and change the bits in the Frame Status (FS) field. These bits are Address-Recognized and Frame-Copied. The transmitting node receives the frame back after the message has passed through all the nodes on the ring and strips the information off and releases the token. The node will be able to determine from the FS if: the destination node is nonexistent/nonactive, the destination node exists but the frame was not copied, or the frame was copied.

4.11.8 ERROR DETECTION MANAGEMENT—Error and detection mechanisms exist to detect both hard and soft errors. Soft errors are logged by the individual nodes to determine the ring's service priority. Hard failures are acted upon immediately by the node upstream from the failure. A MAC (Medium Access Control) beacon is sent to all nodes suspending operation of the token ring until the disruption is removed. Most rings have a dedicated node to monitor the performance of the ring.

4.11.9 FAULT TOLERANCE—Each node can detect open and shorts on the ring and can monitor its own performance via closed-loop (deinsertion from the TCU) methods. Detection of hard faults is performed by individual nodes and system degradation/recovery is performed by a specific node.

4.11.10 DATA RATE—The data rate can be 4 Mb/s or 16 Mb/s.

4.11.11 FRAMING OVERHEAD—The largest frame size, no information or data, is 21 bytes. Assume the ring will allow the transmission of 4 Kbytes of data for a best case. The percentage of overhead is therefore 168/(168+32)=0.004%. Now assume the ring allows only 1 Kb of data to be transmitted. The percentage of overhead is therefore 168/(168+1024)=14%.

4.11.12 LATENCY—In a token pass protocol, latency is affected by the number of nodes on the ring, the maximum length of message allowed and bus loading. In IEEE 802.5, the token has an associated priority, this allows quick access to the bus for higher priority messages. Also, there is a token holding timer that monitors the amount of time a node has the token.

4.11.13 POWER REDUCTION MODE—Not specified.

4.12 Token Slot Network

4.12.1 APPLICATION/AFFILIATION—General Motors developed protocol for high-performance vehicle control and general information sharing.

4.12.2 TRANSMISSION MEDIA—Not specified. Electrical twisted pair or fiber optic media is recommended. Fiber optic Token Slot Networks operating at 1 Mb/s have been demonstrated.

4.12.3 PHYSICAL INTERFACE—Not specified. Multiple access to a logical common bus is required.

4.12.4 BIT ENCODING—NRZ (Non Return to Zero) with opposite logic level bit insertion (stuffing) after five contiguous bits of the same state. Receiving nodes detect and remove inserted bits.

4.12.5 NETWORK ACCESS—The token passing bus network is open, peer oriented, and multimaster. It is non-contention and uses a time slot token passing technique. See Figures 29, 30, and 31.

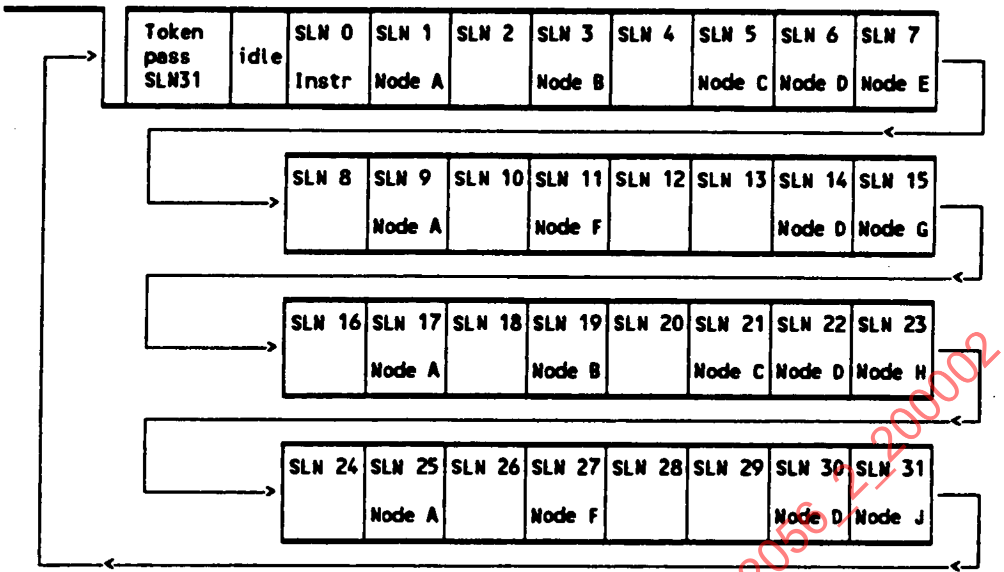


FIGURE 29—A TYPICAL TOKEN SLOT NODE ASSIGNMENT AND SLOT SEQUENCE CYCLE PATTERN

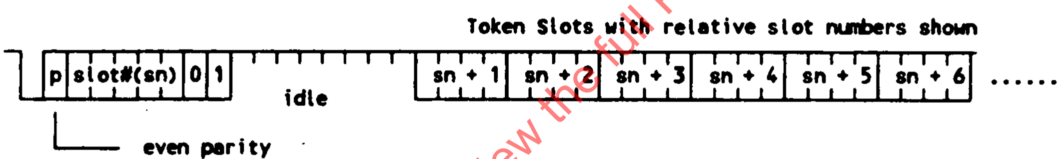


FIGURE 30—TOKEN PASS MESSAGE FORMAT

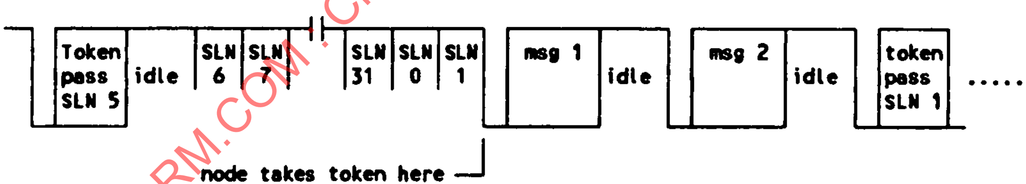


FIGURE 31—TYPICAL TOKEN PASS SEQUENCE

The intent of this bus access protocol is to guarantee periodic opportunities for message transmission by each node on the bus. It is to also ensure that the bus remains operational when devices are dynamically added or deleted and it must provide for quick recovery from error conditions.

After a node has completed sending its message traffic, a sequenced scan of short, equal time intervals (slots) offer bus transmit privileges to the node slot owners as follows (see Figure 30): A token pass message (or a bus jam) instructs all nodes to begin the token slot timing mode. Each node is assigned one or more specific time slots and will activate its transmitter to send a message during its slot only if it is operational and has message traffic to send. Otherwise the token slot interval is allowed to pass. When the transmitter is activated, all other nodes recognize that the token has been taken and they enter the receive mode.