Factors in the Selection of MIL-STD-1553 Couplers,Connectors and Harnesses

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Application Note

AN/251

There are four fundamental issues to be addressed in designing a MIL-STD-1553 data bus network. How they are addressed will have a profound impact on cost, reliability, and repair time. The four issues are as follows:

1. Integrated in-line harness vs. individual couplers
2. Single vs. multiple stub couplers
3. Connectors– multi-pin vs. triaxial, bayonet vs. threaded, and multi channel vs. single channel
4. Cable type– twinax vs quadrax

The circuitry of the coupler itself is defined by MIL-STD 1553 and not subject to design variation. The circuit specifications, though simple and straightforward, do not address variations from transformer to transformer within allowable parameters. Under normal conditions and usage most couplers are satisfactory and interchangeable, even with small variations in fault isolation resistor values, as long as they have the same nominal turns ratio. Some couplers have values as low as 50 ohm while others can be as high as 59 ohm. It must be remembered that their primary function is fault isolation, preventing an RT, BC or monitor stub cable problem from destroying the integrity of the bus.

In marginal networks where the guidelines have been stretched (long buses over 300 feet, long stubs over 25 feet or long uninterrupted runs between couplers groups), it is best to rely on vendors who manufacture their own transformers providing a degree of consistency not available from those who purchase transformers from several sources with differing design and unspecified performance parameters.

Requiring MIL-T-21038 transformers is not sufficient to insure repeatability. Issues such as balance, interwinding capacitance, and reflected energy are not addressed in MIL-STD-1553 and many of today's engineers are reluctant to get into LCR issues and network analysis. Instead, they prefer to go the "build-it-and-try-it" bench set-up route. The danger here is that repeatability/ interchangeability issues are not addressed.

Most networks are not that sensitive, but some are and when they are, you can have problems where certain nodes are sensitive to unspecified parameter variations.

Assuming you have a proper network, its reliability will depend, in large part, on the number and type of connectors used. All else is pretty much fixed by the number of stubs, ie; the number and type of transformers, resistors, PC boards, solder joints, etc. The number and type of connector used is a variable you can control. The number of connectors will be determined by the number of bulkhead feed-throughs in the platform, the type of coupler used, and the LRU connector configuration. Coupler, connector and wire trade-offs are discussed below.

Coupler Types

There are two types of couplers to choose from, the in-line type and the flange-mounted connectorized box type. Examples of each can be seen in Figures 1 through 10. Each has its own advantages and disadvantages.

In-line couplers offer the highest reliability and significantly lower weight but have installation and repair problems. They usually are laced into cable bundles or secured to bulkheads with clamps. To be repaired or replaced the new coupler must be spliced in which entails soldering in with splice kits utilizing high temperature heat guns. Use of a heat gun in a wiring bundle frequently causes damage to the surrounding wires. Splices also suffer from not being inspectable for proper solder flow and joint cleanliness. The system cost compared to the box type is usually a wash, the difficulty of manufacture and testing being offset by fewer connectors.

Box type couplers have the advantage of easy fault isolation, flexibility in updating or bus configuration changes, and ease of installation and repair.

Fault isolation is made easier by the multiple connectorized break points and accessibility. Individual segments can be easily disconnected and/or replaced. Stubs can be swapped and couplers moved around.

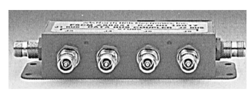

Fig. 1. 4-stub coupler withTriaxial connectors. Used on C-17.

Fig. 2. 2-stub coupler with multi-pin connectors. Used on F-15E.

Fig. 3. DB50010 Flange-Mounted Coupler Used on AC-130U

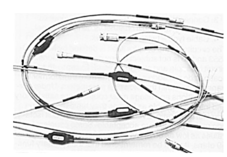

Fig. 4. DB40005 In-line coupler harness.

Updates or configuration changes are easily implemented by strategically locating spare stubs, adding couplers or by replacing one coupler with another having additional stubs. The penalty for this flexibility and ease of maintenance is weight and less initial calculated reliability due to the additional connectors. The point here is that field repairs or splices made necessary by updates and troubleshooting seriously degrade initial reliability. It should be noted that assembling a harness from individual couplers with splices as opposed to having it manufactured without splices has the same problems but to a somewhat lesser degree. The splices, although made under better conditions, still have uninspectable solder joints.

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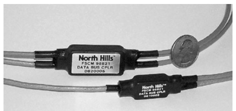

Fig. 5. DB- 20005, Smallest 2-stub coupler

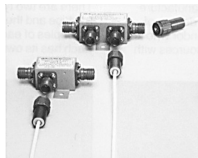

Fig. 6. Flange mounted couplers with MIL-C38999 connectors. Used on V-22

To illustrate this (See the following exhibit), a 16-stub bus network is examined for weight and MTBF (per MIL-HDBK-217) in both configurations — in-line harness and flange-mounted box types.

Flange Mount vs. In-line Couplers 16-Stub Bus Assume:

1. All wiring between LRUs and couplers is the same for both configurations and is excluded.
2. All couplers are single stub types.
3. The harness is a single entity without connectors, except at the LRU ends of the stub wires.
4. LRU connectors are the same for both configurations and are excluded.

Weight			
Item	Qty	Flange Mount	In-Line
Couplers. 1 stub	16	16 x 65 gms = 1040 gms	16 x 8 gms = 128 gms
Mating Conn.	46	46 x 16 gms = 736 gms	0gms
Terminators	2	2 x 20 gms = 40 gms	2 x 6 gms = 12 gms
		1816 gms	128 gms
		3.91 lbs	.30 lbs
		wt = 3.61 lbs.(1676 gms)	

MTBF (=70 C AIRBORNE FIGHTER UNINHABITED)			
Item	Qty	Flange Mount	In-Line
Couplers. 1 stub	16	16 x 1.38 = 22	16 x .7 = 11.2
Crimp Joints #2	136	(3 x 3 x 16) - 2 = .68 (1)	None
Terminators	2	2 x .054 = .11	2 x .054 = .11
		1816 gms	128 gms
		3.91 lbs	.30 lbs
		wt = 3.61 lbs.(1676 gms)	

1. 138 x 9.5x .00026 x 2 x 1 = .68
2. At connectors .3 Joints/ Cable Connector x 3 connectors/ coupler 2 ends with terminators = (3 x 3 x 16) –2 = 138 joint

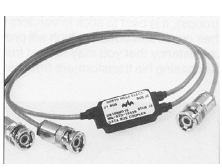

Fig. 7. In-line coupler with connectors. Used on OH-58.

Fig. 8. Flange mounted coupler with multi-pin connector. Used on B-52.

In conclusion, going from flange-mounted couplers to in-lines in an integrated harness can save over 3 1/2 pounds per bus in a 16 coupler configuration. Weight savings will be proportionately higher or lower with fewer or more stubs and may vary if multi-stub couplers are used. In addition, MTBF is vary if multi-stub couplers are used. In addition, MTBF is more than doubled from 43,000 hrs to 88,000, which also will vary with the number of stubs.

The only negatives associated with in-line harnesses is in repairability. Flange-mounted couplers can be easily replaced as can the interconnecting cable, while with an integrated harness, sections are repaired by splicing or replacement of the harness as a unit. Splices require heat in the wire bundle which can cause subsequent problems and the joint is not inspectable. The degradation incurred by splices should not be underestimated.

Most bus network integrity problems and overall weight are associated with the cable connectors, hence integrated harnesses have very real advantages in both reliability and weight due to their elimination. Additionally, in-line couplers generally have a lower VSWR or reflected energy coefficient resulting in smaller reflections on the bus.

A compromise between the flange-mounted box type and the integrated harness type network is the segmented harness type network. By segmenting the harness with a few judiciously placed connectorized breaks and the use of multi-stub couplers, you can significantly improve repairability and maintenance time. The bus can be readily broken down, troubles isolated and faulty segments replaced without splices at a relatively small cost in weight and calculated MTBF. Spares requirements can be reduced if several of the segments can be made identical. Multi-stub couplers in either in-line or flange mounted box types can reduce failure rates simply by eliminating solder joints and/or connectors used to connect single stub couplers.

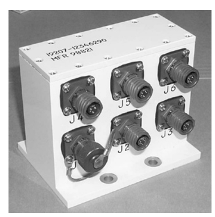

Fig. 9. Coupler for armor. Uses MIL-G-3899 connectors. Used on M1A2, tank.

Fig. 10. NH12864 2-stub flange mounted coupler.

Connector and Cables

All users of MIL-STD-1553 data bus couplers eventually face the decision of what type of connector to use for their bus connections, both at the coupler and at the equipment box. Although quite specific on most technical aspects of the bus, MIL-STD-1553 does not address the connector issues nor do other military or industrial standards with the exception of MIL-STD-1760. Therefore, the following should provide some guidance for making the most appropriate cost-effective solution.

The issues to be addressed are:

- Threaded vs. bayonet vs. acme threaded
- Individual vs. multiple channel
- Multi-pin vs. triaxial

The trade-offs in threaded vs. bayonet vs. acme threaded are cost, lead time, reliability, and maintainability. The highest reliability can be obtained with safety wired threaded connectors. Unfortunately they are prone to crossthreading and the safety wiring is labor intensive. They are not usually stock items and lead times can run to 20 weeks. Price can be high depending on type chosen.

Bayonet types, generally more available, are somewhat less reliable but are used in many applications in the three-lug and four-lug configurations. They are easiest to mate and de-mate and cannot be crossthreaded. Keying can be achieved by using a mix of 3- and 4-lug configurations.

A particular type of threaded connector is the MIL-C-38999 Series III. This connector has an acme (very coarse) thread with ratchet override. The ratchet override provides a torque preload which assures a reliable mate in high vibration and shock environments. They are virtually impossible to crossthread or strip. They are also large, heavy, costly and have long lead times.

There are no right or wrong choices. All types have advantages and disadvantages. The decision should be guided by the real environment, cost, and lead time. Also, some time spares will be needed and 26 weeks lead time may present operational problems, so avoid modified connectors (shortened backs, special plating, etc).

Once the connector type has been selected the insert arrangement must be determined. The choices are:

- Individual triaxial type.
- Multiple triaxial contact type.
- Standard multi-pin.

Individual triaxial connectors are available from several sources. Many have second sources. They are available in standard (BNC size) or subminiature sizes— threaded or bayonet. Threaded versions have various key arrangements and the bayonet versions have two, three, and four-lug variants. Two-lug variants should be avoided for obvious reasons. Three and four-lug types have a good track record. Where weight is a factor the subminiature should be used. All have proven satisfactory in airborne environments and equally satisfactory from an electrical point of view. Certain types are readily available off-the-shelf at modest cost while others will have 10-18 week lead time and can be quite costly. Some feature solder attachment, some tool crimp, and some wrench crimp. Experience shows that the quality of the joint is most dependent on the care of its assembly. All methods appear to work well as long as the operation is performed properly. It is best to avoid any method requiring skill, judgment or proficiency. None of the above types are MIL connectors except for MIL-C-49142 which covers the BNC size types in both threaded and bayonet styles. Unfortunately, these are silver plated, not nickel or tin plated. (more on the plating to follow). MIL-C-38999 Series III also offers a single channel size 9 but it is rather bulky for aircraft use.

Separate connectors for each 1553 cable (as opposed to a single connector for multiple cables) can make troubleshooting easier in the system and ease cable run layout design, but they take up room and will have less reliability since there will be more connectors.

Multiple triaxial contacts in one connector will offer improved reliability and inserts are available in a variety of MIL shell styles and sizes. The size 8 triaxial inserts (M3909/90 and M3909/91) are, however, quite costly and can have quite long lead times. They, as well as the shells, are QPL items and are multiple-sourced. If an insert is available with the proper number of size 8 contacts it is possible that the weight of the one connector will be less than the weight of the individual connectors. When you do the analysis, don't forget to count the back shells and clamp, if required in the installations. Lead time can sometimes be a problem for both the contacts and the shells, particularly if non-standard keying is selected on the shell.

Standard multi-pin connectors have been found to be entirely satisfactory for bus connections with the only caveat being that the shield must be dressed close to the pins, within a half to one inch. The shield termination must be within the backshell. Failure to do this will open the system to interference problems. The advantage of multi-pin connectors is cost, weight, and lead time while the penalty is a slight reduction in calculated MTBF and arguably a vulnerability to pick-up. Virtually any MIL connector can be used as long as there are sufficient pins (in a multi-channel arrangement) to isolate the high and low pairs from each other with ground pins. On a coupler this is not a real problem because all the wires have the same signals, but in an equipment box, channel A should have reasonable isolation from channel B. Experience has shown 60 dB isolation is easily accomplished without problems. Several major systems are operational, including the F-15, which use multi-pin connectors on the couplers and have performed satisfactorily. With judicious connector type selection, the cost savings can be significant. Some argue that the triaxial contact is superior from a performance point of view since the multi-pin will present a large impedance discontinuity, but considering that the coupler interior discontinuity is begun within a half inch of the pin or contact anyway, the point is moot and the effect very small compared to the coupler. Bulkhead joints and feed throughs with cable on both sides are a different matter.

Having selected the connector type and insert arrangement there only remains the question of body **plating and intermetallic compatibility.** With systems having lifetimes measured in decades and connectors being exposed to very vile environments, metallic compatibility is a must. The ideal, from a long-term corrosion point of view, is to have all surfaces and interfaces tin plated. This is not always possible and can be very expensive. Some manufacturers use a nickel plate which experience shows works quite well. 500-hour salt spray tests have been passed with nickel and only cosmetic discoloration occurred. Still, tin on tin works best. Also, keep in mind that all surfaces must be compatible. Mating connectors should always have the same plating. On the couplers, specify that the case be plated with the same material as the connector body. Remember— rust (and corrosion) never sleeps. It works 24 hours a day.

The single stub vs. multiple-stub is not a critical issue unless taken to extremes. Experience has shown there are only a few general guidelines. If only single stubs are to be used they should have several feet separation so there are individual discontinuities in the impedance. If too close they will become one large discontinuity. Multiple-stub couplers work well up to eight stubs. Beyond that the discontinuity becomes larger than desirable for true buses with a finite length. For bench top applications when the couplers tend to resemble a star coupler, more than eight does not seem to present problems. Using multiple-stub couplers in either in-line or flange-mounted box type will be less expensive, lighter weight, and more reliable with no downside. Lumping couplers in multi-stubs configuration should be considered as long as the resulting stub lengths can be kept under twenty five feet and the total wire and coupler weight is less than implementing other solutions. You should also avoid spacing groups of couplers with one hundred foot cable lengths because reflections can cause bit errors by creating multiple zero crossing on the last bit of a data word.

Cable type selection should be governed by several factors, among which are cost, weight, shielding and capacitance. For lab use, the standard MIL-C-17/176-00002 is fine. It is low cost, readily available and provides adequate performance. In aircraft applications, weight and shielding take on added importance. Obviously, weight and shielding trade off against each other. In addition, extra shielding results in a stiffer, harder-to-work-with cable that requires larger bend radii. For severe high noise environments, the cable should have a mu-metal shield for magnetic field attenuation. It is more costly, heavier and hard to work with but a conventional double-shielded cable will not provide the magnetic field isolation that mu-metal does. The mu-metal shield also provides EMP protection from nuclear bursts and is a must for strategic systems. There are several manufacturers. Do not underestimate the bend radii and stiffness issues which can be quite a problem in installation and repair, leading to kinks and subtle system degradation.

Conclusion

These, then, are the issues. How they are weighted must be determined by the application as well as personal preference. Obviously, safety of flight or a hazardous store will require a different weighing of the factors than a maintenance monitor. The decisions are:

- What is an acceptable MTBF level?
  (dollars for MTBF hours versus how much is good enough)
- Where to spend money to improve MTBF to an acceptable level?
- How much is it worth in initial cost and lifetime cost for repairs to go from 45,000 hrs to 88,000 hrs MTBF when the system as a whole has an MTBF of 100-200 hours?
- What is an acceptable trade-off of initial cost vs. total life cost including repairs and maintenance?

"The best" will vary from application to application.

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