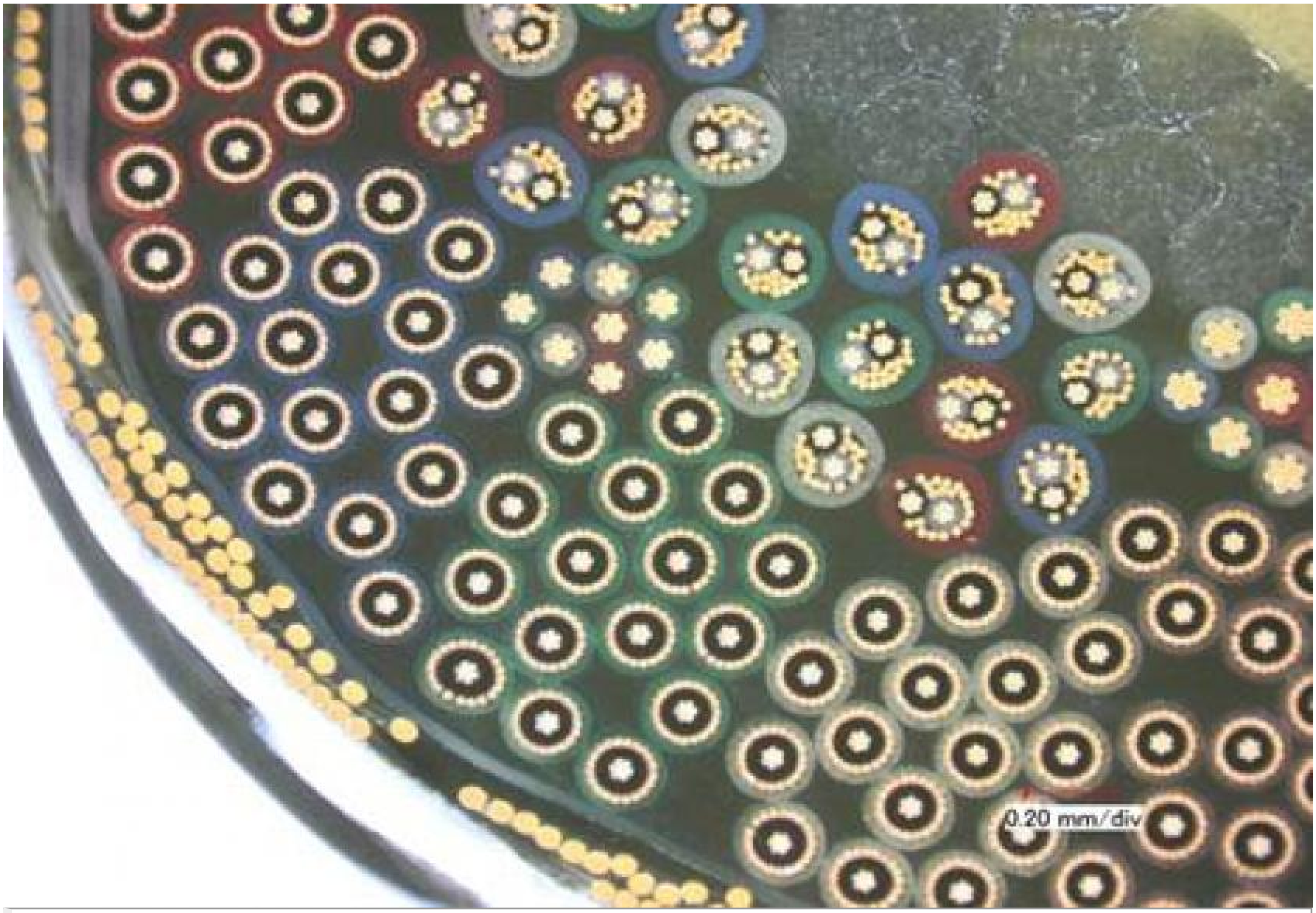
A Simple Cable Modification to Reduce Cost

October 5, 2017



As complexity increases, cable layout and bundling might just make all the difference. The image provided is an example of an extreme close up of a highly complex medical cable showing various gauges, wire styles, and cable groupings. Here bundling, in the sense of the article, is deliberately not implemented given the specific requirements of the design and the cost and manufacturing tradeoffs. Image courtesy of Hitachi Metals and Hitachi Cable America.

Ultrasound medical devices typically employ multiple fine wire gauge cables. There are many aspects to a cable design that can impact cost, but one in particular—color—can have a significant effect on the overall budget.

To begin an examination of such economic considerations, I share an actual email I recently received below:

> *Hey Mike,*
>
> *At some point it would be helpful to go through the cable design from a cost point of view. If we want to do a round of cost cutting, we'd like to know what constraints that we put in place are the biggest cost contributors.*
>
> *Thanks!*

The interesting aspect of this request is that the initial prototype has not yet even been manufactured. However, the process, from the customer's perspective, has already moved on to cost reduction requirements without even testing the performance of this new assembly from both a physical and electrical perspective. Often this is already well known, but the point is still relevant. Being proactively cost sensitive is crucial to customer satisfaction.

As with most new products, in addition to functionality, there is a strong emphasis on cost, both the initial product cost and, in some cases, a future schedule of cost reductions. When the topic of cost is considered, the conversation typically centers on material choices and mechanical details that serve to address a design problem or a product performance issue. It is understood that as the product moves from development to manufacturing, volume will increase and fixed costs will become a smaller part of each unit's cost calculation, thereby resulting in a lower per-piece price. Further, as a vendor becomes more familiar with the product from a manufacturing perspective, additional efficiencies will provide cost-saving opportunities.

However, there are often opportunities to reduce cost that revolve around simply doing things differently. One such opportunity to "design-in" cost savings revolves around an often overlooked cable characteristic: the color code.

While the end use may be very different depending upon the application, the process still remains the same. For example, a hospital operating room at Massachusetts General as opposed to with an oil pipeline in a large Texas refinery obviously will have very different end requirements, yet the basic cable constructions used for these ultrasound applications are very similar. In the example provided below, we will compare various structures using 38 AWG (gauge) high-capacitance micro-coax with the finished cable consisting of 68 coaxes with an overall braid and protected under a ruggedized jacket. (*See Table 1.*) This cable is then terminated to a series of interposers that contain connectors for mounting to the OEM's final NDT probe product.

Table 1

Coax Count	68
Conductor AWG	38
Material	Silver Plated Alloy
Stranding	Solid
Insulation	PFA
Shield	Tin Copper

Jacket	PFA

Table 1: The goal—a finished cable consisting of 68 coaxes with an overall braid and protected under a medical-grade jacket.

Generally, in a construction of this type, the coaxes would be combined into groups of 16-core bundles (4x16 coax bundles) (*Figure 1 at left below*) with two additional pairs in the center. Each coax bundle of 16 would consist of a single-color group of coaxes. From a cost perspective, as it relates to the cable only, this approach makes sense in that it minimizes color changes during manufacturing, since each color change requires a material, line, and reel change out, which increases the cost due to the manufacturing overhead.

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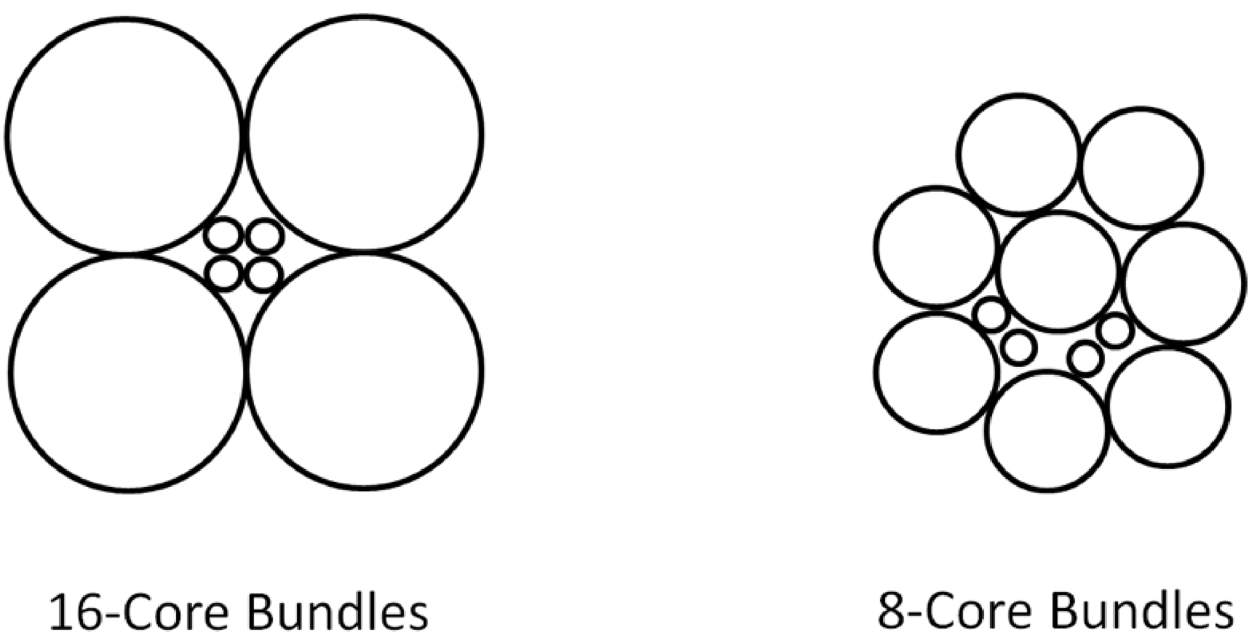

Figures 1 and 2: Consider which of the two options for an ultrasound cable consisting of 68 coaxes makes the most economic sense: Figure 1 (at left), which combines the 68 coaxes into groups of 4 16-core bundles (4x16 coax bundles), or Figure 2 (at right) which organizes the core bundles into 8 groups (8x8 coax bundles), with each core bundle carrying 8 discrete colored coaxes.

The simple counter approach taken by Hitachi to lower the cost was to restructure the 16-core bundles into 8 groups (8x8 coax bundles) (*Figure 2 above at right*), with each core bundle carrying 8 discrete colored coaxes. In other words, the new design uses 8 colors per core for the 8-core bundles versus 1 color per core for the 16-core bundles. In this approach, every one of the 8 bundles is identical and the bundles are then further distinguished during the final cabling process by helically wrapped colored threads. From a high-level design perspective, this approach would seem to add cost rather than reduce it—and that would be a correct assumption. However, the goal is to reduce the cost of the final product, even if that means increasing the cost of an individual component or process.

As Table 2 demonstrates, the degree of the increase could be classified as insignificant. Using a cost of $250 per additional color change, the total increase that this discrete color code adds to the overall cost calculates to less than $0.01 per foot.

Table 2

Construction:	68 coaxes/16 coax bundles plus 4	
Quantity:	1,640 feet / 500 meters	
Color Changes:	4	
Discrete Bundle Colors:	Total Footage per Conductor	Total Meters per Conductor
Black	29,520	9,000
Brown	29,520	9,000
White	26,240	8,000
Blue	26,240	8,000
Total	111,520	34,000

Construction:	68 coaxes/8 coax bundles plus 4	
Quantity:	1,640 feet / 500 meters	
Color Changes:	8	
Common Bundle Colors:	Total Footage per Conductor	Total Meters per Conductor
Black	16,400	5,000
Brown	16,400	5,000
White	13,120	4,000
Blue	13,120	4,000
Orange	13,120	4,000
Yellow	13,120	4,000
Green	13,120	4,000
Red	13,120	4,000

Total	111,520	34,000
Color Change Cost	$250	
Total Cost Adder	$1,000	
Cost increase	**$0.009 per foot**	**$0.029 per meter**

Table 2: In the 4x16 coax bundles approach, each of the 4 bundles of 16 is colored Black, Brown, White, and Blue. Operators need the raw inner materials (conductor, insulator, shield) that are then made into 16 reels of each color. In this example, enough quantity of inner conductor would be extruded using a natural pfa color and the lot would be shielded. Then the material would be jacketed for the 4 different colors. Black would be made first, then the machine would be purged of that color and restarted for the Brown insulation. The color change process would be done four times, resulting in four batches of 16 reels. The cable must then be cabled per the 16-core bundle diagram. This means that a machine is loaded with 16 reels of Brown. The coaxes are then wound together and wrapped with a tape to secure them. An outer jacket is then extruded and this is repeated for the other 3 color bundles. Finally, all four 16-core reels are loaded onto the machine and they are again twisted, tape wrapped, and a final jacket is applied.

In the 8x8 approach, 8 initial colors are produced on large reels. The reels are then loaded onto the machine, and the cores are twisted, taped and then jacketed. When a reel is full, the operator swaps out the reel for an empty one and they continue until the entire batch is complete. Once all the material is made, the 8 color core bundles are then loaded onto the machine, they are again twisted, taped, and jacketed. This requires much less setup and ease of change over after the color operations are completed because it is a common element (i.e., 8 cores with 8 colors per core).

While a modern extruder payoff can be programmed to create reels of any quantity, one might argue that increased set up time at the pre-cabling operation would be required in order to handle the additional four reels added as a result of the smaller coax bundles. We need to consider that the 4x16 core coax bundles would require 4 set ups each with 16 reels—one for each colored bundle—while the discrete code in essence uses one 1 set up for 8 reels from which 8 bundles of the same construction are created. While there will be an additional 4 reels at the final cable set up for the discrete option, at worst the cabling setup cost is offset.

From a final cable run-time perspective, clearly the set-up time to cable these 8 bundles is greater than that required to cable only 4x16 coax bundles. However, in the run quantities generally associated with micro-coax multi-conductor constructions, the impact on cost, much like that associated with color changes, is minimal when considered as part of the total cable cost.

From the assembly perspective, when processing cable bundles in which all the coaxes are of the same color, tools that identify the proper electrical connection are required. This process is often referred to as “buzzing out.” Even with a discrete code and multiple smaller bundles, the sheer number of conductors on the higher conductor count products, such as a 128-coax construction, often requires these same tools to be used. For lower-count products, such as those using the 64-coax product discussed here, or those products with even smaller coax counts, the discrete color code allows the operator to visually identify and place the coax conductors without the use of an electrical test unit, thereby saving immense labor and time in termination.

This advantage alone can translate into significant cost savings when compared with a similar assembly made using the 4x16 coax bundle construction. (*See Table 3 below.*) The discrete color code, with all other things being equal, reduces the final product cost by 4%. Regardless of the margin used to set the commercial price, by using the discrete color code there is a significant cost advantage.

Table 3

Assembly Length	3 meters
Interposers	8
Labor Savings 8 Bundles Discrete vs. 4 Bundles Uni-Colored	10%
Product Cost - 16 Coax Bundles	$155.25
Product Cost - 8 Coax Bundles	$149.04

Table 3: The cost represents a finished assembly with connecting boards (interposers) soldered onto the wires. The devices are typically shipped as sub-assemblies so that the OEMs or their assembly partners can complete the probe attachment and system connectorization.

An argument could also be made that the additional bundles might subtract from the product's flexibility. In considering that position, we need to take into account the 'rope' construction used in uninsulated copper stranding products. (*See Figure 3 below.*) A rope construction—similar to that created when the 4x16 coax bundles are reconfigured into 8x8 coax bundles—is chosen by copper fabricators when flexibility and the ability to maintain its shape during bending are required by their customers for high strand count conductors. This being said, any difference in flexibility, with all other things equal, would be indistinguishable for most constructions.

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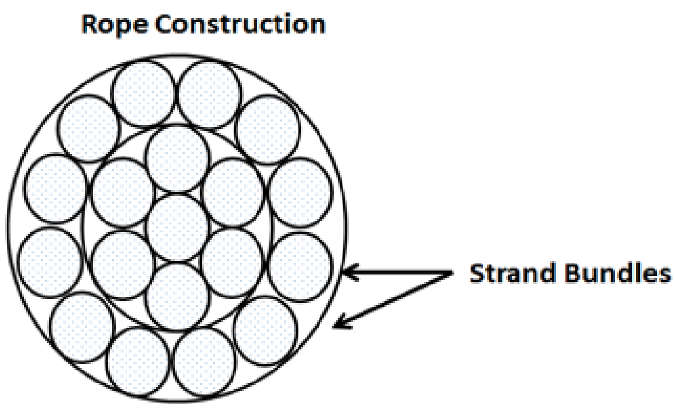

Figure 3: An example of a common cable configuration called a "rope construction." When the wires are twisted in this manner, they provide the benefit of strength, diameter control, and the ability to yield highly flexible cables. Figure 2, in this example, when completed, results in a cable that is closer to a rope construction than the example in Figure 1, so the argument is that it also provides a better end product by nature of the configuration.

From an overall OD perspective, the construction of the 8-core product in lieu of the 4-core geometry yields an overall increase of 0.2 mm, or 0.007 in., with all other parameters being equal. The cost impact of this minor difference would be measured in pennies, similar to the cost impact of the color changes outlined earlier. However, this larger OD could be addressed by reducing the jacket thickness as well. Depending on the thickness, reducing it by 0.0035 mils would provide an additional cost *savings* while not negatively impacting the cable's performance.

Considering both the potential cost savings as well as physical advantages of the smaller discretely colored coax bundles, clearly this is a design avenue worth exploring during the design phase of any cable assembly project that utilizes typical micro-coax constructions. Your cable design partner will be well positioned to examine and quantify the cable dimensions and the potential cost savings with you.