MIL-STD-1553 Tutorial and Reference

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CUSTOMER NOTES:

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This is not a QMS Controlled Document.

Note to the Reader and End-User:

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1553 Tutorial and Reference

MIL-STD-1553 (1553) is a standard that describes a one-megabit serial network physical layer (layer one: physical layer – PHY) and message level protocol (layer two: data link layer). Primarily used in legacy avionics, power, sensor and control systems, 1553 has been deployed on thousands of applications worldwide throughout its 35+ year existence including prototype passenger cars, oil platforms, subway control systems and the International Space Station. The US DoD gave-up oversight of the standard (and most MIL-STD documents) in the early 1990s and the standard is now overseen by the Society of Automotive Engineers (SAE) as commercial document "AS15531."

This overview is designed to complement the referenced MIL-HDBK-1553A document, which provides an excellent detailed review of the 1553 standard (MIL-HDBK-1553A Section 20 provides a summary of MIL-STD-1553B Notice 2). Commercially available chip-sets and network interface cards (like Alta's) "off load" the protocol processing (protocol engine) so the engineer's primary concern is the design and integration of application software (data packet transfers) and cabling issues. For example, Alta products and API software off load the 1553 protocol overhead in the same way an Ethernet network interface card (NIC) and operating system drivers offload Ethernet TCP/UDP/IP transfer protocols; this allow the customer/engineer to concentrate on data processing at the required frequencies of the application (and not worry about the 1553 transfer protocols).

The following paragraphs will highlight the main points of the standard that the design or system engineer needs to know for a successful integration.

> **NOTE**: When referencing the MIL-HDBK-1553A and MIL-STD-1553 documents pay particular close attention to "legal/illegal" and "required" message types and the required support "bits" of an RT Status Word. There are minimum implementation requirements to be a compliant 1553B terminal and the designer should reference this information from the standard.

The following diagram shows a crude example of a simple network with computers (BC, RTs and/or Monitor), bus cabling, transformer couplers, stub cables and bus terminators. More description on these terms is provided in the following sections. The computers shown in the picture could be actual Line Replacement Units (LRUs) or a PC/VME computer with an Alta 1553 interface card.

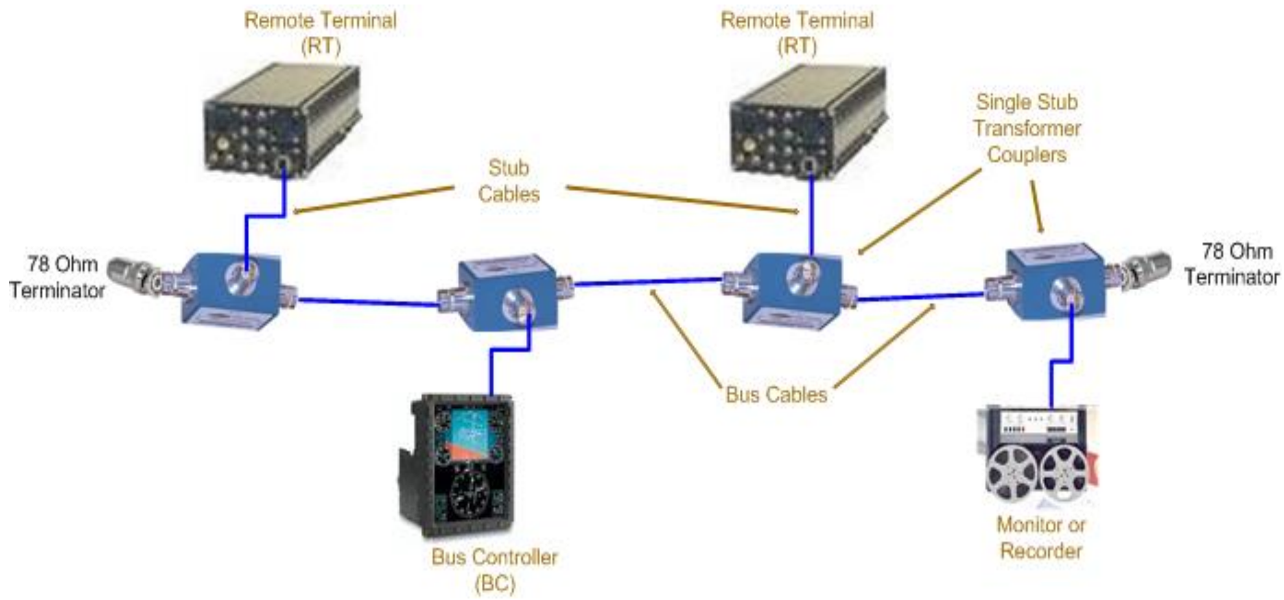


Figure: 1553 Example Single Bus with Two Remote Terminals and One Monitor
(Not to Scale)

A Brief History of Digital Data Busses and History of MIL-STD-1553

Before diving deeper in the review, let's have a brief history lesson…Erwin Gangl was one of the early pioneers in integrating digital computers into military aircraft while working as an electrical engineer at Dayton's Wright-Patterson Air Force Base from 1965 to 1988. In the late 1960s he was assigned to handle the digital computer requirements in the F-15 program office. (Ref1)

"With that came the requirement to set up the inter-communication with all of the other avionic subsystems like the radar navigation controls and displays," said Gangl, who's considered by many to be the father of the data bus standard (Mil-Std-1553) that led to plug-and-play digital avionics. "Where in the past all signals were connected by stringing point-to-point wires, resulting in big cables and connectors, it became very frustrating to me that this couldn't be done digitally. So I recommended that we go to a timeshared digital multiplex data bus concept. The digital conversion is done at the sensor, and a digital signal is sent to the computer via a dual redundant shielded twisted wire pair. This replaced having to have the analog-to-digital converter hardware being part of the computer, and also reduced the number of wire cables needed to connect the computer to the rest of the avionics. It turned out that the concept was accepted, and we developed the Mil-Std-1553 data bus standard that is still in use today." (Ref1)

Today, 1553 is regarded as a low speed computer network standard that can be developed with readily available commercial components and is ideal for environmentally harsh environments (especially environments with electrical noise).

(Ref1 = IEEE-USA http://www.ieeeusa.org/communications/features/100yrs.htm)

1553 Basics

A **1553 network** (or "**data bus**" in older terms) is a heterogeneous architecture where the various computers (terminals) on the network have a master/slave relationship. Message communication is controlled by one master terminal/computer called the **Bus Controller (BC)**. The BC initiates all communications between computer-network end points, which are called **Remote Terminals (RTs).** There can also be passive Monitor terminals ("**Bus Monitor – BM")** that "sniff" or record bus traffic (message packets).

The standard does not describe anything about application processes beyond the layer two data link protocol, so it is completely up to the system designer to architect the message frequencies and physical bus patterns. Since the 1553 topology consists of one central BC computer initiating all communications, very deterministic message timing (to the tens of microseconds, but usually 100s/1000s of microseconds) can be achieved.

1553A and 1553B Variants

There have been two main variants of 1553, the "A" version (1553A) and the current "B" (**1553B**) version. The differences between the two are minor, but important and all new systems (from about 1980) should be using 1553B. Some older aircraft (pre 1985) have 1553A or mixed RT terminals so watch out for these systems. The Alta products support both 1553A and B. **"Notice II" for 1553B was released in 1988 and is the current document that most systems reference (including this discussion).**

1553 Communication Basics

A 1553 network is time division, half duplex communications where all transmissions are on a single cable (unlike full-duplex Ethernet, RS-232/422 or ARINC-429 where separate transmit and receive wires are utilized). Only one computer terminal can talk/transmit at any given time (time division) and the other computers listen/receive (full duplex systems like Ethernet and RS-232 allow simultaneous transmit and receive on different wires).

For safety critical systems, there are one or more standby redundant busses (networks) that are strictly for back-up communications. A common term for a 1553 network is "dual redundant bus," which means there are two independent bus networks (one bus is called the Primary or "A" bus and the other is the Secondary or "B" bus). 1553 messages (data) is usually only transmitted on one of the A or B bus networks at a time, but it doesn't usually matter which bus is used for the message transfers (computers on a 1553 network are supposed to handle messages on either the A or B bus with equal priority). In more safety critical implementations, there may be complete redundant A/B network systems (message priority handling is unique for each system with this configuration).

A simple 1553 network example may have one central computer (BC) and one or more remote computers (Remote Terminals or "RTs"). With more complex systems, there may be several 1553 networks, each one with a single BC and several RTs (up to 31 RTs) to control applications such as flight controls, sensor/power/motor controls, engine management and/or stores management.

The BC is usually the main system computer and often has common names such as flight control computer (FCC) or mission control computer (MCC), etc. In these multiple network scenarios, a BC of one network might be an RT of another network (and thus provide a bridge or gateway between the 1553 networks). In more modern systems, a 1553 network may be a legacy connection to older computers (RTs) that are not in need of redesign (or can't be redesigned due to cost, which it most often the case). Modern systems will often have other networks (e.g. RS-485, ARINC-429, Ethernet/AFDX, Fibrechannel or Firewire) for high rate data transfers between one or more computers.

A Bus Monitor (BM) is simply a network message sniffer or recorder. In older electronics, this function was actually quite complicated and this dedicated function was broken out to separate computers or electronic assemblies. Today, BM capability is often integrated directly in the same chip or interface card (like Alta's cards or Ethernet converter type devices) that performs BC or RT functions.

1553 Layer One: Physical Layer.
Wire, Couplers, Terminators and Bit Encoding

The first thing to know about a 1553 network is how to physically build one bus/network. 99% of 1553 problems (besides getting the software loaded!) are from incorrectly constructed busses or broken bus components. A 1553 bus must be constructed as a 78-ohm balanced topology and it is strongly recommended that transformer coupling be used ("direct coupling" uses T connectors and is only allowed on very old 1553A systems). Notice 2 of MIL-STD-1553 states that direct coupling should be avoided and states that only transformer coupling shall be used for US Army and Air Force systems – see section 30.10.5. The following figure shows a properly constructed bus and its components.

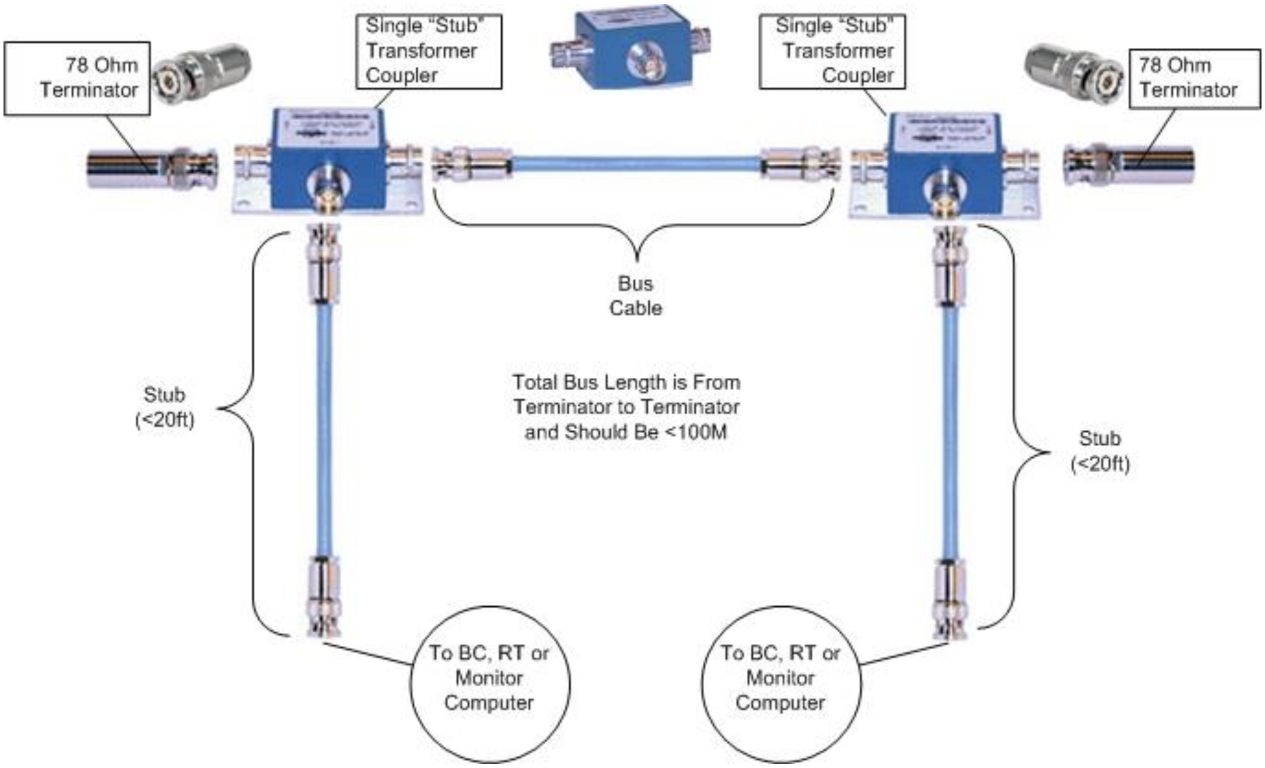


Figure: 1553B Bus Components

Terminology Review:

- **Bus:** The cable between couplers. Technically this can be any length, but the recommended length between couplers is >18 inches (this reduces reflections). The 1553B standard does not specify a maximum length because the general thought was 1553B would go Fiber Optic by the mid 1980s. This was a mistake for wired networks. The 1553A standard referenced a maximum length of 100 meters and this should also be followed for 1553B systems.

- **Coupler:** Transformer interconnect from the bus to the stub of a BC, RT or Monitor. The transformer ratios are a step down from the stub to the bus with a ratio of 1.41. (There is also a 1:1 transformer inside the BC, RT or Monitor computer to isolate internal shorts to the bus). The 1553A standard also allows for "direct" or T connector coupling, which was used on older F-18 systems, **but direct coupling is <u>NOT</u> recommended** (and shall not be used on US Army and Air Force systems – See Notice 2 section 30.10.5).

    - There are multi-stub couplers, which simply mean there are multiple single stub connections in the same box. Don't get confused and use a multi stub coupler to connect the one computer to both the primary (A) or secondary (B) redundant bus. Multi-stub couplers allow multiple computers to be connected to the SAME bus.

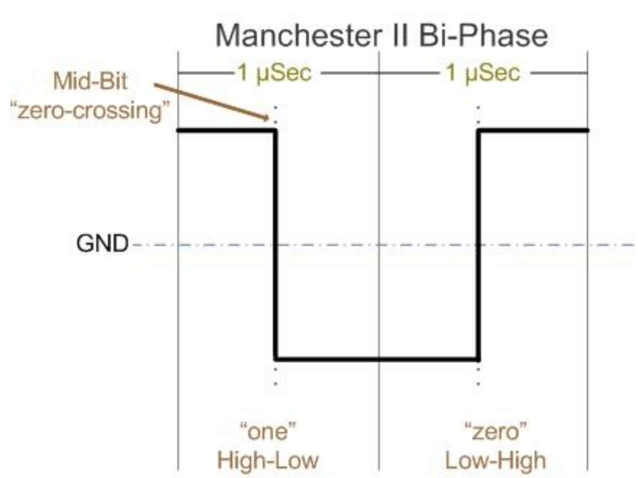
Figure: Multi-Stub Coupler Example - Two Stub and Eight Stub Coupler

- **Stub:** The cable between the transformer and the BC, RT or Monitor. The maximum length of the stub cable is 20ft for a transformer-coupled bus. Recommended lengths are 18 inches to 18 ft. Remember that the total stub length includes backplane and PCB trace lengths to the required isolation transfer inside the BC, RT or Monitor (see the standard for more details – most 1553 chip manufactures provide the proper reference drawings for the circuit card design). Many people try to have stub lengths longer than 20ft and this usually causes problems. Try not to exceed 18ft (this gives a bit of leeway in your design). If you do use direct coupling, your stubs must not exceed 1 foot (12 inches).

- **Terminator:** 78 Ohm End Cap at the end of the bus cable or last coupler on BOTH sides of the bus. Do NOT put terminators on stub connections – this puts a significant load on the bus.

1553 Signal Encoding

1553 uses Manchester II Bi-Phase (Non-Return to Zero, NRZ) encoding for bits. The following figure shows this format for a bit time. When the bus is idle (no transmission), the bus signal should be at ground. Please see the MIL-HDBK-1553A document for details on bus signaling, levels and testing/measurements. The bit rate for 1553 is one mega bit, but the bi-phase encoding means the frequency is 2 MHz. For most 1553 transceivers, the signals are encoded with bi-level signaling from the digital circuit to the PHY transceiver (the various chip manufacturers document this very well).



Bus Problems and Troubleshooting

One common integration problem is where the user tries to cheat and hook-up a BC to an RT with just a single cable. This will not work. A complete bus with stubs, couplers and terminators is required. The simplest bus for two computers is two stub cables, one dual stub coupler with terminators on both sides (and no bus cable). Manufacturers make 1-8 stub couplers (and probably more) – these are great for lab and test scenarios.

Today's ASICs and FPGA protocol engines (like Alta's) that encode/decode 1553 signals are rock solid and rarely fail unless there is excessive loading (improper termination or cabling) or you just got a bad part. 1553 transceivers should be able to handle transmit to ground or high loading, so most issues are usually in the cable plant.

The transformer coupling that protects the bus from DC shorts also prevents common equipment like Time Domain Reflectometers (TDR) from being used to help isolate bus problems/shorts. The best method for troubleshooting a cable length is to have a high impedance load (this is beyond the scope of this discussion). Just remember that if you're having intermittent problems, first check all cabling, couplers and terminators.

1553 Troubleshooting Tips

- Start with the terminators: Terminators are usually the easiest to get access to and simple to swap-out
- Then try shortening the bus in segments to isolate cable runs

In general, you do not need to know or care about 1553 bits and signals are encoded: the chip-set or interface card implement the physical layer for the computer. The MIL-HDBK-1553A document provides good detail on the electrical requirements of the PHY layer.

Layer Two – Data Link Layer: Word and Message Protocols

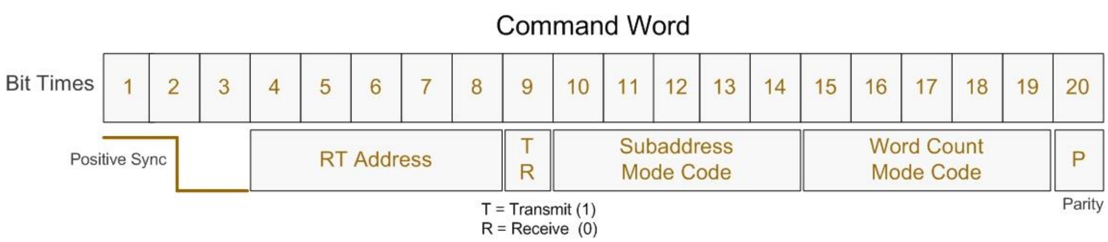
For many 1553 implementations, the designer does not need to know the data link layer: the designer's application programs (or process) will simply make a function call to make a data packet transfer (the various chip and card manufacturers usually provide a proprietary application program interface or API). The API usually performs all the necessary setup for a transfer and the 1553 chip or interface card performs the protocol handshake.

The designer/reader should know the basics of 1553 message structures (layer two: data link layer), which is provided in the following paragraphs. A link is provided for a summary of 1553 word and message structures.

The layer two data link layer is fairly simple header and handshake protocol where the BC sends a “Command” word to direct the data transfers and to initiate minimal bus management commands (called “Mode Codes” – 1553’s version of an Ethernet Simple Network Management Protocol, SNMP). The targeted RT will provide a “Status” response to complete the handshake of data or Mode Code (RTs do not respond to “Broadcast” messages – this is described later in this paper).

1553 Command Words

Before discussing message (packet) structures, a review of the three 1553 “word” types is required. All 1553 words are 16-bit structures with a three bit sync and one bit odd parity (so 20 bit-times total). 1553 is a one mega bit bus so each word takes 20 µSecs of transmission time. A “Command Word” is the first word of every message sent by the BC: this word commands the RT to receive or transmit at a given “Subaddress” with a set number of “Data Words” transferred between the computers. Command Words with a unique subaddress value of zero 0 or 31, 0x1F, signifies that the Command Word is Mode Code bus management command. The figure below details a Command Word structure.



As shown in the figure, Command Words have a 5-bit field for the RT Address, which means there are only 32 possible RT computers allowed on a 1553 network (for 1553B compliant systems, RT Address 31, 0x1F, is reserved to designate a Broadcast function – so only 31 unique RT computers are actually allowed). By their nature, Broadcast commands are “transmit and forget” and receiving RTs do not respond. The Alta protocol engines allow an option to disable Broadcast functions (to be compatible with the older 1553A protocol, which did not provide for the Broadcast function).

The T/R bit is the data direction bit. A bit=1 means the RT will transmit and a bit=0 means the RT will receive data.

The 5-bit Subaddress field allows the BC to designate an internal sub-system or memory area of the RT for the data transfer. The BC is usually "all knowing" of the system design, and thus, directs the RT that the respective data in the message packet is to/from a specific sub process of the RT. As referenced above, a value of zero or 31 (0x1F) is reserved to designate a Mode Code bus management message instead of a normal data transfer message.

The final 5-bit field is the Data Word Count value (unless the command is a Mode Code). In a normal data transfer message, this field directs the RT to receive or transmit the given number of data words for the respective message. If the command message is a Mode Code (by the Subaddress field being zero or 31), then this field is a Mode Code "type" designator and the values correspond to specific Mode Code bus management functions (e.g. Perform Self Test, Transmit BIT Word, etc.). Any command that is not a Mode Code will specify at least one data word. **A value of zero in the word count field means 32 data words.**

1553 Hex Displays

A common industry standard for displaying a Command Word value is to show the RT Address, T/R, Subaddress, Word Count values in separate "1553 hex" fields.

> **For example**: "01 R 04 10" would mean RT Address 01 (one), Receive (0), Subaddress 04 (four) with a Word Count of 16 (0x10 – sixteen).

Most 1553 analyzers will show the Command Word separated in the main fields and the user can select the format or hex or decimal (hex is most common). In a few cases, the Command Word will be shown in a raw 16 bit hex display (for example: 01 R 04 10 would be 0x0890).

The following provides a table of legal 1553B Mode Code Values, Data Word and Broadcast for Command Words (remember the Subaddress will have a value of zero or 31 if the Command Word is a Mode Code).

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Command Word Subaddress (SA) Must be Zero or 31 (0x1F) for Mode Code Designation				
Command Word: Word Count/ Mode Code 5 Bit Field Value	Description	Command Word: T/R Bit Setting	One Data Word Required	Broadcast Command Allowed
0 (0x00)	Dynamic Bus Control	1 (T)	No	No
1 (0x01)	Synchronize	1 (T)	No	Yes
2 (0x02)	Transmit Status Word	1 (T)	No	No
3 (0x03)	Initiate Self Test	1 (T)	No	Yes
4 (0x04)	Transmitter Shutdown	1 (T)	No	Yes
5 (0x05)	Override Transmitter Shutdown	1 (T)	No	Yes
6 (0x06)	Inhibit Terminal Flag	1 (T)	No	Yes
7 (0x07)	Override Inhibit Terminal Flag	1 (T)	No	Yes
8 (0x08)	Reset Remote Terminal	1 (T)	No	Yes
9-15 (0x09-0x0F)	**Reserved**	1 (T)	No	Undefined
16 (0x10)	Transmit Vector Word	1 (T)	Yes	No
17 (0x11)	Synchronize (w/data)	0 (R)	Yes	Yes
18 (0x12)	Transmit Last Command Word	1 (T)	Yes	No
19 (0x13)	Transmit BIT Word	1 (T)	Yes	No
20 (0x14)	Selected Transmitter Shutdown	0 (R)	Yes	Yes
21 (0x15)	Override Selected Transmitter Shutdown	0 (R)	Yes	Yes
22-31 (0x16-0x1F)	**Reserved**	1 (T) or 0 (R)	Yes	Undefined

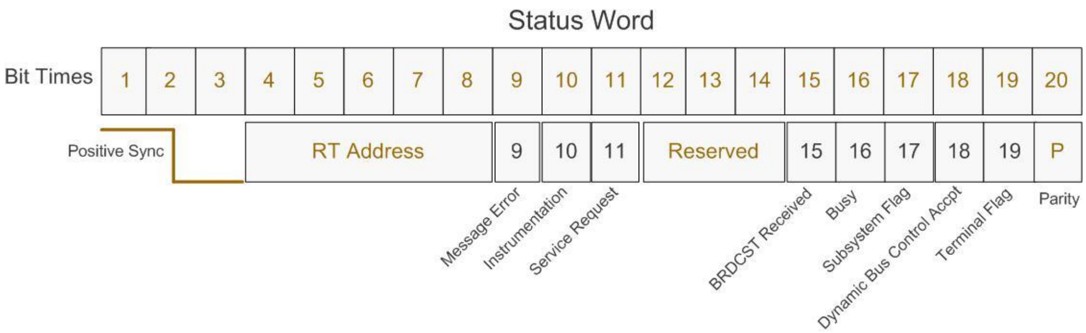
Figure: 1553B Mode Code Table – Predefined Bus Management Messages

1553 Data Words

The Data Word is the information passed between the computers (BC and RTs) on the 1553 network. The figure below shows a Data Word Format. With analyzers, Data Words are usually shown in standard hex nibbles.

1553 Status Word

The Status Word is transmitted by the RT in response to the BC command. The RT must respond with a Status Word for all message types except Broadcast Commands. The first 5 bits of the Status Word is the RT's Terminal Address (same as in the Command Word). The next 11 bits provide status information from the RT to BC. Many of the bits are not used in simple systems. The reader must review section 4.3.3.5.3 of the MIL-HDBK-1553A (page 20-17) for details on the minimum required Status bits. For simple RTs, the Message Error, Service Request and Terminal Flag bits are the most relevant.



Status Words are displayed differently for each analyzer. Most will show a simple hex display, but others will break out the RT Address and the individual bits.

The Alta products automatically strip-off or add-on the sync and parity to the 1553 words so that the designer need only program the 16-bit word values. Most analyzers will not show the sync or parity values (but will show an error if a sync or parity error was detected).

1553B Message Types and Structures

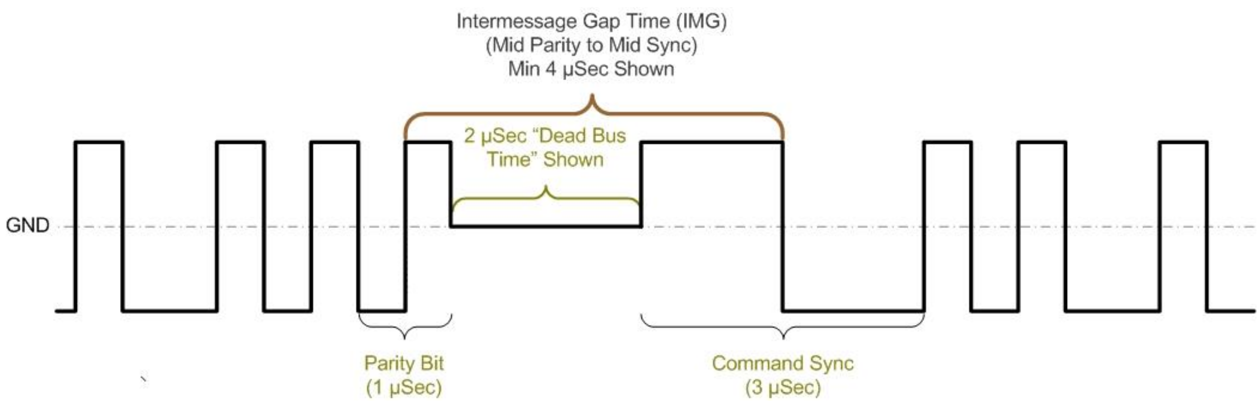
Now it is time to put the words in message packets. The accepted method of describing message transfers is to refer to the direction of data flow to or from an RT: so a “BC-RT” message means data will flow from the BC to the RT(s); and vice versa, a “RT-BC” message means data will flow from the RT to the BC. There is also an “RT-RT” label, which means an RT will transfer data to one or more RTs. As shown in the Command Word discussion, 1553 does allow for Broadcast option (like an Ethernet UDP multi-cast) of certain message types to allow data or Mode Codes to be simultaneously issued to multiple RTs. The 1553 protocol does not implement any CRC or Forward Error Correction – just a simple “command-response” protocol to handshake data. Monitor computers simply listen (or sniff) messages for recording and/or error and status monitoring.

There are 10 different message structures for 1553B. In the figures that follow, the BC words (Command and Data Words) are in brown and RT response words (Status and Data Words) are in olive. Please note that high resolution figures are provided at the end of this document.

The following facts and rules will help explain the caption of the figures:

- All 1553 words are 20 µSecs in time, one bit per µsec and there are 16 bit words with 3 bits of sync and one bit of odd parity.
- An RT has 4-12 µSecs to respond to a BC Command message.
  - The dead bus or wire time is 2-10 µSecs
- The BC will time-out in 14 µSecs if an RT does not respond.
  - The dead bus or wire time is 12 µSecs
- There must be at least 4 µSecs of Intermessage Gap Time (IMG) between messages. There is no maximum intermessage gap time.
  - This is minimum of 2 µSecs dead bus time.

NOTE: The standard measures all timing parameters (RT Response Time, BC Time-Out and IMG) from mid parity of the last word to mid sync of the Command Word of the ensuing message. This *skews* time measurements 2 µSecs because mid parity is 0.5 µsec of the parity bit and mid-sync is 1.5 µsec of the Command Word sync. If the designer really wants to know the, "dead-bus time," or idle time on the bus, then subtract 2 µsec (thus RT Response Times are 2-10 µsec, BC Time-Out is 12 µsec and minimum IMGs are 2 µsec of dead bus time). The following diagram shows IMG verses dead bus timing.



The following paragraphs review the four major categories of message types:

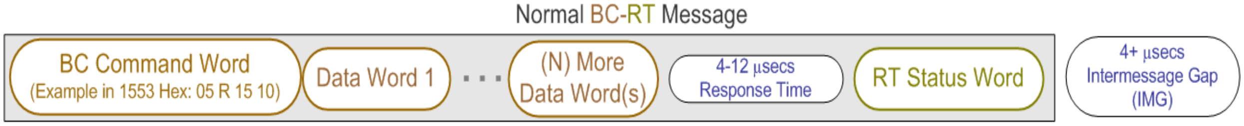
- BC-RT Messages
- RT-BC Messages
- RT-RT Messages
- BC Broadcast Messages

NOTE: The "Wire Message Time" shown in the message figures below is meant to provide the real message time from the start of the sync of the first word of a message (Command Word) to end of the parity bit of the last word of the message. Do not confuse this with Response Time, IMG or No Response Timeout measurements which are measurements of time within the total message wire time. So the Message Wire Time is the raw word 20 uSec time plus any dead bus time.

BC-RT Messages (Normal and Mode Code With and Without Data Word)

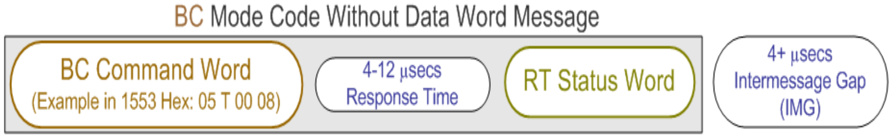
These messages have the BC sending data words or Mode Code messages to a single RT address. These are very common message types.

Normal BC-RT Message



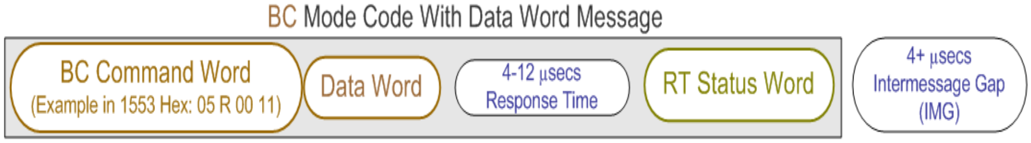
- Minimum Number of Data Words is One
- Maximum Number of Data Words is 32
- The Example Above Would Have 16 Data Words (0x10 hex)
- Command Word Data Word Count Value of 00 = 32 Data Words
- Total Wire Message Time 72-692 µsecs with Max RT Response and Min IMG
- Total Wire Message Time 52-672 µsecs with BC Status Response Time-Out (14 µsec)

BC Mode Code Without Data Word Message



- Only a BC Command Word is Sent for Defined Mode Codes, RT responds with Status Word
- The Example Above Would Have the RT Perform a "Reset"
- Total Wire Message Time is 52 µsecs with Max RT Response and Min IMG times
- Total Wire Message Time is 32 µsecs with BC Status Response Time-Out (14 µsec) if RT does not respond.

BC Mode Code With Data Word Message



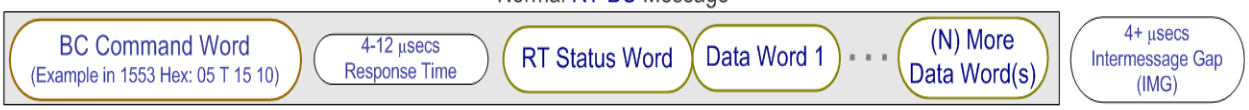
- A BC Command Word and One Data Word is Sent for Defined Mode Codes, RT responds with Status Word
- The Example Above Would Have the RT Receive a BC Synchronize Data Word
- Total Wire Message Time is 72 µsecs with Max Response and Min IMG times
- Total Wire Message Time is 52 µsecs with BC Status Response Time-Out (14 µsec) if RT does not respond.

NOTE: 1553B defines the mode codes without data as having the TRANSMIT bit set. This often causes confusion for those new to 1553: for example, a SYNCHRONIZE mode command without data is sent from the BC to the RT, but the TRANSMIT bit must be set.

RT-BC Messages (Normal and Mode Code with Data Word)

These messages have an RT sending data words back to the BC. These are very common message types.

Normal RT-BC Message



- Minimum Number of Data Words is One
- Maximum Number of Data Words is 32
- The Example Above Would Have 16 Data Words (0x10 hex)
- Command Word Data Word Count Value of 00 = 32 Data Words
- Total Wire Message Time 72-692 µsecs with Max RT Response and Min IMG
- Total Wire Message Time 32 µsecs with BC Status Response Time-Out (14 µsec)

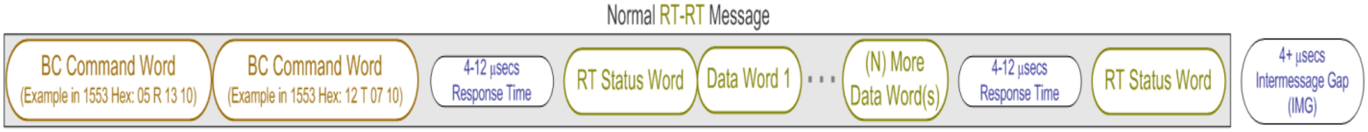
RT-BC Mode Code With Data Word Message

- RT Must Transmit One Data Word for Defined Mode Codes
- The Example Above Would Have the RT Send it's "Vector Word" as the Data Word
- Total Wire Message Time is 72 µsecs with Max RT Response and Min IMG
- Total Wire Message Time is 32 µsecs with BC Status Response Time-Out (14 µsec)

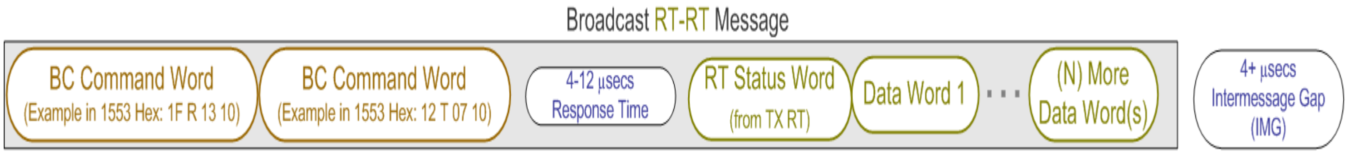
RT-RT Messages (Normal and Broadcast)

These message types have the BC tell an RT to send data to another RT, or with a Command Word Receive (T/R Bit = R) Broadcast address, an RT sends data to all RTs. Normal RT-RT messages (RT to single RT) are fairly common message types, but RT-RT Broadcast messages are relatively rare for most systems.

Normal RT-RT Message



- Minimum Number of Data Words is One
- Maximum Number of Data Words is 32
- The Example Above would have 16 Data Words (0x10 hex) from RT 18 (0x12) to RT 05.
- The Subaddress is User/System Defined (But Cannot be a Mode Code Value of zero or 31 - 0x1F)
- BC Must Send Receive Command Word First Followed by Transmit Command Word
- Command Word Data Word Count Value of 00 = 32 Data Words
- Total Wire Message Time 122-742 µsecs if both RTs Max Response Time and Min IMG
- Total Wire Message Time 102-722 µsecs if the Transmitting RT Max Response Time, but Receiving RT does not respond - BC Status Response Time-Out (14 µsec)
- Total Wire Message Time 52 µsecs if the Transmitting RT does not respond - BC Status Response Time-Out (14 µsec)

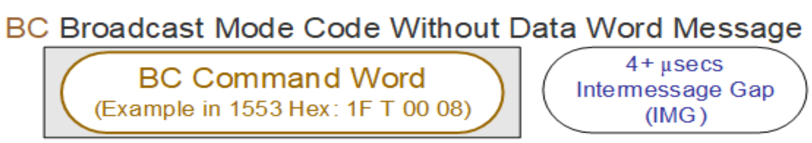


- Minimum Number of Data Words is One
- Maximum Number of Data Words is 32
- The Example Above would have 16 Data Words (0x10 hex) from RT 18 (0x12) to ALL other RTs.
- The Subaddress is User/System Defined (But Cannot be a Mode Code Value of zero or 31 - 0x1F)
- BC Must Send Receive Broadcast Command Word First Followed by Transmit Command Word
- Command Word Data Word Count Value of 00 = 32 Data Words
- Total Wire Message Time 92-712 µsecs with Max RT Response and Min IMG
- Total Wire Message Time 52 µsecs if Transmitting RT does not respond - BC Status Response Time-Out (14 µsec)

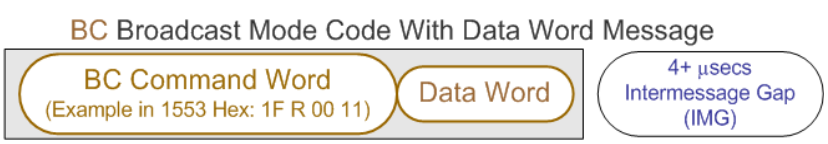
BC-RT(s) Broadcast Messages (Normal and Mode Code)

BC Broadcast messages are implemented sporadically with different systems. A Broadcast message can save a lot of communication time, but avionics systems tend to like a closed-loop transmission scheme (the central computer really wants to know that the message got delivered), so the use of Broadcast Commands is truly system dependent.

- Minimum Number of Data Words is One
- Maximum Number of Data Words is 32
- The Example Above Would Have 16 Data Words (0x10 hex)
- Command Word Data Word Count Value of 00 = 32 Data Words
- Total Wire Message Time 42-662 µsec with Min IMG



- Only a BC Command Word is Sent for Defined Broadcast Mode Codes
- The Example Above Would Have ALL RTs Perform a “Reset”
- Total Wire Message Time is 22 µsecs with Minimum IMG



- A Command Word and one Data Word is sent by BC to all RTs
- The Example Above Would Have ALL RTs Receive a BC Synchronize Data Word
- Total Wire Message Time is 42 µsecs with Minimum IMG

Integration Issues for BC, RT and Monitor Computers

For BC applications, the user will need to know how the messages are timed (their frequency) and how to handle the RT data responses for the particular mission or test system. For RTs, the computer must know what data (the sensor or data reading) and when the BC is going to request data. It is the RT's responsibility to be ready for the BC command request. For Monitors, the designer will need only to make a couple setup function calls (for buffer storage and filter options) and then start logging data from a "polling" or interrupt signal from the API or interface card. Most 1553 chip sets and interface cards are "memory mapped" to the host application or API. The application makes simple API function calls to read or write message buffers.

Application Discussions

BC Review – Application Designs

A 1553 bus is usually connected to various control or sensor systems that require periodic control or monitoring. Often the system will have a "base frequency," which corresponds to the RT that requires the fastest, repetitive service: this frequency will often define the BC's "minor frame" rate.

A minor frame is a group of one or more messages that is repeated at a given frequency – typically in the 1-1000 Hz (1 to 1000 milliseconds – although there is no minimum limit, and in theory, but not practical, a minor frame could be a single message with the fastest rate of 22 µSecs). Most systems rarely go above 100 Hz (10 millisecond) in base frequency operations. A common design practice will "pad" the minor frames with dead bus time at the end of each frame so the BC/system can inject "aperiodic" messages in the frame to handle special on-demand or system interrupt events. A good design practice is to use no more than 50% of the available time in a frame, leaving the rest for error recovery, retries, and future additions to the system.

While most systems have repetitive message framing this is not required: a 1553 system can be an "on-demand" design where the BC sends control messages as system/process events require. All of these scenarios can easily be managed by the Alta protocol engine so the designer's BC application is off loaded from the low level message timing.

The following figure shows an example of BC Frame Options.

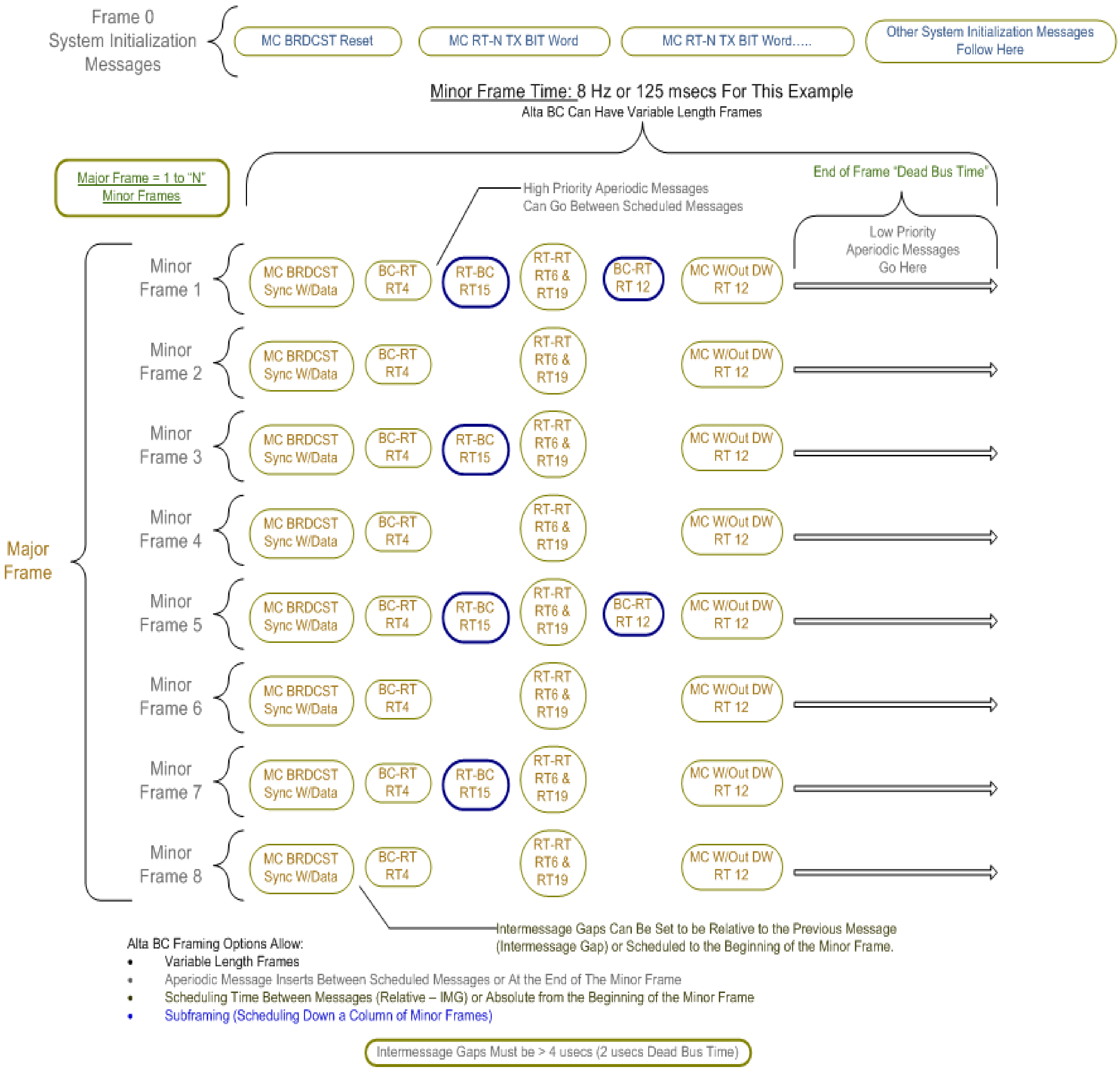


Figure: Example BC Message and Framing Options

RT Review – Application Designs

RTs can be anything from a simple light bank switch, radio controller, motor control unit, power control unit or a complicated radar system. The applications vary as greatly as the thousands of 1553 system designs, and can vary greatly on a single network. The key requirement for an RT design is usually the frequency requirement demand from the BC. The RT design, and its readiness to digest (receive) or present (transmit) data, is usually dictated by the system designer and will typically follow the frequency patterns of the minor frames of the BC. In general, the RT design is required to handle the frequency of the BC messages. 1553 systems usually have strict message patterns and the RT requirements are well known in advance, and thus the RT designer must ensure the unit (often called a Line Replaceable Unit, or LRU) has the processing power to handle the system frequencies (and the RT must perform its main computer function).

1553 Application Review – Polling or Interrupts

The preceding paragraphs reviewed various aspects of message frequency demands a system. A key decision for the design engineer is deciding to use hardware interrupts or software polling to handle 1553 message events. The answer is usually tied to the requirements of the event handling and computer operating (OS) environment. For example, a Windows based system can provide highly accurate hardware interrupt events IF you know the details of writing a “ring zero driver” (which not many people know). A real-time OS (RTOS) can provide the sub-10 microsecond responses and can cost quite a bit per implementation. In recent years, many customers have had success with Linux and Linux RT OS implementations for sub one millisecond event handling (this seems to be a popular trend).

A general rule of thumb is: if the event requires a 10-millisecond response or less, then a hardware interrupt is probably required (especially with Windows) to service the event (and software polling can probably be used for event handling accuracy of greater than 10 milliseconds). Software polling is usually a lot easier to implement, but there will often be a lot of time skew (especially with Windows) in handling the event. If you need hard real-time of less than one millisecond event service, you probably need an RTOS or Linux RT kernel.

Revision Information

Date	Rev	Description
9/21/14	A3	Updated Text, Descriptions and Message Timing Diagrams
1/4/18	A4	General Text Update, Fixed Broadcast Mode Code RT Address Error.