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**A Vehicle Network
Protocol with a Fault
Tolerant Multiplex
Signal Bus**

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A VEHICLE NETWORK PROTOCOL WITH A
FAULT TOLERANT MULTIPLEX SIGNAL BUS

1. A VEHICLE NETWORK PROTOCOL (VNP):

1.1 Introduction: This Vehicle Network Protocol is intended to service all vehicle communication applications which do not require a latency of less than 20 ms. This assumes a 10 Kbit/s bus speed operation. The fault tolerant multiplex signal bus complements the VNP by providing successful operation despite component failures.

1.2 Design Goals: The design goals of the Vehicle Network Protocol include:

- a. Message integrity: assurance that a transmitted message has arrived at the intended receiver(s) as transmitted; an error checking code, such as cyclic redundancy check (CRC), and an acknowledgment of correct reception of data are required.
- b. Bit integrity: assurance that a logic one is distinct from a logic zero; and that noise corruption does not readily cause a logic one to be decoded as a logic zero and vice versa.
- c. Asynchronous bus access: The ability to transmit on an unscheduled or demand basis.
- d. Priority contention: The ability to gain access to the bus based upon a predetermined priority.
- e. Contention resolution: The assurance that the dominant contender maintains control of the bus and will continue message transmission while the losing contender assumes the role of receiver such that contention is resolved in a deterministic manner.
- f. Assignable priority: The ability to prioritize a message independent of its content.

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1.2 (Cont'd.):

- g. Message content arbitration: The ability to resolve bus access contention based upon message content.
- h. Expandability: The ability to accommodate future communication needs by:
 - 1. Providing features which afford flexibility to the system designer.
 - 2. Incorporating a mechanism by which other data formats can be defined which will operate on the same bus.
- i. Functional addressing: The ability to communicate on the basis of functions independent of physical node partitioning and the ability to communicate the function information to multiple receivers simultaneously.
- j. Node to node addressing: The ability to communicate information between two specific physical nodes, a transmitter and a receiver.
- k. Data transfer: The ability to transmit multiple bytes of data to one or more nodes.
- l. Low latency time: guaranteed access (with maximum priority) to the bus within 20 ms.
- m. Optimized baud rate: high enough to provide minimum required message latency, but low enough to allow simple transmission line media and exhibit acceptable automotive radiation.
- n. Microprocessor compatible: assurance that message format is such that encoding and decoding of the message is easily accomplished by eight-bit microprocessors. Byte-orientation is required.
- o. Fault diagnosis: The ability to isolate faults to physical nodes.
- p. Self-clocking waveforms: The ability to synchronize message transmissions on a bit by bit basis.

- 1.3 Bit Waveform Representation: The proposed protocol utilizes a pulse width modulated bit waveform to represent the logic state as well as unique start and end-of-data bits. The waveforms are shown in Fig. 1.1.

LOGIC ONE:

dominant state



passive state

LOGIC ZERO:

dominant state



passive state

START BIT:

dominant state



passive state

END OF DATA BIT:

dominant state

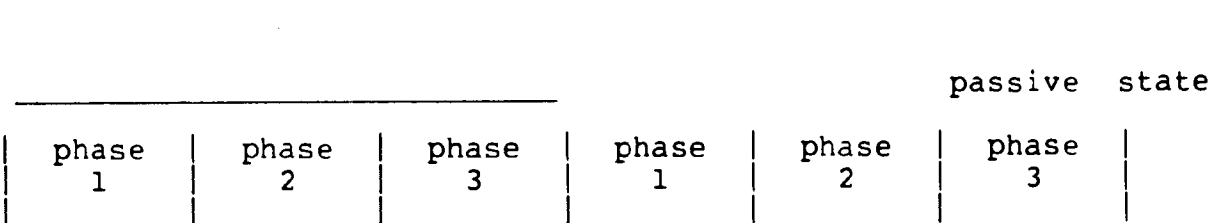


FIG. 1 - BIT WAVEFORMS

- 1.4 General Message Format: In the interest of universal applicability of the VNP, the message format has been left flexible. All users must subscribe to basic rules to access the bus. All messages must begin with a start bit followed by a field which determines bus priority as well as defining the message type. All messages end with a stop bit field. No message may exceed 101 bits in length. Within these constraints, new message types may be invented for the unused message type codes. Fig. 1.2 illustrates the basic VNP format.

- 1.5 Message Types: All messages are composed of fields which have predefined significance. Although the field format for all currently defined message types is consistent, the message type is required to indicate to the target node(s) how the remainder of the message is to be interpreted. All messages must begin with a start bit, contain a priority/type field, and terminate within 101 bit cell times of initiation of the start bit. The general message format is shown in Fig. 1.2.

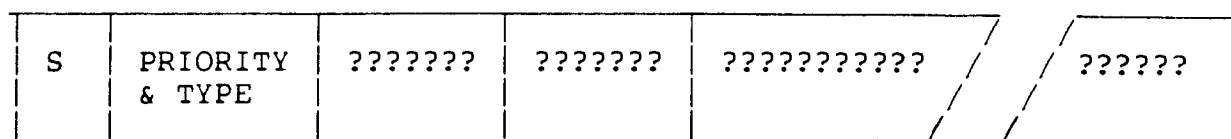
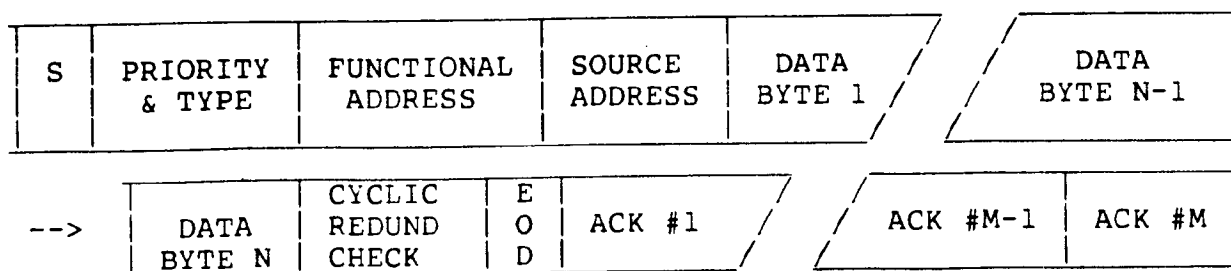


FIG. 1.2 - GENERAL MESSAGE FORMAT

There are currently five defined message types. They are Functional, Functional Read, Broadcast, Physical, and Physical Read.

- 1.6 Functional Message Type: The Functional Message Type is used to communicate data or commands to functional target groups; for example, "coolant temperature = 179" or "windows up." The targets of this type message are indicated by a functional address field which follows immediately after the priority/type field. In the second example above, the functional address field would contain the eight-bit code for the "windows" function. The next field transmitted in this message type contains the initiating node address. The data field which may have a variable length follows. This field will contain data for information transfer, but in the case of functional commands, this field is used to provide specifics of the request: that is, up, down, on, off, left, right, etc. In either case, the length of the data field plus the length of the acknowledge field must not exceed eight bytes total. The data field is followed by the eight-bit Cyclic Redundancy Check (CRC) Field. An End-Of Data bit, after the CRC, signals the receiving unit that the CRC has been received and must be compared with the calculated value. The initiating node ceases transmission at this point. Acknowledging node(s) respond using an arbitration scheme. The format for the Functional Message Type is shown in Fig. 1.3.



M = # of acknowledgers N = # of data bytes M + N ≤ 8

FIG. 1.3 - FUNCTIONAL MESSAGE TYPE FORMAT

- 1.7 Functional Read Message Type: The Functional Read Message is an interrogative message type. It may be used to elicit information from nodes which normally initiate functional commands and/or data transfers. Through this message type, the request and the response are both contained in a single bus transaction. Fig. 1.4 shows the format for this message type. The message begins with a start bit and the priority/type field as do all messages. The functional address field contains the descriptor of the function which is being interrogated. The next field specifies the address of the initiating node. Note that there is no data field transmitted by the initiating node. Consequently, the next field is the Cyclic Redundancy Check (CRC) field which is followed by the EOD. At this point, all nodes which are normally initiators of this function are expected to contend for the bus using their relevant transmission of the single data byte response and then append a single byte CRC for data security. Potential respondents which lose arbitration do not attempt a second time to reply. Only the node with the "highest priority data" will successfully respond to this message type. Because of this, the system designer will be required to judiciously encode the status reply bytes of potential functional read respondents in order to insure desired information transfer. The message length for a Functional Read Message type is fixed at 53 bit cell times.

S	PRIORITY & TYPE	FUNCTIONAL ADDRESS	SOURCE ADDRESS	CYCLIC REDUND CHECK	E O D	SINGLE DATA BYTE	CYCLIC REDUND CHECK
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FIG. 1.4 - FUNCTIONAL READ MESSAGE TYPE FORMAT

- 1.8 Broadcast Message Type: The Broadcast Message type has been specified to provide the possibility of initiating the action of a Functional Message type without incurring the message length penalty associated with the multiple acknowledge bytes. The multiple acknowledges have been replaced by a single acknowledge from the potential respondent with the highest priority node address. The Broadcast Message type consequently does not have the level of message security inherent with the Functional Message type. With the Broadcast Message type, it can be ascertained that the message has been properly received by at least one other node on the network. The format for this message type is represented in Fig. 1.5. It is identical to the format for the Functional Message type, except that the acknowledging receivers arbitrate for one byte only and then give up. Message length varies with the number of bytes in the data field. The number of data bytes may vary from one to seven. The maximum message length is fixed at 101 bit cell times.

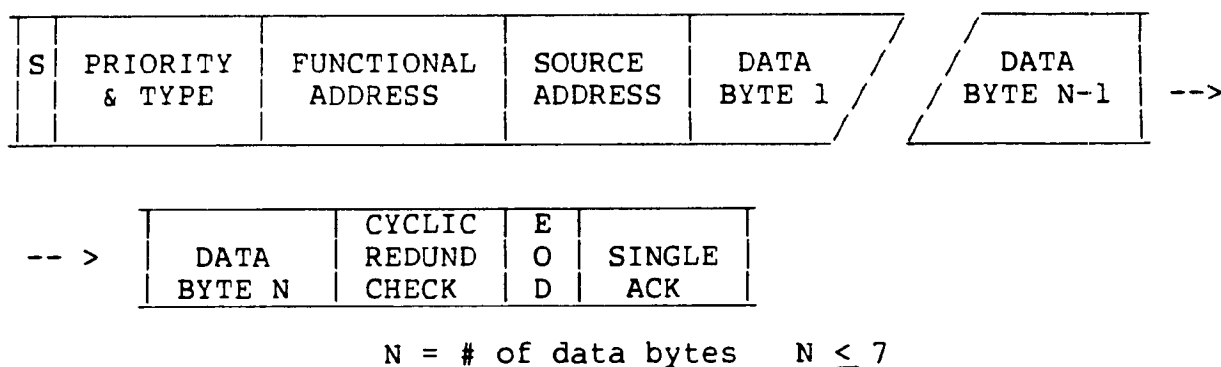


FIG. 1.5 - BROADCAST MESSAGE TYPE FORMAT

1.9 Physical Message Type: The Physical Message type is used to communicate data or commands to a specific physical location (node). It is anticipated that this message type will be useful in performing system diagnostics. The format for this message type is shown in Fig. 1.6. The message begins with a start bit and the priority/type field as do all messages. The physical address field contains the descriptor of the single node which is being addressed. The next field specifies the address of the initiating node. The variable length data field follows. The number of bytes may vary from one to seven. A Cyclic Redundancy Check (CRC) byte is transmitted next to insure message security. The CRC is followed by an End of Data bit (EOD) to signal that the initiator portion of the message is complete and that the CRC should be in the receiver's buffer. At this point, the target node is required to respond with transmission of its node address as confirmation of proper message reception. The maximum message length is 101 bit cell times.

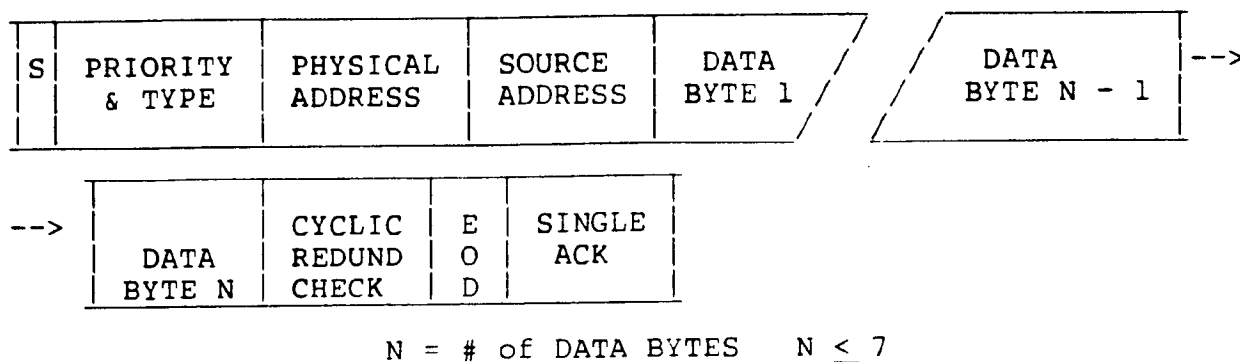
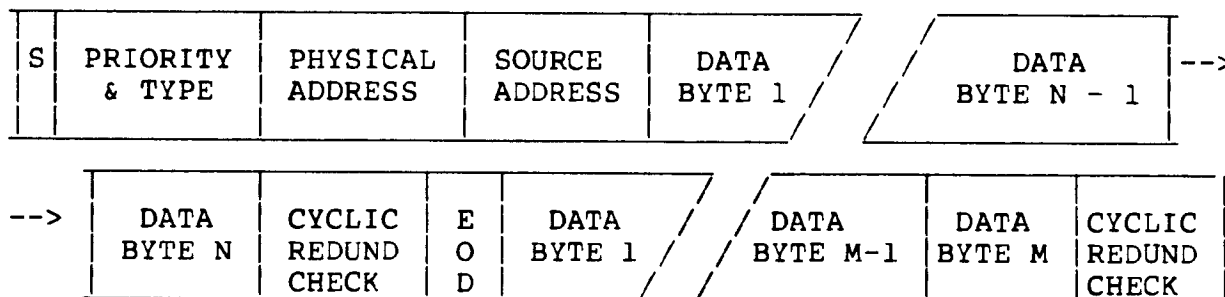


FIG. 1.6 - PHYSICAL MESSAGE TYPE FORMAT

- 1.10 Physical Read Message Type: The Physical Read Message is an interrogative message type. It may be used to elicit the status of individual nodes. Through the use of this message type, the request and response may both be contained in a single transaction. Fig. 1.7 illustrates the Physical Read Message format. The message begins with a start bit and the priority/type field as do all messages. The address field contains the address of the node which is being interrogated. Following the physical address is the address of the initiating node. The next field is a data field. The purpose of this variable length field is to specify what information is being requested. It is anticipated that this data field would normally only require one byte. The CRC field follows, and the EOD is transmitted to indicate end of transmission by the initiator. At this point, the target node will send the required data in response. The number of data bytes sent in response is variable. The number of data bytes transmitted by the initiator plus the number of data bytes transmitted by the respondent must be seven or less. A CRC Byte is appended to the response data field by the responding node. The maximum message length is 101 bit cell times.



M = # of returned data bytes
 N = # of initiator data bytes
 $M + N \leq 7$

FIG. 1.7 - PHYSICAL READ MESSAGE TYPE FORMAT

- 1.11 Design Rationale: The design rationale for the Vehicle Network Protocol (VNP) is as follows:
- a. Physical bus collisions: The waveforms in Fig. 1.1 indicate that a logic one differs from a logic zero only in the level state of the bus during Phase 2. The physical bus is designed to exhibit a passive state and an active state such that the active state dominates in the case that distinct drivers impress both states simultaneously. In this manner, a logic one is dominated on the bus by a logic zero since the bus will be driven active during Phase 2. A start bit is also shown. The start bit is a unique waveform which provides message synchronization among the nodes.