Avionics 101

Databus basics

Outline

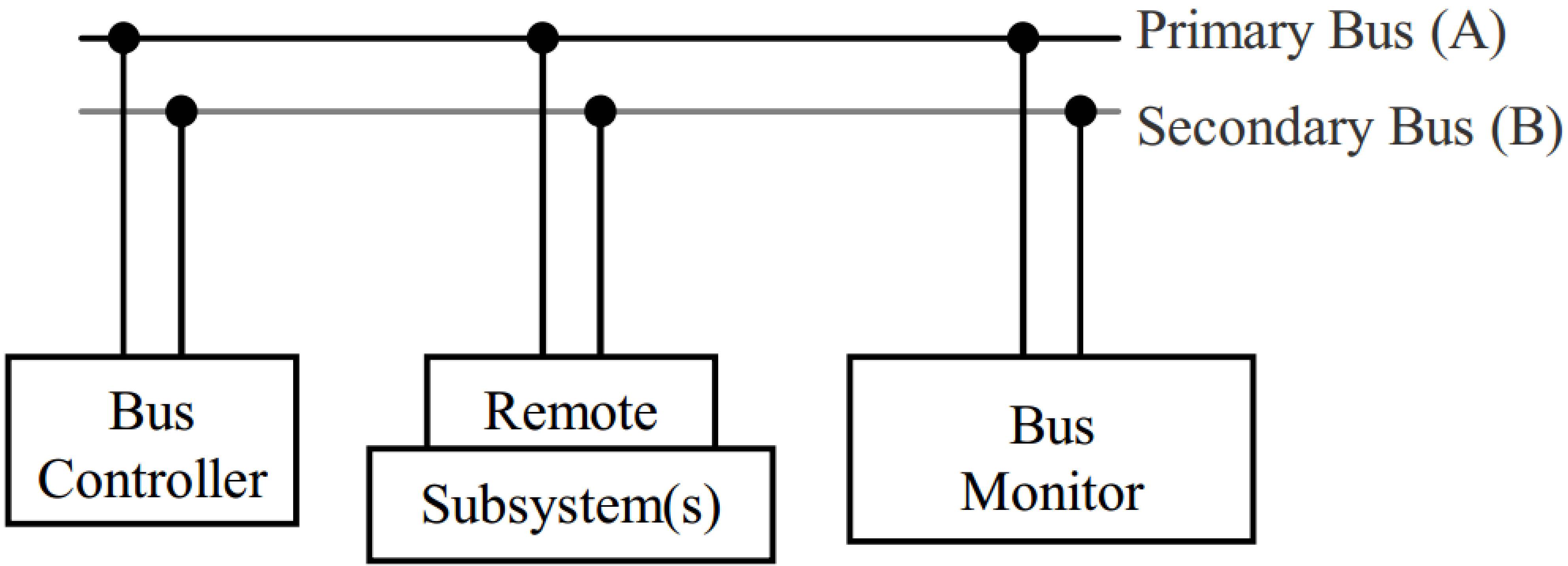
- MIL-STD 1553
- MIL-STD 1760
- ARINC-429
- ARINC-664
- ARINC-708
- Others – not discussed
  - Gigabit Ethernet
  - Fibre Channel
  - 1394B or Firewire

MIL-STD-1553

MIL-STD-1553 is a military standard published by the United States Department of Defense that defines the mechanical, electrical, and functional characteristics of a serial data bus. It features a dual redundant balanced (differential) line, time division multiplexing, half-duplex command/response protocol, and up to 31 remote terminals.

There are 2 versions of the standard: A and B.
MIL-STD-1553A was written in 1975
MIL-STD-1553B was written in 1978

Dual Redundant Bus Structure



MIL-STD-1553 Components

- **Bus Transmission Line**
  - Shielded twisted pair wire of a defined characteristic impedance, frequency response, and attenuation.

- **Bus Terminator**
  - Resistor which terminates the extreme ends of the bus.

- **Bus Coupler**
  - Transformer device which provides the means of connecting a Bus Controller, Bus Monitor, and Remote Terminals to the 1553 bus.
  - The coupler also contains isolation resistors.

MIL-STD-1553 Components

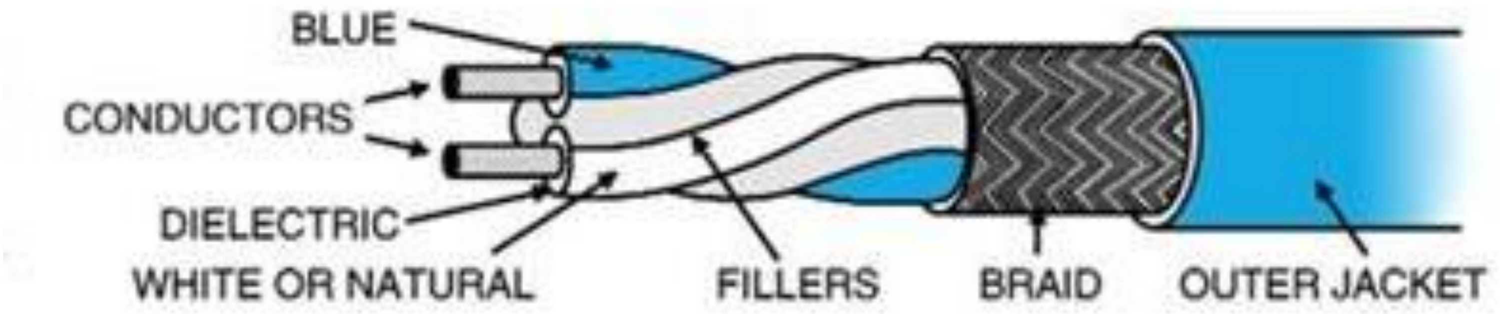
- **Bus Controller (BC)**
  - The terminal assigned the task of initiating information transfers on the data bus
  - Is the “boss” of the bus (typically is the Mission Computer)

- **Remote Terminal (RT)**
  - All terminals not operating as the bus controller or bus monitor.
  - RTs only respond when commanded
  - Each RT is assigned an RT number or address

- **Bus Monitor (BM)**
  - Only listens and does not transmit on the bus.
  - Used within an instrumentation system

1553 Cable

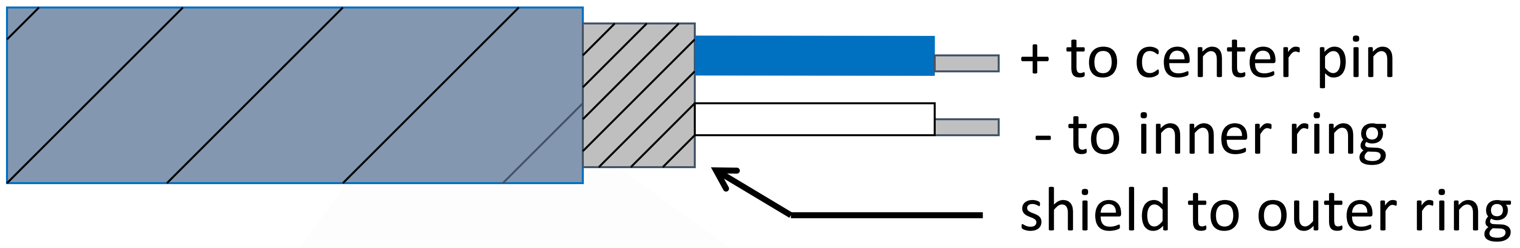
The cable used for the transmission line is a special cable that has the impedance and frequency response specified in the MIL-STD-1553 specification.

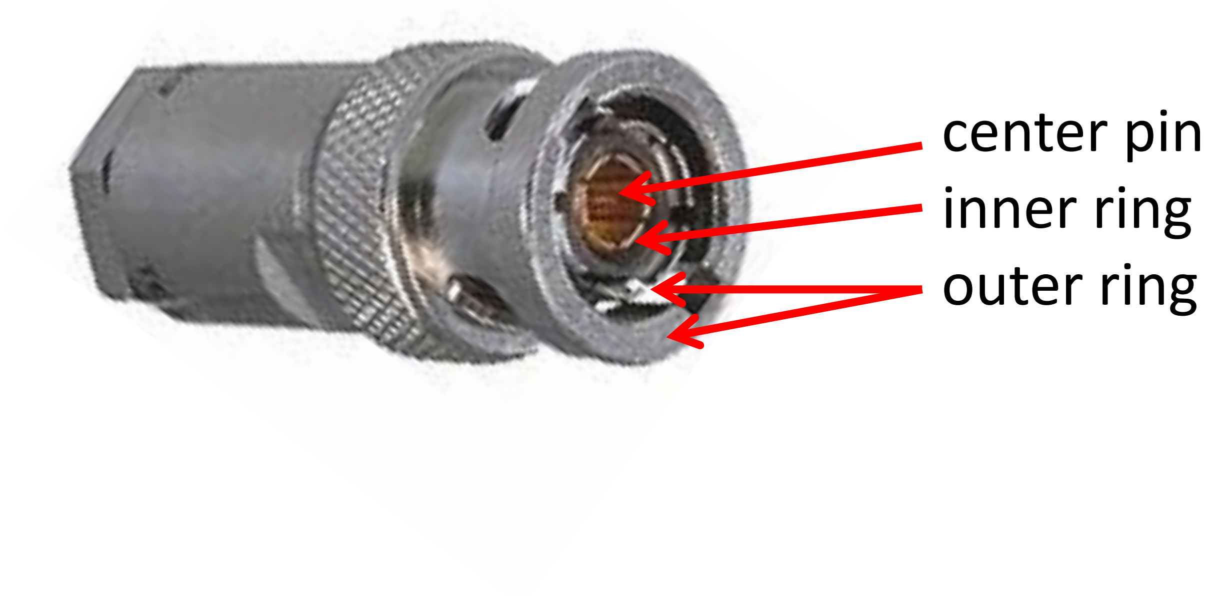


1553 Type	Impedance (Z_0) at 1 MHz	Capacitance	Max Cable Attenuation	Cond Twists	Shield Coverage	Max Length
1553A	70 Ω ± 10%	30 pF/ft	1 dB/100ft	1/inch	80%	300 ft
1553B	70 Ω to 85 Ω	30 pF/ft	1.5 dB/100ft	4/foot	75%	not spec

Tri-axial Connectors

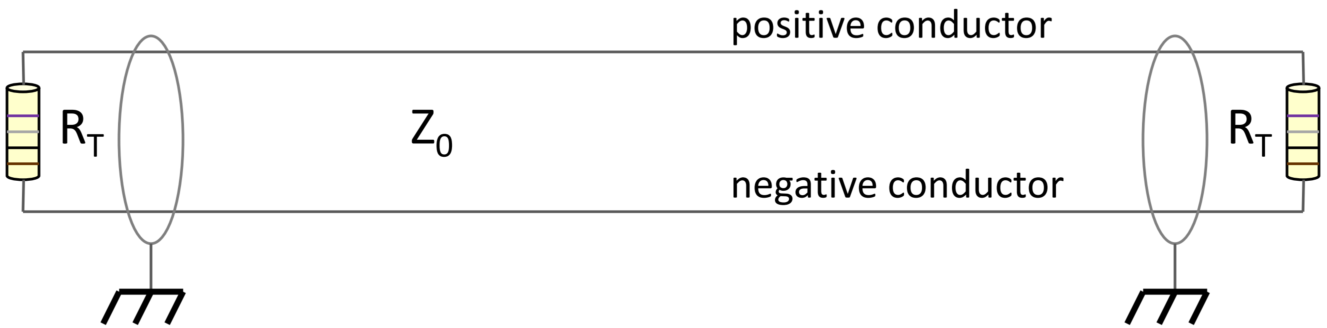
A majority of 1553 busses utilize tri-axial connectors. The signals are assigned as shown below. Circular connectors with multiple pins are used on the bus termination networks.





MIL-STD-1553 Bus

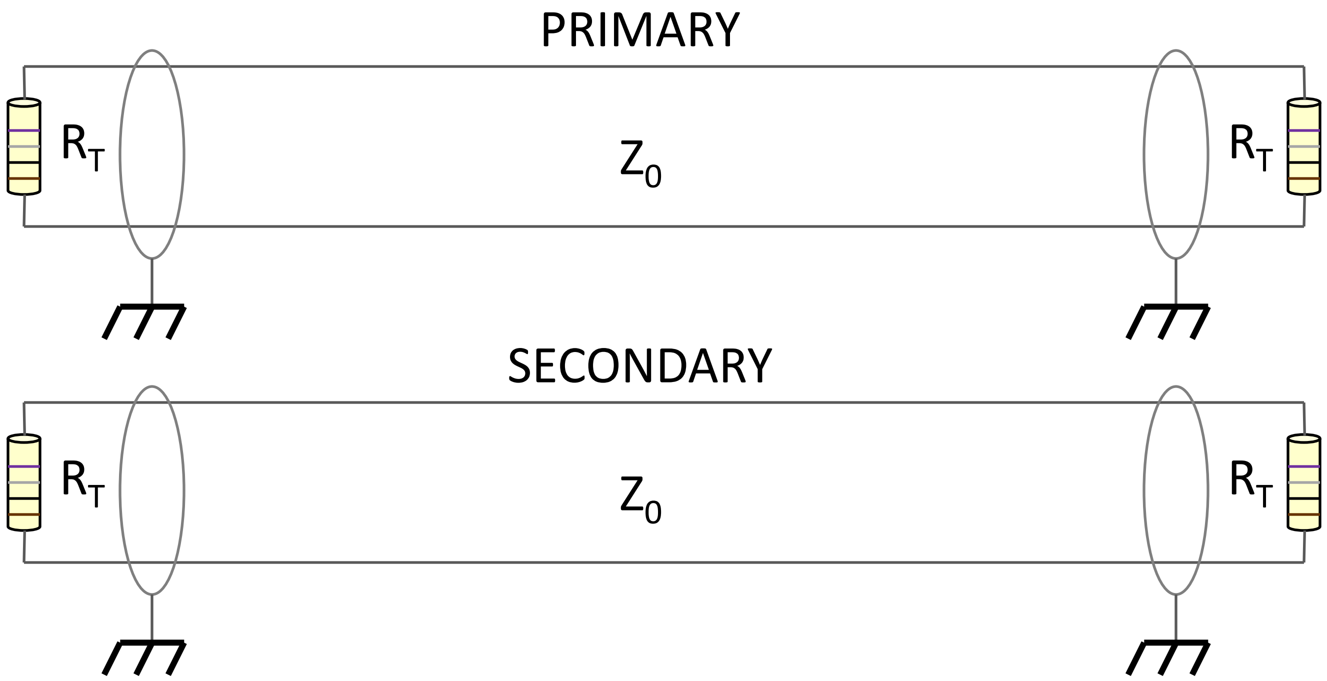
In its most simplistic form, the 1553 bus is a shielded pair of wires with terminating resistors on each end. The resistor values match the impedance of the bus. The shield is terminated to chassis ground at each end.



For 1553A: $R_T = Z_0$
For 1553B: $R_T = Z_0 \pm 2\%$

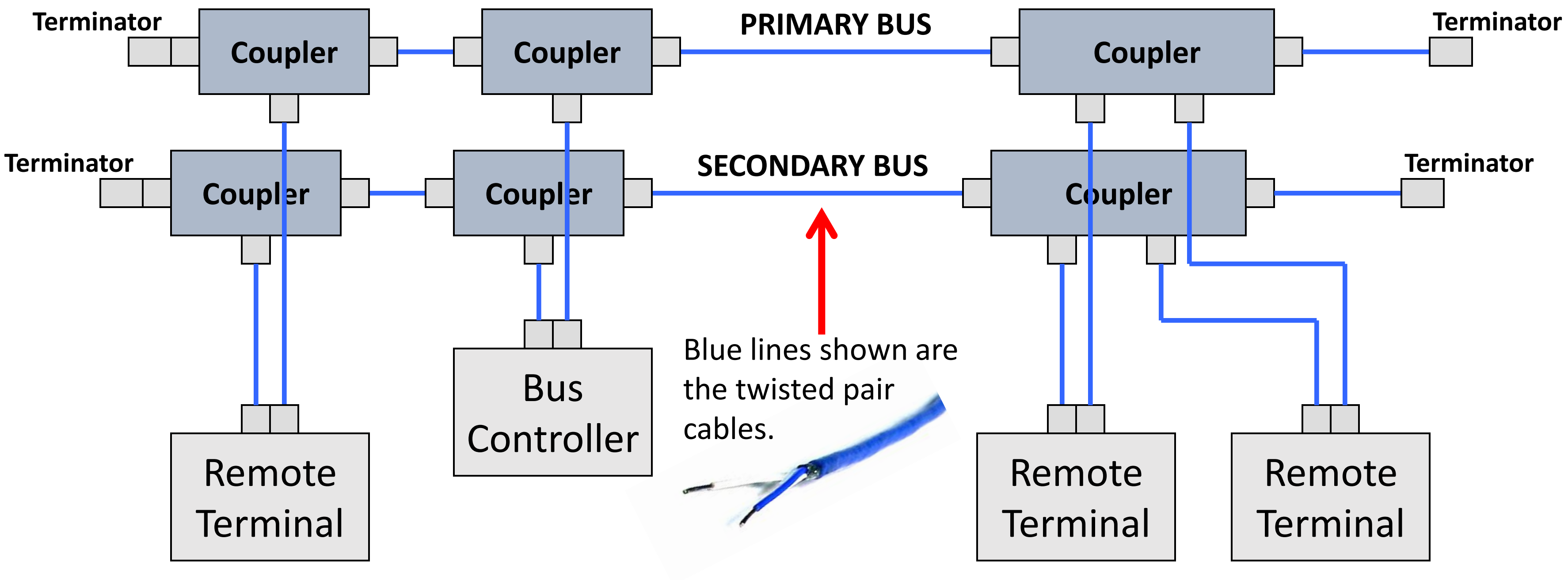
Dual Redundancy

A 1553 bus is actually made up of two busses, a primary and a secondary bus. 1553 messages are not transmitted on both busses simultaneously, but on either one or the other. <u>Both busses must be monitored</u> for data. Usually each bus is run physically apart from one another to avoid damage to both cables.



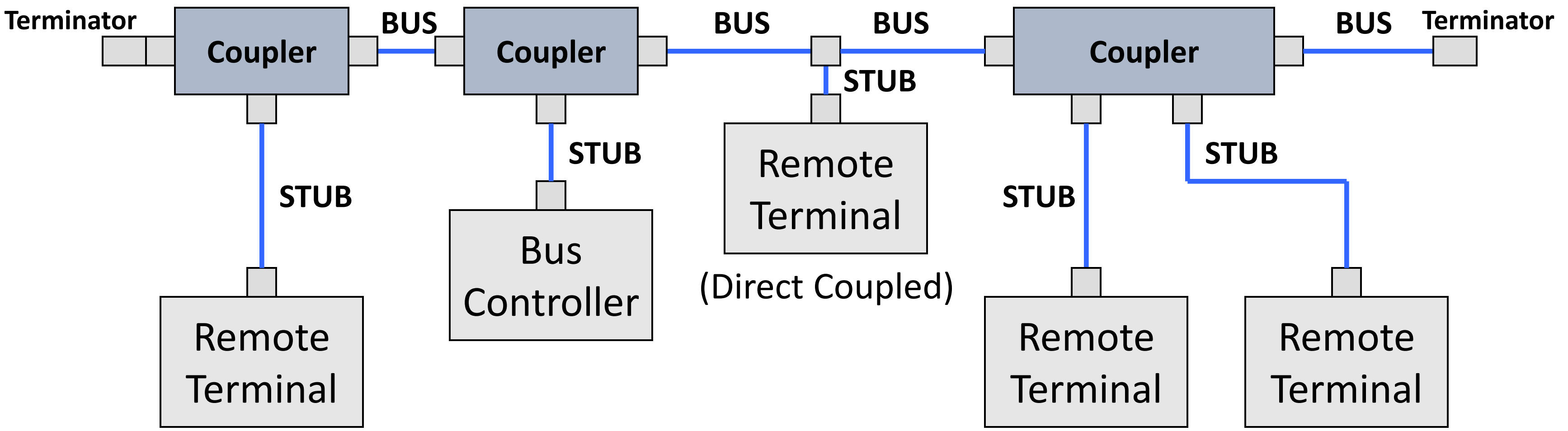
Bus Controller and Remote Terminal Connection to the 1553 Bus

Bus controllers and remote terminals are the components that talk on the bus. This diagram shows the typical connections that need to be made to both the primary and secondary busses.



Bus Controller and Remote Terminal Connection to the 1553 Bus

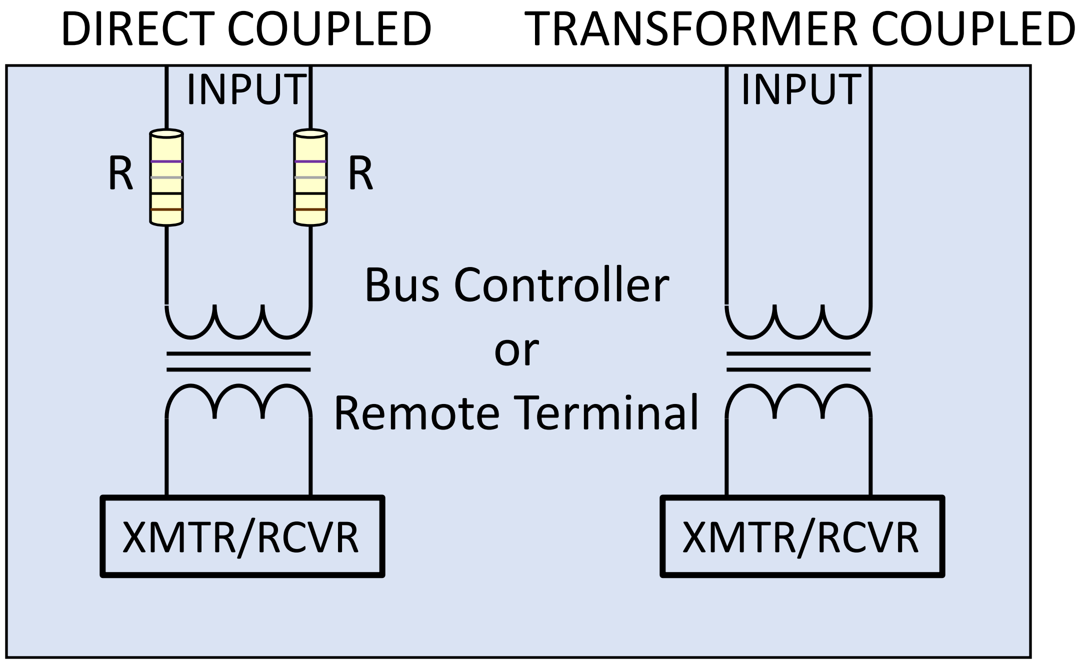
Bus controllers and remote terminals connect to the bus via a stub connection. This is accomplished in one of two ways on the bus: direct coupled, or transformer coupled stub.



From now on through the training only the primary bus is shown. However, keep in mind that a second set of 1553 bus components are needed for the secondary bus.

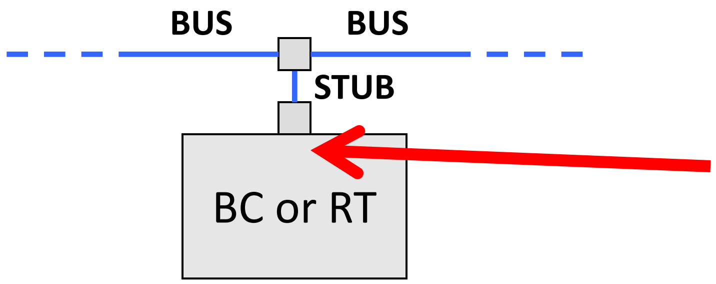
Bus Controller and Remote Terminal Input Connection to the 1553 Bus

Each bus controller and remote terminal has two types of stub inputs. Depending on whether it is direct coupled or transformer coupled determines which input to use. Sometimes they are noted as long and short stub inputs. There will be a pair of each for the primary and secondary bus.



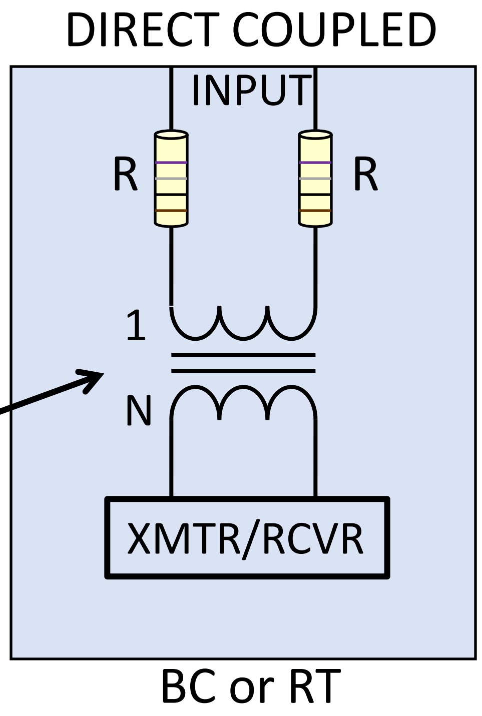
Direct Coupled Inputs

Direct coupled inputs on a BC or RT have isolation resistors and an isolation transformer on the input pins. The value of the isolation resistors depend upon the version of the 1553 bus.



(Direct Coupled)

The turns ratio of the transformer depends upon the power supply used. For example an RT with a 15V power supply, N=1.41 for a 1553B type bus.

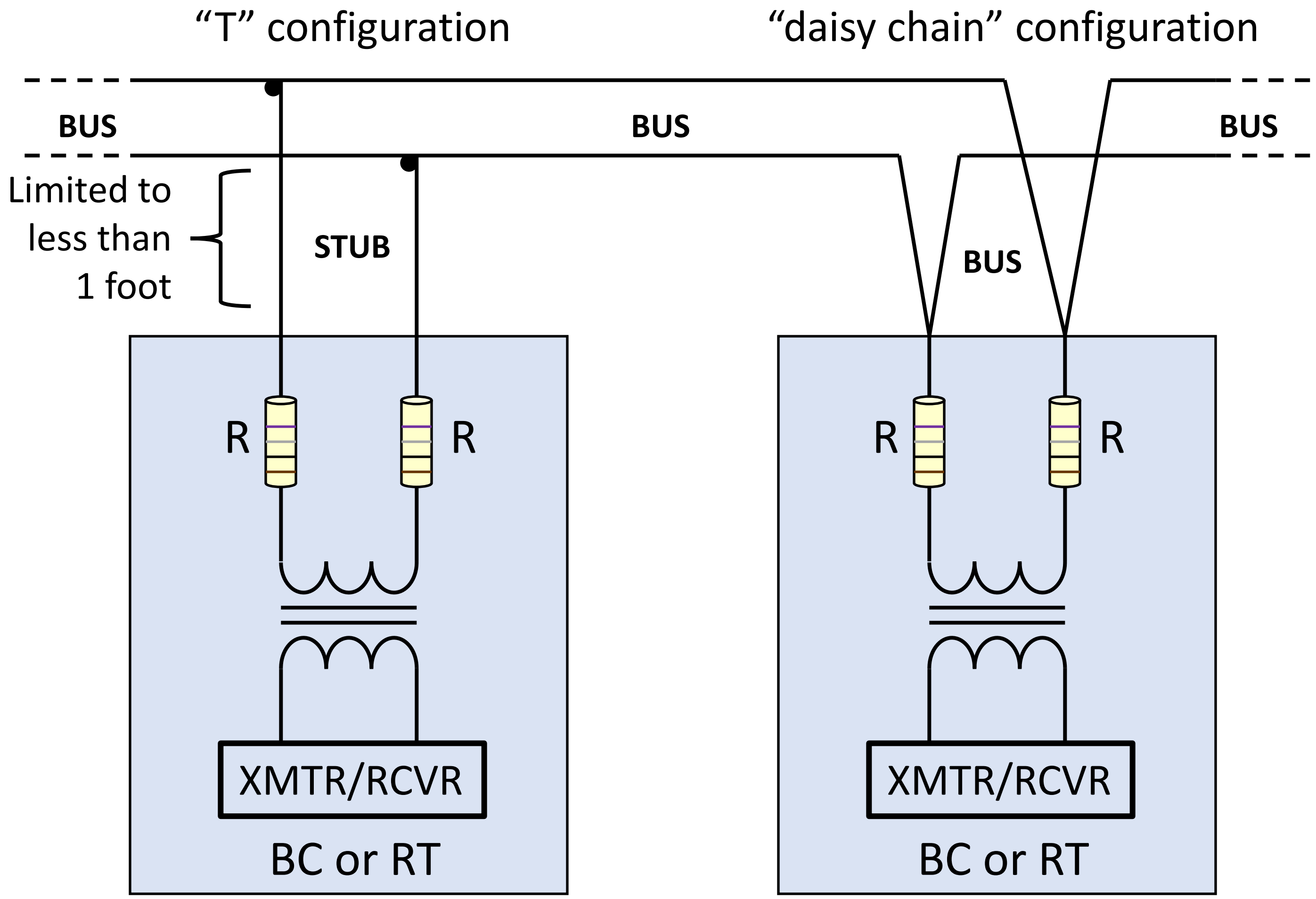


1553A:
$R = 0.75Z_0 \pm 5\%$

1553B
$R = 55\Omega \pm 2\%$

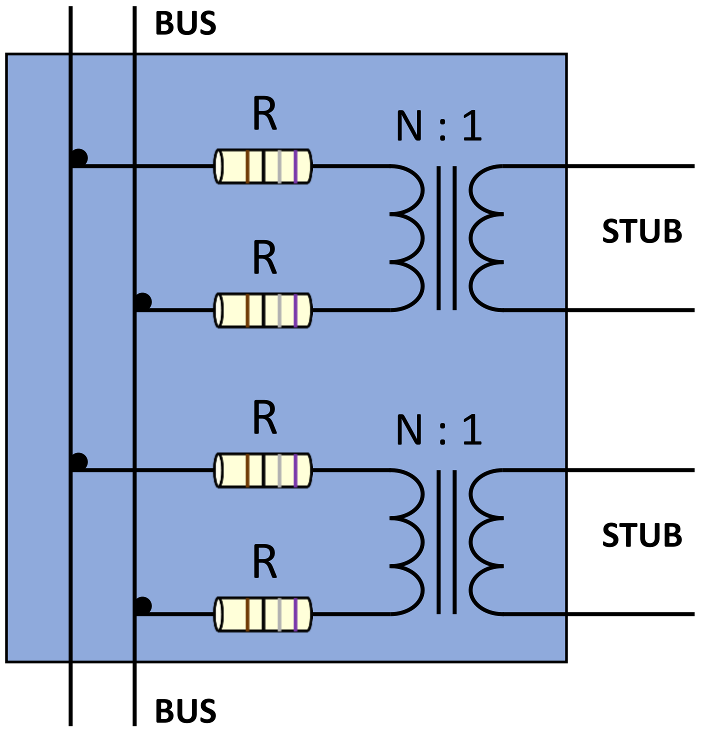
Direct Coupling to 1553 Bus

For direct coupling, the bus is T'd or daisy chained to the input of the BC or RT. If it is T'd, its length is limited to a maximum of 1 foot. An easy way to identify direct coupling is there are no external bus couplers mounted in the aircraft.



Bus Couplers

Bus couplers have two bus connections and one or more stub connections. The isolation resistors and transformer are located within the coupler. Two separate bus couplers are needed, one for the primary and one for the secondary bus.

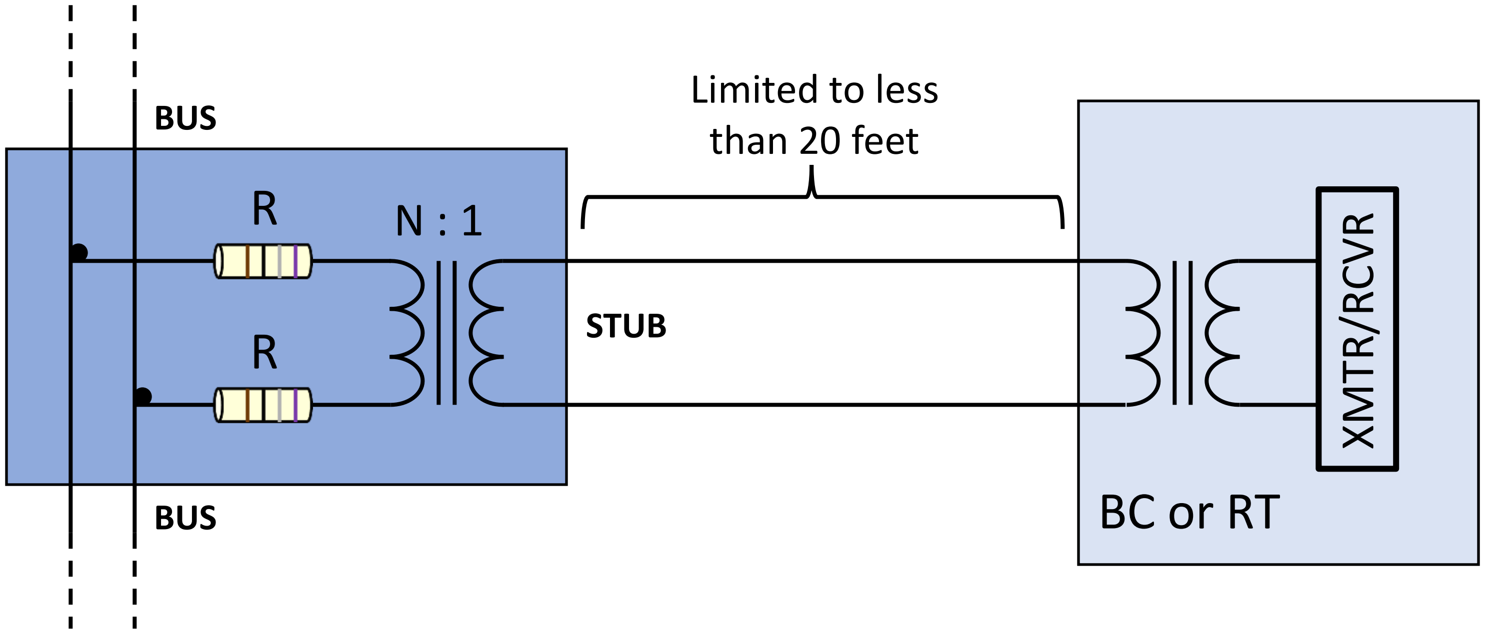


1553A:
$R = 0.75Z_0 \pm 5\%$
$N = 1$

1553B
$R = 0.75Z_0 \pm 2\%$
$N = 1.41 \pm 3\%$

Transformer Coupling to 1553 Bus

For transformer coupled bus taps, the stub can have a length of no more than 20 feet.



A Note on Stub Lengths

We just covered that:

- Direct-coupled stubs are to be no longer than 1 foot
- Transformer-coupled stubs are not to exceed 20 feet

We follow these rules when installing instrumentation bus monitors, but the MIL-STD-1553 is somewhat lenient on stub lengths.

4.5.1.5.1 Transformer coupled stubs. The length of a transformer coupled stub should not exceed 20 feet. If a transformer coupled stub is used, then the following shall apply.

4.5.1.5.2 Direct coupled stubs. The length of a direct coupled stub should not exceed 1 foot. Refer to 10.5 for comments concerning direct coupled stubs. If a direct coupled stub is used, then the following shall apply.

Notice it uses *should* not *shall*.

A Note on Stub Lengths

Furthermore, the standards says:

4.5.1.5 Cable stub requirements. The cable shall be coupled to the terminal as shown on figure 9 or 10. the use of long stubs is discouraged, and the length of a stub should be minimized. However, if installation requirements dictate, stub lengths exceeding those lengths specified in 4.5.1.5.1 and 4.5.1.5.2 are permissible.

So how long of a stub is permissible? – it doesn't say.

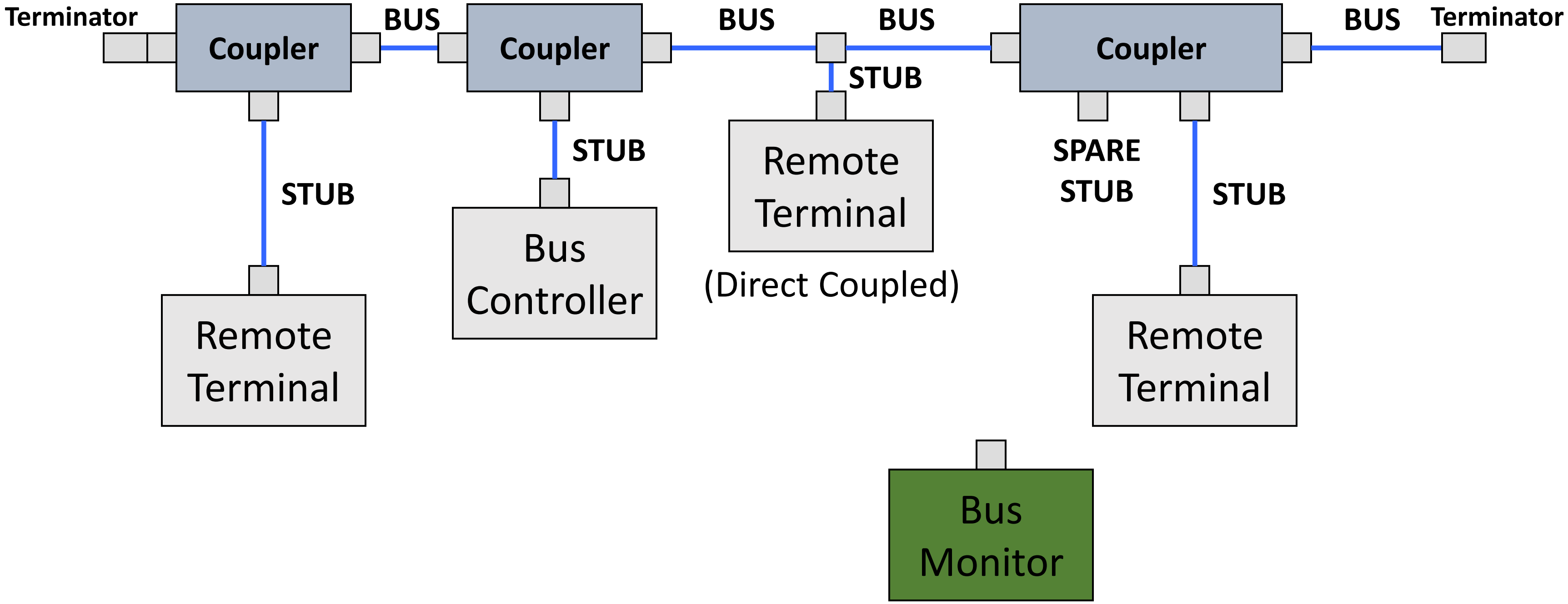
However, in the MIL-HDBK-1553A (page 40-19), it states:

…transformer-coupled stubs are allowed to be up to 20 ft. long (4.5.1.5.1). Actually the figure of 20 ft is only a recommendation, but it is a strong one. Lack of isolation and larger perturbations limits direct-coupled stubs to a 1-ft. length.

There are many factors which limit what the length of the stub should be: bus loading, location of stubs, etc…

Connecting a Bus Monitor to the Bus

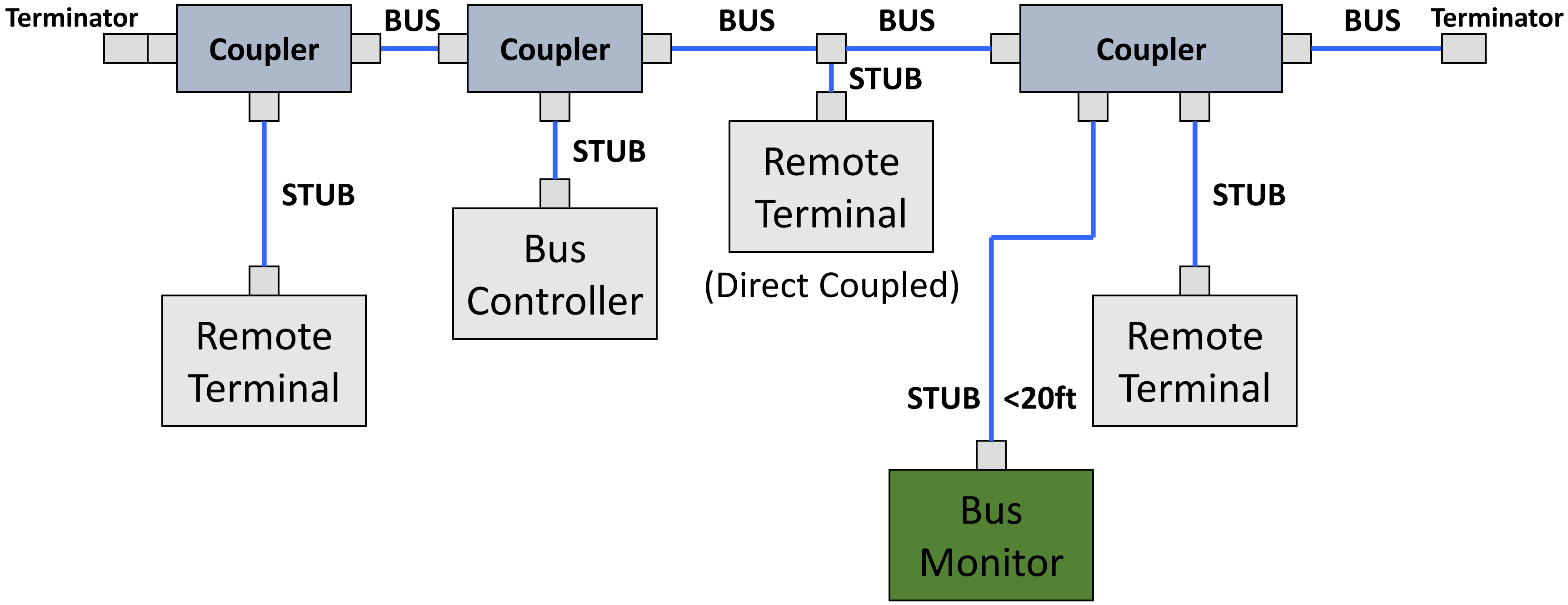
Aircraft with a Spare Stub



Connecting a Bus Monitor to the Bus

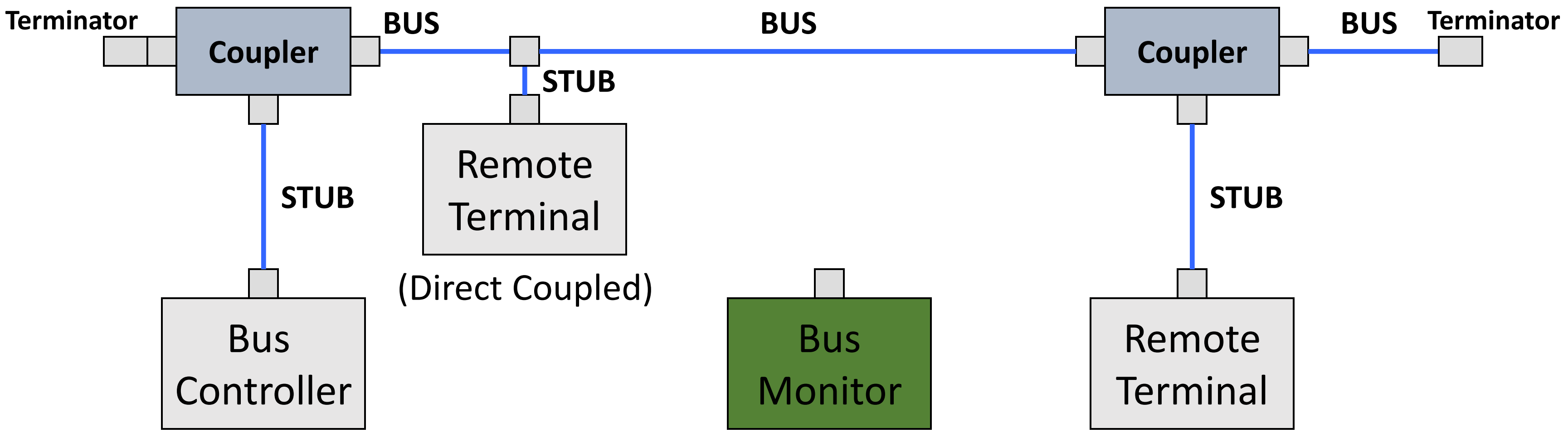
Aircraft with a Spare Stub

This is the easiest way to connect to the 1553 bus. As long as the bus monitor's stub length is within 20 wire-feet, nothing additional need to be done.



Connecting a Bus Monitor to the Bus

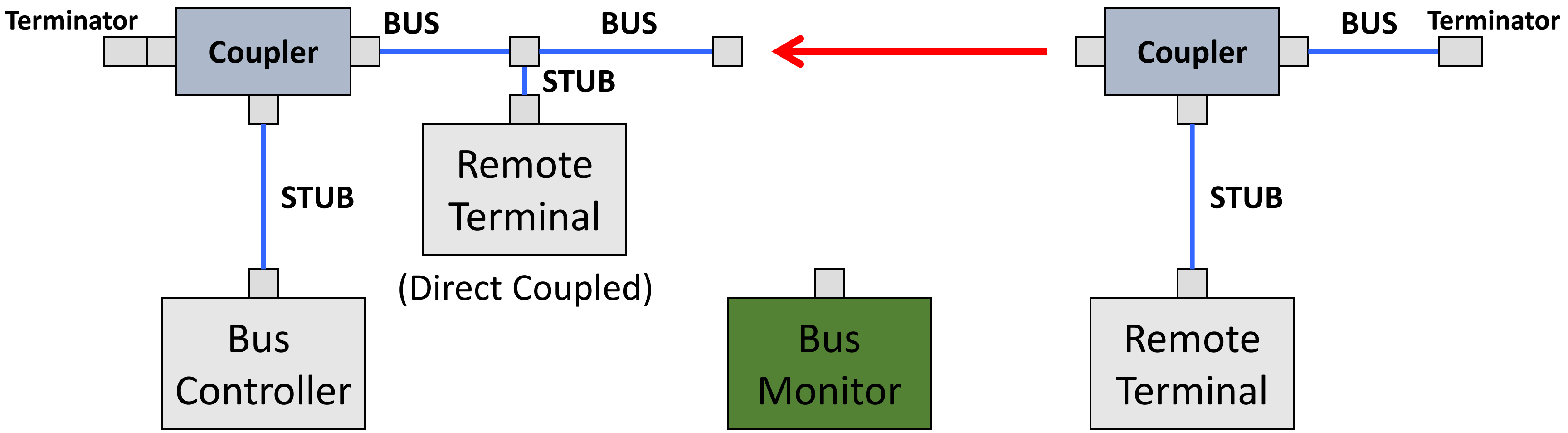
Aircraft with No Spare Stubs



Connecting a Bus Monitor to the Bus

Aircraft with No Spare Stubs

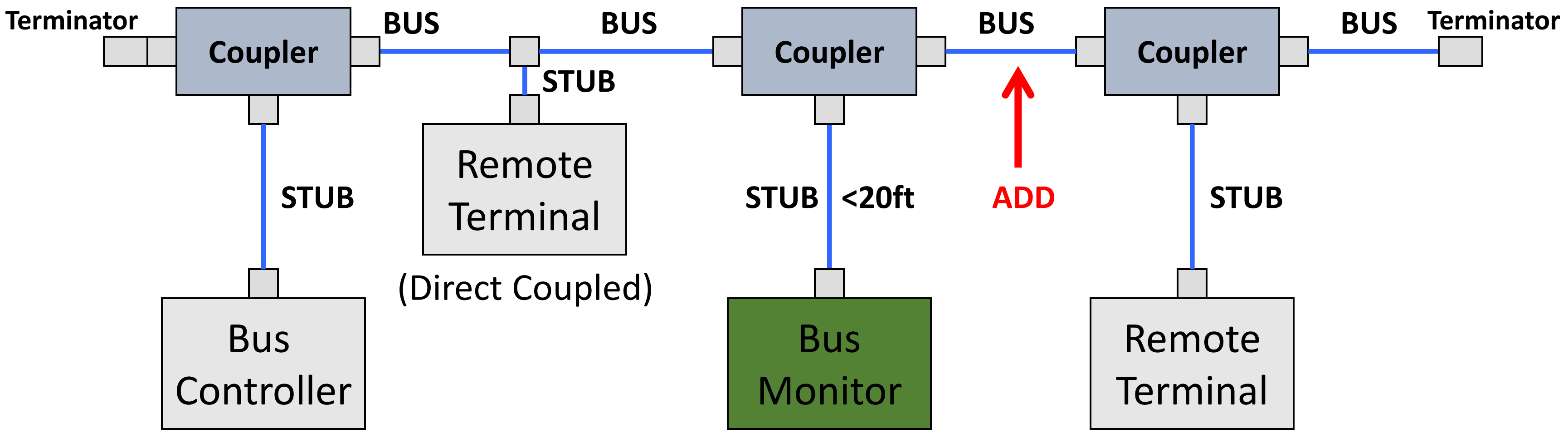
Disconnect the bus from the coupler that is closest to the instrumentation system.



Connecting a Bus Monitor to the Bus

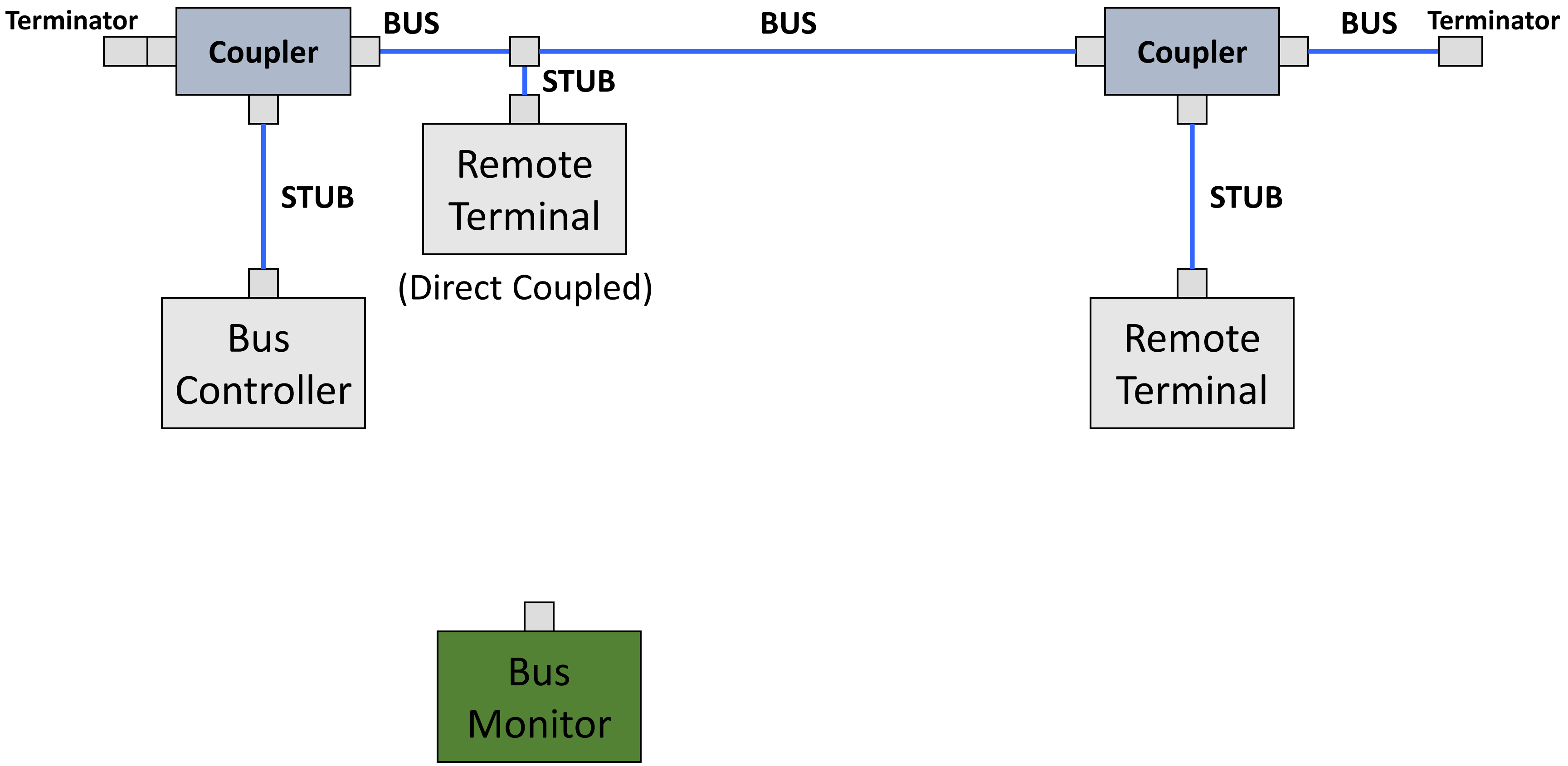
Aircraft with No Spare Stubs

Insert the instrumentation coupler and add an additional bus wire run to the next coupler.



Connecting a Bus Monitor to the Bus

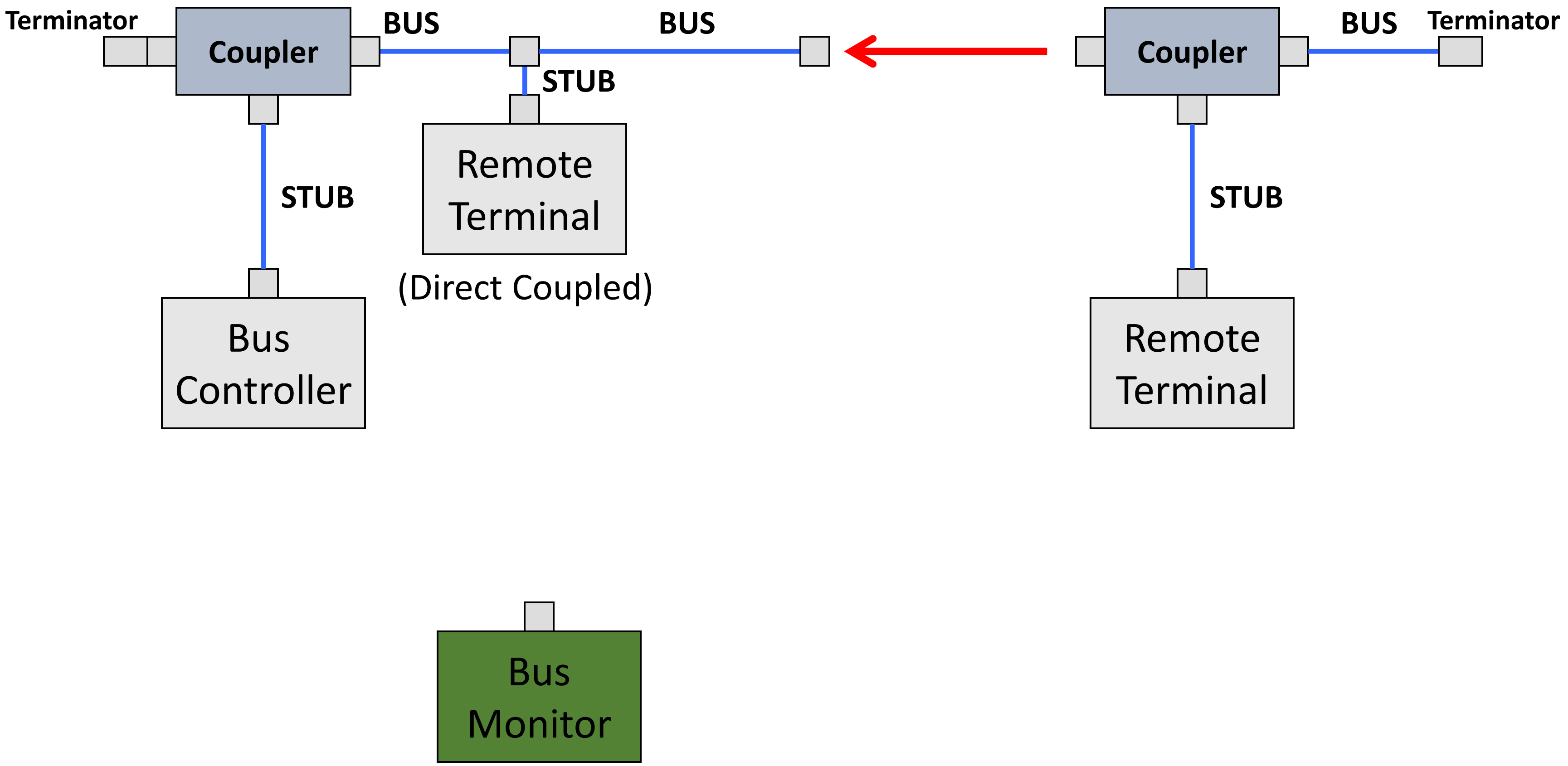
Bus Monitor More Than 20 Feet from the Bus



Connecting a Bus Monitor to the Bus

Bus Monitor More Than 20 Feet from the Bus

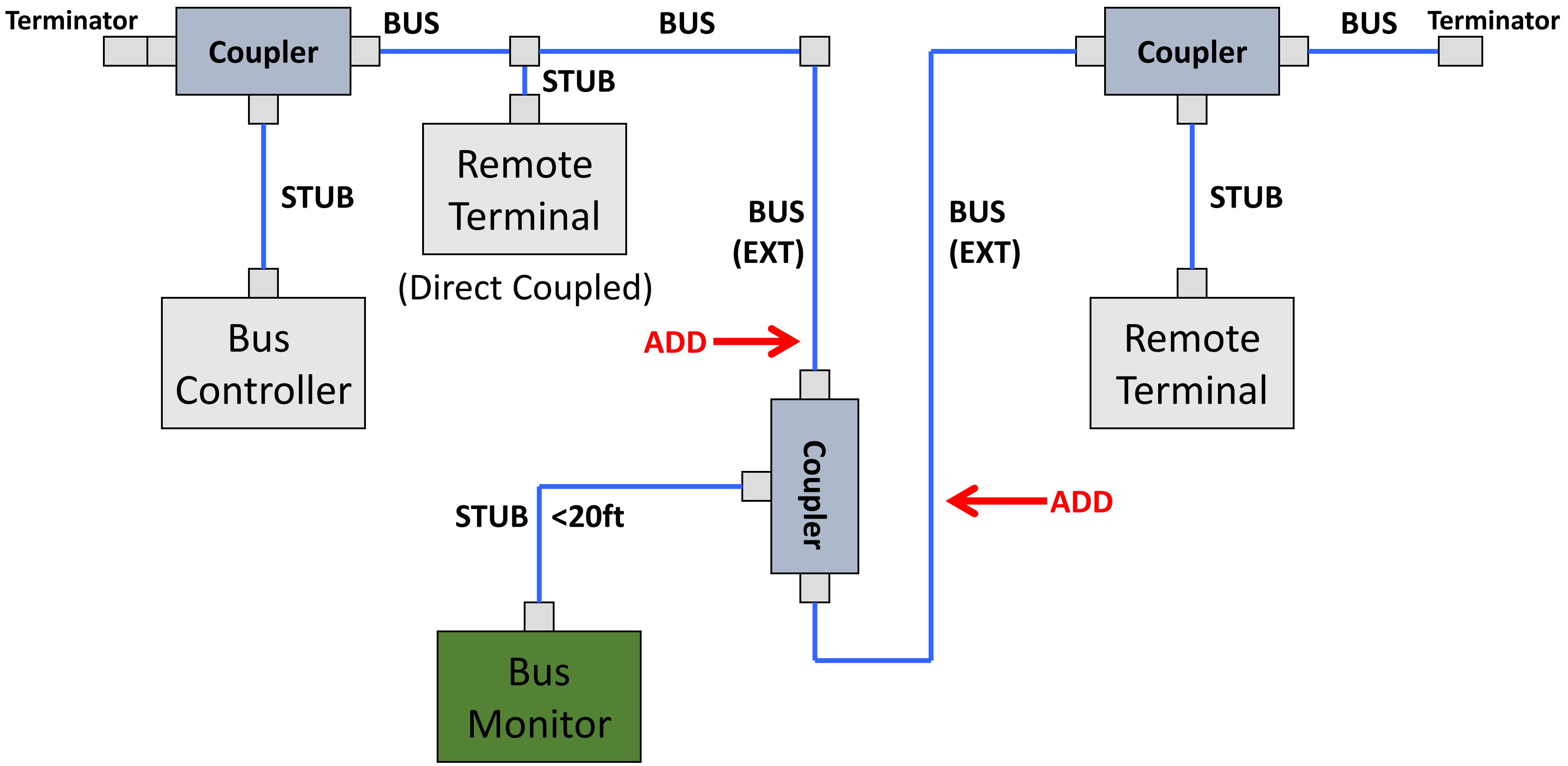
Remove the connector from the closest available coupler.



Connecting a Bus Monitor to the Bus

Bus Monitor More Than 20 Feet from the Bus

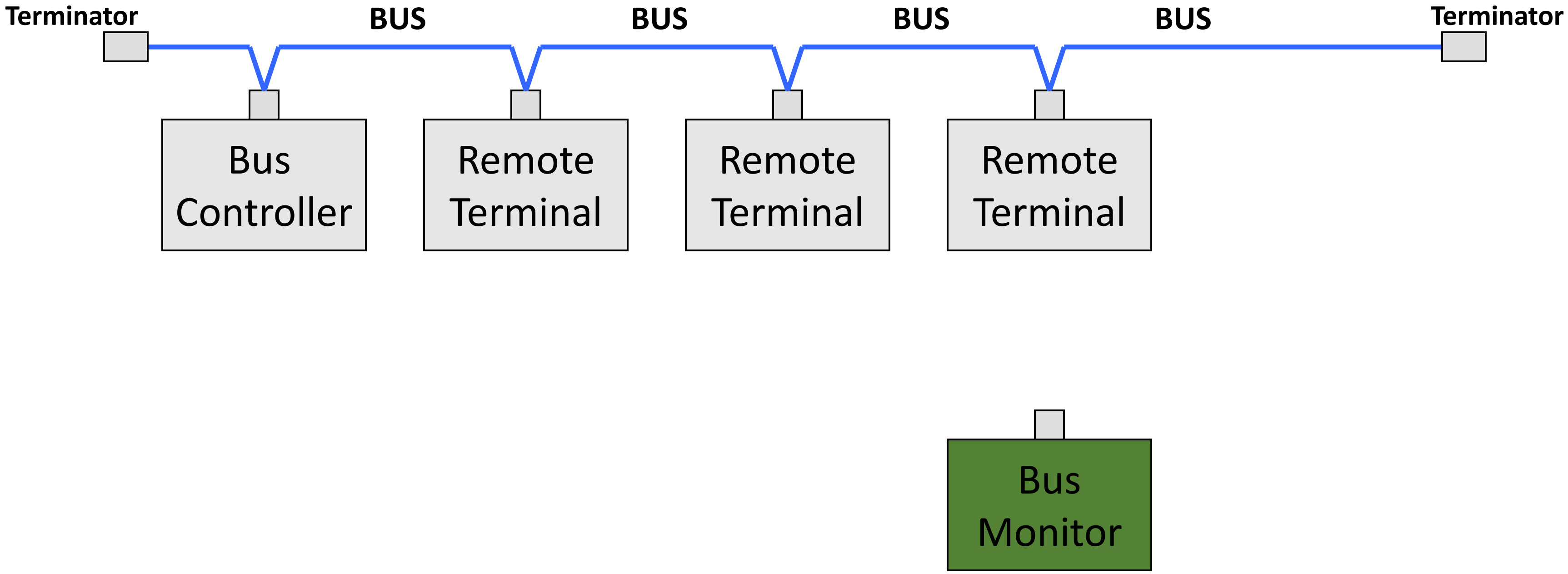
“Extend” the bus to the instrumentation coupler located within 20 feet of the bus monitor. As a rule of thumb, you can extend the bus by no more than 10-20% of its total length. If it must be longer, this should be discussed in the Technical Review Board.



Connecting a Bus Monitor to the Bus

Aircraft that only Utilizes Direct Coupling

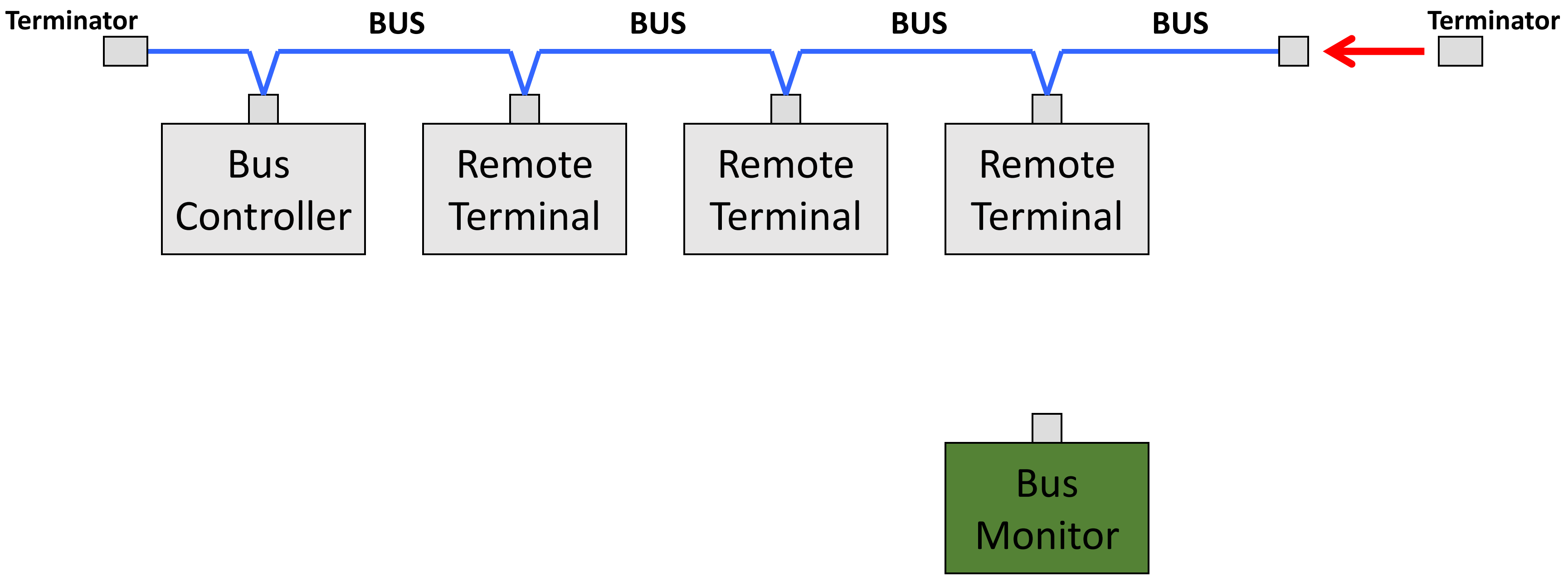
There are no bus couplers installed in the production configuration of the bus.



Connecting a Bus Monitor to the Bus

Aircraft that only Utilizes Direct Coupling

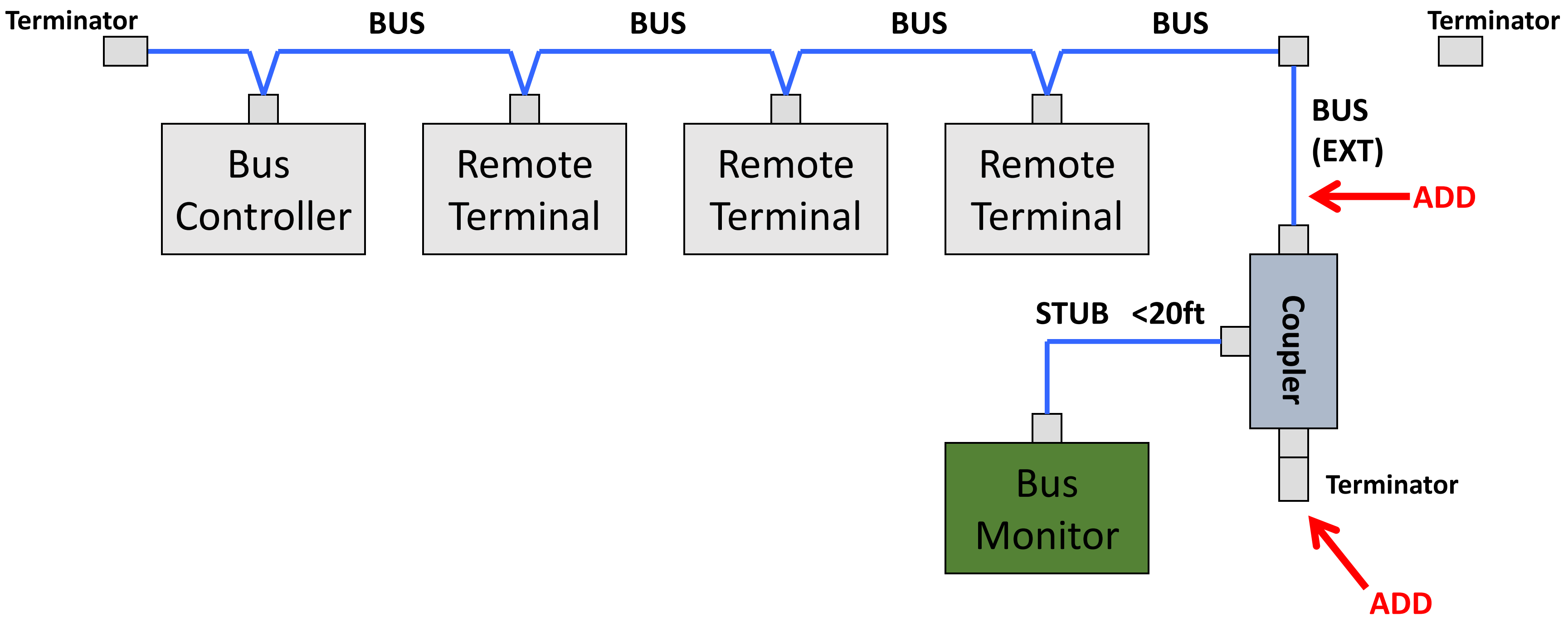
Remove the bus from one of the terminators. This is one of only two locations where there is a connector that can be easily accessed.



Connecting a Bus Monitor to the Bus

Aircraft that only Utilizes Direct Coupling

Extend the bus to the instrumentation coupler and add a terminator to the other bus input of that coupler.



Connecting a Bus Monitor to the Bus

Some of the connector types used:

PL-75

PL-375

PL-155

PL-3155

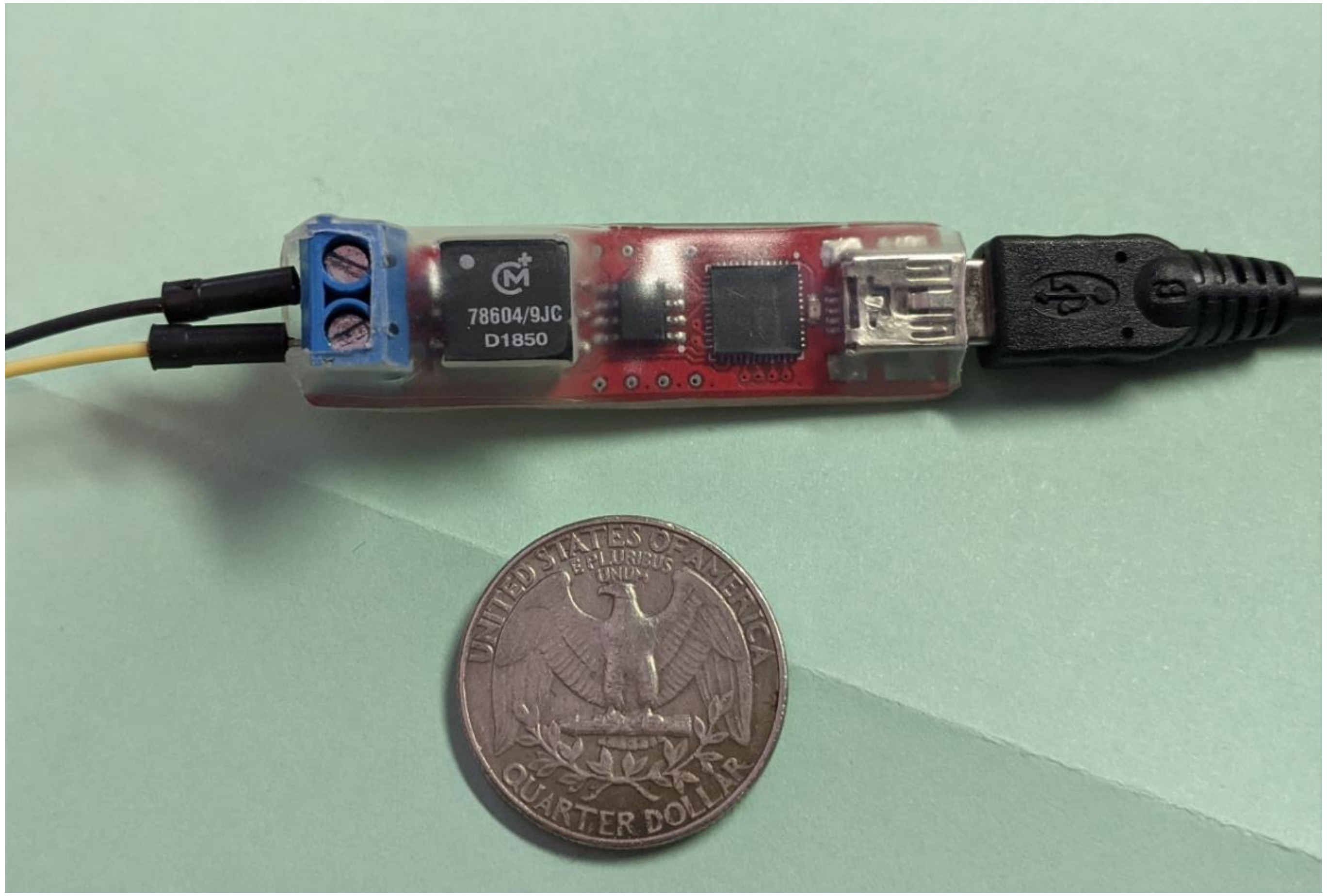
When connecting to any of the production couplers on the bus, make sure you have the correct connectors. It varies from airframe to airframe.

Unused Stubs

Dust Cap

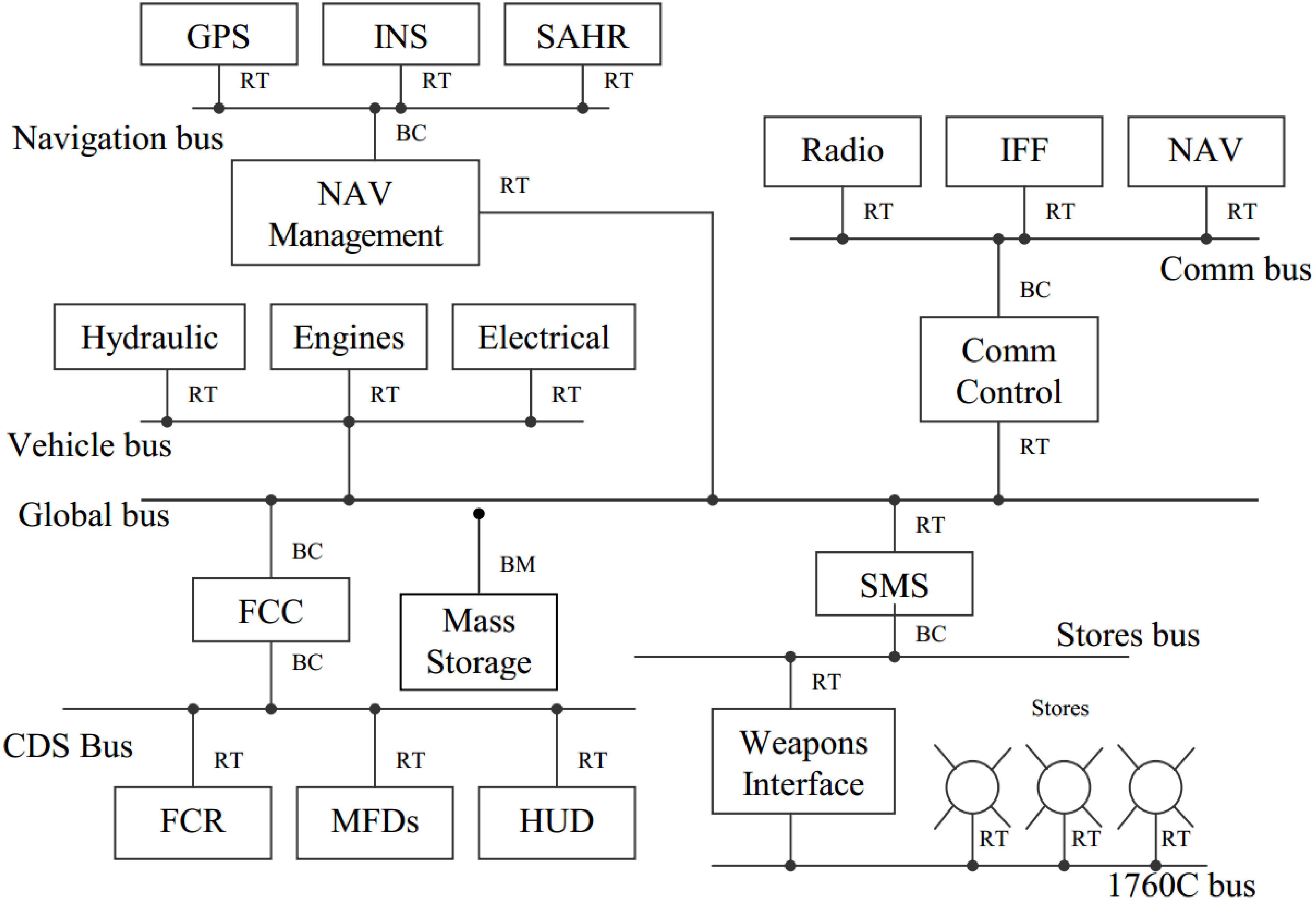
According to Test Systems, Inc. who provides training on MIL-STD-1553, unused stubs should not be terminated with a resistor. It is best to have the stub left open, but a dust cap is recommended.

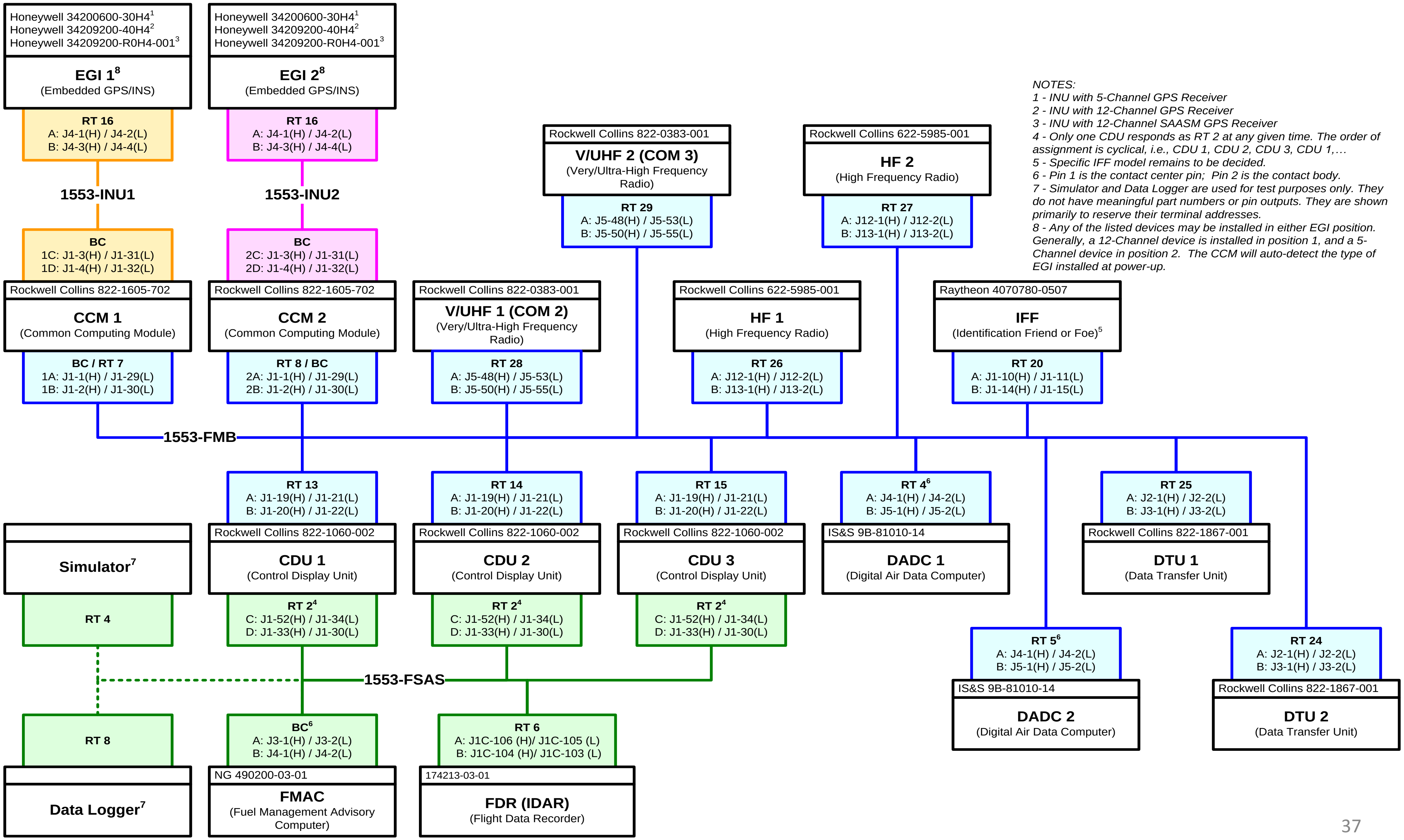
1553 Simulator



1553 Bus Monitor

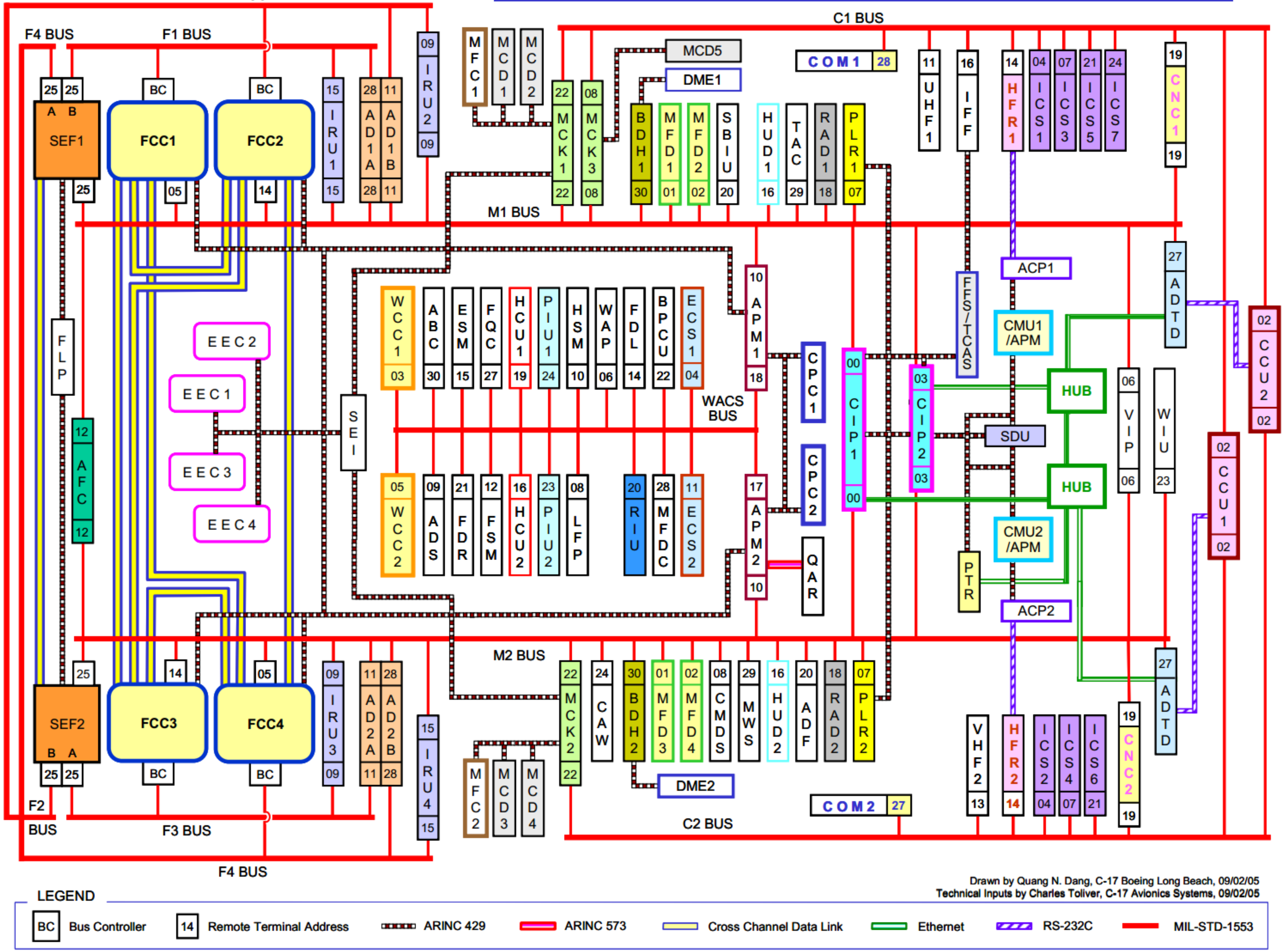
1553 Bus Monitor


GPS
INS
SAHR
RT
RT
RT
Navigation bus
BC
NAV Management
RT
Radio
IFF
NAV
RT
RT
RT
Comm bus
BC
Comm Control
RT
Hydraulic
Engines
Electrical
RT
RT
RT
Vehicle bus
Global bus
BC
BM
RT
FCC
Mass Storage
SMS
BC
BC
Stores bus
RT
Stores
CDS Bus
RT
RT
RT
Weapons Interface
FCR
MFDs
HUD
RT
RT
RT
1760C bus



NOTES:
1 - INU with 5-Channel GPS Receiver
2 - INU with 12-Channel GPS Receiver
3 - INU with 12-Channel SAASM GPS Receiver
4 - Only one CDU responds as RT 2 at any given time. The order of assignment is cyclical, i.e., CDU 1, CDU 2, CDU 3, CDU 1,…
5 - Specific IFF model remains to be decided.
6 - Pin 1 is the contact center pin; Pin 2 is the contact body.
7 - Simulator and Data Logger are used for test purposes only. They do not have meaningful part numbers or pin outputs. They are shown primarily to reserve their terminal addresses.
8 - Any of the listed devices may be installed in either EGI position. Generally, a 12-Channel device is installed in position 1, and a 5-Channel device in position 2. The CCM will auto-detect the type of EGI installed at power-up.

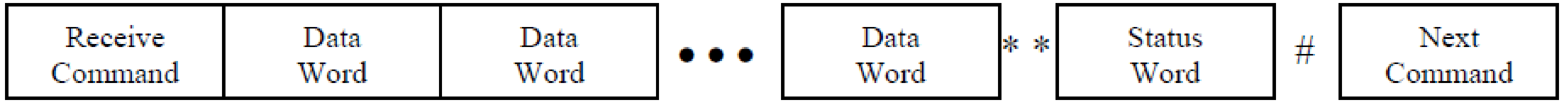
C-17 MULTIPLEX BUS SYSTEM ARCHITECTURE-BLOCK 17



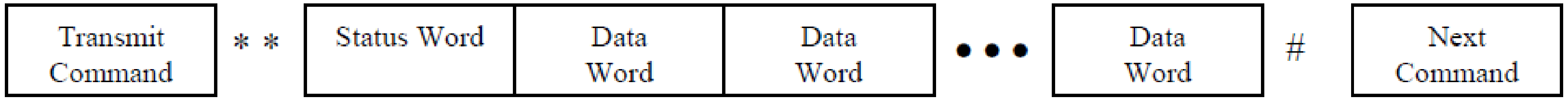
1553 Message Structure

Command Word Bit Usage

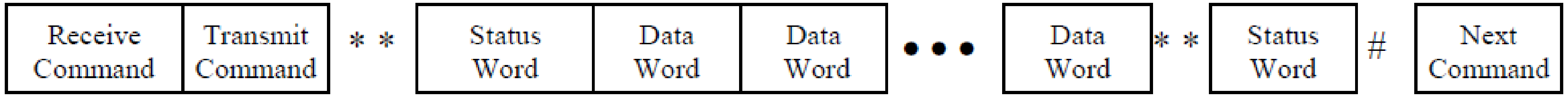
Remote Terminal address (0 - 31)					Receive or Transmit	Location (subaddress) of data (1 - 30)					Number of words to expect (1 - 32)				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16



Controller to RT Transfer



RT to Controller Transfer



RT to RT Transfer

1553 Word Types

The 1553 bus operates on a Command/Response protocol. Each word is 20 bit periods long and transmitted at a rate of 1 Mbps. There are only three word types defined in MIL-STD-1553:

1) Command Word – can only be transmitted by the bus controller

2) Data Word – can be transmitted by either the bus controller or a remote terminal

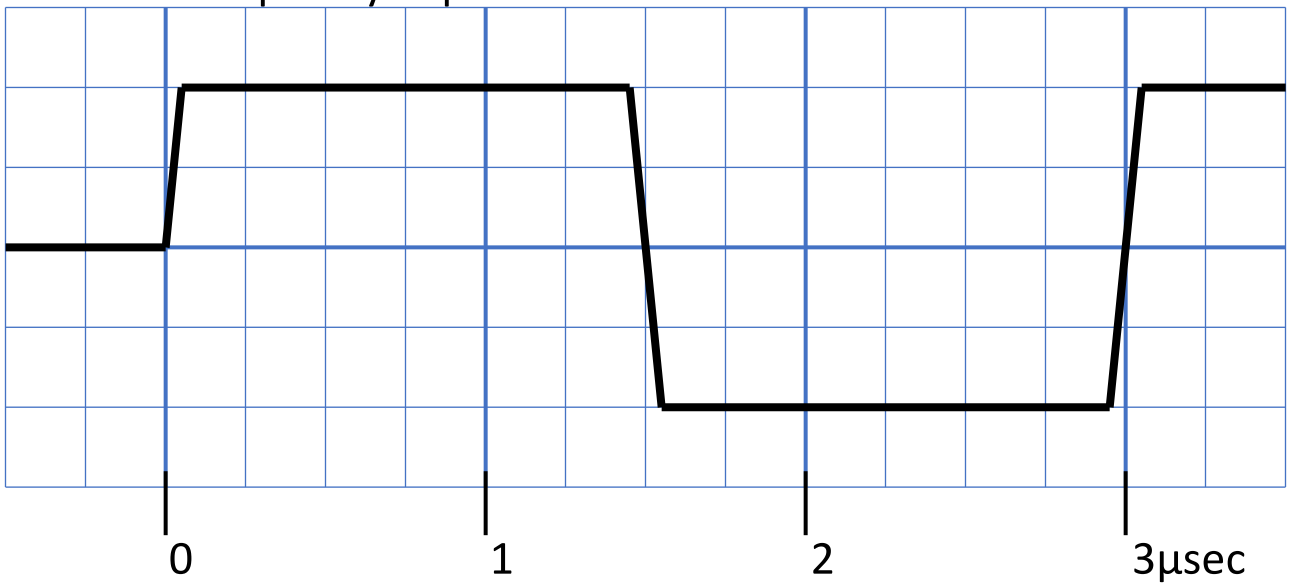
3) Status Word – only transmitted by the remote terminal

We will now go over the structure of each of these word types.

Sync Pulses

In order for the components on the bus to recognize the beginning of words and to identify the type of word, a sync pulse is used at the beginning of every 1553 word.   The sync pulse occupies the first three bit periods of the word (3µsec).

Example: Sync pulse for a command or status word



Command Word

SYNC PULSE	RT ADDR	T/R	SUB ADDR/MODE	WD CT/MODE CODE	P

The command word is always the first word of a message.

SYNC PULSE – a pulse consisting of a “1” followed by a “0” which identifies the word as a command word.

RT ADDR – the address of the RT that is being commanded (5 bits)

T/R – Transmit/Receive bit. Tells the specific RT whether to transmit data or receive data in a message.

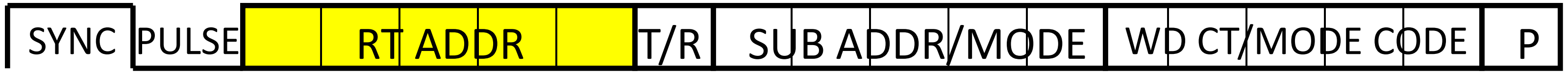
SUB ADDR/MODE – the sub address (message number) or the use of a mode code.

WD CT/MODE CODE – the number of data words contained in the message, or the mode code value

P – odd parity bit

Command Word Fields

RT ADDR



- 5-bit field

- Value ranges from 00 (00000) to 31 (11111)
  - RT address of 31 is sometimes used for a broadcast command – all RTs follow the command.
  - RT address of 31 can also be designated as a normal RT

- The RT specified in this field follows the command, all other RTs ignore the message.

Command Word Fields

T/R

SYNC	PULSE	RT ADDR	T/R	SUB ADDR/MODE	WD CT/MODE CODE	P

- 1-bit field

- Commands the RT to either receive or transmit a message
  - T/R = 1, commands RT to transmit a message
  - T/R = 0, commands RT to receive a message
- A command word with T/R=1 is called a transmit command (RT to BC)
- A command word with T/R=0 is called a receive command (BC to RT)

Command Word Fields

SUB ADDR/MODE

SYNC	PULSE	RT ADDR	T/R	SUB ADDR/MODE	WD CT/MODE CODE	P

- 5-bit field

- Value ranges from 00 (00000) to 31 (11111)
  - 00 indicates a mode code in the WD CT/MODE CODE field
  - 01 – 30 indicates the sub address number
  - 31 indicates a mode code in the WD CT/MODE CODE field
  - Depending upon the configuration of the bus, 00 and 31 can be normal sub address numbers.

Command Word Fields

WD CT/MODE CODE

SYNC PULSE	RT ADDR	T/R	SUB ADDR/MODE	WD CT/MODE CODE	P

- 5-bit field

- Value ranges from 00 (00000) to 31 (11111)
  - if the SUB ADDR/MODE field indicates a sub address
    - the field indicates the number of data words contained within the message. 00 indicates 32 data words
  - if the SUB ADDR/MODE field indicates a mode code
    - the field contains the mode code
    - Some examples of mode codes would be:

      01000 – Reset RT

      00011 – Initiate Self Test

      00010 – Transmit Status Word

Command Word Fields

PARITY BIT

SYNC	PULSE	RT ADDR	T/R	SUB ADDR/MODE	WD CT/MODE CODE	P

The Parity Bit guarantees that the field of 17 bits (excludes the sync pulse) contains an *odd* number of 1s. This function is used to identify any bit errors that may have occurred during transmission.

Some examples are:

1	0	0	1	1	0	0	1	1	1	0	1	1	1	0	0	0

There are <u>nine</u> 1s in the field of 17 bits

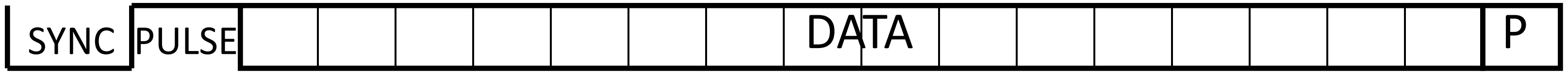
0	1	1	1	0	1	0	1	0	1	1	0	1	1	0	1	1

There are <u>eleven</u> 1s in the field of 17 bits

1	0	1	0	0	1	1	0	1	1	0	0	0	0	0	1	1

There are <u>eight</u> 1s in the field of 17 bits – a bit error has occurred!

Data Word



The data word contains the information being transmitted by the bus controller or the remote terminal..

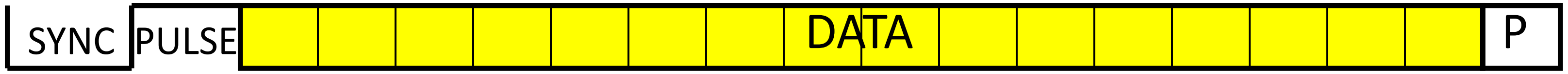
SYNC PULSE – a pulse consisting of a “0” followed by a “1” which identifies the word as a data word.

DATA – 16 bits of information as defined in the bus catalog.

P – odd parity bit

Data Word

DATA



- 16-bit field

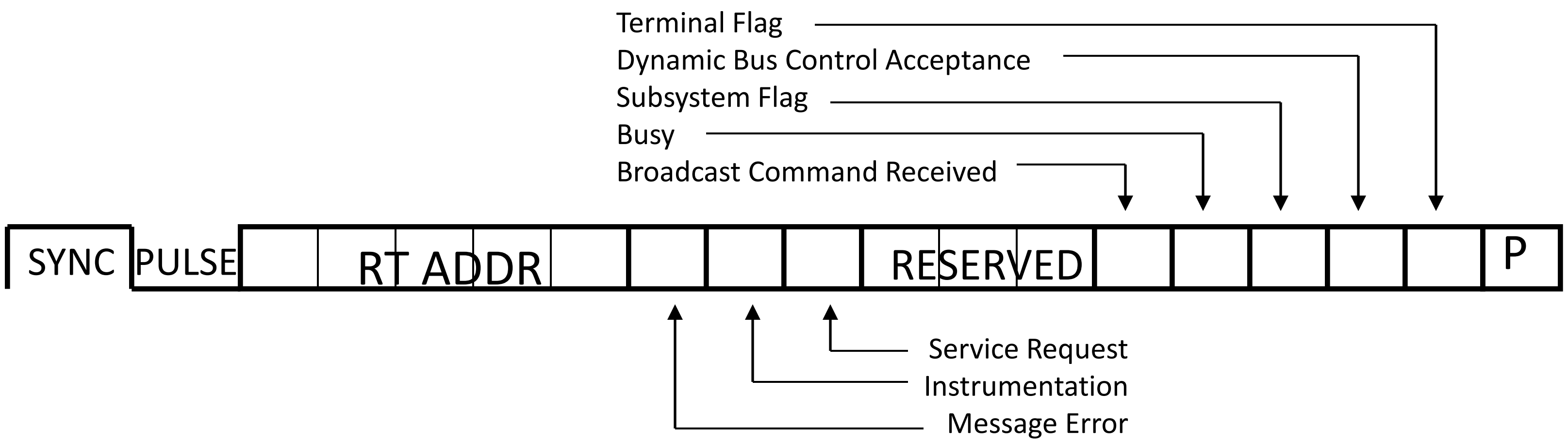
- Values range from 0 to 65,535

- The EU value of the data results from the count value multiplied by a coefficient defined in the bus catalog.

- Data longer than 16 bits will continue into the next data word.

- The field can contain more than one measurement such as discrete data (WOW, Gear up and locked, etc…)

Status Word



The status word is only transmitted by the remote terminal.

SYNC PULSE – a pulse consisting of a “1” followed by a “0” which identifies the word as a status word. It is distinguished from the command word because it is not the first word of the message.

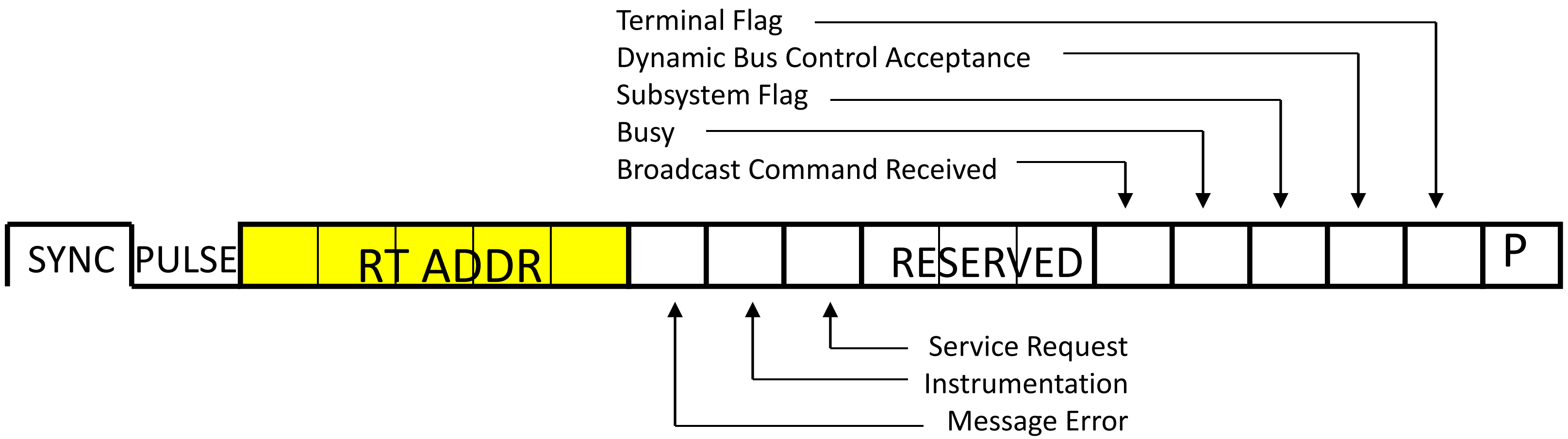
RT ADDR – the address of the RT that sent the status word

FLAG and **STATUS BITS** – gives status feedback to bus controller

P – odd parity bit

Status Word

RT ADDR

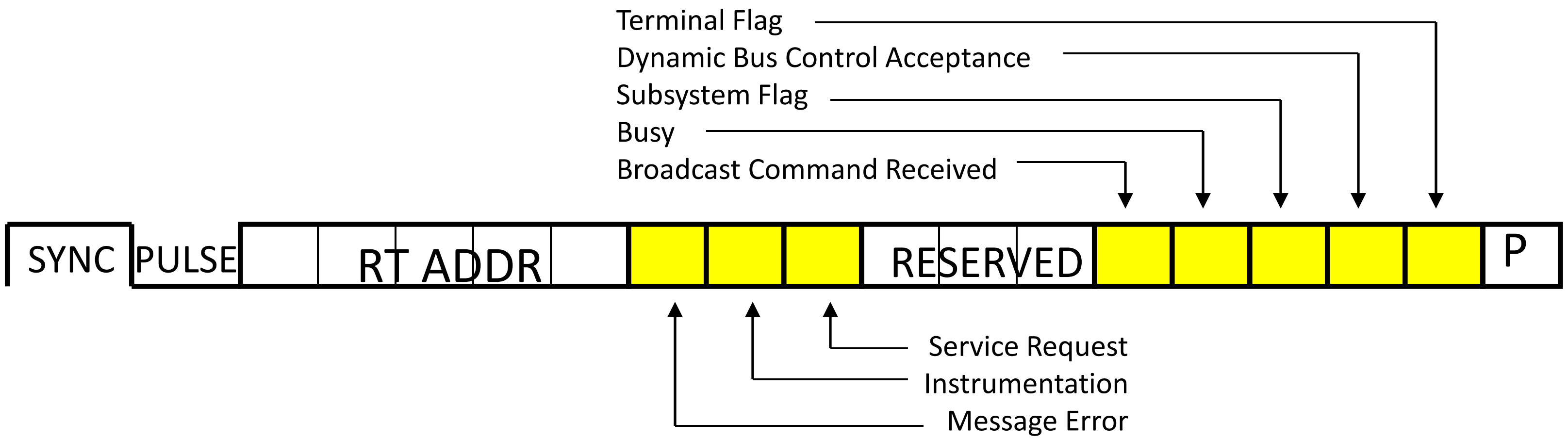


- 5-bit field

- Value ranges from 00 (00000) to 30 (11110)
  Remote 31 (11111) is reserved for the broadcast option

Status Word

Flag and Status Bits



- Eight 1-bit fields

- Provides information to the bus controller regarding the command or the received data.

1553 Messages

1553 messages are made up of command, data, and status words described earlier.

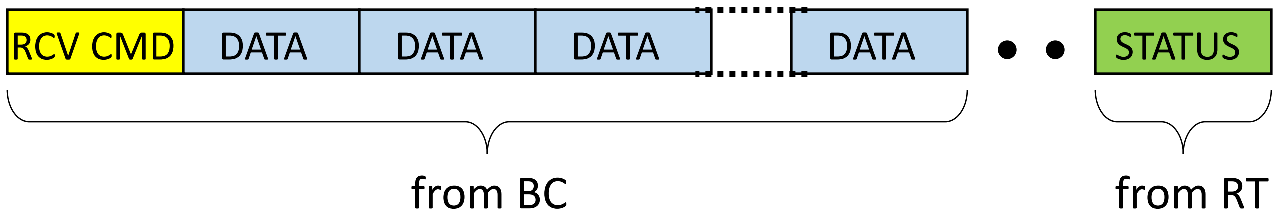
There are three basic types of messages:

1. BC to RT transfer
2. RT to BC transfer
3. RT to RT transfer

A 1553 messages can contain:
1 or 2 command words,
between 1 and 32 data words,
and 1 or 2 status words depending upon the type of message.

BC to RT Message Transfer

The BC to RT transfer tells the selected RT to receive (T/R bit = 0) the allotted number of words. When the data is received, the RT responds with a status word.

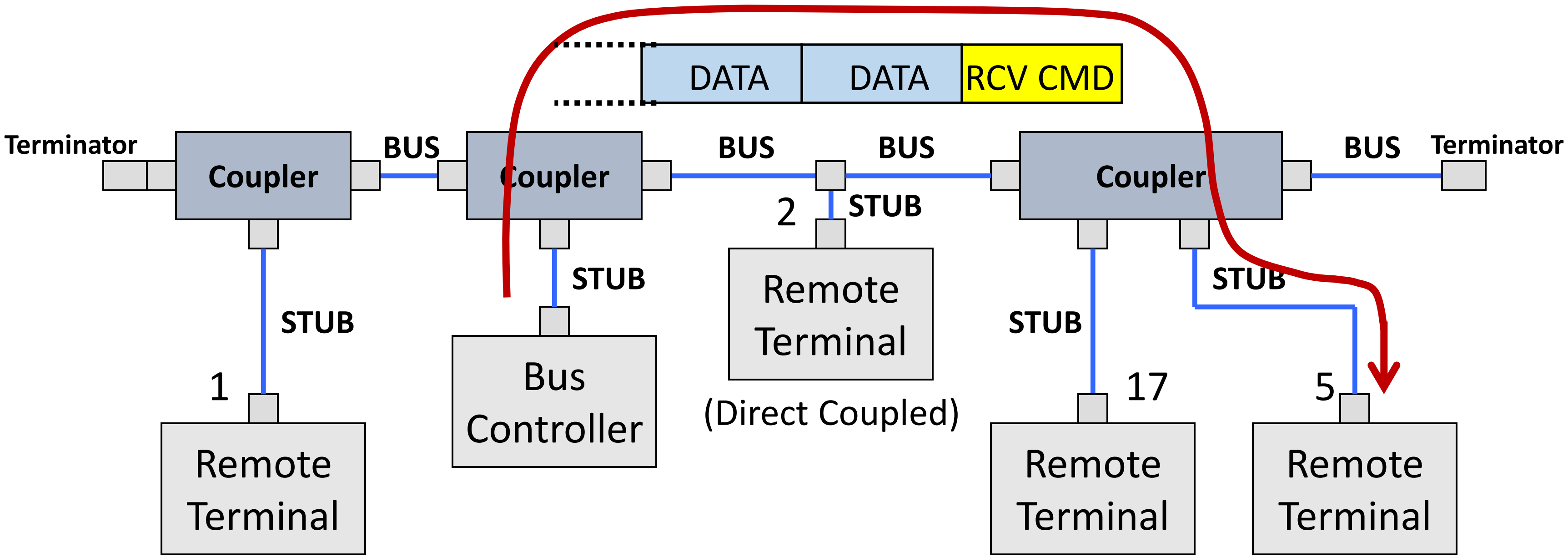


"••" is the time that it takes the RT to respond with its status of receiving the command. This time will be defined in more detail later in this training.

BC to RT Transfer

EXAMPLE

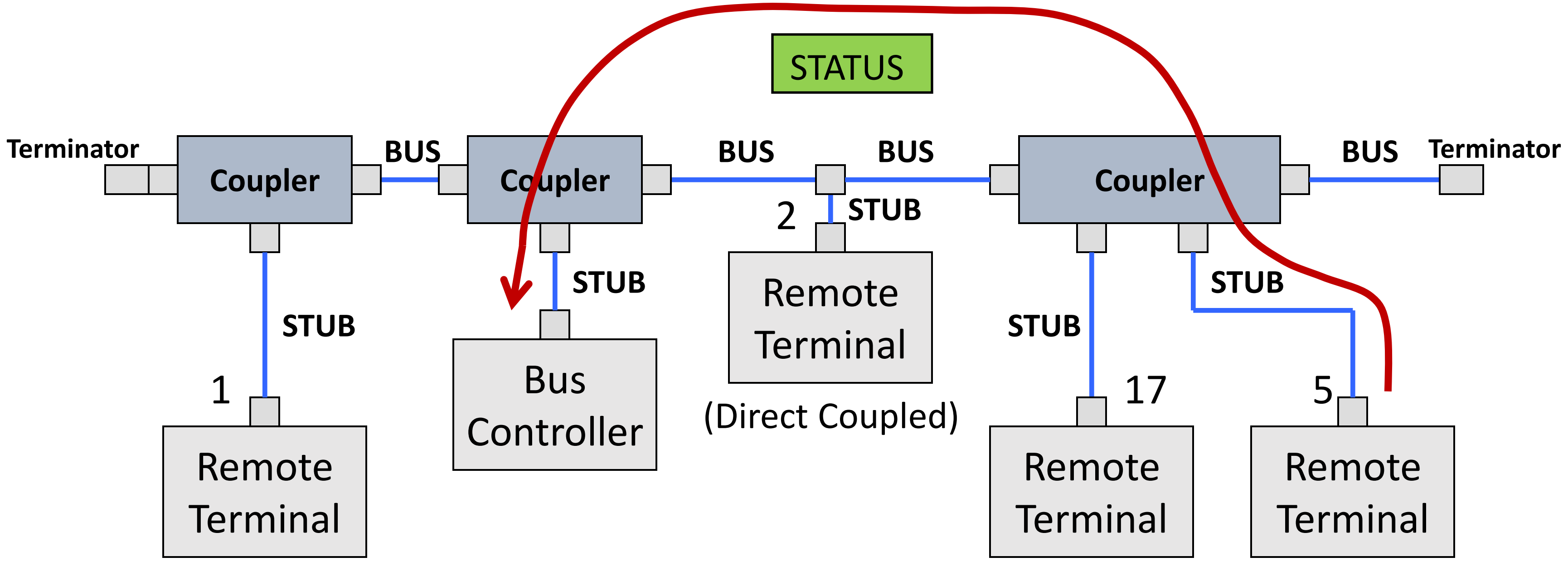
The bus controller sends out a receive command to remote terminal 5. Remote terminal 5 knows to receive the number of data words defined in the receive command. The other RTs see the command at their input but ignore the message because they did not receive the message to receive.



BC to RT Transfer

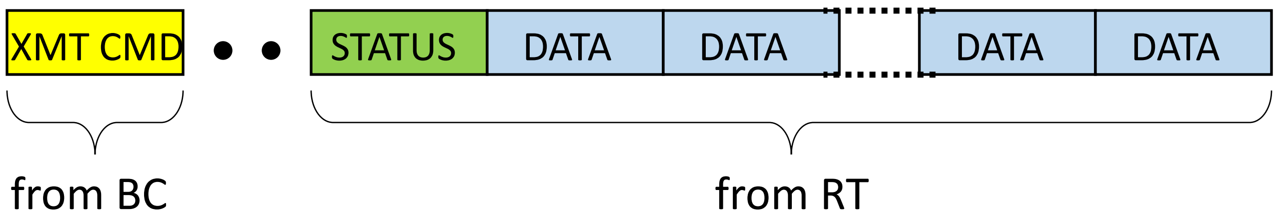
EXAMPLE

After the last data word is received, RT 5 responds with a status to let the bus controller know that it received the data. If there are errors, the bus controller may try again, or attempt to transmit the message on the secondary bus.



RT to BC Message Transfer

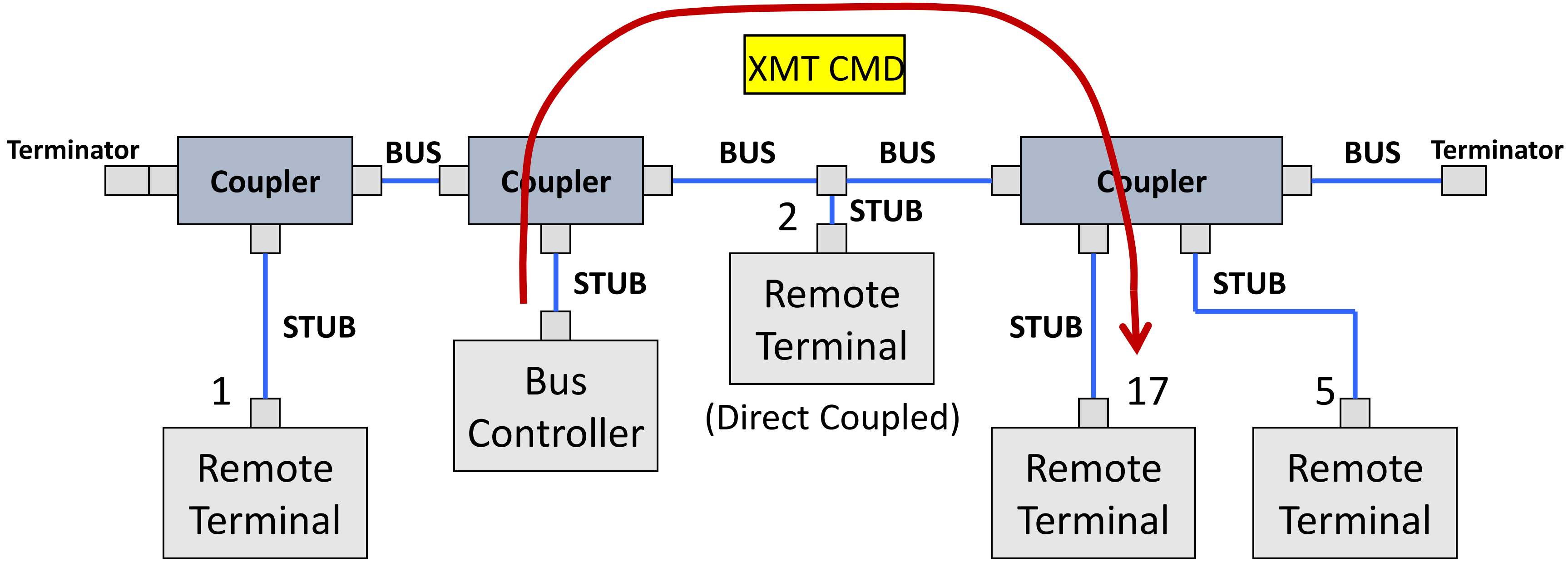
The RT to BC transfer tells the selected RT to transmit (T/R bit = 1) a message specified by the bus controller. After the command is received, the RT responds with a status word followed by the requested data.



RT to BC Transfer

EXAMPLE

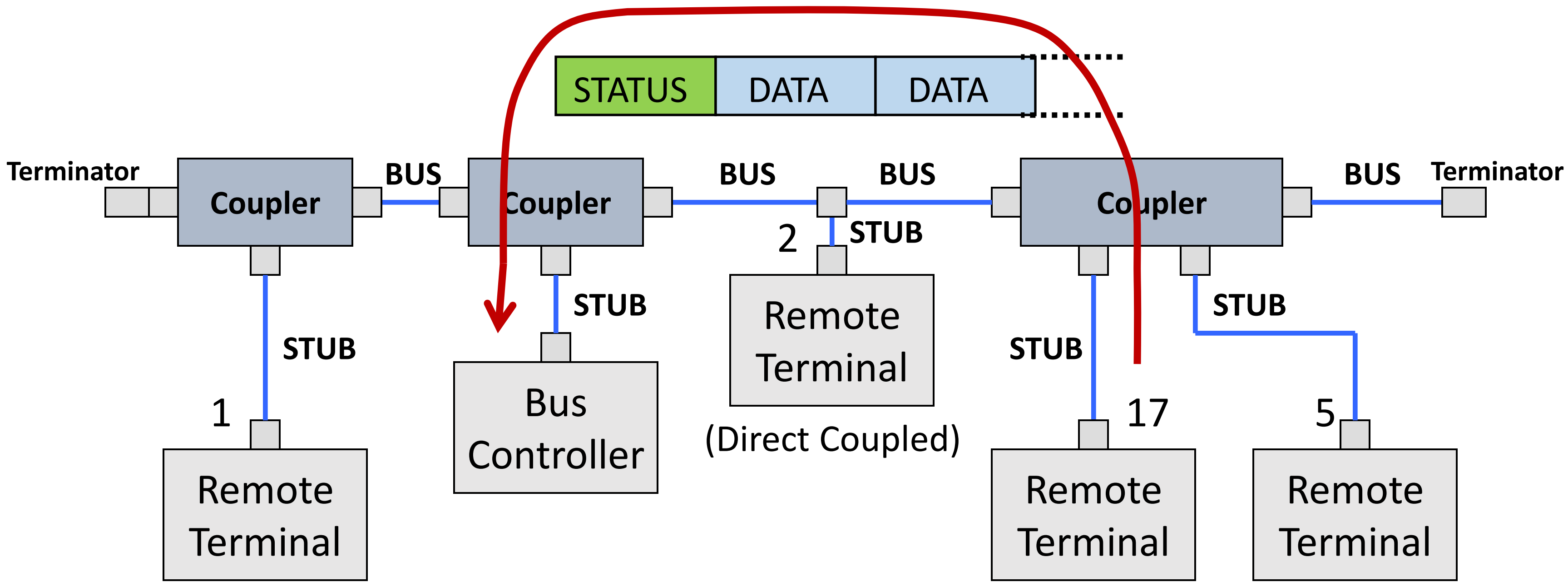
The bus controller sends out a transmit command to remote terminal 17. Remote terminal 17 knows to transmit the number of words requested from the specified sub address in the transmit command. The other RTs see the command at their input, but ignore the message because their RT number was not in the command word.



RT to BC Transfer

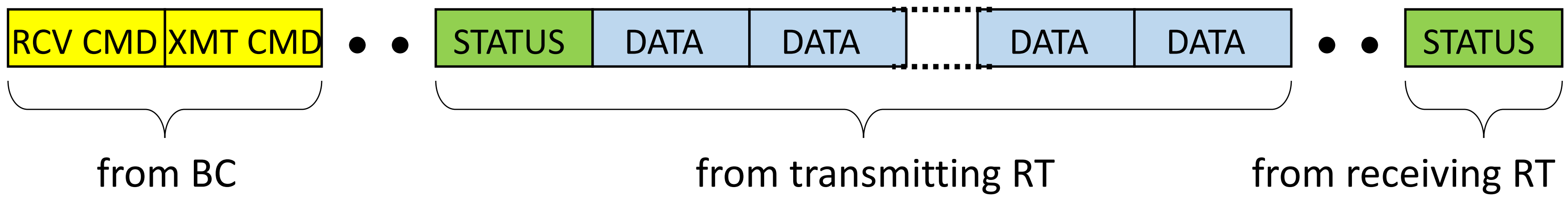
EXAMPLE

RT 17 responds with a status word along with the requested data.



RT to RT Message Transfer

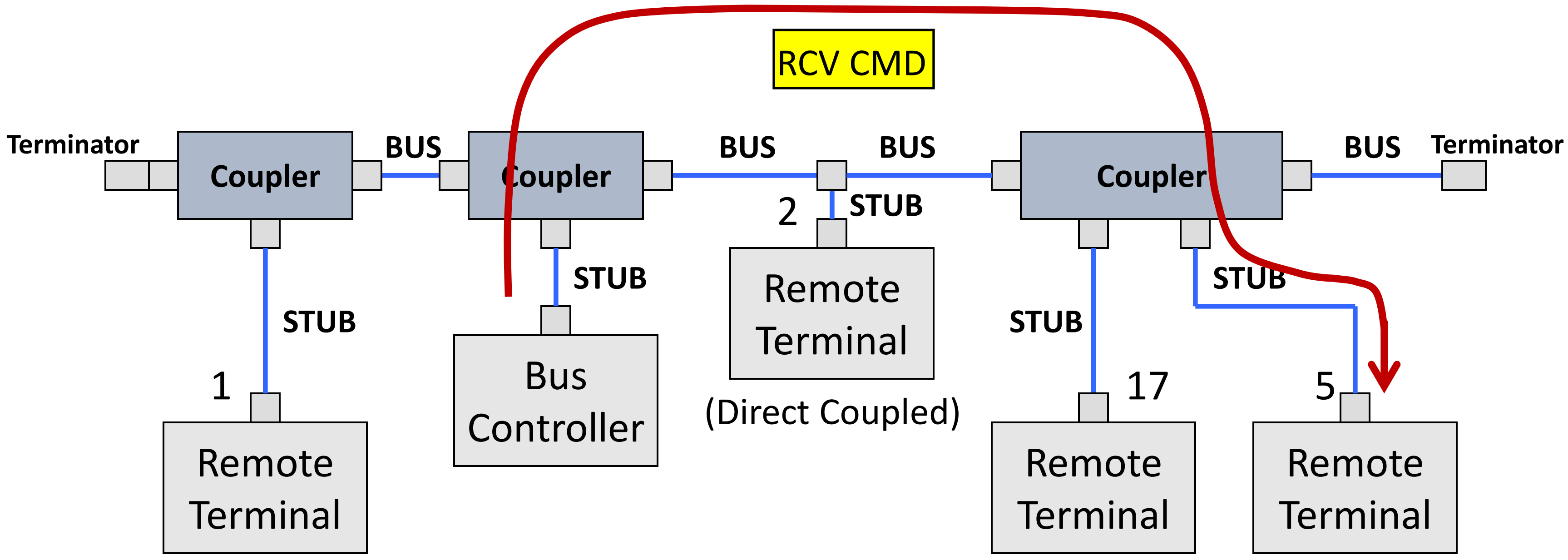
The RT to RT transfer allows data to be passed from one RT to another. The bus controller commands the receiving and transmitting RTs. The receive command <u>always</u> comes first.



RT to RT Transfer

EXAMPLE

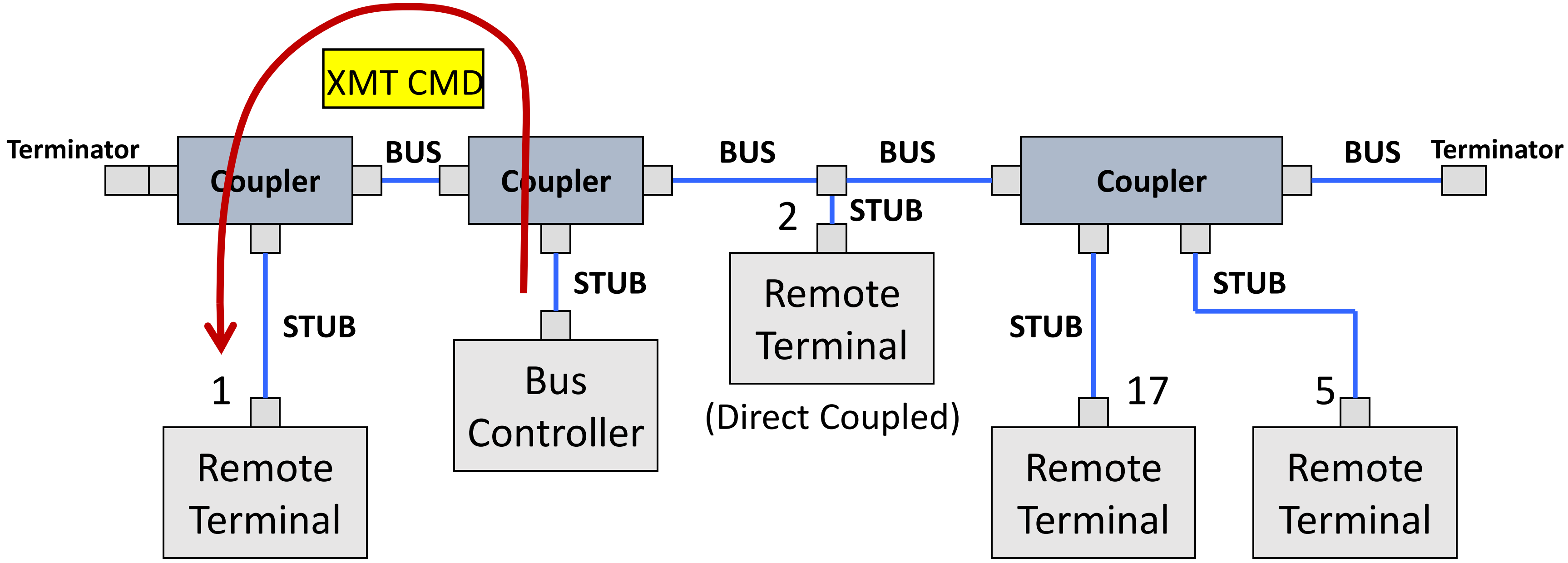
The bus controller commands RT 5 to receive data from RT 1. First the bus controller commands RT 5 to receive the message.



RT to RT Transfer

EXAMPLE

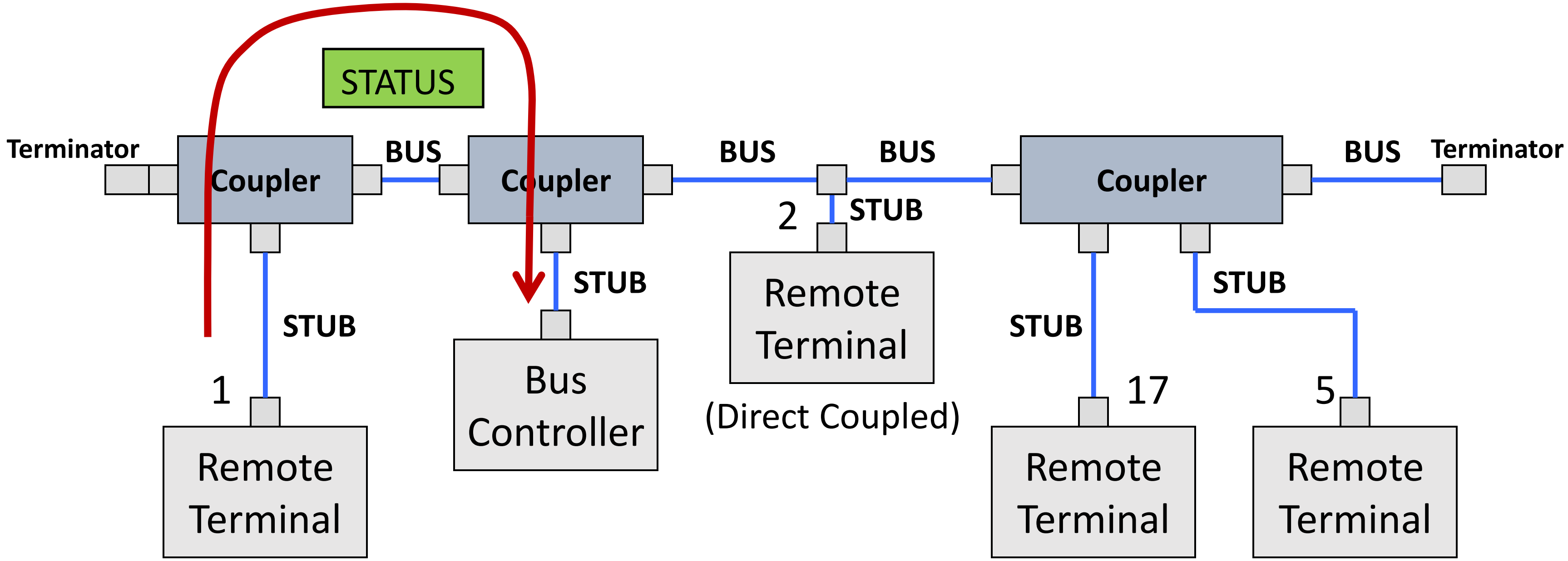
Next the bus controller commands RT 1 to transmit data from a specified sub address.



RT to RT Transfer

EXAMPLE

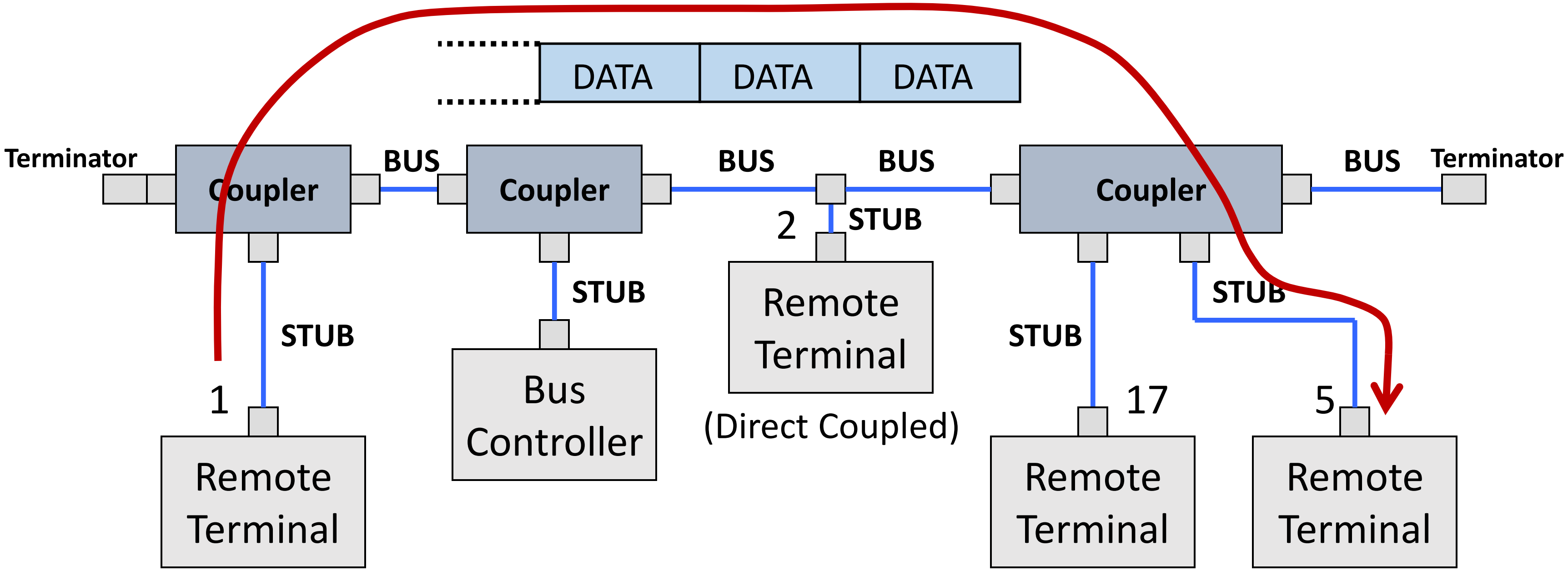
RT1 first sends out a status word that acknowledges that it received the transmit command word. If the bus controller does not get a response or the status indicates an error, the command may be resent on the redundant bus.



RT to RT Transfer

EXAMPLE

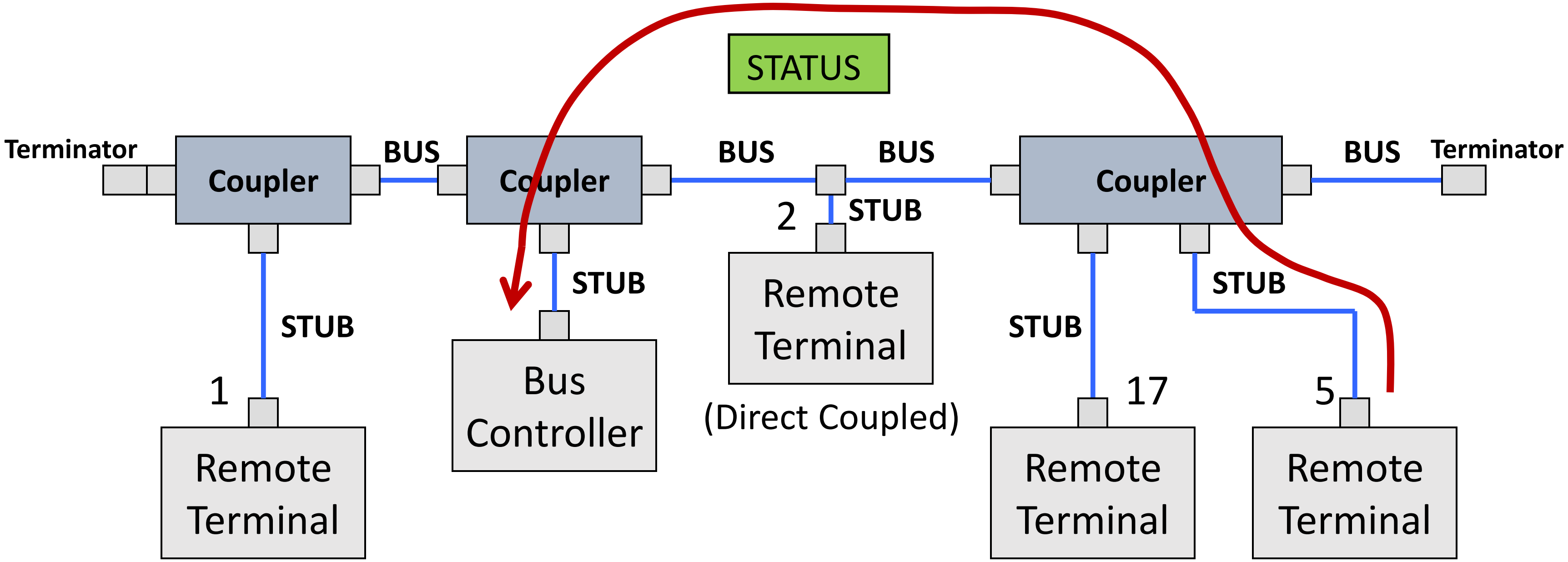
RT 1 immediately follows the status word with the requested data. RT 5 receives the data words as commanded.



RT to RT Transfer

EXAMPLE

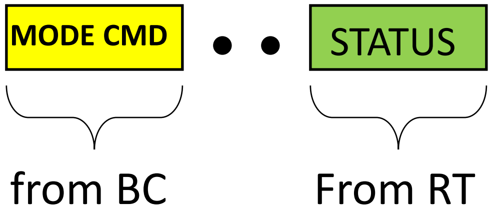
RT 5 responds with a status word to let the bus controller know all data words were received. If there was an error flagged in either RT 1's or RT 5's status word, the bus controller would reattempt the message transfer.



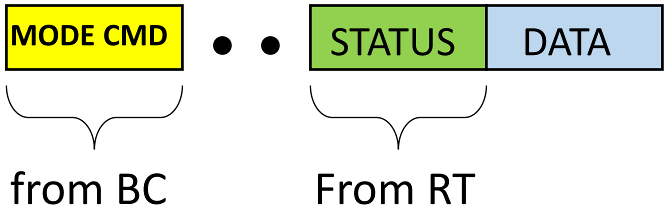
Mode Command Message Transfers

There are other message transfers that occur. Below are the mode command message transfers that may occur

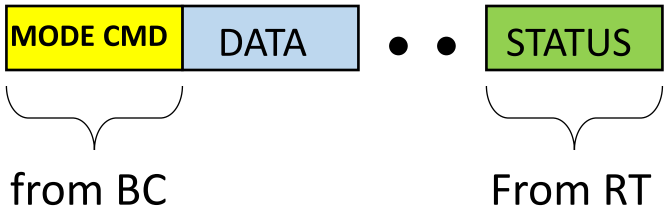
Mode Command without Data Word



Mode Command with Data Word (Transmit)



Mode Command with Data Word (Receive)

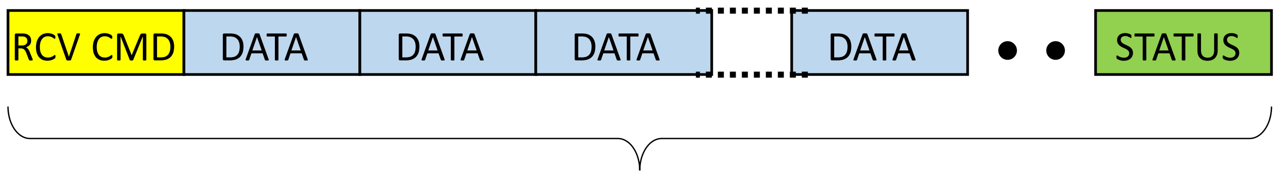


Mode commands from the bus controller tell RTs to perform maintenance functions such as: transmit the last command, synchronize, reset, or run a self test.

Message Transfers on the Primary and Secondary Busses

The bus controller and remote terminals can transmit on either the primary or secondary bus. But a single message cannot be split between the primary and secondary bus.

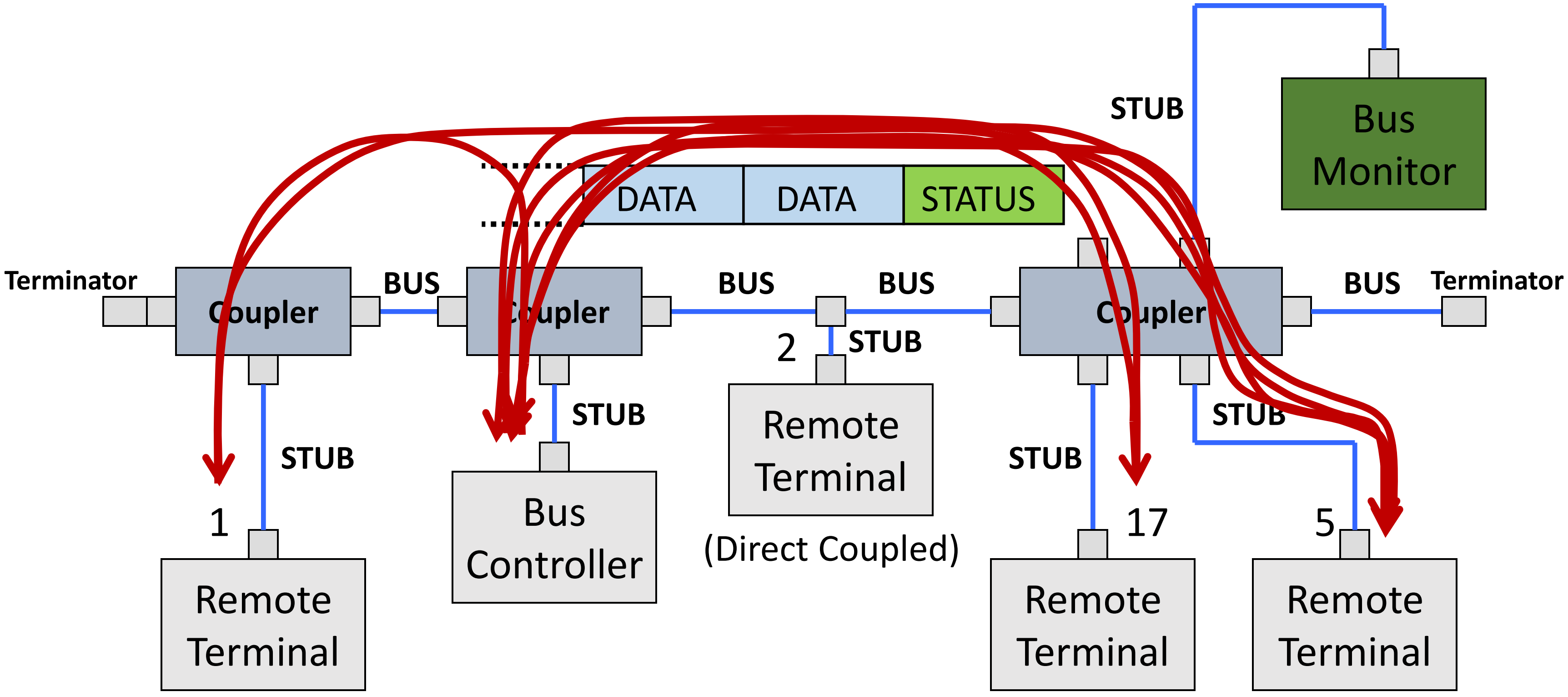
Just because a message is transmitted on the primary bus, does not mean that it cannot be transmitted on the secondary bus on another transmission of that message.



Entire message transmitted on either the primary or secondary bus.

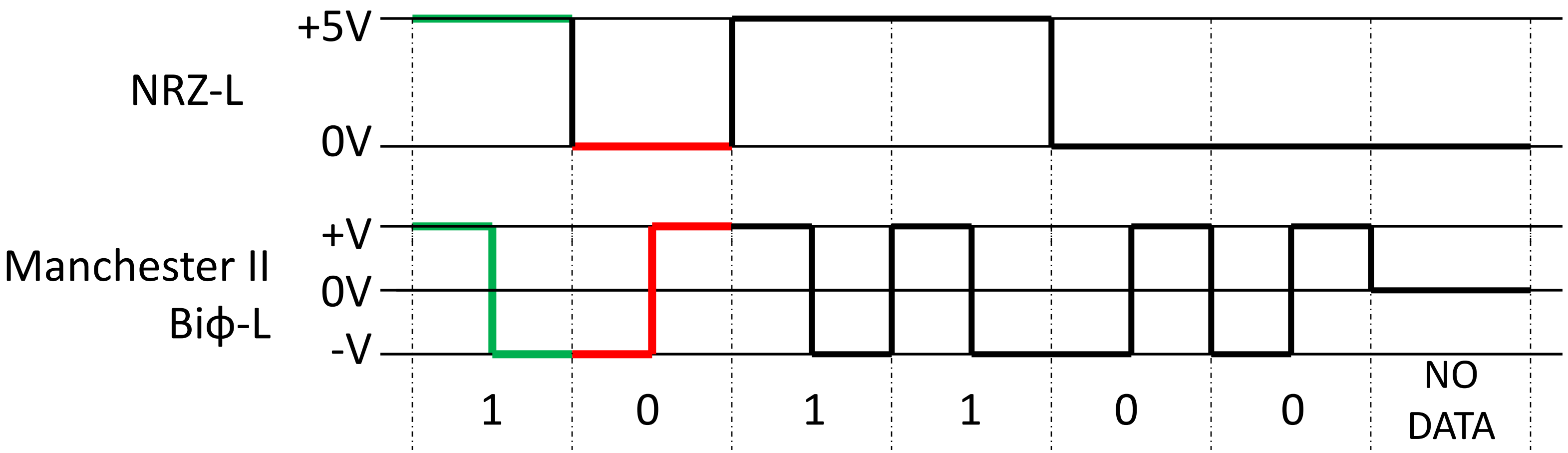
Bus Monitors and 1553 Messages

As all the messages are being transmitted on the bus, the bus monitor is listening in. Depending upon the type of bus monitor, it may be only storing selected messages or all the messages.

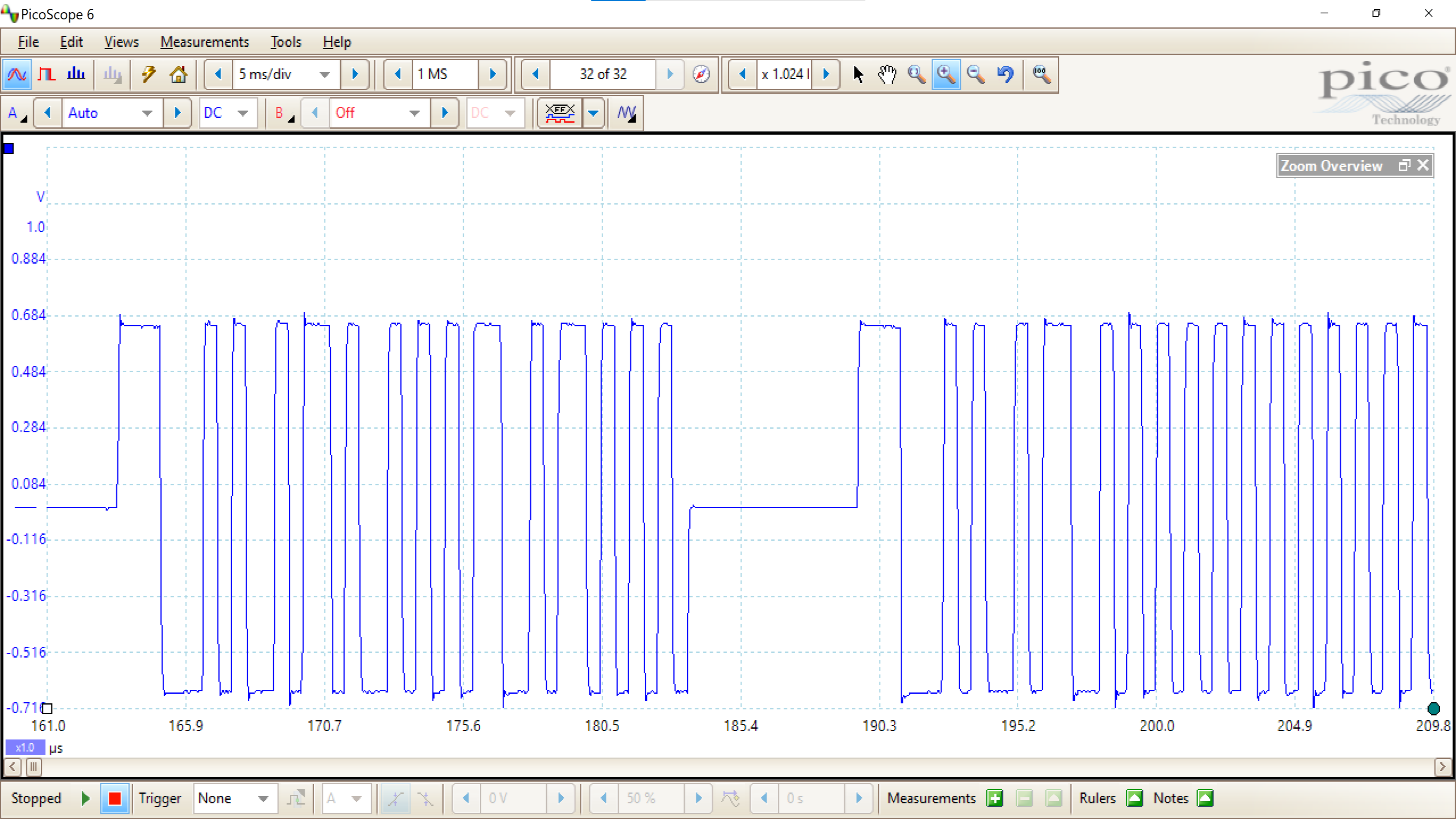


MIL-STD-1553 Electrical Specifications

The electrical characteristics of a 1553 waveform is a differential Manchester II Biϕ-L at a bursted bit rate of 1 Mbps. A "1" is represented as a high to low transition, a "0" is a low to high transition. When no data is being transmitted on the bus, the output voltage is 0.

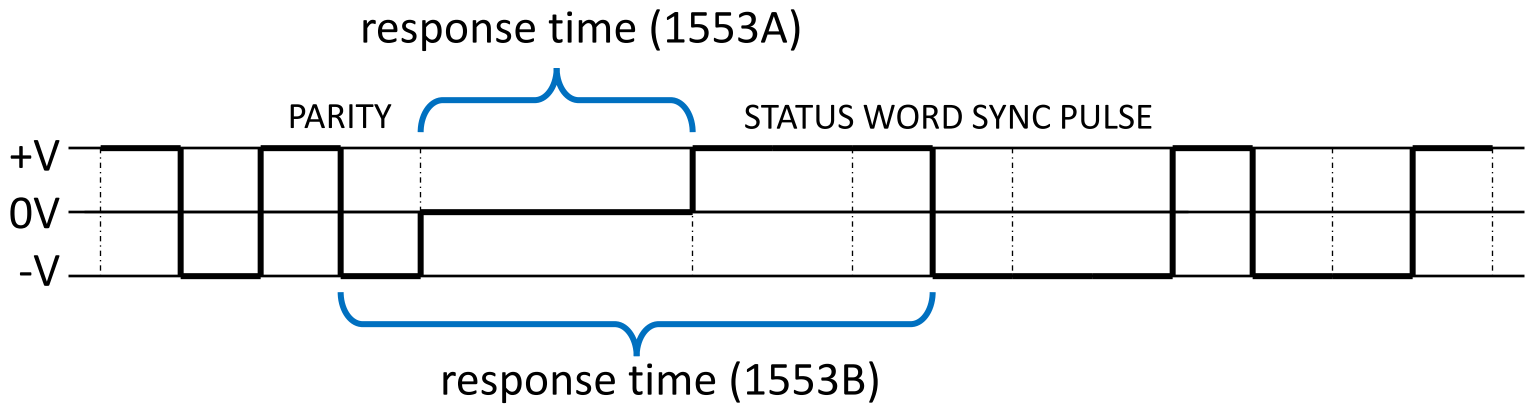


The line-to-line voltage *at the stub input* to the BC or RT is specified to be the following:
1553A: 0.5 to 10 Vpp
1553B: 1 to 14 Vpp


PicoScope 6
File
Edit
Views
Measurements
Tools
Help
5 ms/div
1 MS
32 of 32
x 1.024
pico
Technology
A
Auto
DC
B
Off
DC
Zoom Overview
V
1.0
0.884
0.684
0.484
0.284
0.084
-0.116
-0.316
-0.516
-0.716
161.0
165.9
170.7
175.6
180.5
185.4
190.3
195.2
200.0
204.9
209.8
x1.0
μs
Stopped
Trigger
None
A
0 V
50 %
0 s
Measurements
Rulers
Notes

Response Time

The response time is the time it takes for the RT to respond with a status word after the BC sends out a command. Depending upon the bus version, it is measured in two ways.

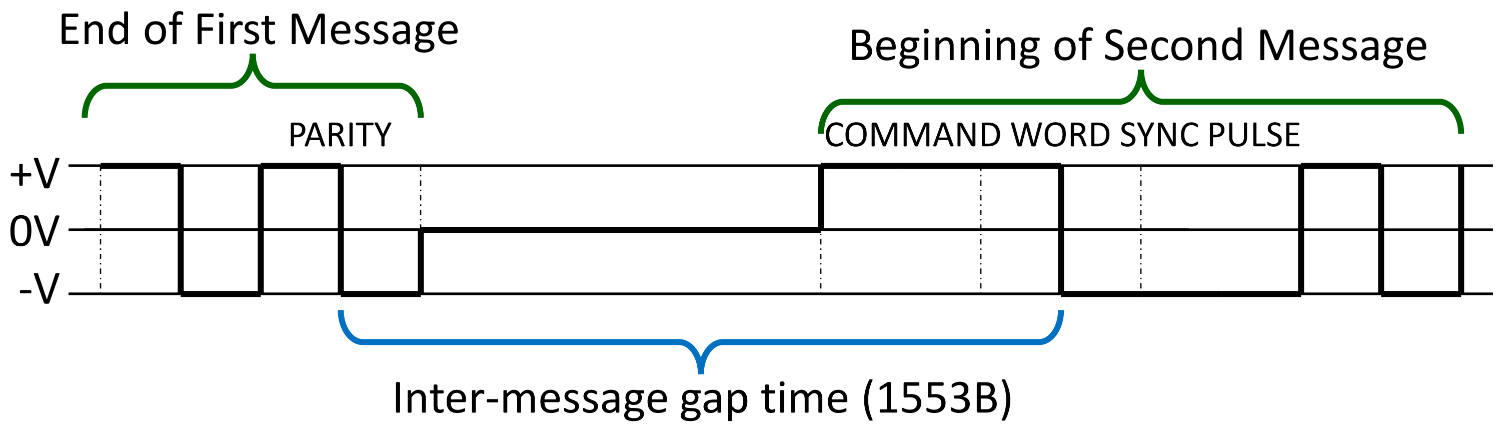


1553A: 2.0 to 5.0 µsec
Measured from the end of last bit (parity) of the command word or transmitted data word to the beginning of the sync pulse of the status word.

1553B: 4.0 to 12.0 µsec
Measured from the midpoint of last bit (parity) of the command word or transmitted data word to the midpoint of the sync pulse of the status word.

Inter-message Gap Time

This is the time between messages where there are no bits transmitted.

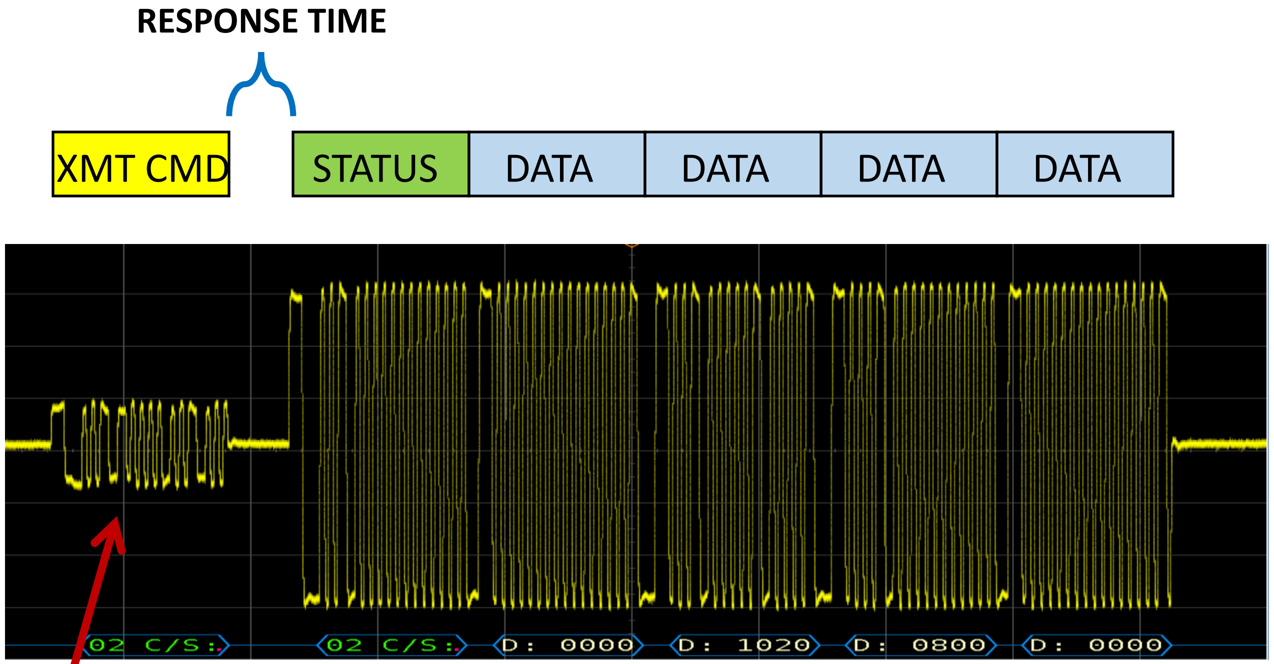


1553A: inter-message gap time is not specified

1553B: minimum of 4.0 µsec
Measured from the midpoint of last bit (parity) of the command word to midpoint of the sync pulse of the status word.

Actual 1553 Waveforms

RT to BC Transfer

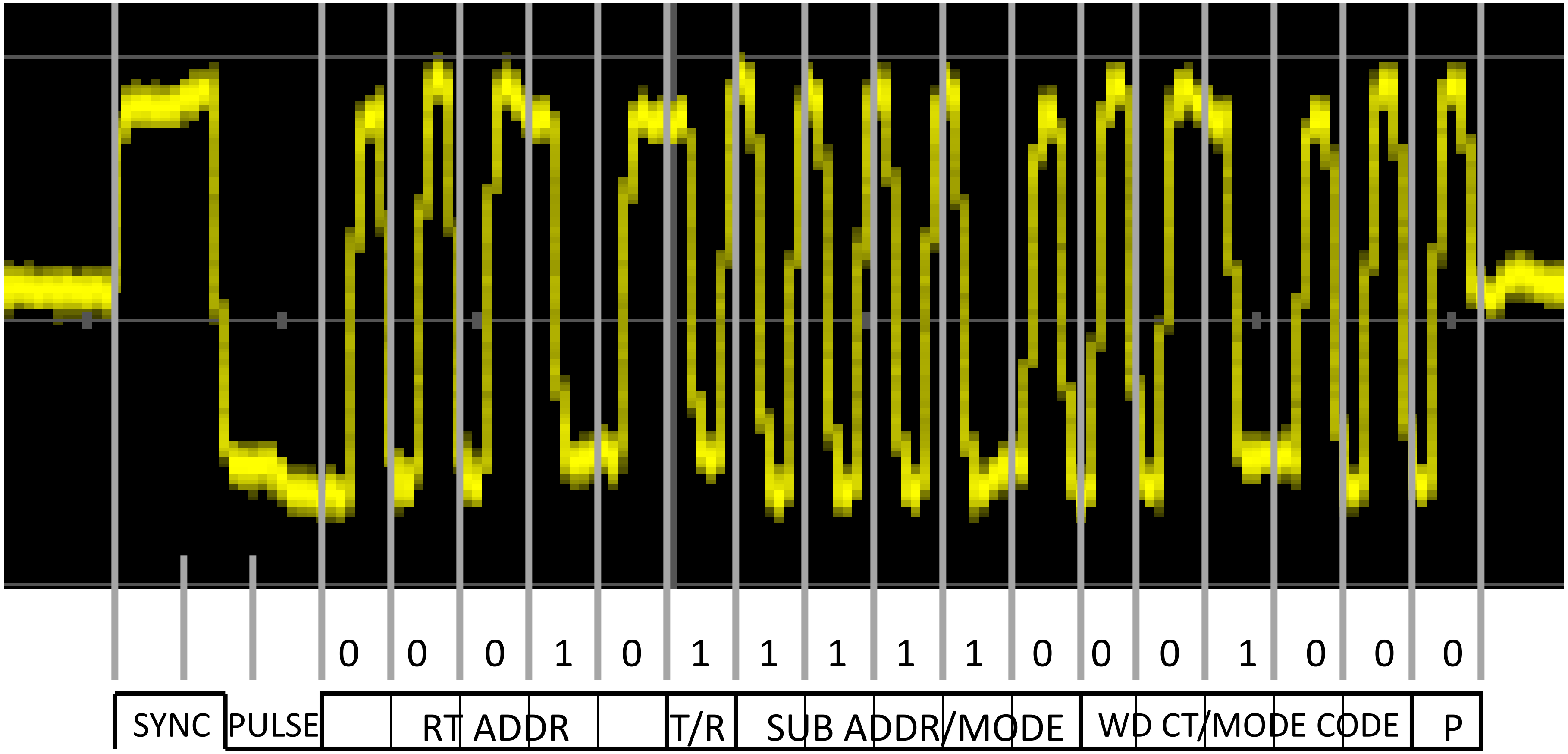


Measured at the stub of the RT

Let's decode the transmit command word!

Actual 1553 Waveforms

XMIT COMMAND WORD

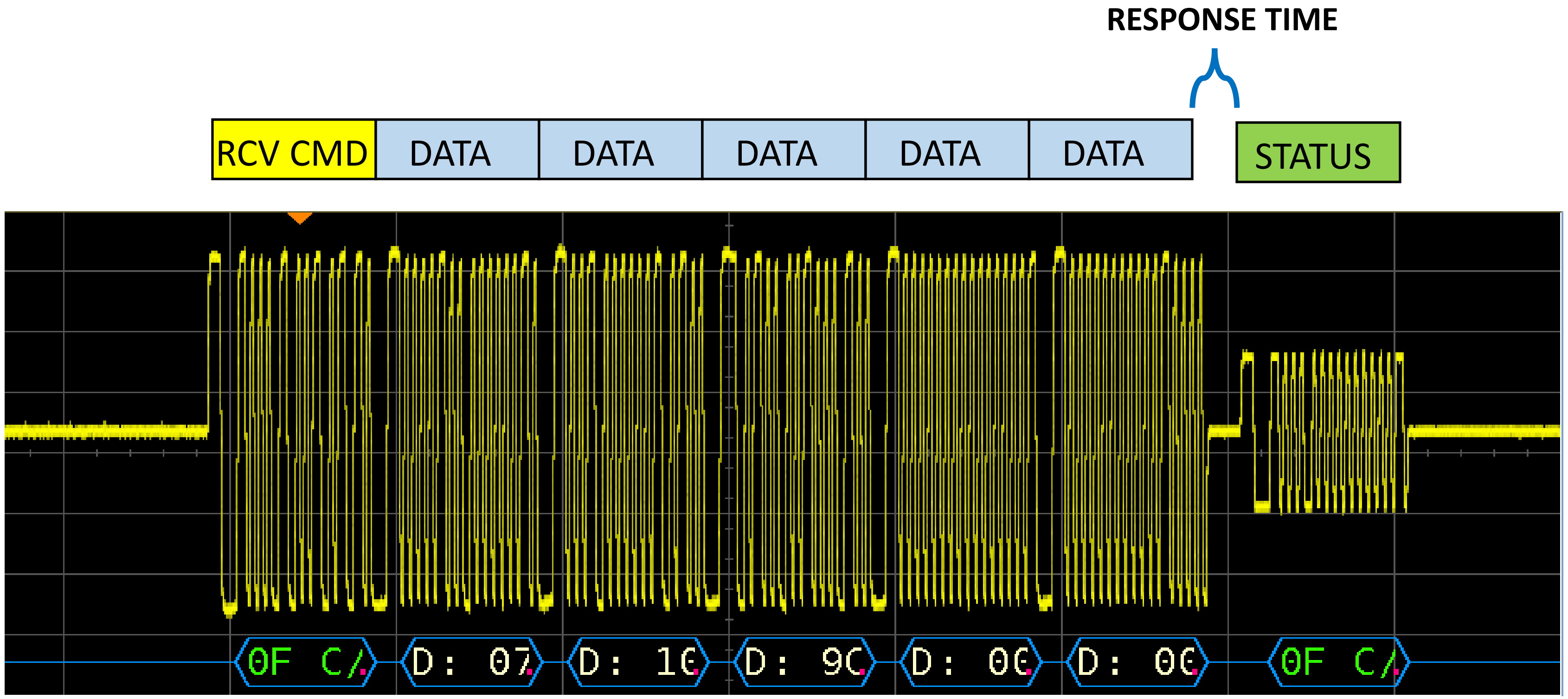


RT NO = 2
T/R BIT = 1 (transmit)
Sub Address = 30

Word Count = 4 (see previous slide)
Parity = 0 (parity is odd, there are seven 1's)

Actual 1553 Waveforms

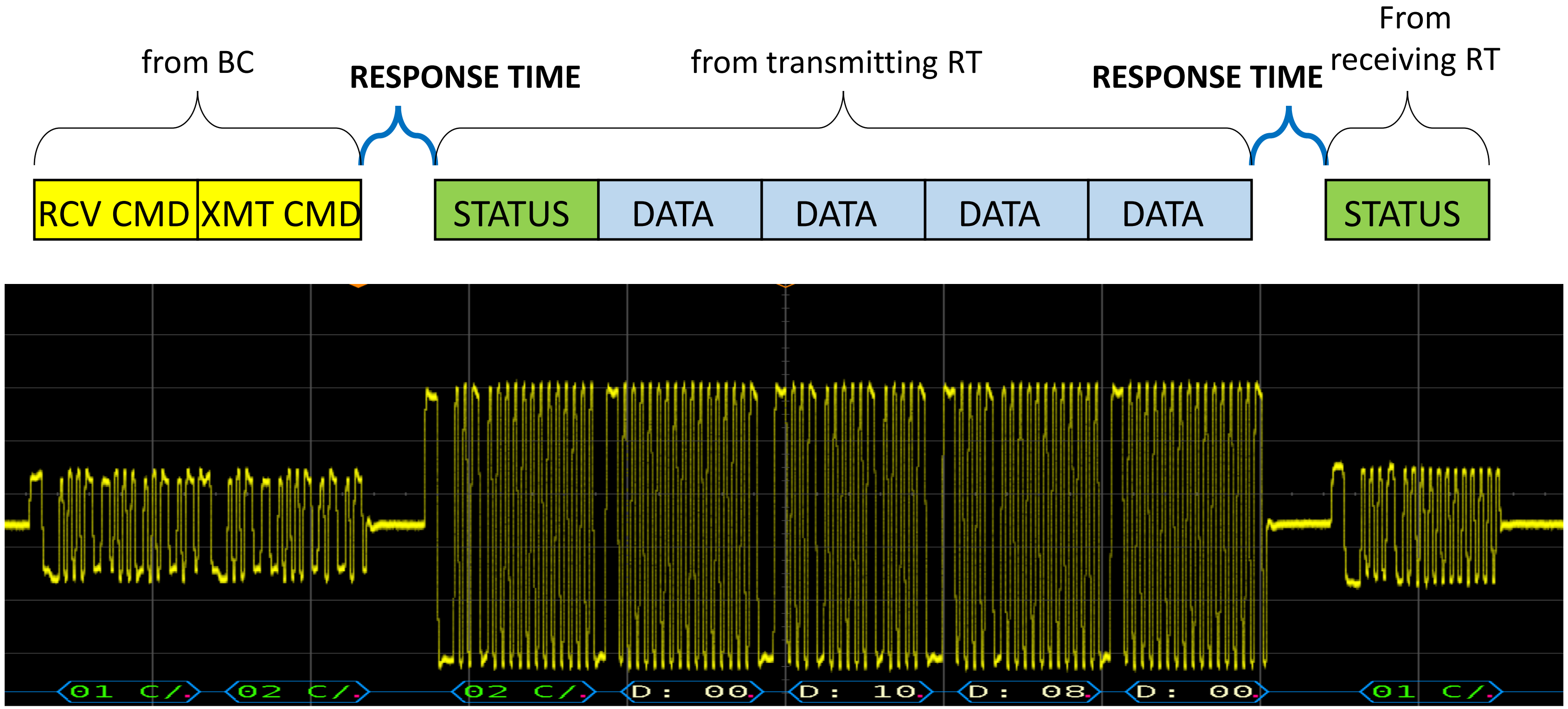
BC to RT Transfer



Measured at the stub of the BC

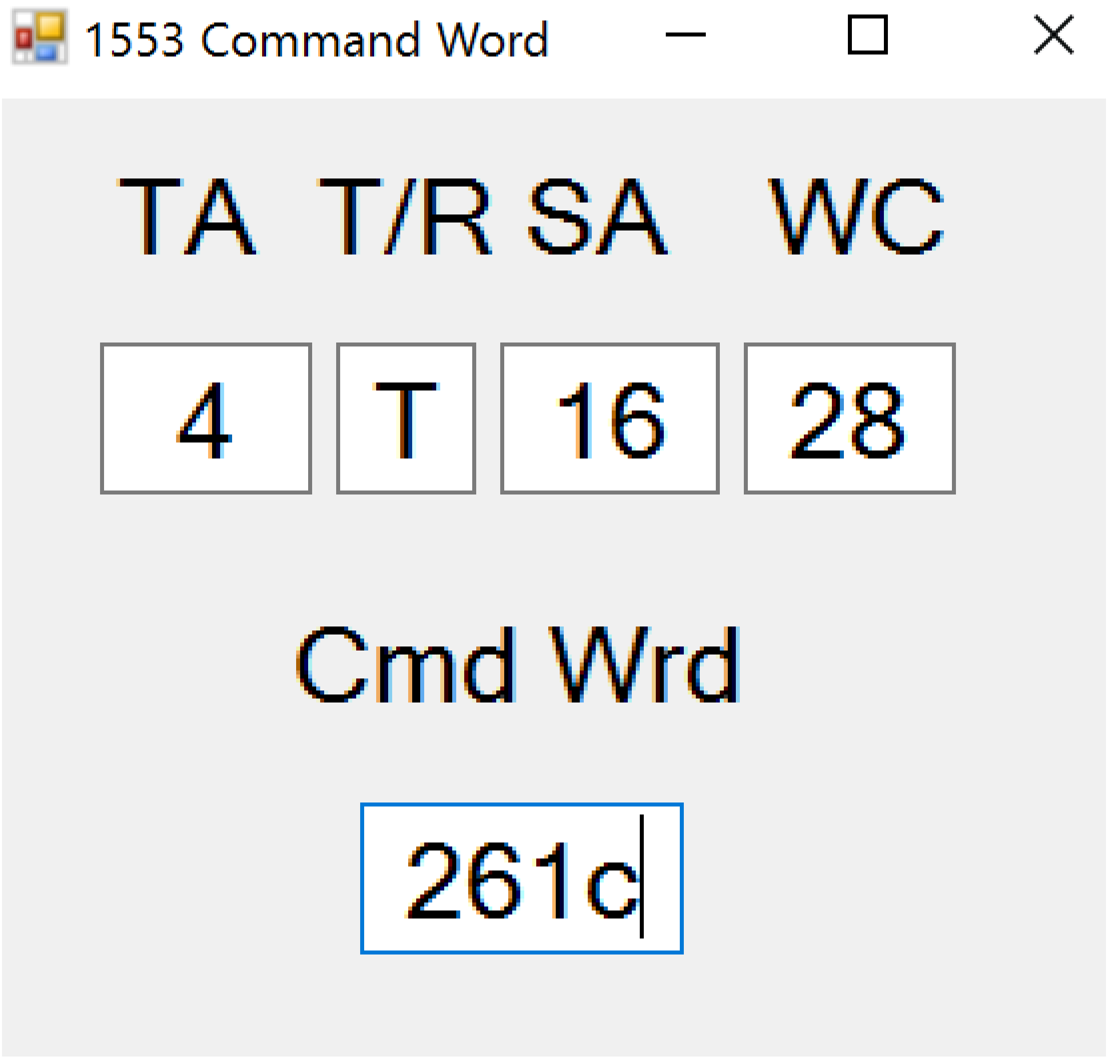
Actual 1553 Waveforms

RT to RT Transfer



Measured at the stub of the transmitting RT

Command Word Tool



Error Conditions

- Most common is response timeout
  - BC sends message to RT and doesn't get a response
  - Other errors could indicate termination or connection issue
  - i106stat program will show errors

```
ChanID   7 : 1553IN : UAR80-2-3
   RT  0  R  SA  0  Msgs   4142581  Errs   4142581
   RT  0  R  SA  1  Msgs   2417096  Errs   2417096
   RT  0  R  SA  2  Msgs    459121  Errs    459121
   RT  0  R  SA  3  Msgs    749541  Errs    749541
   RT  0  R  SA  4  Msgs    999803  Errs    999803
   RT  0  R  SA  5  Msgs     78607  Errs     78607
   RT  0  R  SA  6  Msgs    528683  Errs    528683
   RT  0  R  SA  7  Msgs     74320  Errs     74320
   RT  0  R  SA  8  Msgs    402284  Errs    402284
   RT  0  R  SA  9  Msgs      5901  Errs      5901
```

ICD Information

RxSA	Function	Words	Rate (Hz)	Source
1R	User-Entry Message (FMAC)	4	10	BC
2R	Misc Inputs (FMAC)	32	10	BC
3R				
4R				
5R	Remote Synchro Module Data	5	10	BC
6R				
7R				
8R	CDU Keep Alive	1	40	BC
9R				
10R	CDU 1 Discrete Outputs	5	10	BC
11R	CDU ARINC Tx Msg 1	32	OD-40	BC
12R	CDU ARINC Tx Msg 2	32	OD-40	BC
13R	CDU ARINC Tx Msg 3	32	OD-40	BC
14R	AIP Aero Parameters - Right (CR6)	9	4	BC
15R	AIP Aero Parameters - Left (CR7)	9	4	BC
16R	AIP Parameters - Right (CR8)	28	1	BC
17R	AIP Parameters - Left (CR9)	28	1	BC
18R	AIP Parameters 2 - Right (CR10)	26	1	BC
19R	AIP Parameters 2 - Left (CR11)	26	1	BC
20R	CDU BIT Command	2	1	BC

Parameter Information

Function	Words		
AIP Aero Parameters - Right (CR6)	1	Pitch and Roll Discretes	
(CCM to CDU #1 14R)	2	INU 1 Pitch Angle	
	3	INU 1 Roll Angle	
	4	429 Label	
	5	429 Label	
	6	429 Label	
	7	429 Label	
	8	VRS Pitch Angle	
	9	VRS Roll Angle	

INU1 Pitch Angle

Message: AIP Aero Parameters - Right (CR6)
Word 2: INU 1 Pitch Angle

Bit	Description
	INU 1 Pitch Angle
1	0 = Positive (Nose Up), 1 = Negative (Nose Down)
2	MSB = 0.5
.	
.	
16	LSB = MSB/2^14

Notes:
Bits 0-15
Units: Semicircles
Format: Two’s Complement
Comment: Zero reference is level

Parameter Information

Function	**WRD**		**Reference:** See DADC ICD for BIT definition	
ADC C01 Message	1	DADC Mode		
(ADC 17T to CCM)	2	Data Validity C01		
	3	Pressure Altitude		
	4	Pressure Altitude		
	5	Baroset Corrected Altitude		
	6	Baroset Corrected Altitude		
	7	True Airspeed		
	8	Mach Number		
	9	Spare		
	10	Indicated Airspeed		

Pressure Altitude

SIGNAL NAME: PRESSURE ALTITUDE
SUB-ADDRESS: 10001
UNITS: FEET

SOURCE: DADC	MSB: 16,777,216 FT	MAX: 55000 FT
DESTINATION: BC CDU	LSB: 2 FT	MIN: -1500 FT
MSG ID: C01	CODING: 2's COMP	SCALE FACTOR: 1
WORD NO: 3, 4		RESOLUTION: 2.0 FT
MSG - LENGTH: 23		ACCURACY: SEE REMARKS
TRANSMISSION RATE: 10 HZ TYP. TO BC CDU		COMPUTATION RATE: 10 HZ MIN

1553
32-bit parameter

Actually 25-bits
Remaining are SPARE
BIT-01 is most significant (MSB)
Resolution is 2 feet

BIT- 01	SIGN BIT (1 = NEGATIVE)
BIT- 02	16,777,216 = (MSB)
BIT- 03	8,388,608
BIT- 04	4,194,304
BIT- 05	2,097,152
BIT- 06	1,048,576
BIT- 07	524,288
BIT- 08	262,144
BIT- 09	131,072
BIT- 10	65,536
BIT- 11	32,768
BIT- 12	16,384
BIT- 13	8,192
BIT- 14	4096
BIT- 15	2048
BIT- 16	1024
BIT- 17	512
BIT- 18	256
BIT- 19	128
BIT- 20	64
BIT- 21	32
BIT- 22	16
BIT- 23	8
BIT- 24	4
BIT- 25	2 = (LSB)

Chapter 10 actual data

```
MSG 1:
  Computed IRIG Time 064:18:36:29:994203  669949942034
  BlockStatus: 0000  REF TIME: 009B FC20 D912  GAPTIMES: 0041  MSGLEN: 0032

     2637 2000 0000 F9E0 001B D380 001B D280
     0C7C 02A7 0000 0824 0000 0000 0000 FDD8
     FFFF 1DEA 6F54 0000 0000 0000 0000 0000
     0000
```

```
001B D380 = 0000 0000 0001 1011 1101 0011 1000 0000
Data = 37A7 = 14,257 X 2 = 28,494 ft
```

Enhanced GPS / INS (EGI)

EI-30: Air Data from CADC

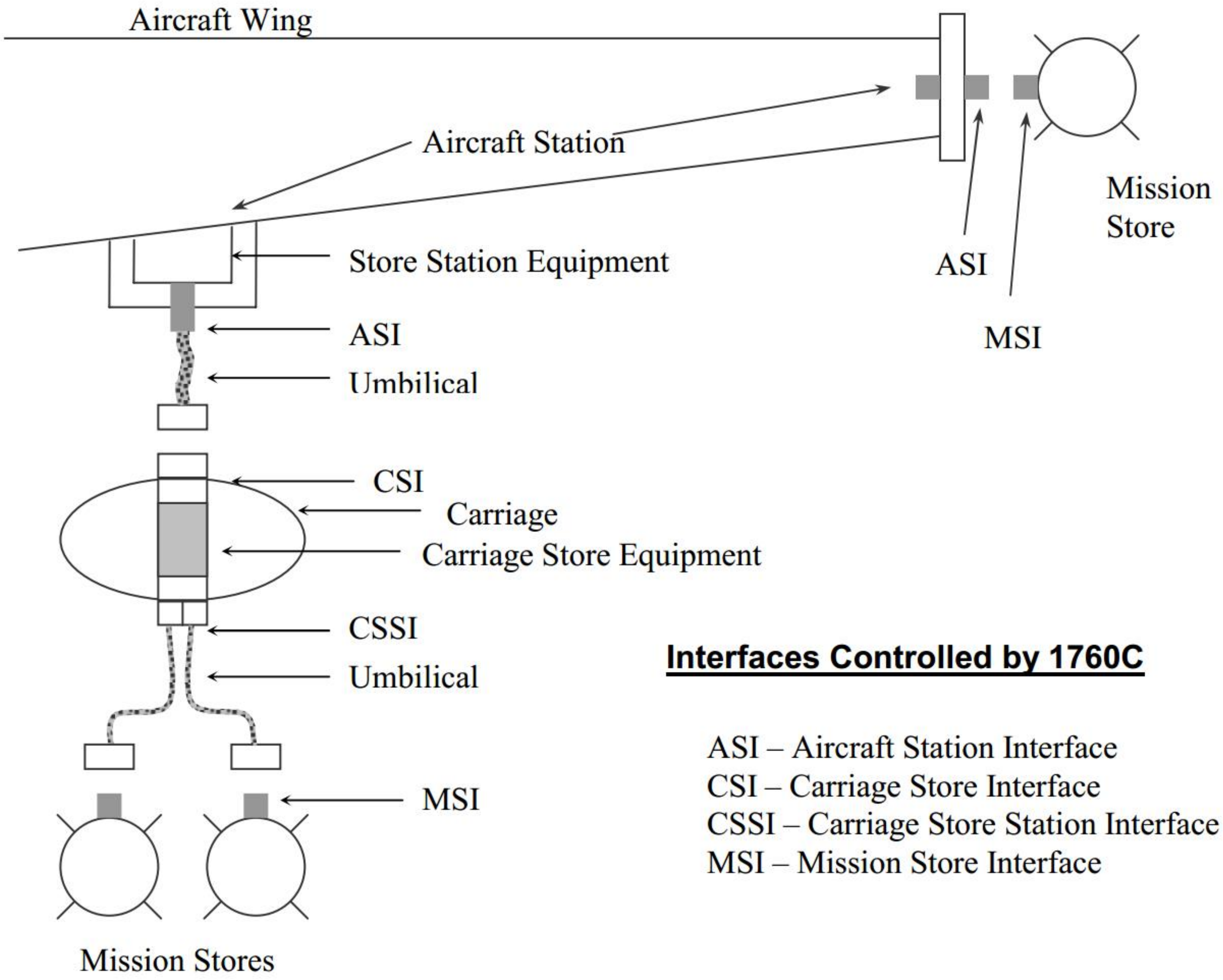
Word ID	Word Description
EGI-IN 30-01	CADC Mode Word
EGI-IN 30-02	Pressure Altitude
EGI-IN 30-03	Barometric Reference Altitude
EGI-IN 30-04	True Airspeed
EGI-IN 30-05	Mach Number
EGI-IN 30-06	Calibrated Airspeed
EGI-IN 30-07	True Angle of Attack
EGI-IN 30-08	Pressure Ratio
EGI-IN 30-09	Air Density Ratio
EGI-IN 30-10	True Freestream Air Temp
EGI-IN 30-11	Reserved

Mil STD 1760

MIL-STD-1760 defines a standardized electrical interface between a military aircraft and its carriage stores.

The MIL-STD-704 power connections provide the store with access to 28 VDC, three-phase wye 400 Hz, 115/200 VAC and 270 VDC aircraft power; it is usual to route only one of the last two supplies, however, if both are made available, then they are never made active simultaneously.

High-Speed 1760 specifies a gigabit-speed interface based on Fibre Channel, operating at 1.0625 Gbit/s over a pair of 75 ohm coax cables. The Fibre Channel upper layer protocols for High-Speed 1760 are FC-AE-1553, based on MIL-STD-1553, for command and control messages and file transfers; and FC-AV for video and audio.



<u>Interfaces Controlled by 1760C</u>

ASI – Aircraft Station Interface
CSI – Carriage Store Interface
CSSI – Carriage Store Station Interface
MSI – Mission Store Interface

Universal Armament Interface

- Defines messages used to communicate between aircraft and weapon or smart bomb rack (BRU-61)
- Enhanced Bit Rate (EBR) Mil-STD 1553
  - 10 MB/Sec

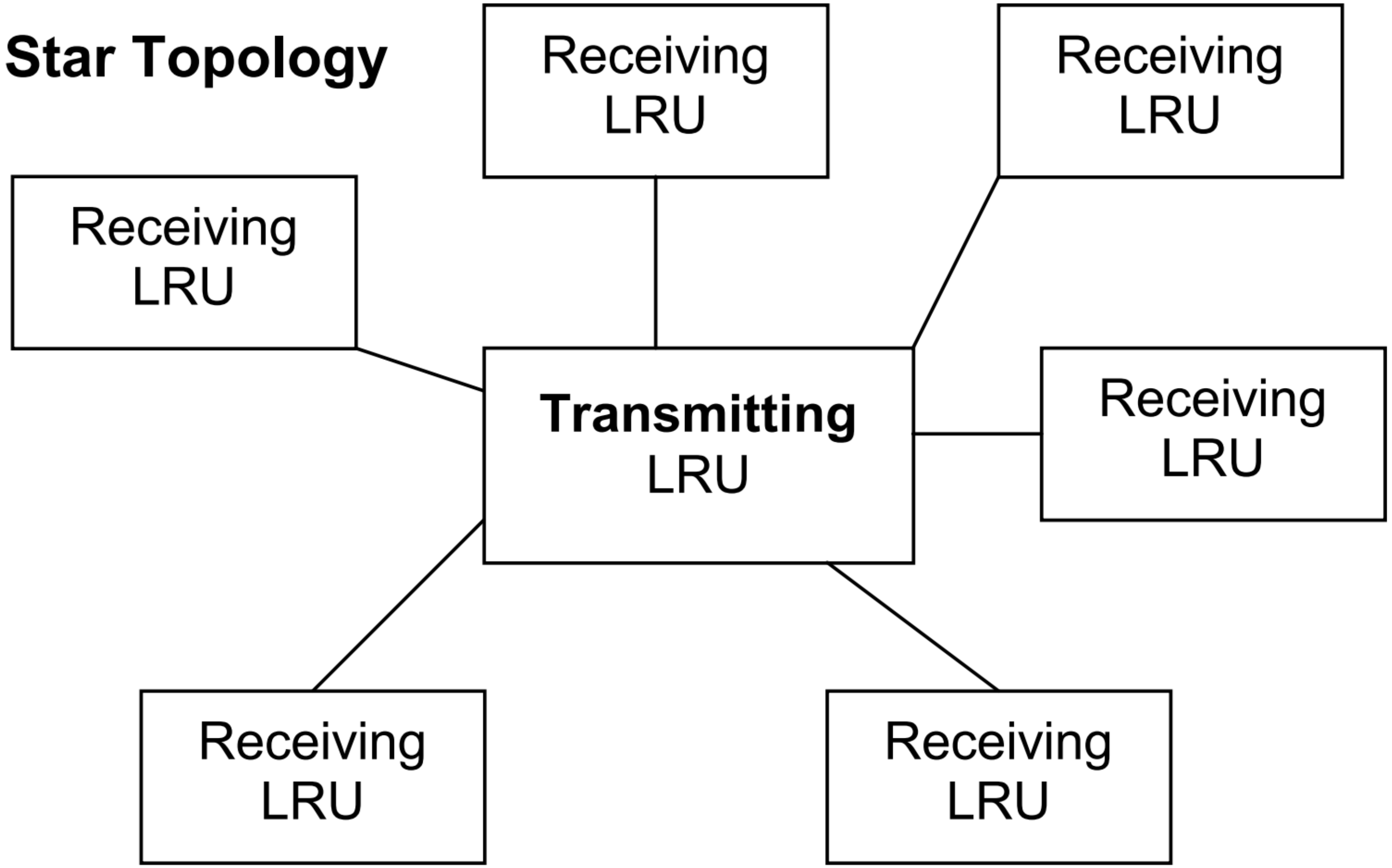
ARINC-429 Standard

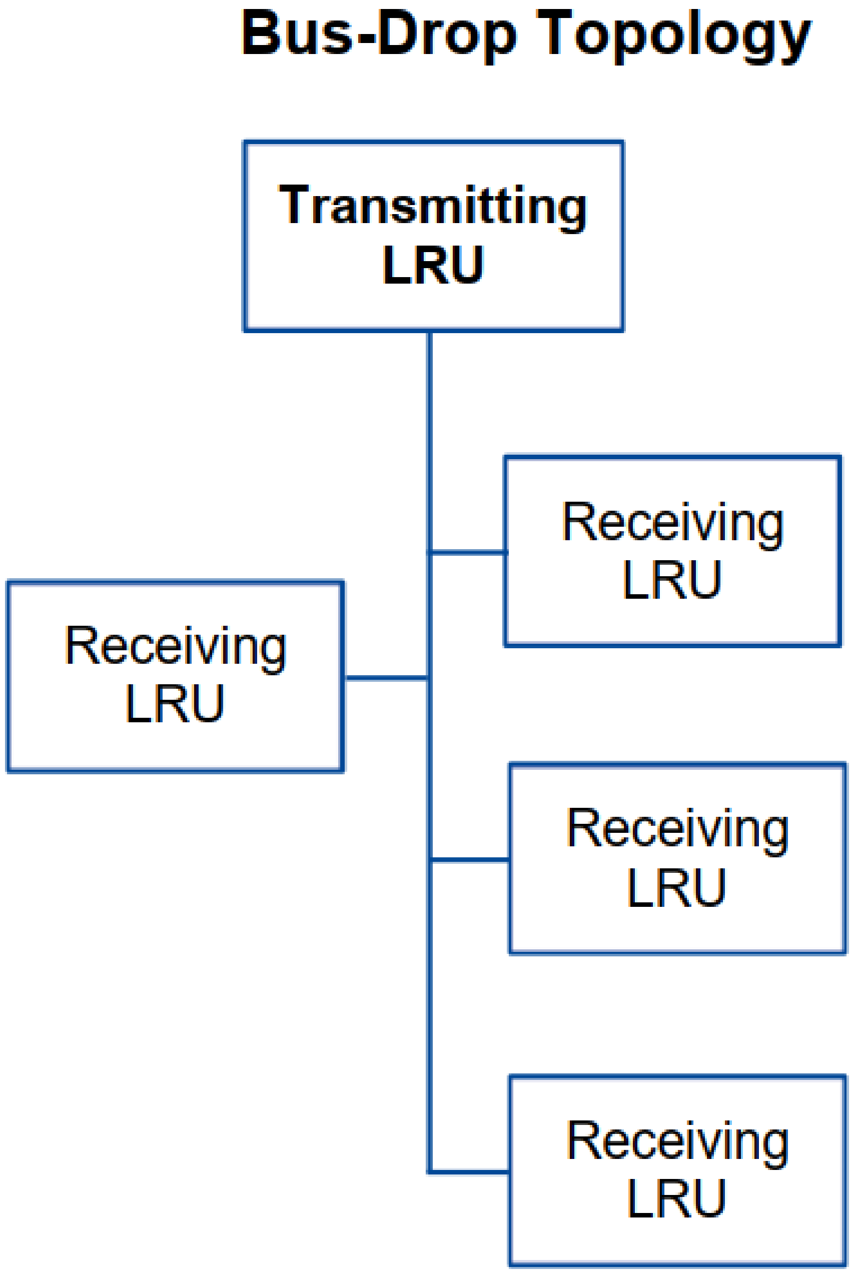
The ARINC 429 Specification developed out of the original commercial aviation digital communication spec, the ARINC 419 Specification. The ARINC 419, first released in 1966 and last revised in 1983, describes four different wiring topologies, including a serial, twisted shielded pair interface used by the Digital Air Data System (DADS), known as the ARINC 575 or DADS 575 Spec. This serial topology evolved into the ARINC 429 Specification, first released as ARINC 429-1 in April 1978, and currently exists as ARINC 429-15.

ARINC 429 Communication

ARINC 429 defines both the hardware and data formats required for bus transmission. Hardware consists of a single transmitter – or source – connected to from 1-20 receivers – or sinks – on one twisted wire pair. Data can be transmitted in one direction only – simplex communication – with bi-directional transmission requiring two channels or buses. The devices, line replaceable units or LRUs, are most commonly configured in a star or bus-drop topology. Each LRU may contain multiple transmitters and receivers communicating on different buses. This simple architecture, almost point-to-point wiring, provides a highly reliable transfer of data.

ARINC 429 Topology





ARINC 429 Data Rates

- ARINC 429 specifies two speeds for data transmission. Low speed operation is stated at 12.5 kHz, with an actual allowable range of 12 to 14.5 kHz. High speed operation is 100 kHz ± 1% allowed. These two data rates can not be used on the same transmission bus.

429 Message Structure

32	31	30	29 11	10	9	8 1
P	SSM		DATA → ← PAD ← DISCRETES MSB LSB	SDI		LABEL

- ARINC convention numbers the bits from 1 (LSB) to 32 (MSB).
- The least significant bit of each byte except the label is transmitted first, and the label is transmitted ahead of the data in each case. The order of the bits transmitted on the ARINC bus is as follows: 8, 7, 6, 5, 4, 3, 2, 1, 9, 10, 11, 12, 13 … 32.
- Labels are typically represented as octal numbers.

429 Data Types

- BCD = Binary Coded Decimal
- BNR = Binary data
- Discrete Data
- Maintenance Data and Acknowledgement
- Williamsburg / Buckhorn Protocol – bit oriented file transfer

429 BCD type

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
P	**SSM**		**Digit 1**			**Digit 2**				**Digit 3**				**Digit 4**				**Digit 5**				**SDI**		**Label**							

ARINC 429 BCD Word Format

- Binary Coded Decimal, or BCD format uses 4 data field bits to represent each decimal digit. Up to 5 subfields can be utilized to provide 5 binary values, with the Most Significant subfield containing only 3 data field bits (for a maximum binary value of 7). If the Most Significant digit is greater than 7, bits 27-29 are padded with zeros and the second subfield becomes the Most Significant digit allowing 4 binary values instead of 5 to be represented. The SSM field is used to provide the sign of the value.

429 Binary data

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
P	**SSM**		**MSB**									**Data**									**LSB**	**SDI**		**Label**							

ARINC 429 BNR Word Format

- Binary, or BNR, encoding stores data as a binary number. Bit 29 is utilized as the sign bit with a 1 indicating a negative number – or South, West, Left, From or Below. Bit 28 is then the data's Most Significant Bit (MSB), or ½ of the maximum value of the defined parameters scale factor. Bit 27 is ½ the value of Bit 28 or ¼ of the scale factor. Bit 26 is ½ the value of Bit 27 or 1/8 the scale factor and so on.

Sign / Status Matrix

- Bits 31-30 are assigned as the Sign/Status Matrix field or SSM. Depending on the words Label, which indicates which type of data is being transmitted, the SSM field can provide different information.
- This field can be used to indicate sign or direction of the words data, or report source equipment operating status and is dependent on the data type.

LM 429 FIDO Format

```
    3 3 3 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 1 1 1 1 1
    2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1
   +---------------------------------------------------------------+
1  |P|SSM|        DATA1 (MSB)            | EXT |SDI|     LABEL     |
   | |   |                               |     |   |               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-|
2  |P|SSM|        DATA2 (LSB)            | F |S|SDI|     LABEL     |
   | |   |                               |   | |   |               |
   +---------------------------------------------------------------+
```

```
Where: F is the format indicator with the following definition;

       00 --- R, Raw data format (should be displayed in HEX)
       01 --- F, Floating point format (IEEE 32-bit float)
       10 --- I, Integer format (32-bit signed integer)
       11 --- U, Unsigned integer format (32-bit unsigned integer)

SDI bit setting will be as follows;

       01 --- Indicates the first word in the two word transmission.
       10 --- Indicates the second word in the two word transmission.
```

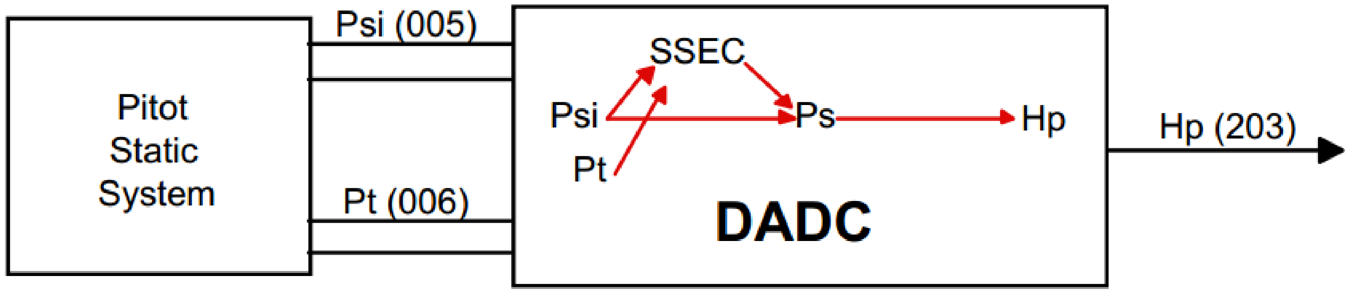
ICD Information

ENG Data Ch. A					
Producer Label	Source LRU: DCU		Consumer(s)		
Number	Rate (Hz)	Name	IOC 1	MFD 1C	EEID
040	10	Engine Fan RPM (N1 Actual) (Engine 1)	x	x	x
041	10	Engine Fan RPM (N1 Demand) (Engine 1)	x	x	x
042	10	Flaps Indicator (LH Outboard)	x	x	x
043	10	Engine Oil Pressure (Engine 1)	x	x	x
044	10	Engine Turbine RPM (N2) (Engine 1)	x	x	x
045	10	Exhaust Gas Temperature (EGT) (Engine 1)	x	x	x
046	10	Engine Oil Temperature (Engine 1)	x	x	x
047	10	Fuel Flow (Engine 1)	x	x	x
060	1	EOP Calibration Point 1 (Engine 1)	x		x
061	1	EOP Display Point 1 (Engine 1)	x		x
062	1	EOP Calibration Point 2 (Engine 1)	x		x
063	1	EOP Display Point 2 (Engine 1)	x		x
064	1	EOP Calibration Point 3 (Engine 1)	x		x
065	1	EOP Display Point 3 (Engine 1)	x		x
071	1	EOP Calibration State Return	x		

Pressure Altitude

ARINC 429 MESSAGE	203	Pressure Altitude (H_p)

SIGNAL TYPE	Digital serial data bus (ARINC 429)
UNITS	Feet
RANGE	-1,000 to 50,000
WORD RANGE	131,071
RESOLUTION	1 ft
ACCURACY	± 20 ft or 0.2% whichever is the greatest
DESTINATION	Altimeter's, GPWS



429 Parameter Definition

Bit Number	Value	Bit Number	Value
1	1	17	32 ft
2	0	18	64 ft
3	0	19	128 ft
4	0	20	256 ft
5	0	21	512 ft
6	0	22	1024 ft
7	1	23	2048 ft
8	1	24	4096 ft
9	SDI code	25	8192 ft
10	SDI code	26	16384 ft
11	Pad	27	32768 ft
12	1 ft	28	65536 ft
13	2 ft	29	0 = Plus, 1 = minus* ft
14	4 ft	30	SSM Code
15	8 ft	31	SSM Code
16	16 ft	32	Parity (Odd)

* = 2's complement

Sign Status Matrix (SSM)		
Bits		Meaning
31	30	
0	0	Failure
0	1	No Computed Data
1	0	Functional Test
1	1	Normal Operation

SDI Code		
10	9	Value
0	0	Not Used
0	1	Left Unit
1	0	Right Unit
1	1	Not Used

Chapter 10 429 data

```
637A70C1 (203)  LO    0    0       3569  064:18:36:30:001140
```

Data = 0110 0011 0111 1010 0111 0000 1100 0001
Value = 6F4E = 28,494 ft

ARINC-664 Standard

The ARINC 664 standard utilizes a profiled version of an IEEE 802.3 network per parts 1 & 2, which defines how commercial off-the-shelf networking components will be used for future generation Aircraft Data Networks (ADN). Airbus patented the term Avionics Full-Duplex Switched Ethernet (AFDX) which is a specific implementation of ARINC-664. The six primary aspects of an ARINC-664 / AFDX data network include full duplex, redundancy, determinism, high speed performance, switched and profiled network.

AFDX Frame Structure

Preamble	Start Delimiter	MAC Header	IP Header	UDP Header	AFDX Payload	AFDX Sequence Number	FCS
7	1	12	22	8	17…1471	1	4

Frame Size:	64…1518 Bytes
Preamble + Start Delimiter + InterFrame Gap:	20 Bytes
Duration of Minimum Frame:	6.72 usec (84 Bytes a 80ns)
Duration of Maximum Frame:	123.04 usec (1538 Bytes a 80ns)

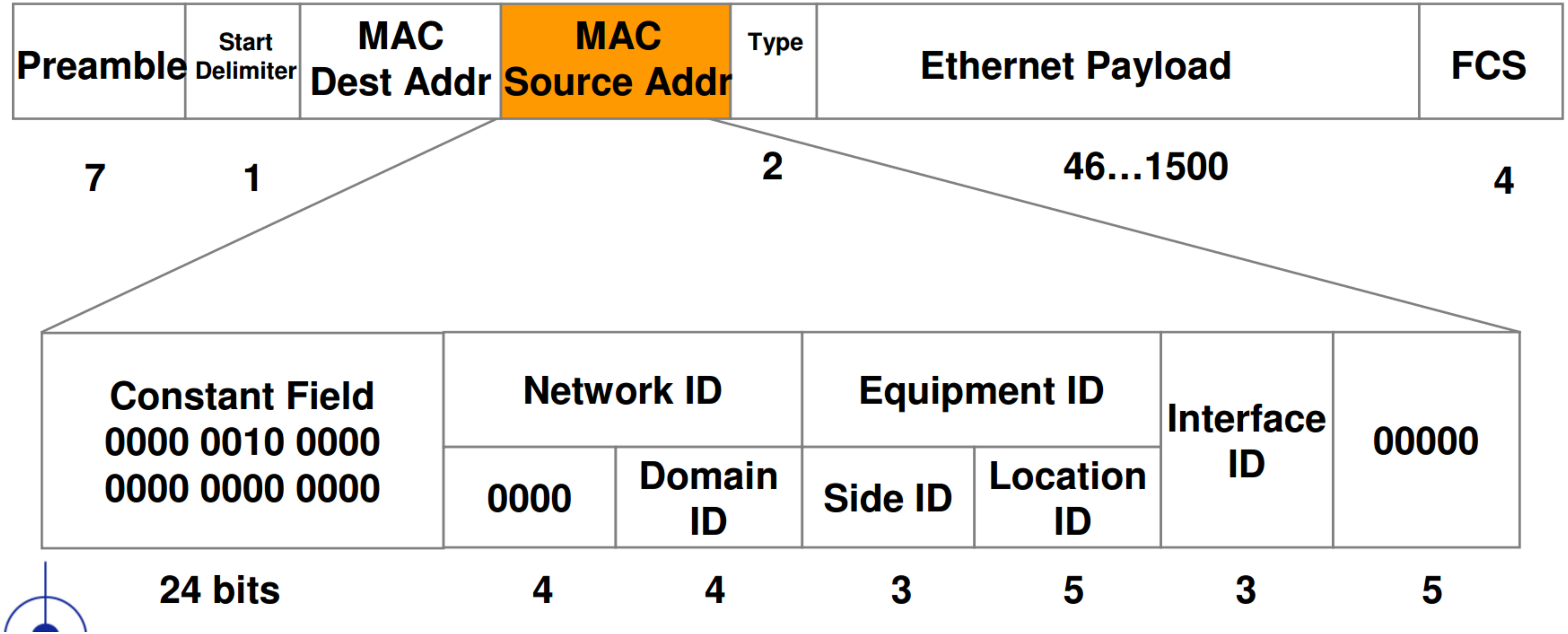
AFDX MAC Layer 2

- MAC header comprises a Source and Destination Address, and a Type Field
- Each address is 48 bits wide
- The Destination Address identifies the Virtual Link
- The Source Address is (must be) a Unicast Address
- The Destination Address is (must be) a Multicast Address

Preamble	Start Delimiter	MAC Dest Addr	MAC Source Addr	Type	Ethernet Payload	FCS
7	1	6	6	2	46…1500	4

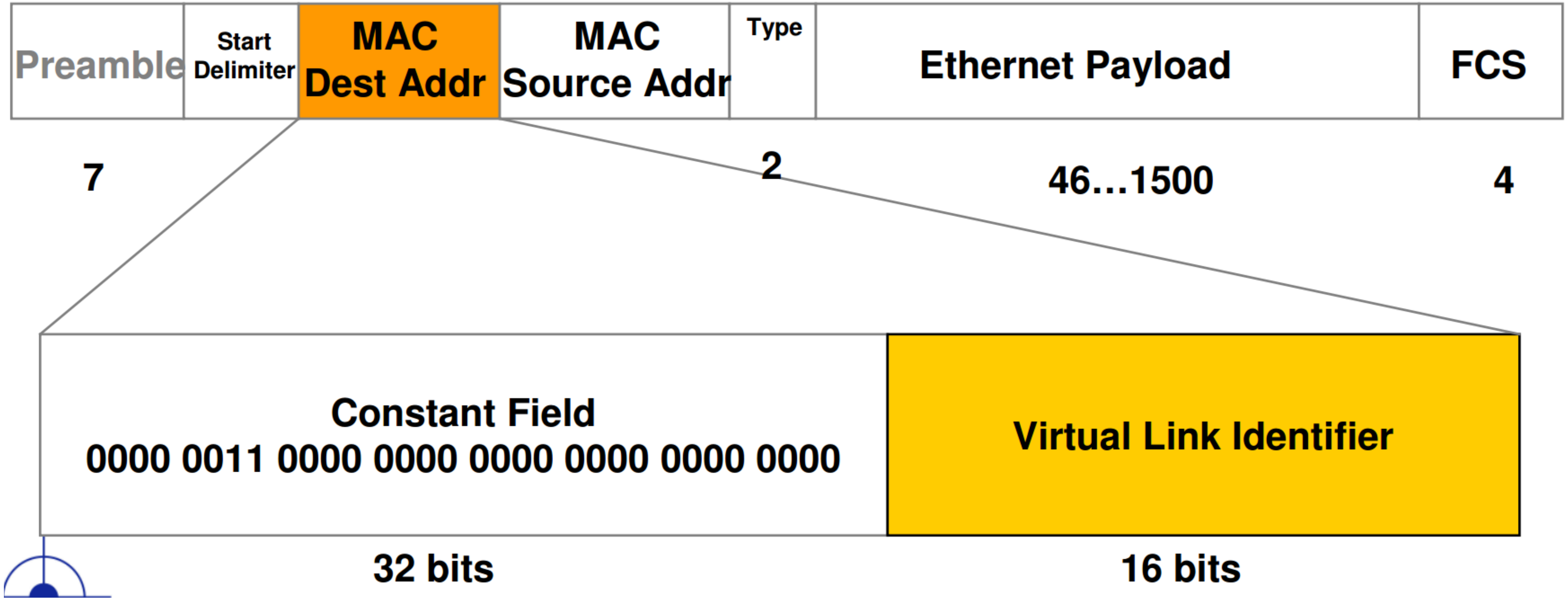
MAC Source Address

- **MAC Source Address encodes the unique "Source" of the frame**



MAC Destination Address

- **MAC Destination Address identifies the Virtual Link**



Addressing

- **IP Addressing**
  - IP Source is always a Unicast Address, Class A Private IP (→ single source) Example: **10**.x.x.x
  - IP Destination either Multicast (→ multiple receivers* in a End System e.g. **224.224.**x.x) or Unicast (→ single receiver* in End System e.g. **10**.x.x.x)

* a "receiver" e.g. means an application. In other words: data addressed to a unicast IP destination address shall be used by only one application, data addressed to a multicast IP destination address can be used by multiple applications in side the same End System. The Specifications are also using the term "partition" in sense of an "application".

ARINC-708 Standard

- The ARINC 708 standard defines the protocol for transmitting weather RADAR information.
- Utilizes Manchester encoding similar to Mil-STD 1553
- Non-standard word sizes
- 512 3-bit color bins

Matrix code [Pixel Value 3 bits]	Weather Condition	Bin *N* Bit *n2*	Bit *n1*	Bit *n0*	Display Color Example
0	No precipitation [< Z2]	0	0	0	Black
1	Light precipitation [Z2 to Z3]	0	0	1	Green
2	Moderate precipitation [Z3 to Z4]	0	1	0	Yellow
3	Heavy precipitation [Z4 to Z5]	0	1	1	Red
4	Very heavy precipitation [> Z5]	1	0	0	Magenta
5	Reserved[1]	1	0	1	
6	Medium turbulence	1	1	0	
7	Heavy turbulence	1	1	1	

ARINC-708 Word Format

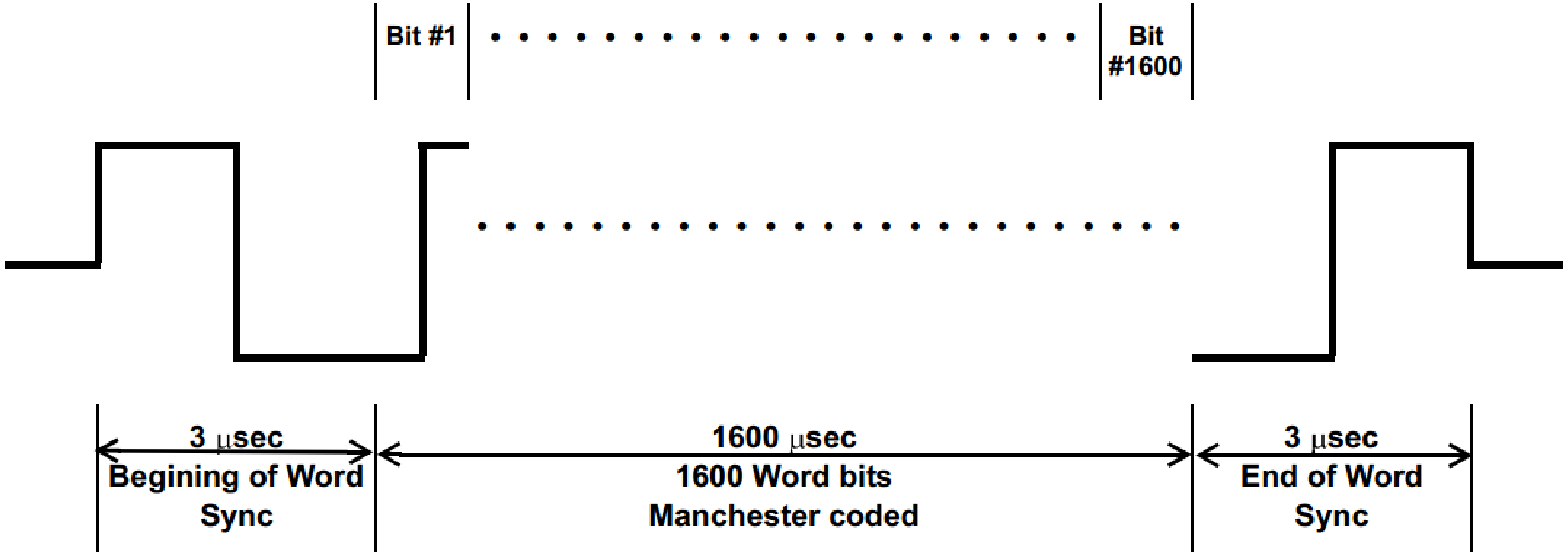
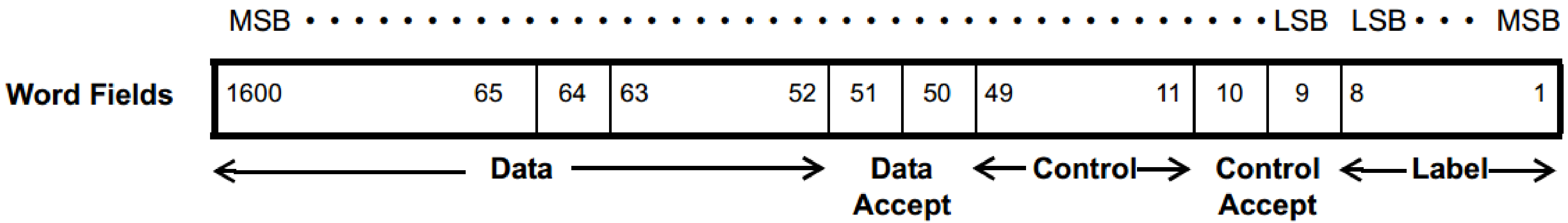


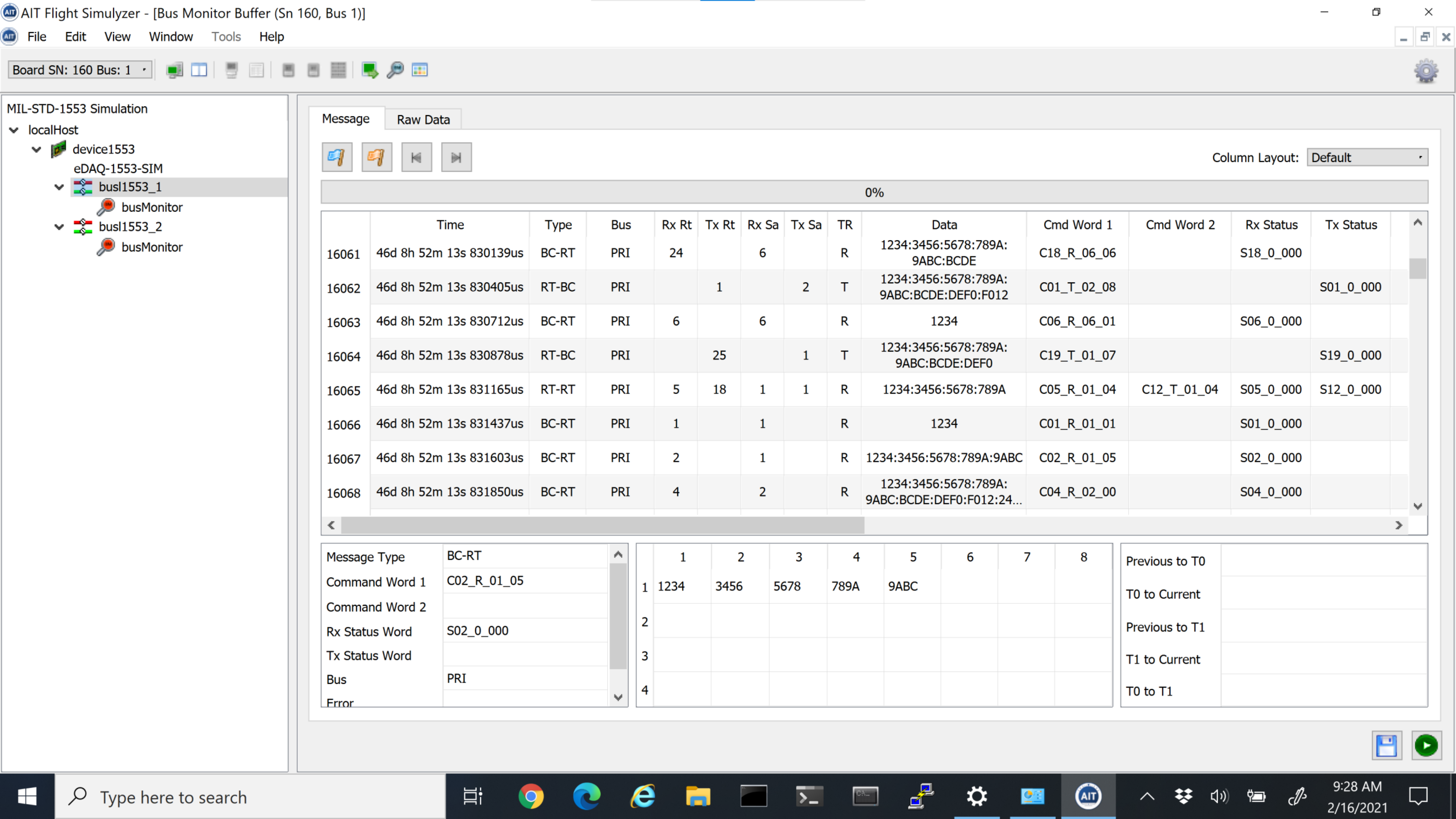
Figure A-1 ARINC 708 Waveform Pattern



ARINC-708 Data Fields

Bits	Data Display	Function details
01– 08	Label	055 (octal)
09 – 10	Control Accept	see **Table A-2 Control Accept Functions**
11	Slave	0 = Master (Normal) 1 = Slave
12 – 13	Spare	
14 – 18	Mode Annunciation	see **Table A-3 Mode Annunciation**
19 – 25	Faults	see **Table A-5 Faults**
26	Stabilization	0 = Stabilization OFF 1 = Stabilization ON
27 – 29	Mode	see **Table A-6 Operating mode**
30 – 36	Tilt	see **Table A-7 Tilt data**
37 – 42	Gain	see **Table A-8 Gain data**
43 – 48	Range	see **Table A-9 Range Data**
49	Spare	
50 – 51	Data Accept	see **Table A-10 Data accept**
52 – 63	Scan Angle	see **Table A-11 Scan angle**
64	Spare	
65 – 67	Bin 1	
⋮	⋮	see **Table A-12 Weather Condition / Reflectivity Data**
1598 – 1600	Bin 512	

Questions?


AIT Flight Simulyzer - [Bus Monitor Buffer (Sn 160, Bus 1)]
File Edit View Window Tools Help
Board SN: 160 Bus: 1
MIL-STD-1553 Simulation
localHost
device1553
eDAQ-1553-SIM
busl1553_1
busMonitor
busl1553_2
busMonitor
Message
Raw Data
Column Layout:
Default
0%
Time Type Bus Rx Rt Tx Rt Rx Sa Tx Sa TR Data Cmd Word 1 Cmd Word 2 Rx Status Tx Status
16061 46d 8h 52m 13s 830139us BC-RT PRI 24 6 R 1234:3456:5678:789A:9ABC:BCDE C18_R_06_06 S18_0_000
16062 46d 8h 52m 13s 830405us RT-BC PRI 1 2 T 1234:3456:5678:789A:9ABC:BCDE:DEF0:F012 C01_T_02_08 S01_0_000
16063 46d 8h 52m 13s 830712us BC-RT PRI 6 6 R 1234 C06_R_06_01 S06_0_000
16064 46d 8h 52m 13s 830878us RT-BC PRI 25 1 T 1234:3456:5678:789A:9ABC:BCDE:DEF0 C19_T_01_07 S19_0_000
16065 46d 8h 52m 13s 831165us RT-RT PRI 5 18 1 1 R 1234:3456:5678:789A C05_R_01_04 C12_T_01_04 S05_0_000 S12_0_000
16066 46d 8h 52m 13s 831437us BC-RT PRI 1 1 R 1234 C01_R_01_01 S01_0_000
16067 46d 8h 52m 13s 831603us BC-RT PRI 2 1 R 1234:3456:5678:789A:9ABC C02_R_01_05 S02_0_000
16068 46d 8h 52m 13s 831850us BC-RT PRI 4 2 R 1234:3456:5678:789A:9ABC:BCDE:DEF0:F012:24... C04_R_02_00 S04_0_000
Message Type BC-RT
Command Word 1 C02_R_01_05
Command Word 2
Rx Status Word S02_0_000
Tx Status Word
Bus PRI
Error
1 2 3 4 5 6 7 8
1 1234 3456 5678 789A 9ABC
2
3
4
Previous to T0
T0 to Current
Previous to T1
T1 to Current
T0 to T1
Type here to search
9:28 AM
2/16/2021

AIT Flight Simulyzer - [Bus Monitor Buffer (Sn 160, Bus 1)]

File Edit View Window Tools Help

Board SN: 160 Bus: 1

MIL-STD-1553 Simulation
- localHost
  - device1553
    - eDAQ-1553-SIM
    - busl1553_1
      - busMonitor
    - busl1553_2
      - busMonitor

Message | Raw Data

	Bus	Time Tag	Data	ntermessage Ga	Response Time	Error
189929		TT-HI 46d 8h 52m				
189930		TT-LO 13s 8499...				
189931	PRI		C CC27 (C19_T_...	102.00us		
189932	PRI		S C800 (S19_0_0...		8.00us	
189933	PRI		D 1234			
189934	PRI		D 3456			
189935	PRI		D 5678			
189936	PRI		D 789A			
189937	PRI		D 9ABC			
189938	PRI		D BCDE			
189939	PRI		D DEF0			
189940		TT-HI 46d 8h 52m				
189941		TT-LO 13s 8502...				
189942	PRI		C 2824 (C05_R_...	102.00us		
189943	PRI		C 9424 (C12_T_0...			
189944	PRI		S 9000 (S12_0_0...		8.00us	
189945	PRI		D 1234			
189946	PRI		D 3456			
189947	PRI		D 5678			
189948	PRI		D 789A			
189949	PRI		S 2800 (S05_0_0...		8.00us	
189950		TT-HI 46d 8h 52m				
189951		TT-LO 13s 8505...				
189952	PRI		C 0821 (C01_R_...	102.00us		

Type here to search

9:29 AM
2/16/2021