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INTRODUCTION TO THE MIL-STD-1553B SERIAL MULTIPLEX DATA BUS

by

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SUMMARY

This memorandum reproduces a paper prepared for the Microprocessors and Microsystems journal (Vol 12 No 1 January/February 1988). Mil-Std-1553B is a well established serial, digital multiplex data bus standard used in military realtime system applications. The standard is now finding applications in the commercial and industrial sector because of its inherent flexibility and durability in harsh environments. The history and main features of the standard are presented, together with an indication of why it was developed and how it is applied in systems design. A brief comparison is made with three commercial counterparts (ARINC 429, BITBUS and ETHERNET) and possible future developments are discussed.

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1 INTRODUCTION

MIL-STD-1553B[1] is the latest issue of a series of multiplex data bus standards first developed for use in military aircraft avionic sytems in the early 1970s by the USAF. It has now become one of the most widely used data bus systems for real time weapon system applications throughout the USA and Europe and is the subject of International standardisation, in the UK as DEF-STAN 00-18/(PART 2)[2] and in NATO as STANAG 3838[3].

The MIL-STD-1553B standard defines an asynchronous, time division serial multiplex data bus using a command/response protocol in a half duplex manner. The basic signalling rate is 1 Mbit/s using Manchester bi-phase coding on an electrical bus medium consisting of a twisted shielded pair cable terminated resistively at each end. Terminals are connected in a multi-drop configuration from the main bus medium using stubs (up to 20 ft in length) and transformer coupling. A typical system would consist of two buses (dual redundant configuration), a single bus controller and up to 31 addressable remote terminals which interface the bus to the user sub-systems.

2 DEVELOPMENT

Nowadays military aircraft depend more and more on the effectiveness of their avionic systems to perform such roles as navigation, weapon aiming, weapons management and flight control to complete a successful mission. High reliability, high integrity and accuracy are therefore all basic design requirements not only for the avionic sub-systems but also the data transmission system

In meeting these requirements the late 1960s and early 1970s saw the introduction of digital avionics, particularly for the navigation and weapon aiming sub-systems, which required the use of elaborate sensors, real time processing and effective control and display interaction with the aircrew. A typical system of this type would require data transmission between several avionic sub-systems such as the navigation sensor, air data computing, weapon aiming, communications and the pilot's controls and displays.

This was originally achieved by using dedicated point to point data transmission links between the avionic sub-systems and a central computer configured in a star structured architecture (Fig 1) and involved a variety of different transmission methods (analogue, synchro, digital, etc), some of which requiring signal conversion (analogue/digital, synchro/digital, etc) when interfacing to the computer.

While this was adequate for small systems it was soon realised that the ever present demand for more capability created the need for increased speed, throughput and memory size in the central computer which technology at the time could not provide. Furthermore there were problems with physical congestion at the central computer interface caused by all these point to point links converging into a large interface and signal conversion unit making the whole approach inefficient, unreliable and difficult to maintain. Also system updates were made very expensive and time consuming due to the requirement for additional wiring and interfaces to be fitted, together with revision of software in the main computer.

The solution was to reduce the load on the central computer by breaking the task down into more manageable and distributed packages that could be handled by smaller processors distributed in the avionic sub-systems and move away from the dedicated point to point links by coupling the avionics sub-systems together using a serial multiplex data bus (Fig 2).

The benefits of using a standardised serial multiplex data bus approach were seen as offering common interface design, reduced cabling, reduced size and weight of interface hardware, improved reliability and good electromagnetic compatibility and were the main drivers behind the original development of MIL-STD-1553B.

3 HISTORY

The history of MIL-STD-1553B[4] spans back at least 15 years with many of the basic features coming from two US aircraft projects started in the late 1960s, the McDonnell Douglas F15 air superiority fighter and the Rockwell B1 strategic bomber. Indeed the F15 was the first military aircraft to employ serial multiplexing within its avionic system and since that time just about every US military aircraft project contains use of one of the variants of MIL-STD-1553. The first was MIL-STD-1553 (USAF) published in 1973 followed in 1975 by a US Tri-service updated and agreed version known as MIL-STD-1553A. Finally after much National (US) and International debate the standard was revised again and published in 1978 as MIL-STD-1553B which is the current version, subject to two minor amendments known as Notice 1(USAF) published in 1980 which has now been superseded by Notice 2 published in 1986.

MIL-STD-1553B has seen many years of practical use and development to what is now a mature and well understood standard supported by a large number of component, system and test equipment manufacturers throughout Europe and the USA. Many of these components are second and third sourced and the UK currently has a totally self sufficient manufacturing capability of all 1553B hardware.

4 MAIN FEATURES

MIL-STD-1553B was designed at the outset to offer high integrity, high reliability data transmission in an adverse military environment (ie, in the avionic bays of aircraft). These include requirements for: operation over a wide temperature range, high reliability, fault tolerance, redundancy, error detection and good electromagnetic compatibility (EMC). The design concepts of 1553B therefore reflect the choices that would logically be made for any serial data bus design, using an electrical bus medium, that could meet these demanding performance requirements.

Starting at the basic level the bus is a low impedance twisted shielded (screened) pair cable terminated at each end with resistors equal to the characteristic impedance of the cable, which for 1553B is in the range 70 to 85 ohms.

Coupling of terminals is achieved using either direct (Fig 3) or transformer (Fig 4) coupled stub configurations using the same twisted pair cable as the main bus. This provides in the first case for short (less than 1 foot) stub connections to the bus and in the second, longer (up to 20 foot) connections to the bus through coupling transformers and isolation resistors. The transformer coupled option is generally preferred as it offers an additional common mode noise rejection (CMR) of >45dB at 1MHz with the extra benefits of:

(a) Electrical isolation of the stub preventing fault propagation.

(b) Protection of main bus from short circuits in stubs through the use of isolation resistors.

(c) Increased stub impedance reflected on the main bus resulting in reduced waveform distortion.

This basic configuration together with the use of Manchester II bi-phase level, pulse code modulation (Fig 5) which is a bi-polar, self clocking, signalling code combine to give a very robust transmission path tolerant against the effects of electromagnetic interference and short circuits in the stubs and terminals through the protection afforded by the coupling transformers and isolation resistors.

There are three types of terminal specified for use on the bus:

(a) The Bus Controller (BC), which is the only terminal assigned the task of setting up or initiating data transfers on the bus.

(b) Remote Terminals (RTs), which interface the user sub-systems to the bus and provide the sources and sinks of data.

(c) Monitoring Terminals, which can "listen" to bus traffic for recording and analysis purposes but not take active part in any bus transactions.

In the basic configuration (Fig 6) remote terminals may exist as either stand alone units or be embedded within the sub-system enclosures. There is also a capability for the bus, including all stubs, couplers and transceiver electronics, to be replicated to provide transmission path redundancy in the event of damage or failure. However, no provision is made for simultaneous operation of these buses, only one bus being specified to be active at any one time.

For any given 1553B configuration up to 31 addressable remote terminals (RTs) may be connected, together with a single bus controller (BC) and any passive monitoring terminals. The most common level of redundancy is dual buses but most microcircuit RT hardware will support at least up to four buses.

(5) <u>BUS PROTOCOL</u>

Turning to the bus protocol, there are three basic types of word: (Fig 7)

(a) Command words, which are only transmitted by the bus controller and contain a five bit RT address field, a five bit subaddress/mode field, a five bit word count/mode code indicator field and a single transmit/receive bit.

(b) Data words which contain the transmitted information in sixteen bit fields.

(c) Status words, which are only transmitted by remote terminals in response to valid commands and contain a five bit RT address and eight single bit flags used for indicating RT and sub-system status.

Each of these words is 20 bit times long which includes a 3 bit time word synchronisation waveform, 16 information bits and a single parity bit. The three word types are used together to form messages which allow communication between the bus controller and addressed RTs.

There are three basic message formats: (Fig 8)

(a) (BC) to (RT) transfer. In this case the bus controller issues a command word to an addressed RT indicating it is to receive a message with a specific word count in the range 1 to 32, followed by the correct number of data words. After validation of the message the RT responds to the bus controller with its status word. This completes the BC to RT transfer.

(b) (RT) to (BC) transfer. In this case the bus controller issues a command word to an addressed RT indicating it is to transmit a message with a specific word count in the range 1 to 32. After command word validation the RT transmits its status word followed by the correct number of data words. The bus controller validates the incoming message. This completes the RT to BC transfer.

(c) (RT) to (RT) transfer. In this case the controller issues a command word to an addressed RT to receive, followed by a command word to another addressed RT to transmit, both containing the same specific word count in the 1 to range 32. After command word validation the transmitting RT transmits its status word followed by the correct number of data words. After validation of the message the receiving RT transmits its status word. This completes the RT to RT transfer.

In all these cases reference was made to command and message validation. This is a strong feature of 1553B in that all incoming messages to terminals are subject to validation checks. This minimises the possibility of external interference causing an undetected error to be introduced in the transmission path and for the validation checks specified in 1553B gives a theoretical undetected error rate performance of 10^{-12}. However, if this is inadequate CRC or BCH type checks may be included in standard 1553B data words to provide error detection/correction capability at a higher level.

For messages that do fail any of the 1553B validation checks listed below the whole message is rejected and not used in any way by the receiving terminal or its associated sub-system. Under these conditions RTs also suppress transmission of their status word which is noted by the BC through application of a "time out" mechanism.

Validation checks are carried out by terminal hardware at the following three levels:

(a) All bits are checked for correct Manchester bi-phase coding.

(b) All words are checked for correct synchronisation waveform, sixteen information bits and odd parity.

(c) All messages are checked for correct number of words received.

In addition to the basic message formats mentioned above 1553B offers an optional broadcast capability which allows either BC to RTs or RT to RTs communication through the use of a special reserved broadcast address (decimal 31). RTs receiving a broadcast message do not transmit their status words otherwise there would be multiple transmissions on the bus. However, the broadcast received bit is set in the RTs status register which can be examined by the bus controller later during a normal status response to non-broadcast messages. Also the bus controller has the option to selectively interrogate RTs using a transmit status word mode command, which is described below, for confirmation of valid reception of broadcast messages. The broadcast option may be used with any or all of the RTs on a given bus providing a selected broadcast or multicast capability.

The standard also defines a series of mode commands allowing the bus controller to perform bus management tasks such as error recovery and re-configuration. Mode commands are invoked by setting 11111 or 00000 in the command word subaddress field which is recognised by the RT as a switch to decode the contents of the word count field as a mode code.

The following is a list of the mode commands available with an indication of their uses:

(a) Dynamic bus control. This command allows a current bus controller to offer control to a potential bus controller, currently acting as an addressed RT. If the RT accepts the offer it sets a complementary bus control acceptance bit in its status word reply and then changes mode of operation to that of bus controller. Thus a dynamic change of bus controller is possible using this command.

(b) Synchronise. This command causes a pre-determined event (defined by the system designer) to take place within an RT/sub-system combination triggered by the reception of the command. Another version of the command offers an associated data word which passes a sixteen bit parameter which can be used to preset internal timers or start sequences, etc.

(c) Initiate self test. This command allows the bus controller to initiate a pre-defined self test sequence within the RT and is used for remote terminal health monitoring purposes.

(d) Transmit built in test (BIT) word. This command allows the bus controller to recover the results of the RT self test sequence started by the initiate self test mode command. The remote terminal transmits its status word followed by an additional sixteen bit data word containing the results of the self test sequence.

(e) Transmit status word. This command allows the bus controller to interrogate an RT for its current status which is useful for examining the state of flags such as the broadcast received and dynamic bus control acceptance bits mentioned above. Other status bits include the sub-system and terminal flags used to report hardware failure, busy and service request which are generally sub-system initiated and instrumentation and message error used for health monitoring purposes.

(f) Transmit last command. This command allows the bus controller to interrogate an RT for the contents of the last valid command seen by the RT, excluding the transmit status and transmit last command mode commands which is useful for error recovery and health monitoring purposes.

(g) Transmitter shutdown and override transmitter shutdown. These are used by the bus controller, in dual redundant configurations, to shut down and enable bus transmitters associated with the other bus relative to the one on which the commands were received. When more than two buses are used there are complementary selected transmitter shutdown and override selected transmitter shutdown mode commands which use an additional sixteen bit data word to identify the bus to which the commands apply. These mode commands are used for re-configuration of primary and secondary buses etc.

(h) Reset remote terminal. This command is used by the bus controller to set an RT or RTs to a power up initialised state which is useful for system wide re-starts or as a last resort in RT error recovery procedures.

(i) Transmit vector word. Although 1553B operation is command/response there is a 'latent interrupt' capability which allows user sub-systems to set a service request bit in the RT status word to alert the bus controller to the need for a special message transfer to take place. The transmit vector word mode command is the way in which the bus controller interrogates an RT which set its service request bit for further information, via an associated sixteen bit data word, as to the source and/or reason for this request.

As you can see these mode commands offer a powerful capability for the bus controller to monitor the health of the bus system, react to user service requests and take direct action to recover from error or fault conditions. All these actions are determined by programming in the bus controller and can vary from simple retry of failed messages to reconfiguration of the entire system.

MIL-STD-1553B is thus a comprehensive multiplex data bus standard covering the electrical interface specifications, protocol options and bus management capability with built in error/fault detection.

6 SYSTEMS DESIGN

The 1553B data bus standard only provides end to end digital data transmission capability within a system and does not solve the overall system design problem. The standard offers a flexible data transmission capability with a wide range of options from which the system designer chooses an optimum set able to meet his design requirements. Some of the system design issues are discussed below but considerably more information is available in MIL-HDBK-1553[5] which is the official companion document to MIL-STD-1553B.

Several buses may be used in a system using a hierarchical architecture (Fig 9). In this example, which is typical of a modern avionic architecture, it can be seen that the upper level might be a mission bus integrating the main avionic sub-systems together, whereas the weapons and communication sub-systems now have local 1553B buses of their own to connect to the weapon pylons and radio equipment respectively. This approach has the advantage of reducing the number of terminals per bus with a consequent reduction in bus loading, although in this example there is added complexity in the weapons and communications controllers which now require two 1553B interfaces. As a result, careful analysis has to be made of the data flow requirements between terminals on different buses using a hierarchical architecture as there is a store and forward delay across the bus to bus interfaces together with additional delays due to the asynchronous operation of the two buses which can result in message latency problems.

MIL-STD-1553B is compatible with a wide variety of upper level control formats which can allow the bus to be used in a variety of non-standard ways. A couple of examples, of which there are many, are pseudo-time-slot and polled sequence operation. In the first case bus control could be allocated using a central timing source to enable different bus controllers in a pre-determined time slot sequence providing user sub-system control of the bus for a known but restricted period of time. In the second case a bus controller can be programmed to poll RTs on a sequential basis until a service request bit is set in a status word reply. A transaction would then be generated in the bus controller to service the RTs request. Neither of these examples is in widespread use, or indeed recommended modes of operation, but they serve to show how 1553B can be used to meet differing upper level requirements.

When designing any system using 1553B an analysis must be made of the functional and data flow requirements by taking into account the input/output requirements of individual sub-systems in terms of iteration rates, message/word lengths and formats, and, at a higher level, operational modes, redundancy philosophy and error management, etc. All these requirements are then distilled into the programming of the bus controller.

Physically the bus controller may be a stand alone device or be incorporated within one of the sub-system enclosures. For a simple system it could be a repetitive sequencer with no intelligence to handle errors etc. However, in larger systems it would be normal to associate the bus controller with a general purpose processor so that higher level control algorithms can be implemented to handle executive functions such as system health monitoring and reconfiguration etc.

The heart of any bus controller is the message list or set of transaction tables which define the sequence and types of message transfers to be used on the bus. For avionics, repetitive or periodic type transfers dominate and generally relate to the transfer of navigation or aircraft attitude type data, typically up to 64 times a second. So bus traffic is generally organised into a major frame/minor cycle format where all bus transactions have a relationship in time at different but sub-multiple iterations of the highest update rate (ie, 32, 16, 8, etc). The fastest update rate group is generally termed a minor cycle and the lowest a major frame or cycle. Within this concept free time is generally left available within the minor cycles or major frame for message error retries and aperiodic message requirements.

A number of different methods exist for producing these tables and computer aided tools exist for sorting, checking and analysing the result. Typical examples include the "Bus Analysis and Checking Utility System" (BACUS)[6] produced by British Aerospace and the "System Architecture Verification and Design Analysis" (SAVANT)[7] tool developed by RAE Farnborough.

One of the most important parameters examined in any system design using 1553B is bus loading which is generally expressed as a percentage of the ratio between actual bus transmission time and the maximum possible transmission time over a specified period. It is generally accepted that buses used in avionic applications shall not exceed 50% loading when first in service to allow growth potential to accomodate future expansion and updates.

7 COMPARISON WITH COMMERCIAL BUSES

MIL-STD-1553B is ideal for all real time command and control applications, particularly where severe environments are encountered. It has been adopted as the multipoint bus standard by CERN in Geneva and a number of other nuclear research establishments. Other commercial and industrial applications have previously been limited primarily by the cost of components essentially designed for the military market only.

This situation is changing rapidly as manufacturers offer low cost monolithic transceivers and plastic packaged interface/protocol chips. Test and development equipment is also becoming available at reasonable cost including IBM PC based systems. As the product volume increases to satisfy the much larger non-military market, component and equipment prices will fall accordingly to much the same level as for existing commercial buses.

The comparison of MIL-STD-1553B with commercial systems is made difficult because industrial buses use different terminology and are expected to fit the "open systems" framework of standards which is not generally used for describing military real time systems. This makes identification of similar systems difficult and an objective assessment almost impossible. Therefore the commercial counterparts chosen for this comparison have been limited to three fully developed buses which are all bit serial, baseband, multidrop systems using two conductors for the transmission media.

ARINC 429 was chosen as it is the main bus system used in the avionic systems of civil transport aircraft and is an obvious candidate to compare with 1553B, whereas BITBUS is probably the closest commercial counterpart to 1553B and ETHERNET one of the most well known industrial LAN systems.

Table 1 shows this comparison, which is believed to be accurate using information freely available. The table covers some of the main aspects such as product support, performance, transmission characteristics and protocol features, etc.

7.1 ARINC 429

This is the most common bus system used in civil aircraft applications and is configured around a single transmitting terminal connected up to a maximum of twenty receiving terminals. There are no physical addresses and all terminals "listen" to bus traffic. Data is transmitted with an associated tag or identifier which is recognised by the receiving terminals to decode the required information. The bus can therefore be considered to be in a permanent broadcast or multicast mode of operation. There are two alternative data rates of 100 kbit/s and 12-14 kbit/s and a separate bus is required for every transmitter of data.

ARINC 429 differs from 1553B in the following main respects:

(a) Data tagging instead of terminal addressing.

(b) Permanent broadcast mode of operation.

(c) Direct coupling of transmitter and receiving terminals.

(d) RZ bipolar signalling code (Tri-level states, hi/null/lo) instead of Manchester bi-phase.

(e) Lower data rate (100 kbit/s max) instead of 1 Mbit/s.

It can be seen that ARINC 429 is more limited in capability offering lower speed data communications designed to meet the more benign environment of commercial aircraft. It is also a simpler system requiring no bus controller and reduced interface electronics.

7.2 BITBUS

BITBUS developed by Intel Corporation and put into the public domain in 1983 is described by them in their databook[8] as an interconnect for the construction of real time distributed control systems. Both synchronous and self clocked versions are available with the option of repeaters for longer transmission distances. For the purpose of comparison with 1553B, the self clocked mode without repeaters has been used.

BITBUS is similar to 1553B in that it uses twisted pair cable to communicate between 28 nodes, one of which is assigned master (ie, bus controller) and the rest are slaves (ie, remote terminals). Mastership may be passed between nodes. The bus access method is also time division multiplexed as used in 1553B with message acknowledgement facilities provided between master and slaves.

BITBUS differs from 1553B at the physical level in the following respects:

(a) Direct coupling of transceiver to bus with no isolation by transformer or other methods.

(b) NRZI signalling code instead of Manchester bi-phase.

(c) Lower signalling levels using RS485 standard transceivers.

(d) Lower data rate (375 kbit/s Max) instead of 1 Mbit/s

All these differences combine to reduce performance and fault protection, particularly in severe environments. The only fundamental advantage is the saving in the cost of coupling transformers plus at present the reduced cost of interfaces and transceivers.

The protocol used by BITBUS is based on SDLC, an old IBM standard. BITBUS is able to handle longer messages than 1553B, 248 bytes as compared with 64 bytes with only a 5 byte fixed overhead regardless of message length. The minimum data message length is 2 bytes.

The SDLC like protocol provides message services between master and a single slave. Slave to slave, broadcast and multicast capability is not provided thus increasing the average data transfer time for many types of message transaction. The lack of slave to slave communication is considered by some people to be a severe disadvantage in control applications where "reflex action" between sensor and actuator or alarm type capability is required. This is due to the extra delay caused by having to pass all data through the master for slave to slave communication, which itself could be subjected to further delay due to the affects of software interrupts etc.

The main conclusion from this brief comparison is that BITBUS can compete with 1553B for "softer" less demanding industrial applications whereas for high integrity real time control in severe environments 1553B has the superior specification and performance.

7.3 ETHERNET

This is described in the "Blue book" ETHERNET specification[9] as a local area network which provides a communication facility for high speed data exchange among computers and other digital devices within a moderate sized geographic area. It was designed and first implemented by Xerox in 1975 and is now supported by DEC and Intel. The topology of a full ETHERNET network is that of a branched non-rooted tree which for comparison with 1553B is considered to be only a single branch.

1553B and ETHERNET have very little in common except for the use of baseband, Manchester bi-phase signalling and the use of transformer isolation. ETHERNET does not have a bus master, all nodes being connected to stations with equal priority and there is no pre-determined bus access control mechanism. Stations attempt access by monitoring a carrier sense signal and waiting for passing traffic until the channel is clear. Transmission collisions can still occur due to media propagation time so a collision detection mechanism is provided which causes a random delay before re-transmission. The method is known as CSMA/CD, carrier sense multiple access with collision detect.

ETHERNET combines CSMA/CD with a signalling rate of 10 Mbit/s over a coaxial cable medium to give high speed communication when the bus is lightly loaded. However, as the bus traffic increases there comes a point where throughput drops rapidly as bus collisions occur and re-transmission is required. This makes ETHERNET ideal for information transfer system applications (ie, in the office environment) where long block transfers are required and occasional delays can be tolerated during periods of high usage. For real time systems however, the non-deterministic nature of the bus access mechanism makes the system quite unacceptable unless measures can be taken to prevent bus transmission collisions.

The ETHERNET protocol is inefficient when dealing with short messages due to the fixed overhead of 18 bytes per message, a minimum data block of 46 bytes and an interframe spacing of approx 10us. Even with no bus contention a

4 byte message requires a similar transfer time to 1553B (61us vs 82us) despite the 10 times faster signalling rate offered by ETHERNET. However, the ETHERNET protocol is better suited to long messages offering a maximum of 1500 bytes which can be transferred in 1.22ms. This would take 24 separate messages using 1553B with a transfer time of 16ms (assuming minimum intermessage gaps and response times).

It is clear that 1553B and ETHERNET address different applications and are based on different requirements. Both are leaders in their field and do not directly compete with one another. However this short comparison is useful to show these facts.

8 FUTURE DEVELOPMENTS

The basic 1553B standard can be enhanced in a variety of ways to improve performance, one of the most popular being the use of fibre optics. Due to optical losses it is not possible to construct an all fibre optic bus providing 32 ports using the linear "tee" coupling topology as used by the electrical version without using repeaters. In practice the only way to provide a passive optical interconnect for a 1553B system is to use a single or multiple star topology network.

Both these topologies have different attributes. For example the single star topology offers a reduced range of optical losses between terminals but suffers from a potential single point of failure, which is particularly undesirable for aircraft applications, and requires generally longer lengths of cable to connect to a larger more complex central star coupler. The multiple star topology however, while suffering a wider range of optical losses between terminals, can be configured to provide path redundancy in the event of failure, uses smaller less complex couplers which can be located adjacent to groups or clusters of terminals and can result in a generally more elegant solution with reduced cabling requirements.

Both these approaches are suitable for 1553B and hardware has been developed such as the STC transceiver set which offers a compatible fibre optic interface capability for use with standard 1553B protocol chip sets. These optical transceivers replace the electrical tranceiver/transformer combination and are equally suitable for incorporation into new designs as well as providing an optical retrofit capability for existing systems.

Having engineered a 1553B system using a fibre optic network there is scope for updating the system in the future to make use of the much higher bandwidth provided by the optical transmission media. This can be achieved using a number of techniques varying from interleaving high speed transmissions in the 1553B intermessage and response time gaps to utilising frequency division multiplex (FDM) and wavelength division multiplex (WDM) techniques to provide parallel information channels. These extra channels could carry further 1553B systems or other services such as audio and video distribution.

Another area for future development is the association of the 1553B protocol with control of higher speed data transfer systems. This is currently the subject of a NATO study which has resulted in draft STANAG 3910. In this approach a fibre optic 20 Mbit/s bus has access controlled by a standard 1553B bus. Early implementations would utilise separate interconnect media for the 1553B and 20 Mbit/s buses, but later implementations could share the same optical interconnect using FDM or WDM capability.

9 CONCLUSIONS

MIL-STD-1553B is a very well established, well proven, serial data bus system for military real time system applications and has qualities well suited to command and control applications in severe environments. It compares well against a number of related commercial systems and given the availability of lower cost interface components could well provide an appropriate solution for many industrial applications.

The standard is in the public domain and not the property of any single vendor or manufacturer which encourages the availability of even more products to support its application both at the component, system and test equipment levels. The standard will be in use for many years to come which together will some of the enhancements described, such as the use of fibre optics, will be compatible with upgrading to higher speed systems at a later date.

Table 1. COMPARISON OF SERIAL DIGITAL DATA BUSES (2 conductor transmission medium, baseband, without repeaters)

Aspect	MIL-STD-1553B	BITBUS (Async)	ETHERNET	ARINC 429
Support				
Standardisation	DEF-STAN, STANAG, ASCC,	None	IEEE 802.3/ISO 8802.3	ARINC
Status	Published (2 notices)	Proprietary Standard	Published	Published
Primary sponsor	USAF	Intel	Xerox	AEEC/SAI
Primary Supporters	US DoD, UK MoD, NATO		DEC, Intel	Civil Airlines
Present silicon support	DDC, MEDL, SMC, STC, MCE, Harris, Ferranti, UTMC, MATRA, Intel	Intel	Intel, AMD, Fujitsu, National Semiconductor, SEEQ	Harris, MCE, Western Digital Garrett, Boeing
Performance				
Signalling rate: max	1 M Bit/s	375 kBit/s	10 M Bit/s	100 kBit/s
min		62.5 kBit/s		12-14 kBit/s
Bus access	Pre-determined	Pre-determined	Not-determined	Fixed (single transmitter)
Time for 4 byte transfer	82 us	192 us minimum	61 us	680 us minimum
Electrical/reliability				
Signalling Standard	Manchester biphase	NRZI	Manchester biphase	RZ bipolar
Transceiver Standard	MIL-STD-1553B	RS485	IEEE 802.3	ARINC 429
Coupling	Transformer	Direct	Transformer	Direct
Common mode rejection	10V peak, DC-2MHz	-7V to +12V DC	0-5V DC	Not specified
Redundancy	Multiple	Not specified	Not specified	Not specified
Error checking:				
Bit validation	Manchester codecheck	None	Manchester codecheck	None
Word validation	Word length & parity	None	Octet boundary alignment	Odd parity
Message validation				
(mandatory)	Word count	CRC	CRC	None
(optional)	Checksum/BCH (MIL-HBK-1553)	None specified	None specified	None
Maintenance/configuration				
Live insertion/disconnection	Yes	Yes	Yes	Yes
Transfer master to back-up	Yes	Yes	No master	No master
Dynamic master transfer	Yes	Yes	No master	No master
Autoconfiguration	Possible	Possible	No configuraton	No (fixed configuration)
Multi Vendor Support				
Mixed vendors on bus	Yes	Unlikely	Yes	Yes
Plug compatible	Possible	Unlikely	Possible	Possible
Component pin compatible	No	No	No	No

Table 1 (Cont) COMPARISON OF SERIAL DIGITAL DATA BUSES (2 conductor transmission medium, baseband, without repeaters)

Aspect	MIL-STD-1553B	BITBUS (Async)	ETHERNET	ARINC 429
Protocol Features				
Access method	Time division	Time division	CSMA/CD	Fixed (single transmitter)
Hierarchy	Master-slave	Master-slave	No Master	No master
Protocol standard	MIL-STD-1553B	SDLC	ISO 8802.2	ARINC 429
Data word length (bits)	16 + 3 sync + 1 parity	8	8	18 + 1 parity
Data message length (min)	2 bytes	2 bytes	46 bytes	2 bytes
(max)	64 bytes	248 bytes	1500 bytes	unlimited
Node addresses	31 + master	27 + master	1024	None (data labels used)
Sub addresses (physical)	30 per slave	not specified	(various address modes supported in 48 bit wide field)	None (data labels used)
Total addresses (physical)	930	250	(various address modes supported in 48 bit wide field)	None (data labels used)
Services : Master to slave	Yes	Yes	No master	Yes (master assumed to be transmitting terminal)
Slave to master	Yes	Yes	No master	No
Slave to slave	Yes	No	Yes	No
Broadcast from master	Yes	No	No master	Yes
Broadcast from slave	Yes	No	Yes	No
Multicast from master	Possible	No	No master	Yes
Multicast from slave	Possible	No	Yes	No
Physical Features				
Media (standard)	Screened twisted pair	Screened twisted pair	Co-axial cable	Screened twisted pair
(option)	Fibre optic	Unscreened twisted pair	Fibre optic	None
Characteristic impedance	70-85 ohms	120 ohms	48-52 ohms	60-80 ohms
Trunk length	Not defined	300m at 375 K bit/s 1200m at 62.5 K bit/s	500m (single branch)	Not defined
Spur/Stub length	6.1m maximum	Not specified	50m	Not defined
Number of nodes	32 + monitor terminals	28	100	21
Connector type	Twin axial	IDC, 9 pin D-type	Co-axial, N-type (main trunk)	twin axial/ multipin
Connector standard	None	None	15 pin D-type with slide lock (drop cable)	None

REFERENCES

No.	Author	Title, etc
1	US Dept of Defense	MIL-STD-1553B, Aircraft internal time division command/response multiplex data bus' (1978)
2	UK Ministry of Defence	Defence Standard 00-18(PART 2)Issue 1, Avionic data transmission interface systems, PART 2: Serial, Time Division, Command/Response Multiplex Data Bus (1980)
3	NATO Military Agency for Standardisation	Standardisation agreement, STANAG No 3838, Subject: Digital Time Division Command/Response Multiplex Data Bus (1981)
4	D.R.Bracknell	The MIL-STD-1553 multiplex data bus past and present, RAE TM FS(F)661 (1987)
5	US Dept of Defense	MIL-HDBK-1553 Military handbook, Multiplex applications handbook (1984)
6	A.M. Airnes S.A.Woods	The EAP data buses - an overview of the implementation approach ERA report 86-0237, MIL-STD-1553B: Applications, Developments and components seminar proceedings, London UK (1986) pp 1.2.1-1.2.13
7	A.A.Callaway	SAVANT a database manipulation technique for system architecture verification and design analysis, RAE TR 80101 (1981)
8	Intel	Distributed control modules databook (230973-002), Intel, Hillsboro, OR, USA
9	Xerox/Intel/Digital	The Ethernet, a local area network: data link layer and physial layer specifications, version 1.0 Xerox Intel Digital Equipment, USA (1980)

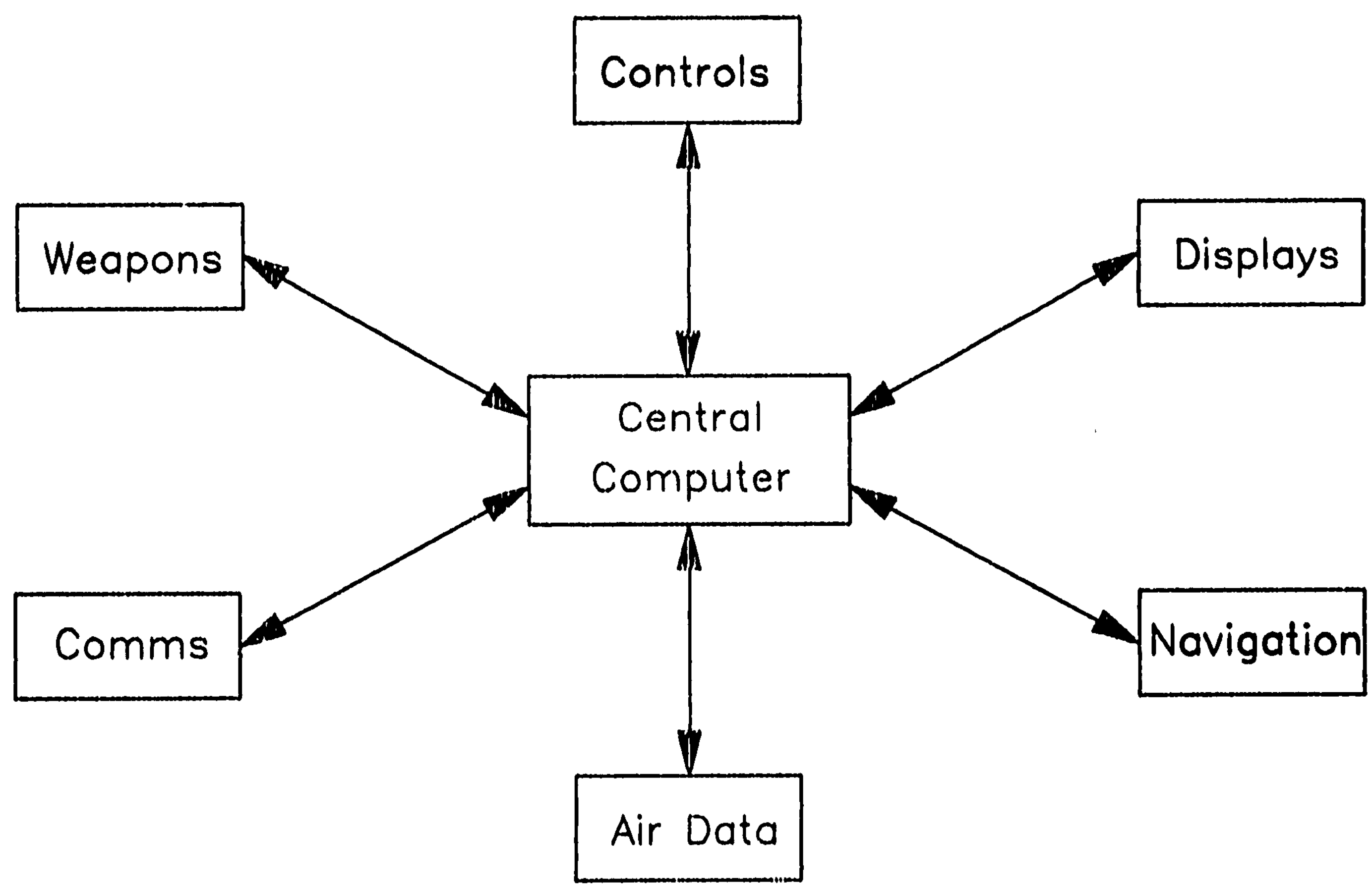


Figure 1. Star structured architecture

Fig 2

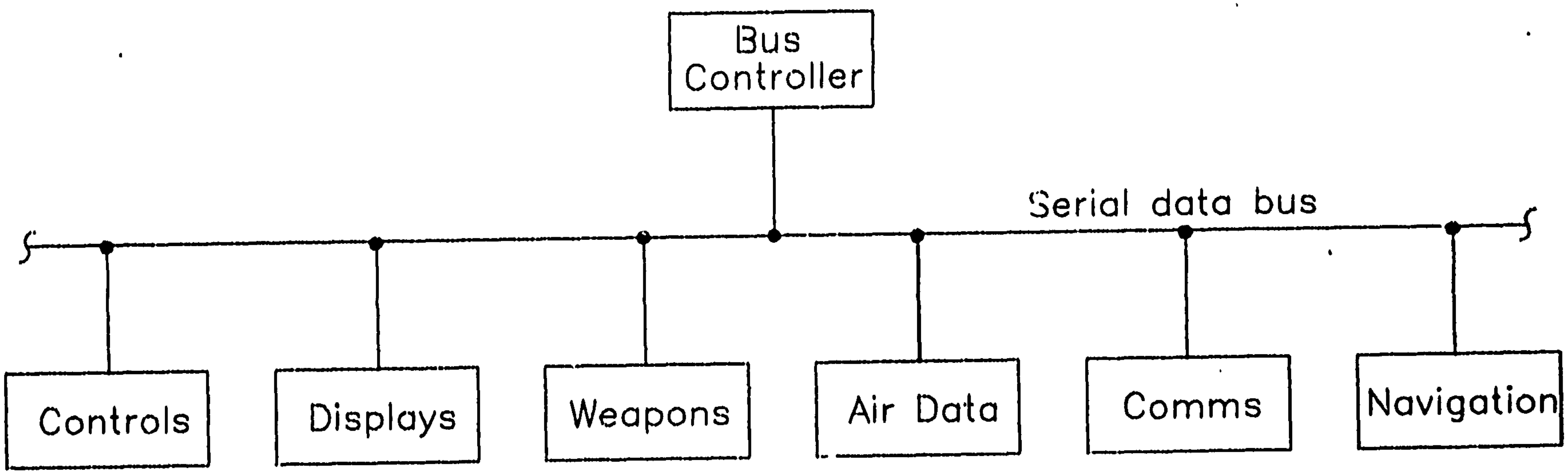


Figure 2. Serial data bus architecture

Fig 3

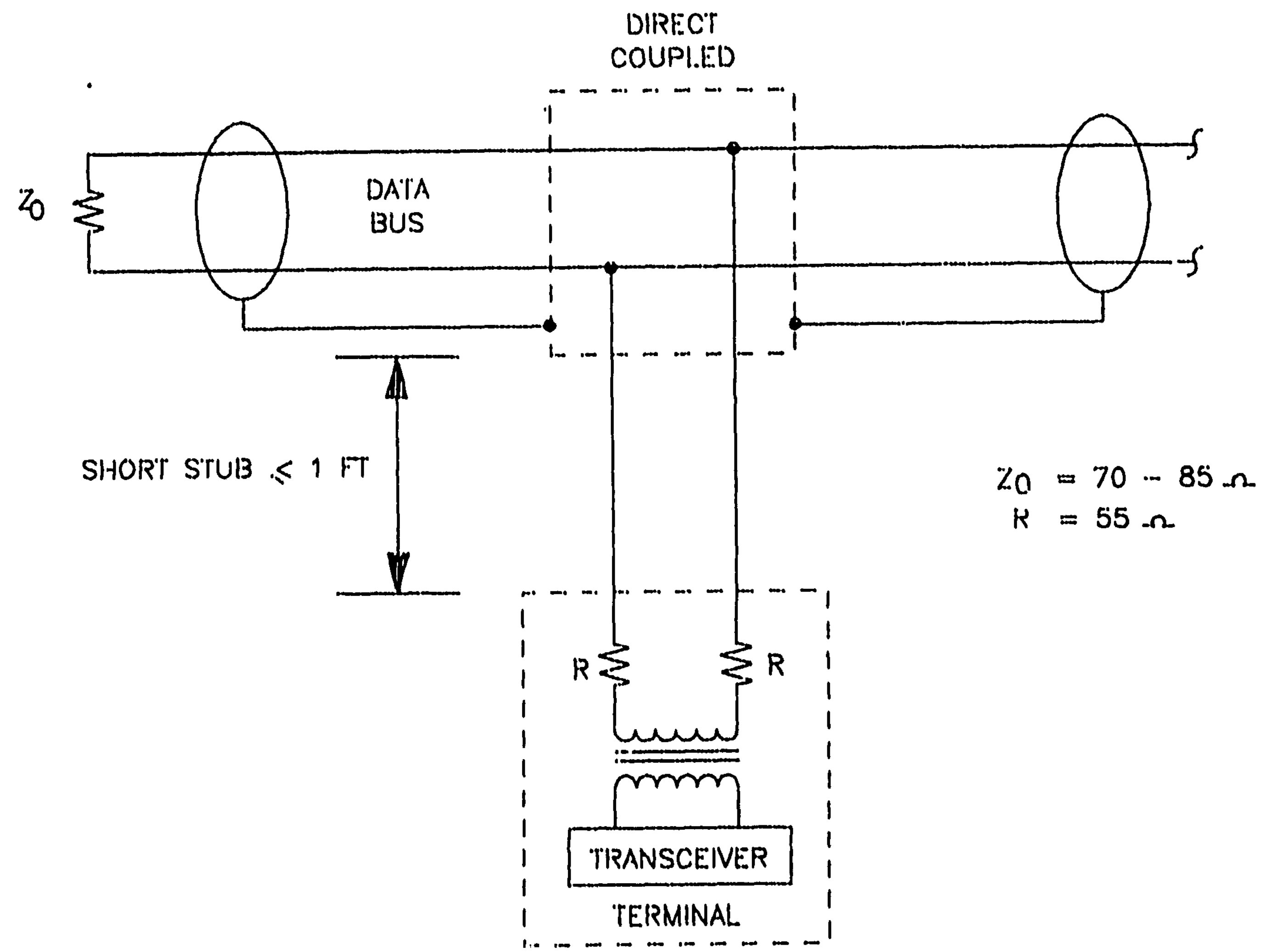


Figure 3. Direct bus coupling

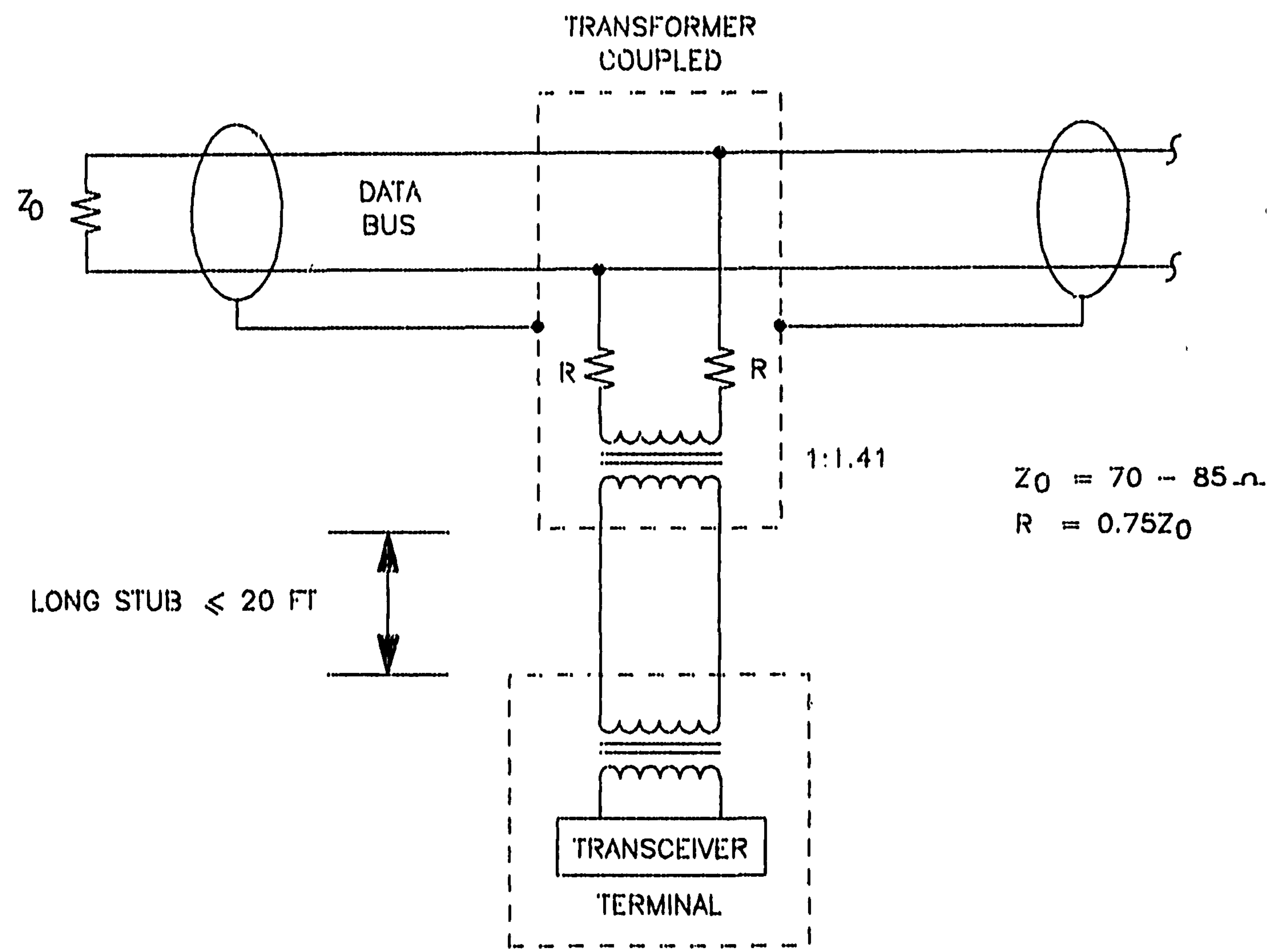


Figure 4. Transformer bus coupling

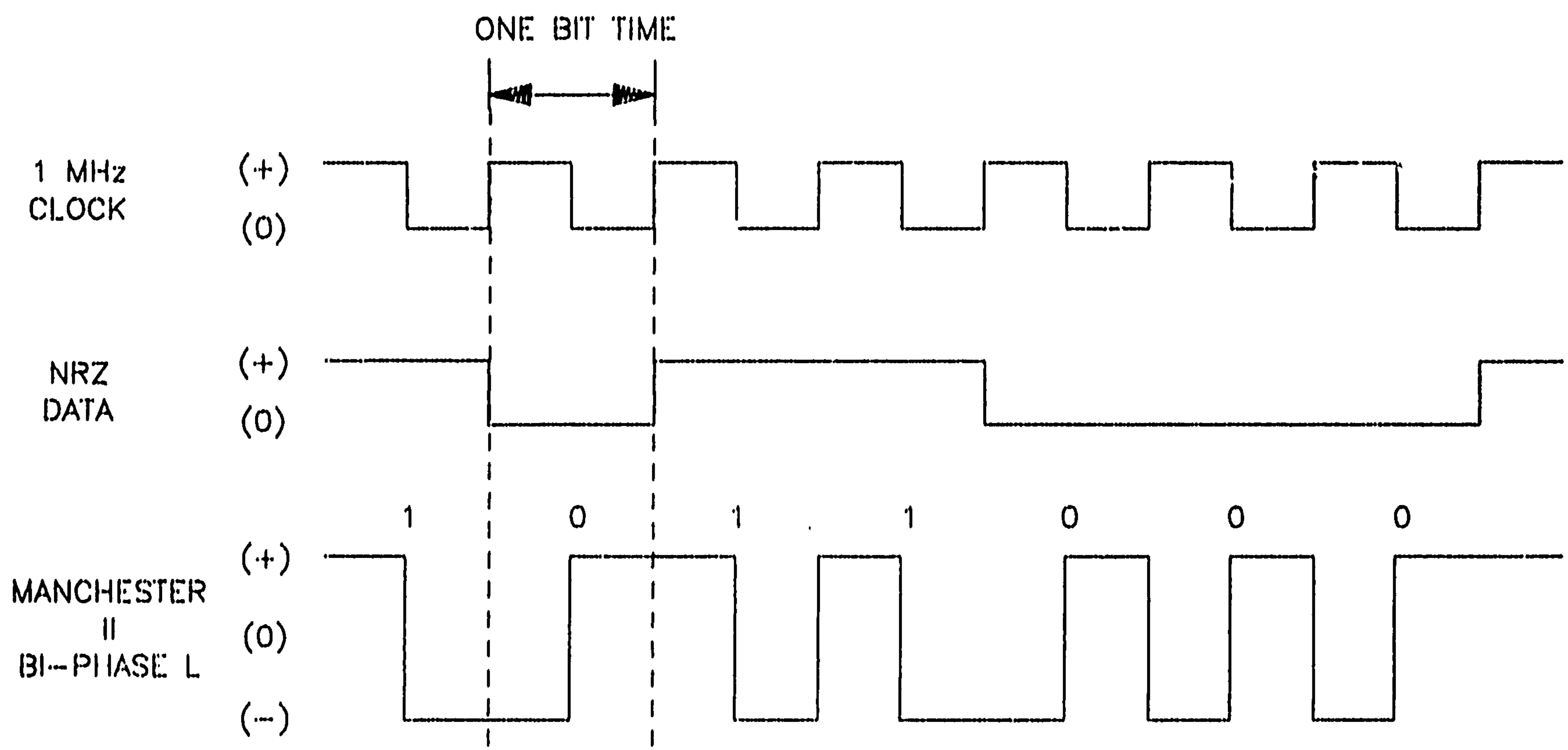


Figure 5. Data encoding

Fig 5

Fig 6

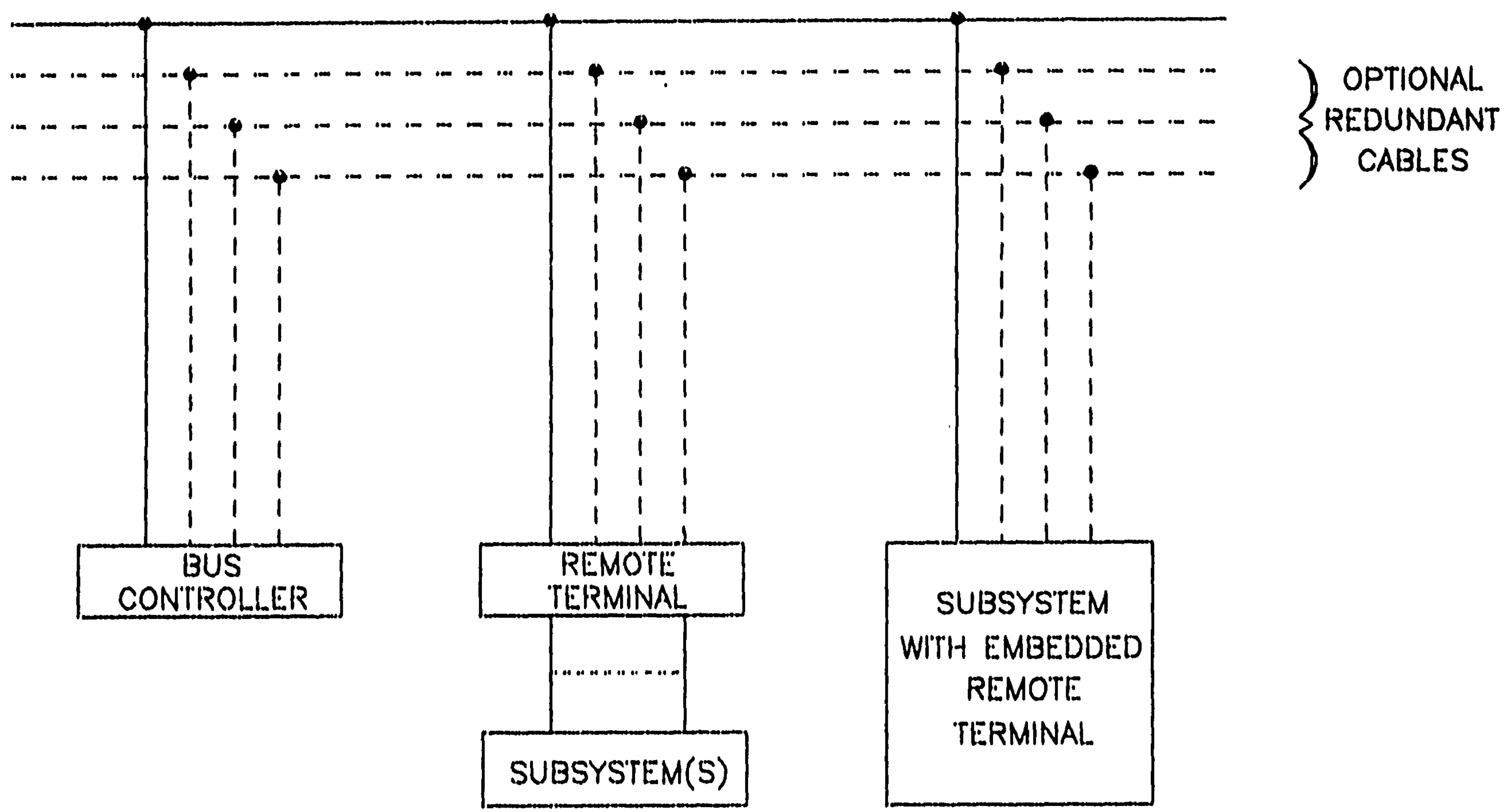


Figure 6. Basic configuration

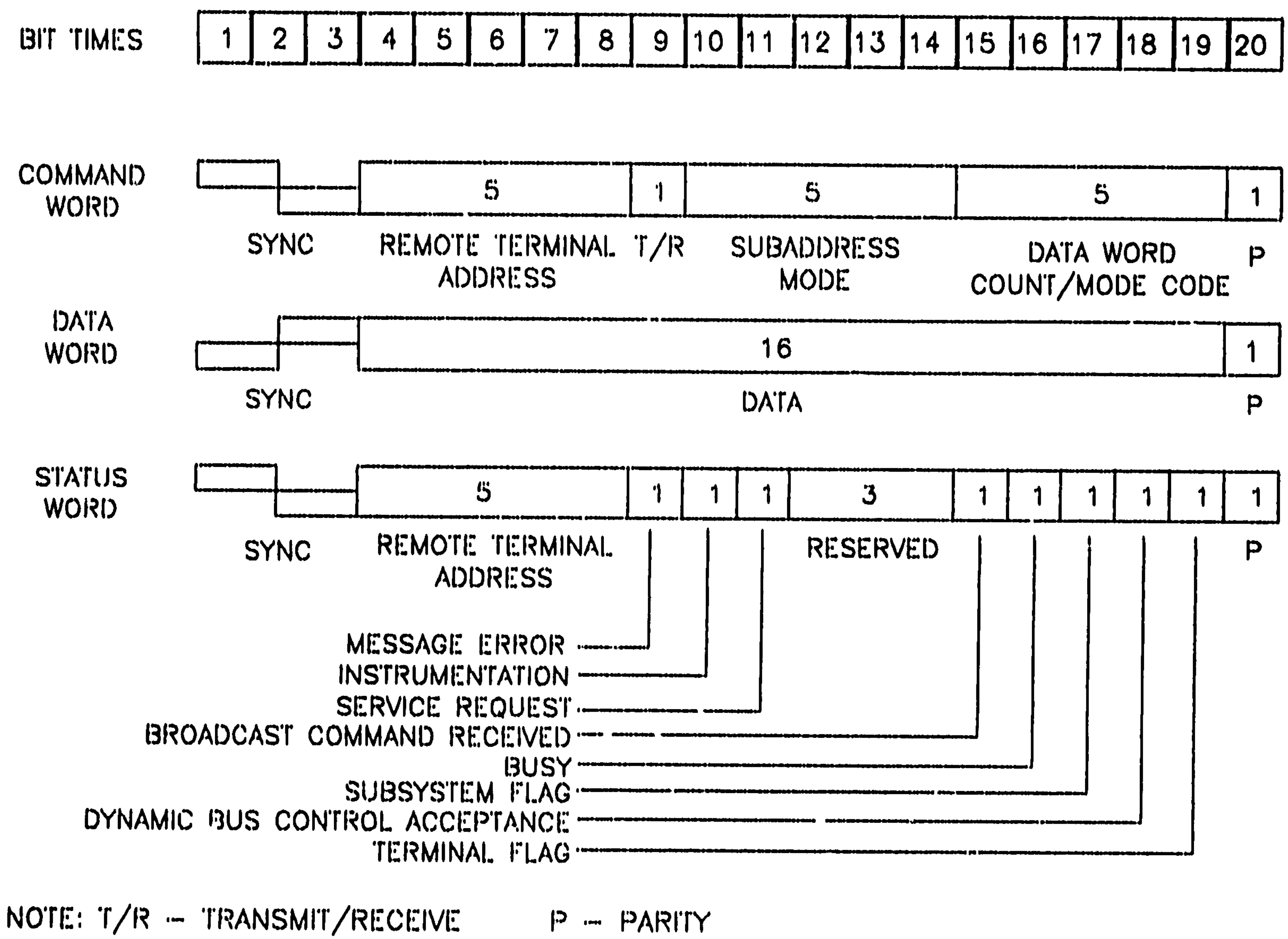
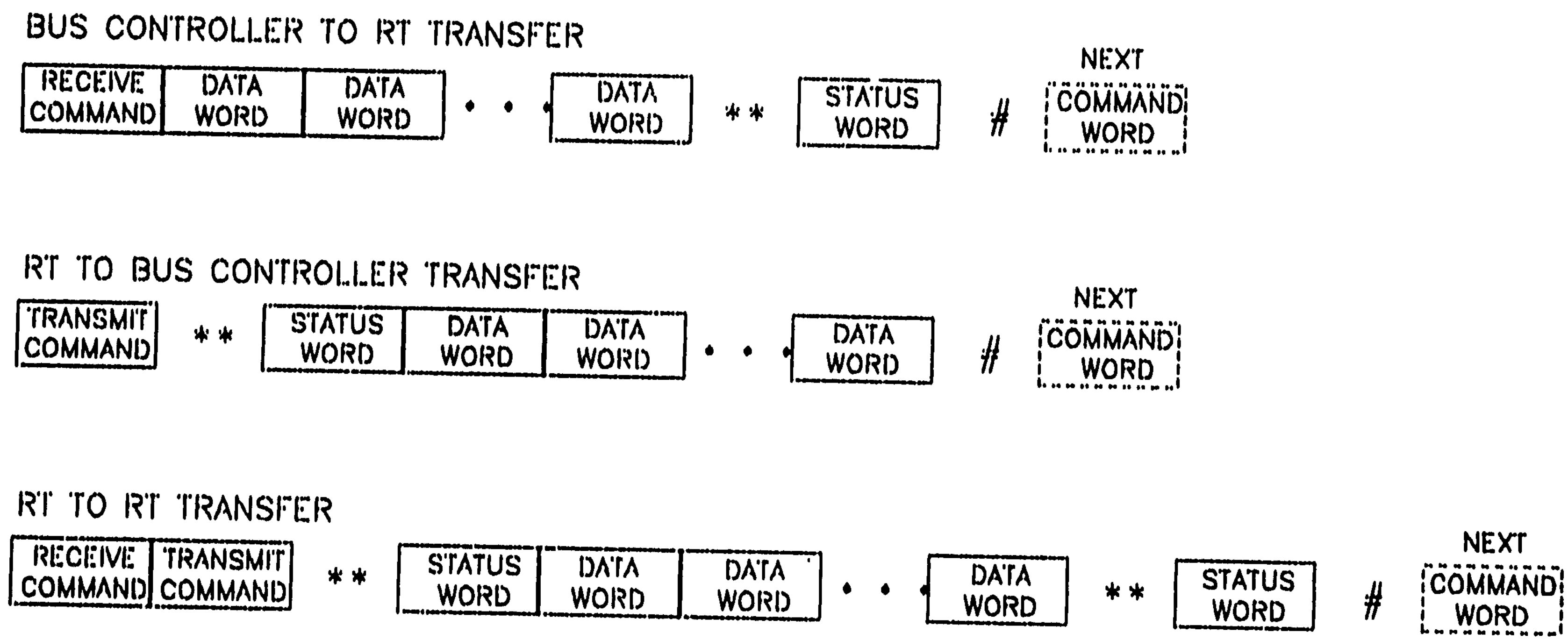


Figure 7. Basic word formats

Fig 7

Fig 8



NOTE: ** RESPONSE TIME # INTERMESSAGE GAP

Figure 8. Basic message formats

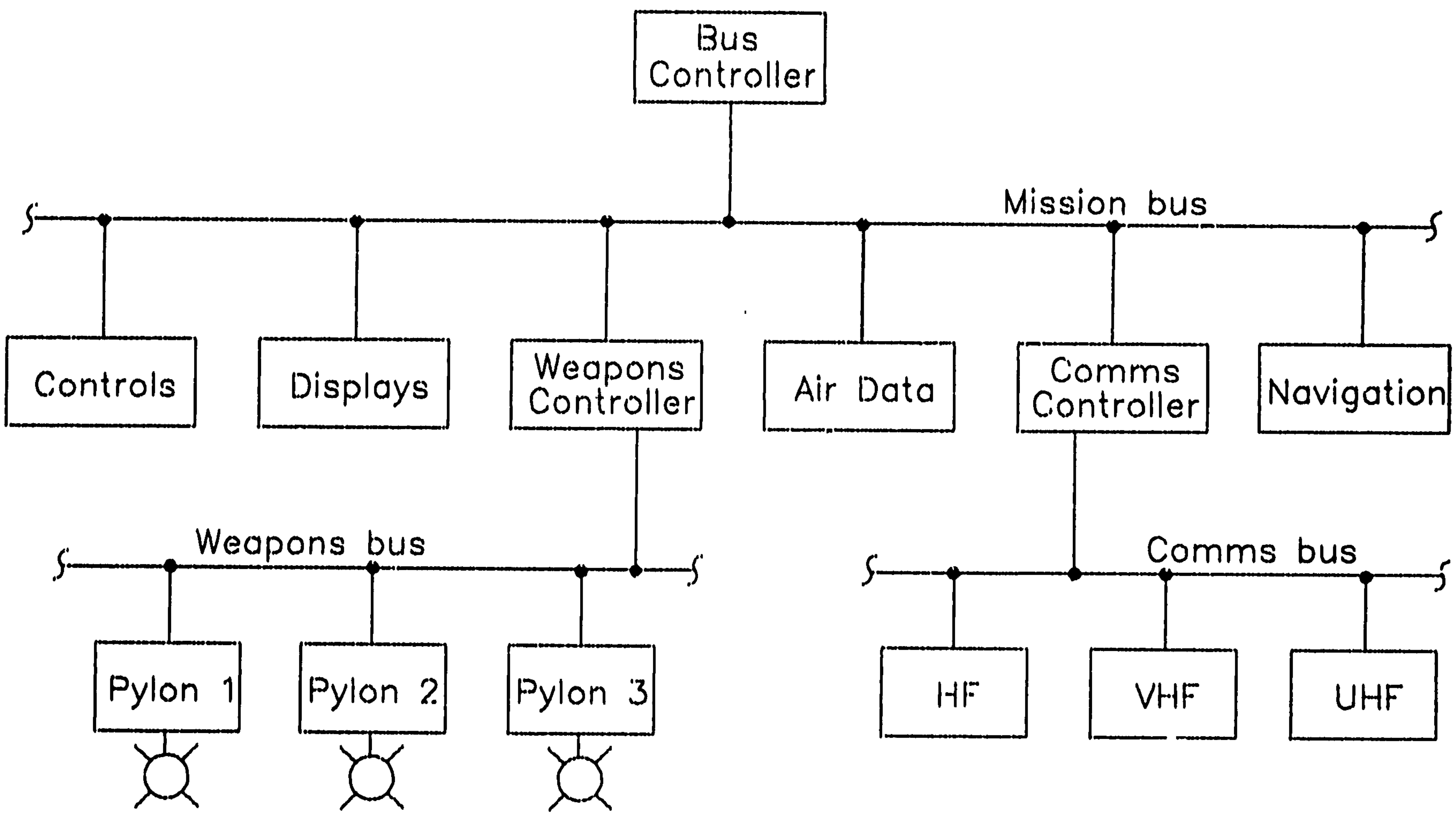


Figure 9. Hierarchical bus architecture

REPORT DOCUMENTATION PAGE

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Bracknell, D.R.			September 1988	26	9

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16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Databus. Multiplex. MIL-STD-1553B. Bitbus. Ethernet. Arinc 429.

17. Abstract

This Memorandum reproduces a paper prepared for the Microprocessors and Microsystems Journal (Vol 12, No.1 January/February 1988). MIL-STD-1553B is a well established serial, digital, multiplex data bus standard used in military realtime system applications. The standard is now finding applications in the commercial and industrial sector because of its inherent flexibility and durability in harsh environments. The history and main features of the standard are presented, together with an indication of why it was developed and how it is applied in systems design. A brief comparison is made with three commercial counterparts (ARINC 429, BITBUS and ETHERNET) and possible future developments are discussed.

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