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A Review of MIL-STD-1553 Bus Trends and Future

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Abstract: MIL-STD-1553 communication bus is in the defense field since last 45 years and is still a preferred bus in Defence and Space all over the globe. The 1553 bus initially developed by US to use in the defense Aircrafts to satisfy the robust communication bus in terms of protocols and hardware for weapon delivery subsystems. The main advantage is that the communication is highly deterministic and reliable compared to all other communication buses. Due to this feature the 1553bus made inroads into major programs all over the globe and reached installed base more than one million and spread from aircrafts to the other defense areas like Ships, Submarines, Battle tanks, also into Space vehicles. Because of it's full fledge acceptance in avionics, today it is continue to find its way into Military, Aerospace, Space programs and entered into commercial Aircrafts too. Keeping in view the strategic importance of 1553 Bus, we made an extensive survey on 1553 for this review Article, starting from the beginning to the present state, to be useful to the future Engineers for their understanding the 1553 Bus.

Keywords: Include at least 4 keywords or phrases.

I. INTRODUCTION

The Author of MIL-STD-1553 communication bus is Mr.Erwin Gangl and he initiated the development of 1553 schemes, protocols, connectivity hardware etc and it took from 1968 to 1973 to release first version of MIL-STD-1553 [1].MIL-STD-1553 is a serial, time division multiplex data bus that has been used as the primary command and control data interconnect in military aircraft for the past three decades. The use of MIL-STD-1553 is not limited to military aircraft. MIL-STD-1553's use is pervasive in military ground vehicles, military ships, and satellite systems. All of these applications share common requirements for a deterministic, fault tolerant data bus that will operate in relatively harsh environments.[2]
MIL-STD-1553 bus has evolved into acceptable standard bus used in the military platforms. Today, the 1553 bus has expanded beyond its traditional domain of US Air Force and Navy aircraft to combat vehicles, ships, satellites, missiles, and the International Space Station and into advanced commercial avionics.

MIL-STD-1553's robust performance, high level of interoperability, large installed based, and well established infrastructure of vendors has made MIL-STD-1553 the network of choice for military avionics systems and it is going to be continue for another couple of decades[2].

MIL-STD-1553 military standard that describes a one megabit serial & time division multiplex data bus used as command & control data interconnecting systems on a network. The 1553 bus is a dual redundant balanced line physical layer (layer one: physical layer) and time division multiplexing, half-duplex command/response protocol (layer two: data link layer). The maximum terminal can be connected on Bus is 31.

II. PRE LOAD

Initial stages of Aircrafts development the control & instrumentation was on individual subsystems wiring/connectivity was point-to-point & jiz-jag manner, as the subsystems are increasing the connectivity becoming more complex[3]. The "Society of Automotive Engineers (SAE)-USA" formed a sub-committee of government and industry personnel during 1968, to the realize a communication bus to be used in the Aircrafts and started releasing 1553 bus standards as mentioned below[4] [14]:

- First version MIL-STD-1553 was introduced during 1973 in U.S. Air Force F-16 Falcon jet fighter.
- Second version MIL-STD-1553A was implemented during 1978 in U.S. Navy and Marine Corps F/A-18 Hornet jet fighter-bomber
- The final version MIL-STD-1553B (tri-service/NATO standard) was Implemented in all aircrafts from 1978 onwards.. F-35 Joint Strike Fighter etc and also NASA's crew exploration vehicles (CEV).
- Subsequently Four change notices were released on MIL-STD-1553B during the 1980, 1986, 1993 and 1996 respectively.
- During 1999 MIL-STD-1760C was released as Interface Standard for Aircraft and Stores Electrical Interconnection System

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- Further to increase the speed of MIL-STD-1553B by 100 times standard "Extended 1553 (E1553) was flight tested during 2007-08 on F-16, F-18 & C-130.
- Also for higher speed another standard "HyPr-1553 was flight tested on Boeing F-15E-1 during 2005-06.

III. THE AVAILABLE INDUSTRY STANDARDS

#	Standard/Date	Details
1	MIL-STD-464 March 18, 1997	Electromagnetic Environmental Effects Requirements for Systems,
2	MIL-HDBK-1553A March 23, 1995	Multiplex Application Handbook
3	MIL-STD-1553B Notice 1-4, January 1996	Department of Defense Interface Standard for Digital Time Division Command/Response Multiplex Data Bus
4	MIL-STD-1760C March 2, 1999	Interface Standard for Aircraft/Store Electrical Interconnection System
5	SAE AS4111 October 1998	Validation Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Remote Terminals
6	SAE AS4112 January 1989	Production Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Remote Terminals
7	SAE AS4113 January 1989	Validation Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Controllers
8	SAE AS4114 January 1989	Production Test Plan for the Time Division Command/Response Multiplex Data Bus Controllers
9	SAE AS4115 January 1989	Test Plan for the Digital Time Division Command/Response Multiplex Data Bus System
10	SAE AS4116 September 1990	Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Bus Monitors
11	SAE AS4117 March 1991	Test Plan for the Digital Time Division Command/ Response Multiplex Data Bus Couplers, Terminators, and Data Bus Cables

IV. MIL-STD-1553 ECO-SYSTEM

The 1553 Bus Controllers hardware designed initially[5] i.e 1973 using TTL chips and subsequently over the years become single chip i.e SoC/FPGAs.. few details captured below:

- During 1973's F-16 fighter plane Used tradition TTL chips and made it in three cards and connected to transformers
- During 1980's ASICs (Application Specific Integrated Circuits) were produced offering a single chip that could handle the entire digital portion of the 1553 board
- During 1900's Gate Array IC's ASIC's (Architecture Specific IC's) were developed and brought out a single chip that could handle the entire digital portion of the 1553 card
- During 2000's Combining an IP core with an FPGA to create an optimized 1553 solution is gaining widespread as a single chip solution

Combining an IP core with an FPGA to create an optimized 1553 solution is gaining widespread popularity with the present day designers. This approach offers numerous advantages over using traditional 1553 ICs & ASICs in terms of reduced cost, size, footprint, easy to upgrade, easy to re-program, improved availability and lifecycle control also Time to market is drastically reduced At this juncture the 1553B devices are available in the market in the form of ASIC in small foot prints and FPGAs with 1553 IP protocols. The major players are:

#	Organization	Nature of 1553 products
1	Data Device Corp USA	1553 Devices
2	Holt Integrated Circuits	1553 Devices
3	Actel	FPGAs, SoCs and IP cores
4	National Hybrid	1553 Devices
5	Sealevel Systems, Inc - USA	1553 systems & IP Cores
6	Sital technology	1553 systems & IP Cores

Apart from the 1553 Controllers the Bus components i.e cables, transformers, couplers etc are also major contributors to the quality and ruggedness of the 1553 Bus, the following firms are very active in the market for the Bus components:

#	Organization	Nature of 1553 products
1	Beta Transfer technology Corp	components
2	Data bus Products Corp – USA	components
3	Tyco Electronics	components

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4	North Hills Signal Processing	components
5	Alta Data Technologies - USA	controllers & components
6	Phoenix Logistics	components

Many players who are solution provider using the above 1553 controllers & Bus components also designers/suppliers of 1553 bus Test & validation equipment, as listed below:

S.No	Organization
1	Acq Inducom-netherlands
2	Actis Computers SA Switzerland
3	Aeroflex Colorado Springs
4	AIM GmbH Germany
5	AIM-USA LLC
6	Alphi Technology Corp
7	Ballard Technology Corp
8	BCF Designs-UK
9	CMAC Microtechnology UK
10	Curtiss-Wright Controls Embedded computing
11	Dynatem
12	Edgewater Computers Systems
13	Excalibur Systems
14	GE Fanuc Intelligent Platforms
15	Kontron Germany
16	Parvus
17	Sital technology
18	DragoonITCN
19	National Instruments

Over the years "1553 bus" made inroads into major programs and over 1million systems are in the defence and space fields the details are at[14] , MIL-STD-1553B was released by three services i.e Air Force, Army, and Navy/Marine Corp, during 1978. Since then, 1553 Bus was implemented in many systems during 1981, the standard was released as a STANAG 3838 i.e NATO Standardization and European countries started implementing. During 1985, MIL-STD-1553 was become communication link for smart bombs also and started implementing in munitions. USA introduced into space i.e International Space Station, Space Shuttle, Delta launch vehicles, Atlas launch vehicle, Centaur launch vehicle, and numerous military and commercial satellite programs (including GPD, SBIR, Advanced EHF) also spread into commercial aircrafts, such as the Airbus A350 XWB aircraft [19]

Many countries i.e Russia, Israel, Chain, Japan, Taiwan, Turkey, all over the globe implemented MIL-STD-1553 in their defence and space programs. Indian perspective the MIL-STD-1553 is major programs like LCA Light Combat Aircraft, ALH (Advanced Light Helicopter), CHANDRAYAAN lunar probe, GEOSAT communication satellite using.

MIL STD 1553B is being used extensively in the defence since last four decades, it follows command-response protocol and guarantees the delivery of packet in real time every time. The standard proved its ruggedness and fault tolerance feature for all the real time & mission critical applications even though it's Speed is 1Mbps. However, the data traffic is exponentially increasing due to the rapid development of embedded system and digitization of sensors, controllers etc. and puts the need for higher bus speed/bandwidth to handle the same.

DDC studies conducted and carried out a combination of empirical and theoretical[15] methods to determine if a MIL-STD-1553B network can support 200 Mbps data rate without much changes. The results of DDC's analysis is that for some MIL-STD-1553 buses there is sufficient bandwidth to implement a broadband system in which legacy 1 Mbps 1553B waveforms could coexist with new 200 Mbps waveforms, thus providing an incremental high speed communication channel to existing MIL-STD-1553 buses.

DDC proposed two approaches [2] "Turbo 1553" and "HyPer1553" and proved the speed can reach upto 5Mbps & around 100Mbps respectively. The first approach is to simply increase data rate without changing any of 1553's architectural features (modulation technique, line code, coupling methods, etc). The second approach, is to implement a high frequency broadband waveform using alternate line codes and modulation methods, it can coexist with traditional 1 Mbps 1553 on the same wire.

Edgewater Computer Systems Inc. (ECSI) in Ottawa are demonstrating high-speed 1553 named Extended 1553 (E1553) and achieved the throughput rates of to 200 Mbps per second with an eye down the road toward possibly achieving 500Mbp

S.no	Standard	Organization	Bus Speed
1	MIL-STD1553B		1MBps
2	Turbo 1553	DDC	5Mbps
3	High Performance 1553 (HyPer-1553)	DDC	10 to 100Mbps
4	Extended 1553 (E1553)	Edgewater	200Mbps

V. MIL-STD-1553 PRESENT TREND

The present trends in 1553 Bus is to realize the bus controllers i.e BCs, RTs & MTs using FPGAs with IP Core protocols to realize a System-On-Chip(SoC). The major advantages are in terms of Integrating the application firmware along with 1553-STD in a single FPGA. This reduces the space, increases the reliability also increases the handling capacity of emerging complex algorithms, all in a single FPGA. It also results in very

high data throughput to handle routine communications. The present demand in the combat & weapons systems field and aircrafts require more computing bandwidth, in a small foot print. One such method is to implement MIL-STD-1553 systems along with Application within a FPGA. The latest technology pushes FPGAs with greater capabilities to handle the bulk of the actual processing in high-bandwidth and compute intensive applications.

VI. CONCLUSIONS

With the above Review, it is evident the MIL-STD-1553 bus will exist in the future may be for few more decades, with increased Speed without losing its ruggedness, deterministic feature and reliability.

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