## Table of Contents



This section attempts to provide assistance with most of the considerations applicable to the design of cable and harness assemblies. Caution must be used to ensure that the design is appropriate for a particular application.

Tyco Electronics provides this information as a design aid and assumes no responsibility for and makes no representation regarding the suitability of a design for a specific application.

**Note:** Users should independently evaluate the suitability of the product for their application. Before ordering, check with Tyco Electronics for most current data.





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## Harness Design

A Raychem molded part provides strain relief on the back end of a connector.

Tyco Electronics offers a range of Raychem components for wiring harnesses and cable assemblies in commercial, industrial, automotive, and defense and allied industries. Our components are approved to widely recognized standards (UL, CSA, CE, SAE) and to the military specifications of various governments.

A variety of component material systems can be used to design a rugged, reliable, repairable, shielded, and environmentally sealed harness. We also offer individual components that can be used independently to meet a specific sealing, insulation, strain relief, protection, identification, or electrical interconnection need.

Harnessing system components include:

- Heat-shrinkable tubing
- Heat-shrinkable molded shapes
- Adhesives
- Adapters
- Assemblies
- Electrical interconnect components
- Wire and cable
- Solder termination devices
- Application equipment

In many cases, properly selected components can raise the performance of a harness to acceptable levels compatible with even very demanding environments where cables are exposed to water, temperature extremes, EMI-radiated fields, or fluids.

Tyco Electronics is the established leader in automotive, aerospace, marine, mass transit, industrial, and military harnessing. Call us for ideas on protecting your harness—whether it's a typical UL wiring system or a harness assembly for demanding environments.

### Harness Design

Designing wiring harnesses for demanding applications such as defense and aerospace is a complex business:

- Many different parts need to be selected while taking account of various environmental factors and mating part conditions. There can be a large number of alternative design solutions to analyze and the constraints imposed upon harness design are becoming more demanding.
- Weight and space are especially important in missile and aerospace applications. With the additional electrical equipment now in products such as cars, these factors are becoming a bigger issue in these industries.
- Electromagnetic interference (EMI). Harnesses can either radiate interference to, or pick up interference from, nearby equipment. With the increasing use of sensitive electronics in cars, aircraft and military equipment this is a major problem.
- Resistance to environmental hazards including corrosion, high temperature or fire, chemical and nuclear agents. The additional costs of totally sealed wiring harness systems are becoming easier to justify as products and the lives of those who use them, become more dependent upon the fault free operation of electrical systems.
- Repair and maintainability. Electrical and electronic systems in military vehicles and naval vessels now need to be upgraded or modified several times during the life of the main mechanical platform. There are now parts and harness design techniques that make this work easier to accomplish.



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## Harness Design (Continued)

This section provides information about the basic components in a harness design, the factors to consider in designing a harness, and the Tyco Electronics Harn*Ware* Harness Design CAD software. With this information and the selection tables that follow, you will be able to choose from this catalog the right components for an integrated military or high-performance industrial harnessing system.

The checklist on page 2-4 covers some of the factors to consider in the design of a harness.

### Harness Components

Connectors and wires are the two basic components of a harness that need to be specified. Once they have been chosen, compatible protection, shielding and identification follow.

### Connectors

Connectors come in two opposite types: plugs and receptacles. Both contain contacts, usually made of plated copper. The contacts, called pins or sockets, are joined to the conductors and are designed to mate or join with contacts of the opposite type.

The front or joining end of the connector is designed to mate only with a connector having the right configuration. The back end of the connector is where the wires are terminated to the metal contacts.

Connectors for indoor or internal use are generally not designed to resist moisture. Connectors that will be exposed to moisture are generally sealed to meet a specific requirement.

### Wires

In this discussion, a wire is defined as an insulated conductor and a cable is defined as two or more wires with or without a common jacket or shield. Conductors are usually made from copper.

A copper conductor can be solid or, when flexibility is important, can consist of smaller strands of copper wire twisted together. The strands can be coated with tin, nickel, or silver to make them easier to terminate or more resistant to corrosion.

Conductors are sized in metric units ($mm^2$) or by AWG (American Wire Gauge), a holdover from the days when wire was made of steel in steel mills. The AWG refers to the number of passes it takes to draw the wire down to the required size - the larger the AWG, the smaller the wire. Making a 26 AWG wire, for example, requires more passes through reduction dies than are required for a 4 AWG wire.

A 26 AWG stranded wire, however, is made of many smaller wires, such as seven strands of 32 AWG wire (sometimes shown as 7/32 or 7x32).

The choice of insulation for a conductor depends on a number of factors:

- Operating, design, and excursion temperatures of the system
- Size and weight limitations
- Mechanical performance desired
- Flexibility requirements
- Resistance to various fluids
- Specialized requirements, such as:
  - low fire hazard or low halogen
  - low outgassing





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## Harness Design (Continued)

### Harness Design Checklist

**Connectors**

- ☐ Sealed or unsealed?
- ☐ Made of plastic or metal?
- ☐ Crimp or solder contacts?
- ☐ Pins or sockets?
- ☐ Mating frequency?
- ☐ Keyway angle?
- ☐ Exposed to electrical noise (EMI)?

**Geometry**

- ☐ Dimensions?
- ☐ Point to point or branched?
- ☐ Configuration of ends - straight, 90°, 45°?

**Environment**

- ☐ Exposed to sunlight?
- ☐ Exposed to moisture?
- ☐ Immersed?
- ☐ Temperature extremes?
- ☐ Temperature cycling?
- ☐ Normal operating temperature?
- ☐ Exposed to abrasion?
- ☐ Exposed to mechanical abuse?
- ☐ Exposed to dust?
- ☐ Exposed to corrosive fluids?
- ☐ Exposed to flexing?
- ☐ Repairable?
- ☐ Circuit identification?
- ☐ Cable identification?*
- ☐ Shielding effectiveness?
- ☐ Magnetic-field–induced signals?

**Circuit**

- ☐ Voltage?
- ☐ Current?
- ☐ Signal transmission (impedance, velocity, frequency, etc.)?
- ☐ Circuit layout?
- ☐ Is circuit integrity critical? What if the circuit fails?

*Tyco Electronics Identification products information available at www.tycoelectronics.com

### Protection

Once the connectors and wires have been specified, the method of protection must be considered. Various jacket materials are available to protect the wires and these can be extruded or heat-shrink. Jacket material formulations are compounded to meet a wide range of environmental demands.

Similarly, protection for the wire termination must be considered. In general, the wires will be terminated to connector contacts. Protection products must protect the joints from damage caused by mechanical stress such as flex, torque and tensile load, and corrosion or electrical breakdown from fluid ingress, while retaining the ability to be repaired. All these influences and more must be considered when choosing the termination protection method.

### Shielding and Shield Termination

Step 3 of the component selection process discussed later in this section gives advice on choosing the appropriate shielding products for the gross shield. Consideration must also be given to the individual cable shield terminations. Can they be pigtailed together with a common termination to a contact or to earth, or should they have individual terminations? If using a solder device, the correct choice is based, not only on size, but also temperature rating or compatibility with the cable braid.

### Identification

Circuit identification is important, both in manufacture, where an assembly operator must ensure correct wire to contact termination, and in repair, where a damaged connector may need replacing in difficult circumstances and contact positions have to be easily identified. Individual wire markers help with these two circumstances. Where a cable is severed and access to the ends is prevented, unique identification on the wires, or wire color coding aids repair.

Consideration given to the identification of harness legs is also important. Connectors will normally be chosen with unique keying to prevent incorrect mating but end identification will speed up plugging, particularly for multi-connector harnesses.

It is also good practice to label the harness with its part numbers and other relevant information for traceability purposes.

The Tyco Electronics Identification Products Group offers a variety of products that are compatible to the Harn*Ware* software design process.

For complete information regarding these products visit our website at www.tycoelectronics.com.



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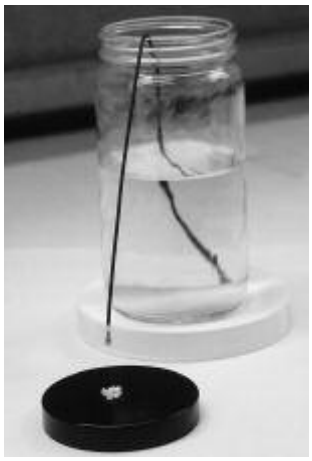
## Protection of Harness Components



A salt deposit can be seen beneath the end of this 18-AWG, 19-strand wire. The other end of the wire has been immersed in salt water for 24 hours.

Harness components are vulnerable to corrosion, stress, strain, and electromagnetic interference (EMI).

### Corrosion

Humidity, moisture, salt, and corrosive fluids can corrode conductors and contacts. What is worse, the corrosion can take place well beyond the point of penetration because of the small tube-like voids—capillaries—between the individual strands of copper that make up the conductor. Called "capillary action," the penetration of a fluid can "wick" many feet in a relatively short time (see photo above), depending on the specific characteristics of the affected wire. As the copper in the conductor is depleted by corrosion, the conductor can no longer sustain mechanical or electrical loads and the metal will fail. Mechanical failure can thus occur anywhere in the wiring system.

Even before mechanical failure occurs, electrical performance can be adversely affected by the presence of nonconductive by-products from galvanic or aqueous corrosion. Moisture within a connector body may cause an impedance mismatch, increase noise in a signal circuit, or modify the waveform. Even small amounts of corrosion or other contaminants can have a significant impact on contact surfaces and the efficiency with which signals flow through them.

If a chemical solution contacting the electrical connection is itself conductive it can cause a short circuit between conductors. Pure water, not itself a conductor, can also facilitate a short circuit by providing a medium into which conductive salts can dissolve. These salts may be the by-products of corrosion or the result of earlier contamination.

High humidity and temperature cycling in some situations cause condensation, the accumulation of which can also result in a short circuit. Depending on circumstances, the resulting short circuit may be intermittent, significantly complicating the process of identifying the underlying cause.

To prevent corrosion, sealing may have to meet the performance requirements of applicable military specifications or the International Protection (IP) Code.

### Stress and Strain

Wires that are attached to the connector pins need help to withstand stresses and strain from the cable, which could break the wires from the pins. It is almost always necessary to prevent strain from occurring in a weak spot, such as where the wire is attached to the contact. This is called strain relief and can be provided in a variety of ways, from mechanical devices, such as adapters, to molded boots and heat-shrinkable tubings.

### EMI (Electromagnetic Interference)

EMI is similar to the noise heard on an AM radio when the radio is close to high-voltage lines. EMI causes the wire or cable to act like an antenna and pick up electrical signals, which interfere with the signals on the wire and can cause malfunctions in sensitive electronic circuits.

Wiring systems are susceptible to two types of EMI:

- *Radiated emissions* (the electromagnetic energy a wiring system radiates to its surrounding environment), such as the EMI a high-voltage line radiates to its surroundings. (There are regulations on the amount of radiated energy a circuit is allowed to produce.)
- *External radiated emissions* (the electromagnetic energy in the environment), such as the EMI an AM radio picks up from a high-voltage line, causing distortions in the conducted signal. Conducted EMI is noise carried by the cable into the receiving circuit and needs to be filtered.

To reduce susceptibility to radiated emissions from the cable or from external sources, the harness must be grounded, shielded, and/or filtered, depending on the sensitivity of the equipment and the strength and frequency of the EMI.





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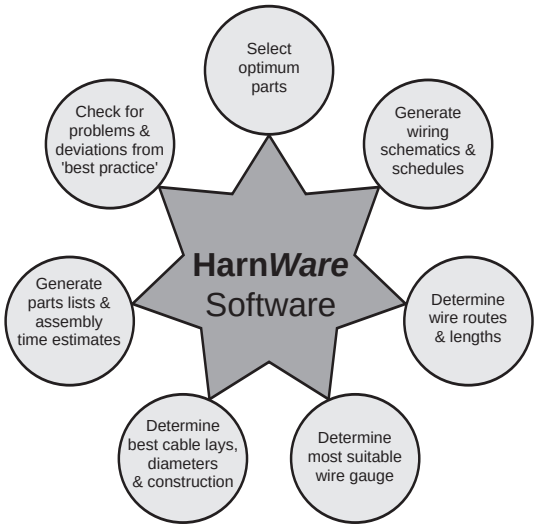
## Harn*Ware* Harness Design Software




Harn*Ware* Design Software is Tyco Electronics' harness design CAD software. Originally developed for use by our own harness designers it is now offered to our customers so they can benefit from this powerful tool.

From a simple input of geometry, dimensions, connector and wiring details, Harn*Ware* software can suggest a design sequence and help with many aspects of wiring harness design (see diagram).

Harn*Ware* software is used interactively by harness design engineers. The choices and calculations made by the system can always be modified to suit specific requirements. Design data is saved with each shape in the harness drawing. This data can be reviewed simply by moving the mouse over the parts listed in the Design Wizard. It is, therefore, very easy to incorporate design changes, modify design constraints or analyze alternative design solutions. Moreover a design checker can be used to search for deviations from 'best practice'.

### Some Harn*Ware* Software Outputs

The following are some examples of the outputs that Harn*Ware* software can generate:

- High quality engineering drawings. Clear and reliable drawings play a crucial role in the success of any design project.
- Point-to-point wiring lists, including calculated wire lengths.
- Fully detailed parts lists. Harn*Ware* software automatically generates the parts list table and adds item number balloons into the drawing. Parts lists can also be exported to a spread sheet, database or word processor.
- Assembly time estimates. Harn*Ware* software automatically adds the design details into a 'spread sheet' containing standard assembly time synthetics.
- Wiring schematics and schedules are quickly produced using connector plan form data and wiring details from the wire list.
- Lists of codes of practice describing harness assembly techniques and other issues that are relevant to the parts included in the design.
- Files containing cable marker details can be exported ready for use in marker printing systems such as the Tyco Electronics WinTotal* system. A drawing page showing these cable marker details can also be generated.

A sample set of documents produced by Harn*Ware* software is shown at the end of this section.

*Tyco Electronics Identification product information available at www.tycoelectronics.com



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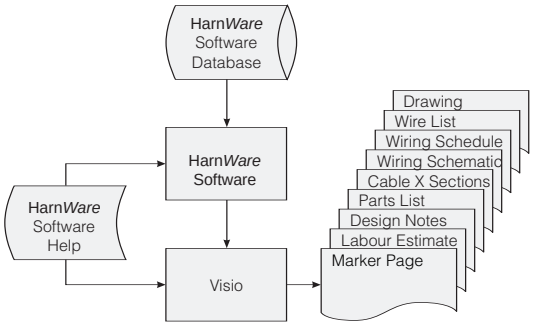
## Harn*Ware* Harness Design Software (Continued)

### System Building Blocks

Some key features of Harn*Ware* software are:

- Runs under Microsoft Windows on affordable PC's.
- The user interface is similar to that of commonly used software such as Microsoft Word and Excel.
- Uses the Visio drag and drop drawing system for creating harness drawings more quickly and more easily than with other computer aided design (CAD) systems.




- A growing library of 400 intelligent drawing shapes and a 110,000 record design database which can generate 100,000s of part descriptions for Raychem wiring harness products in their various material and finish permutations.
- Software that traces wire routes through harnesses and automatically creates wiring schematics and calculates wire lengths.
- Analysis options to determine the optimum lay of cables containing mixed diameter wires and to suggest the most appropriate wire gauge for specified current and temperature rise limits.
- Software to help identify the parts most suitable for use within the given design constraints and to fit the mating parts, cables, etc.
- On-line help systems for guidance on using the system and on Raychem wiring harness products.

### Designing a Harness With Harn*Ware* Software

Shapes, representing Raychem harnessing products, are dragged and dropped into the harness assembly drawing. The shapes automatically snap and glue together and it takes very little time to produce a high quality drawing. Pages from a sample Harn*Ware* software document set can be seen on page 2-14. Dimensions and connector references are entered by clicking a shape and typing in the numbers and references.

The Harn*Ware* Software Design Wizard analyzes the drawing and lists the parts and operations in the suggested design sequence. The wizard also provides quick access to details on each part in the harness and the connections between parts. When the mouse is moved over the parts listed by the wizard, Harn*Ware* software outputs such details as part dimensions, materials, finishes, etc.

Harn*Ware* software indicates the Raychem harness material system that is most suited to the given application, operating temperature range and required defense specifications.





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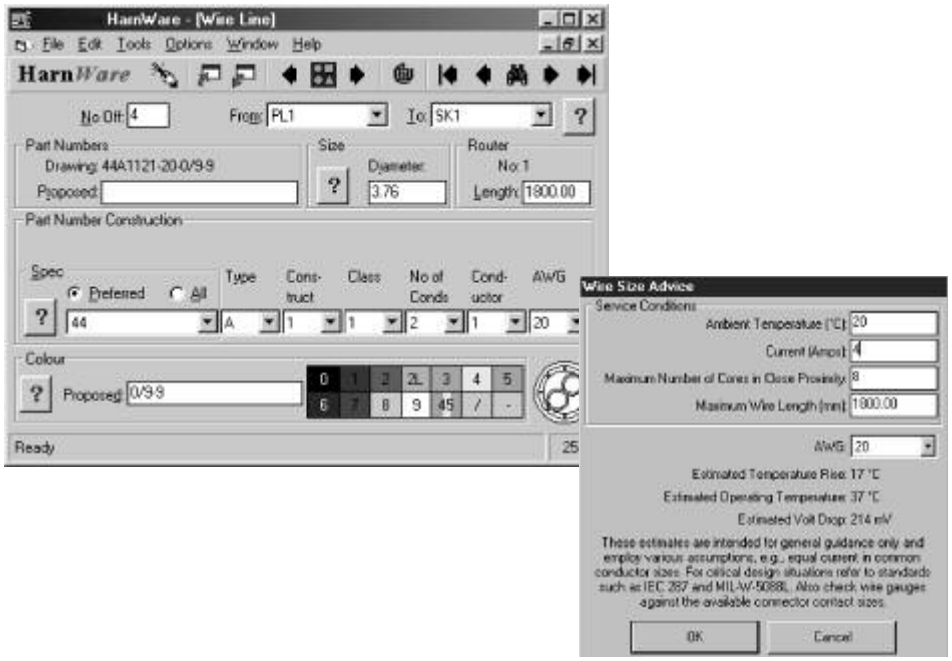
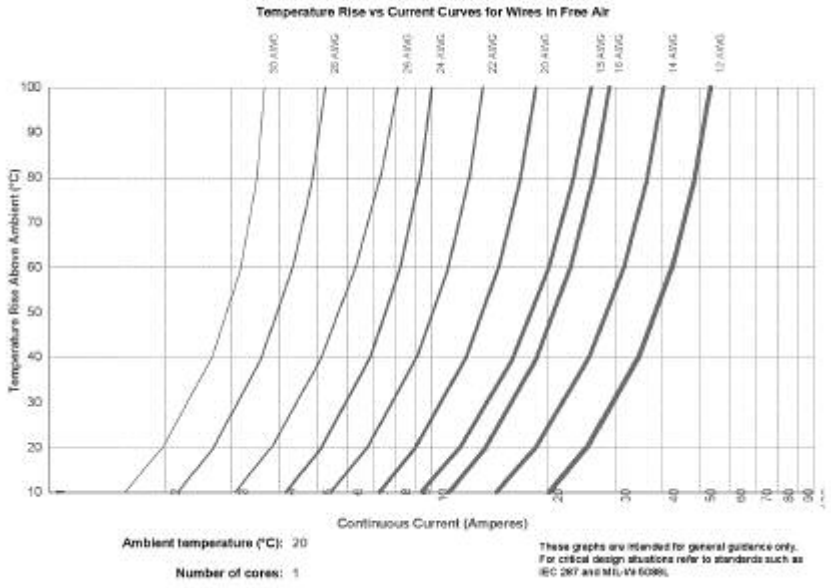
## Harn*Ware* Harness Design Software (Continued)




### Wire Selection

The wire most suited to the particular environment and service conditions is selected using design rules encoded in the Harn*Ware* software and database. If the wire selected is a non-preferred option, alternative types and colors can be identified which may also suit the design requirements and be available on shorter delivery times.

Guidance is also available for choosing the wire gauge most suited to given current loading, ambient temperature, length, number of conductors, etc. For each available wire size Harn*Ware* software estimates temperature rises, operating temperatures and voltage drops.



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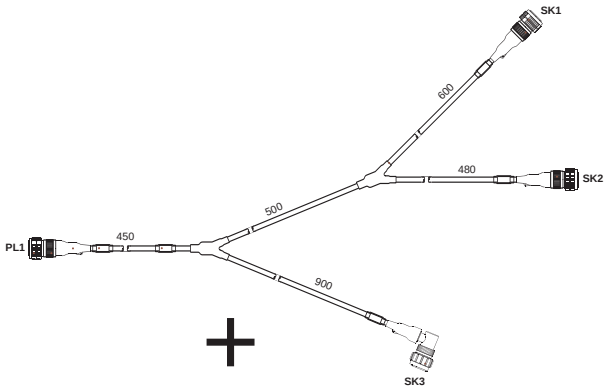
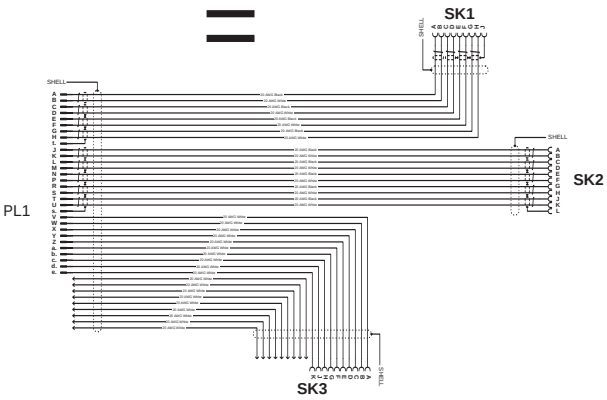



| WIRE LIST | | | | | | | |
|---|---|---|---|---|---|---|---|
| WIRE NO | ITEM NO | QTY | FROM | TO | PART NO | DIA | LENGTH |
| 1 | 2 | 4 | PL1 | SK1 | 44A1121-20-0/9-9 | 3.76 | 1800.00 |
| 2 | 2 | 5 | PL1 | SK2 | 44A1121-20-0/9-9 | 3.76 | 1668.00 |
| 3 | 1 | 19 | PL1 | SK3 | 44A0111-20-9 | 1.40 | 1590.00 |

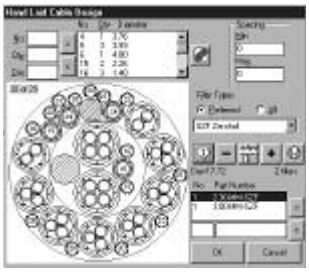



### Wire Selection (Continued)

From-To connector references are specified to form a point-to-point wiring list. Wiring schematics can be generated automatically from the information included in the wire list. These schematic diagrams show the pin to pin wiring for all the connectors and wires in a harness design.

Harn*Ware* software automatically:

- Traces the route of each wire in the point-to-point wire list through the harness geometry contained in the drawing.
- Calculates wire lengths by summing the lengths of the harness legs through which each wire is routed. Adjustments are applied based on a variety of design rules relating to the parts through which wires pass.
- Determines the cable sub-assembly structure that would save the maximum amount of labor in assembling the harness.
- Determines the optimum lay of wires in each harness leg and produces a cable cross-section drawing. Alternative lays of cables containing mixed diameter wires are automatically analyzed to identify the smallest diameter and most even construction. In the example below, the listbox contains the quantity of each wire diameter for which Harn*Ware* software has automatically developed 29 alternative design solutions. The minimum diameter alternative is shown which is 17.72 [.698] diameter and uses 2 fillers to achieve a sufficiently round lay.







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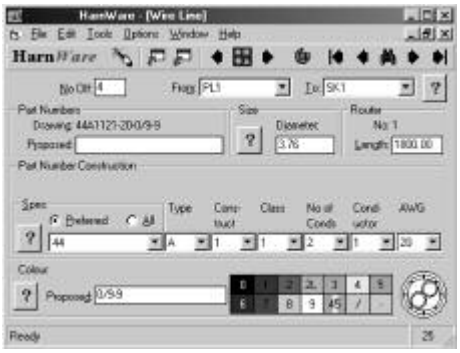


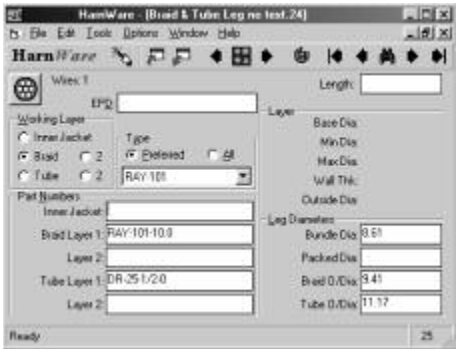


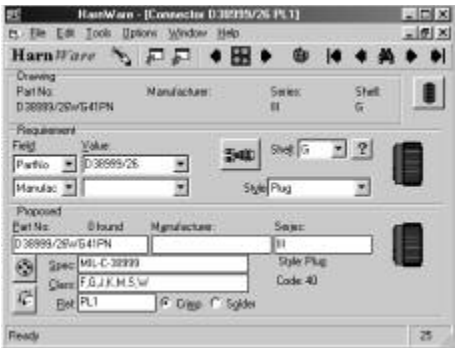


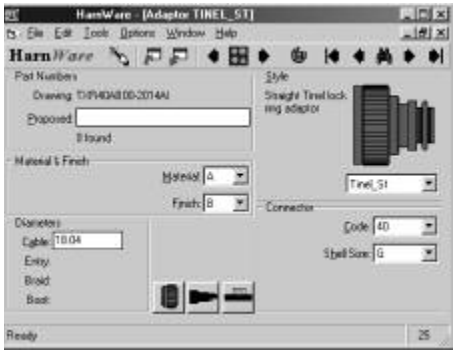


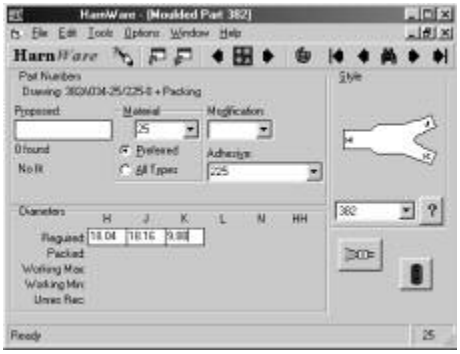



### Part Selection

All the parts in a harness can be specified. The key steps in selecting parts include:

- Clicking a shape in the harness drawing or the design wizard.
- Harn*Ware* software automatically obtains design data and dimensions from the shape and from mating parts in the harness assembly drawing. In the case of a Raychem boot, for example, Harn*Ware* software extracts the required style of boot from the shape and the diameters from the mating harness leg and adapter.
- The database is searched for parts suited to the dimensional constraints. The choice is further refined by the service conditions which determine the best materials, finishes and adhesives. When alternative parts are found in the database, Harn*Ware* software offers the best option first, which the designer can compare with the other alternatives. The on-line help systems contain details and advice on the various types of parts, materials and finishes and their suitability to different service conditions.

Among the parts that Harn*Ware* software helps to select are:

- Adapters
- Braid
- Connectors
- Databus couplers, etc.
- Feedthroughs
- Heat-shrinkable tubing
- Marker sleeves*
- Molded parts
- Adhesives
- Solder sleeves
- Wire

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UK: 44-1793-528171

## Harn*Ware* Harness Design Software (Continued)

PARTS LIST

| ITEM | DESCRIPTION | PART NUMBER | SPEC/REMARKS | QTY | UNIT |
|---|---|---|---|---|---|
| 1 | Wire | 44A0111-20-9 | Raychem | 30.3 | M |
| 2 | Wire | 44A1121-20-0/9-9 | Raychem | 15.6 | M |
| 3 | Filler | 2.75-MM-SZF | Raychem | 0.5 | M |
| 4 | Filler | 3.50-MM-SZF | Raychem | 0.5 | M |
| 5 | Braid | RAY-101-10.0 | Raychem | 1.2 | M |
| 6 | Braid | RAY-101-12.5 | Raychem | 1.2 | M |
| 7 | Braid | RAY-101-7.5 | Raychem | 1 | M |
| 8 | Tubing | AT099-43 | Raychem | 2 | Pc |
| 9 | Tubing | DR-25-1/2-0 | Raychem | 1.6 | M |
| 10 | Tubing | DR-25-1/2-0-50MM | Raychem | 1 | Pc |
| 11 | Tubing | DR-25-1-0 | Raychem | 1 | M |
| 12 | Tubing | DR-25-3/4-0 | Raychem | 0.6 | M |
| 13 | Tubing | RNF-100-3/16-0-15MM | Raychem | 4 | Pc |
| 14 | Tubing | RNF-100-1/2-0-20MM | Raychem | 3 | Pc |
| 15 | Tubing | RNF-100-1-0-20MM | Raychem | 1 | Pc |
| 16 | Tubing | RT-375-1/2-X-65MM | Raychem | 1 | Pc |
| 17 | Tubing | RT-375-1-X-65MM | Raychem | 1 | Pc |
| 18 | Tubing | RT-375-3/4-X-65MM | Raychem | 1 | Pc |
| 19 | Insulation Cap | TC4001-9 | Raychem | 1 | Pc |
| 20 | Adaptor | TXR40AB00-1208AI | Raychem | 1 | Pc |
| 21 | Adaptor | TXR40AB00-1410AI | Raychem | 1 | Pc |
| 22 | Adaptor | TXR40AB00-2014AI | Raychem | 1 | Pc |
| 23 | Adaptor | TXR76AB90-1208AI | Raychem | 1 | Pc |
| 24 | Moulded Part | 202K142-2S/225-0 | Raychem | 1 | Pc |
| 25 | Moulded Part | 202K153-2S/225-0 | Raychem | 1 | Pc |
| 26 | Moulded Part | 202K163-2S/225-0 | Raychem | 1 | Pc |
| 27 | Moulded Part | 382A034-2S/225-0 | Raychem | 1 | Pc |
| 28 | Solder Device | B-051-01-01 | Raychem | 1 | Pc |
| 29 | Solder Device | B-051-02-01 | Raychem | 1 | Pc |
| 30 | Solder Device | ST63-3-55-20-90 | Raychem | 1 | Pc |
| 31 | Marker Sleeve | TMS-NR501-NR19-4-CS-65 | Raychem | 1 | Pc |
| 32 | Marker Sleeve | TMS-NR501-NR19-4-CS-65 | Raychem | 1 | Pc |
| 33 | Marker Sleeve | TMS-SCE-1/2-2.0-4 | Raychem | 1 | Pc |
| 34 | Marker Sleeve | TMS-SCE-1-2.0-4 | Raychem | 1 | Pc |
| 35 | Marker Sleeve | TMS-SCE-3/4-2.0-4 | Raychem | 1 | Pc |
| 36 | Connector | 62GB-56T12-10P | Raychem | 1 | Pc |
| 37 | Connector | D38999/26WC98PN | Raychem | 1 | Pc |
| 38 | Connector | D38999/26WD18SA | Raychem | 1 | Pc |
| 39 | Connector | D38999/26WG41PN | Raychem | 1 | Pc |
| 40 | Filler Plug | MS27488-20 | Raychem | 1 | Pc |

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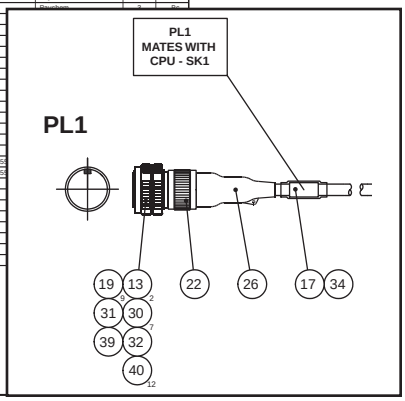



### Parts Listing

During the parts listing process Harn*Ware* software automatically:

- Extracts part details from the drawing
- Generates a sorted and totalized parts list table
- Adds item number balloons to the drawing cross referencing the parts to the parts list table.

Harn*Ware* software parts list data can be written to a structured text file ready for use in a variety of other systems including spread sheets, databases or word processors. The parts lists for a number of harnesses can also be combined to form a composite parts list that totalizes all the parts for a set of harnesses on a project. Other parts listing options include the ability to:

- Retain existing item numbers when a design is modified.
- Include gaps in the item numbering sequence.
- Convert part numbers to customer numbers or to VG or other industry standard numbers.

### Other Features

Among the other Harn*Ware* software features and options are:

- 3D modelling system for visualizing harness designs. Harn*Ware* software automatically generates to-scale 3D models which provide virtual prototypes of harnesses designed. The user can see what a harness will look like with lengths, diameters and parts shown to scale thus reducing the potential for errors.
- Lay-up (nail) board designs. Harness lay-up board design can be modeled with pegs automatically positioned along the harness legs. Drawn output can be used on the lay-up board.
- Weight calculation. Most components weights are stored in the Harn*Ware* software database and this enables the software to estimate the weight of the harness.





Catalog 1654025
Revised 12-04

www.tycoelectronics.com

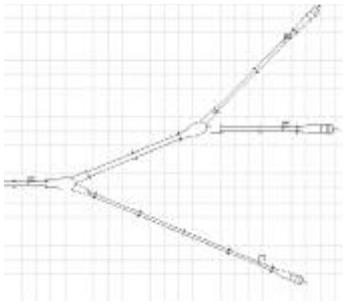
Dimensions are in millimeters and inches unless otherwise specified. Values in brackets are U.S. equivalents.

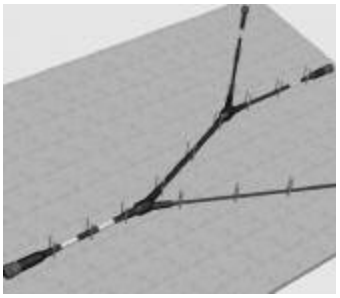
Dimensions are shown for reference purposes only. Specifications subject to change.

USA: 1-800-522-6752
Canada: 1-905-470-4425
Mexico: 01-800-733-8926
C. America: 52-55-5-729-0425

South America: 55-11-3611-1514
Japan: 81-44-900-5102
Singapore: 65-4866-151
UK: 44-1793-528171

## Harn*Ware* Harness Design Software (Continued)





**Other Features** (Continued)

- Labor estimator. Harness drawings can be analyzed and details automatically added to a spread sheet containing assembly time standards. While estimating harness assembly times can never be an exact science, the estimates produced are sufficiently accurate for such purposes as comparing the cost effectiveness of alternative design solutions. A labor estimate is contained in the attached sample Harn*Ware* software document set.
- Cable analyzer. This option analyzes the harness topology, wire lengths, etc. in order to suggest where machine, rather than hand, built cable sub-assemblies could result in the maximum cost savings.
- Drawing translator. Drawings can be translated into a number of foreign languages, including French and some Asian languages such as Korean and Japanese. Harnessing phrases, rather than individual words, are translated in order to achieve more meaningful and grammatically correct results.
- Design checker. This analyzes the contents and structure of a harness design against a set of rules. Where potential problems or deviations from 'best practice' are found, Harn*Ware* software outputs a warning. The relevant parts in the harness design drawing can be flagged and the warning messages can also be listed in a table for use in design reviews. The warning flags and the messages are all linked to an on-line help system which contains further details on each specific problem.
- Codes of practice. A list can be generated of the codes of practice that are relevant to the parts included in the design. These describe harness assembly techniques and other issues.
- On-line help system. An extensive on-line help system covers system operating procedures and details on many aspects of harness design procedures and Raychem products. The help system is context sensitive and extensively cross-referenced using hyperlinks including links to the on-board manual or the Tyco Electronics website.
- User parts library for non-standard parts. A database to allow identification and retrieval of regularly used parts.
- Multi-core cable database. A database to allow selection of standard or regularly used cables.
- Databus module. Software for the design of MIL-C-1553 databus harness assemblies using Tyco Electronics components.
- Conduit module. Software for the design of Tyco Electronics conduit harnesses.



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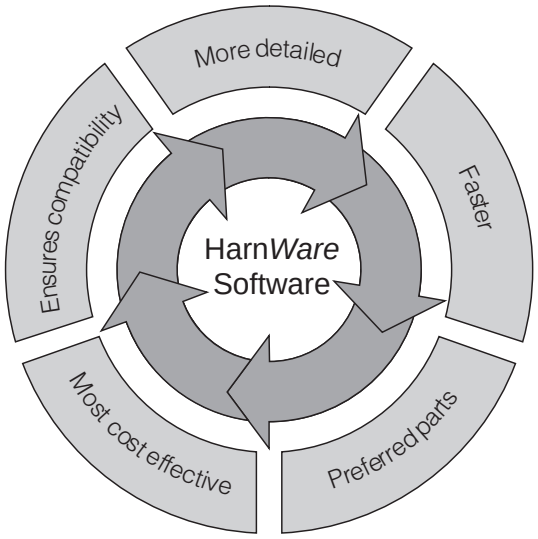


### System Integration

Harn*Ware* software can be linked to many other computer systems using a variety of interfaces including:

- Parts list data can be exported in structured text files suitable for reading by such systems as spread sheets, databases and word processors.
- Drawings can be imported and exported using industry standard formats such as DXF and IGES.
- Cable marker data can be transferred to marker printing systems such as Tyco Electronics WinTotal* system.
- Wiring connectivity data export for test equipment.
- X, Y coordinates of nail positions on lay-up (nail) board for NC drilling.

### Benefits

The five key benefits of using Harn*Ware* software are:

1) More detailed and accurate design.
2) Up to 20 times faster design and quotation.
3) Preferred part selection, to ensure best delivery and price.
4) More cost effective design.
5) Ensures parts are compatible with the intended service conditions and with mating parts.

Hundreds of users around the world can confirm the benefits of using Harn*Ware*.

### Harn*Ware* Software Document Set

The following partial set of drawings and associated documents is a simple example of what can be produced using Harn*Ware* software.

*Tyco Electronics Identification product information available at www.tycoelectronics.com





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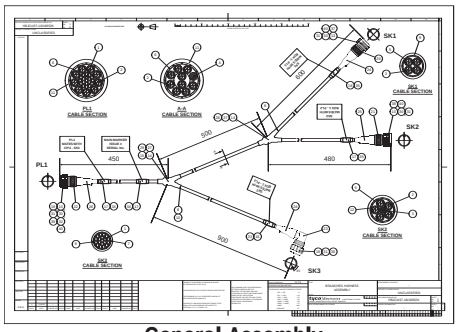
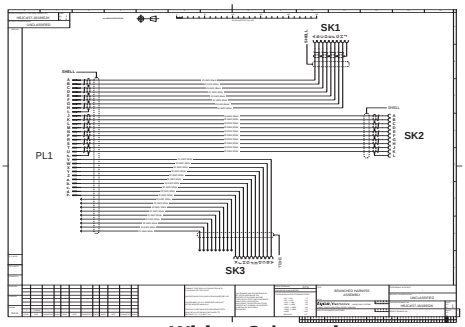
## HarnWare Harness Design Software (Continued)

**General Assembly, Wiring Schematic, Parts List, Labor Estimate, Marker Sleeve and Codes of Practice Pages**



General Assembly



Wiring Schematic

PARTS LIST

| ITEM | DESCRIPTION | PART NUMBER | SPEC/REMARKS | QTY | UNIT |
|---|---|---|---|---|---|
| 1 | Wire | 44A0111-20-9 | Raychem | 30.3 | M |
| 2 | Wire | 44A1121-20-0/9-9 | Raychem | 15.6 | M |
| 3 | Filler | 2.75-MM-SZF | Raychem | 0.5 | M |
| 4 | Filler | 3.50-MM-SZF | Raychem | 0.5 | M |
| 5 | Braid | RAY-101-10.0 | Raychem | 1.2 | M |
| 6 | Braid | RAY-101-12.5 | Raychem | 1.2 | M |
| 7 | Braid | RAY-101-7.5 | Raychem | 1 | M |
| 8 | Tubing | AT099-43 | Raychem | 2 | Pc |
| 9 | Tubing | DR-25-1/2-0 | Raychem | 1.6 | M |
| 10 | Tubing | DR-25-1/2-0-50MM | Raychem | 1 | Pc |
| 11 | Tubing | DR-25-1-0 | Raychem | 1 | M |
| 12 | Tubing | DR-25-3/4-0 | Raychem | 0.6 | M |
| 13 | Tubing | RNF-100-3/16-0-15MM | Raychem | 4 | Pc |
| 14 | Tubing | RNF-100-1/2-0-20MM | Raychem | 3 | Pc |
| 15 | Tubing | RNF-100-1-0-20MM | Raychem | 1 | Pc |
| 16 | Tubing | RT-375-1/2-X-65MM | Raychem | 1 | Pc |
| 17 | Tubing | RT-375-1-X-65MM | Raychem | 3 | Pc |
| 18 | Tubing | RT-375-3/4-X-65MM | Raychem | 1 | Pc |
| 19 | Insulation Cap | TC-4001-9 | Raychem | 18 | Pc |
| 20 | Adaptor | TXR40AB00-1208AI | Raychem | 1 | Pc |
| 21 | Adaptor | TXR40AB00-1410AI | Raychem | 1 | Pc |
| 22 | Adaptor | TXR40AB00-2014AI | Raychem | 1 | Pc |
| 23 | Adaptor | TXR76AB90-1208AI | Raychem | 1 | Pc |
| 24 | Moulded Part | 202K142-25/225-0 | Raychem | 2 | Pc |
| 25 | Moulded Part | 202K153-25/225-0 | Raychem | 1 | Pc |
| 26 | Moulded Part | 202K163-25/225-0 | Raychem | 1 | Pc |
| 27 | Moulded Part | 382A034-25/225-0 | Raychem | 2 | Pc |
| 28 | Solder Device | B-051-01-01 | Raychem | 1 | Pc |
| 29 | Solder Device | B-051-02-01 | Raychem | 1 | Pc |
| 30 | Solder Device | ST63-3-55-20-90 | Raychem | 14 | Pc |
| 31 | Marker Sleeve | TMS-NR501-NR19-4-CS-65571 | Raychem | 4 | KT |
| 32 | Marker Sleeve | TMS-NR501-NR19-4-CS-65572 | Raychem | 1 | KT |
| 33 | Marker Sleeve | TMS-SCE-1/2-2.0-4 | Raychem | 1 | Pc |
| 34 | Marker Sleeve | TMS-SCE-1-2.0-4 | Raychem | 2 | Pc |
| 35 | Marker Sleeve | TMS-SCE-3/4-2.0-4 | Raychem | 2 | Pc |
| 36 | Connector | 62GB-56T12-10P | Amphenol | 1 | Pc |
| 37 | Connector | D38999/26WC98PN | MIL-C-38999 | 1 | Pc |
| 38 | Connector | D38999/26WD18SA | MIL-C-38999 | 1 | Pc |
| 39 | Connector | D38999/26WG41PN | MIL-C-38999 | 1 | Pc |
| 40 | Filler Plug | MS27488-20 | - | 20 | Pc |

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TITLE: BRANCHED HARNESS ASSEMBLY | CREATOR: D Hammond | DATE: 13/03/01 | FILENAME: PicHarn.vsd | Page 3 of 8

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LABOUR ESTIMATE

| Element | Time (mins) | | Qty / Length | Total mins |
|---|---|---|---|---|
| Unpack Check Kit | 15 | per kit | 0 | 0 |
| Cut EPD to Length | 1 | per metre | 0 | 0 |
| Jacket Stripping for Con. Ends | 5 | per end | 4 | 20 |
| Remove EPD Jacket | 5 | per metre | 0 | 0 |
| Identify Wires | 1.3 | per wire | 60 | 78 |
| Strip/Crimp/Insert | 2.5 | per cont. | 50 | 125 |
| **Solder Wires** | | | | |
| Up to 16AWG (Tin/Strip/Insulate) | 3.5 | per term | 10 | 35 |
| 14 to 12AWG (Tin/Strip/Insulate) | 5 | per term | 0 | 0 |
| Power Cable | 15 | per term | 0 | 0 |
| Lugs Crimp | 10 | per term | 0 | 0 |
| Lugs Solder | 15 | per term | 0 | 0 |
| Repair Loops Up to 55 Way Con. | 0.5 | per wire | 60 | 30 |
| Above 55 Way Con. | 0.75 | per wire | 0 | 0 |
| Solder/tact | 4 | per term | 0 | 0 |
| **Screen Termination** | | | | |
| Individual Term. | 3 | per term | 14 | 42 |
| Coaxial Term. | 6 | per term | 0 | 0 |
| Insulating Screens | 2 | per term | 4 | 8 |
| Filler Plugs | 1 | per fit/plug | 20 | 20 |
| Spare Wires | 0.5 | per wire | 18 | 9 |
| Ring Tags Crimp | 2 | per term | 0 | 0 |
| Ring Tags Solder | 2.5 | per term | 0 | 0 |
| RF one-step | 8 | per term | 0 | 0 |
| **Adaptors (includes Braid Term / Torque)** | | | | |
| Spin Coupling | 7.5 | per term | 0 | 0 |
| Braided Adaptor | 12 | per term | 0 | 0 |
| Tinel | 10 | per term | 4 | 40 |
| Whipping/Soldering | 5 | per term | 0 | 0 |
| **Tubing** | | | | |
| DR25 < 1/4 | 4 | per metre | 0 | 0 |
| 1/4 to 1/2 | 7 | per metre | 1.50 | 10.5 |
| 3/4 to 1 | 10 | per metre | 1.43 | 14.3 |
| 1 1/2 + | 15 | per metre | 0 | 0 |
| Viton, YPB +25% | 0.25 | ) Enter | 0 | 0 |
| ZHTM -25% | -.25 | ) 0 for No | 0 | 0 |
| CGPT & Versafit | -.25 | )1 for Yes | 0 | 0 |
| Tubing Installation on Multi-Leg Harness | 2 | per metre | 2.93 | 5.86 |
| **Wire Layup** | | | | |
| Legs <=4 Metres: < 20 wires | 1 | | 27.38 | 27.38 |
| 20 - 30 wires | 1.5 | | 12.60 | 18.9 |
| >30 wires | 2 | | 0 | 0 |
| Legs >4 Metres: < 20 wires | 1.5 | | 0 | 0 |
| 20 - 30 wires | 2 | | 0 | 0 |
| > 30 wires | 2.5 | | 0 | 0 |
| | Enter 1 to add 30% for mixed wire sizes | | 1 | |

| Element | Time (mins) | | Qty / Length | Total mins |
|---|---|---|---|---|
| **Moulded Parts** | | | | |
| **Rayaten** | | | | |
| 121 to 142 | 17 | per piece | 0 | 0 |
| 152 to 163 | 25 | per piece | 0 | 0 |
| 174 | 30 | per piece | 0 | 0 |
| **Standard** | | | | |
| 11 to 42 | 12 | per piece | 2 | 24 |
| 52 to 63 | 15 | per piece | 2 | 30 |
| 74 | 20 | per piece | 0 | 0 |
| 85 | 25 | per piece | 0 | 0 |
| **Uniboot** | | | | |
| 611 to 621 | 10 | per piece | 0 | 0 |
| 632 to 642 | 12 | per piece | 0 | 0 |
| 653 to 663 | 15 | per piece | 0 | 0 |
| **KTKK** | | | | |
| Small | 5 | per piece | 0 | 0 |
| Medium | 6 | per piece | 0 | 0 |
| Large | 7 | per piece | 0 | 0 |
| **Transitions** | | | | |
| **3 Outlets** | | | | |
| 11 to 19 | 16 | per piece | 0 | 0 |
| 22 to 48 | 20 | per piece | 2 | 40 |
| 56 to 91 | 23 | per piece | 0 | 0 |
| **4 Outlets** | | | | |
| 11 to 19 | 21 | per piece | 0 | 0 |
| 22 to 48 | 25 | per piece | 0 | 0 |
| 56 to 91 | 29 | per piece | 0 | 0 |
| **5 Outlets** | | | | |
| 11 to 19 | 25 | per piece | 0 | 0 |
| 22 to 48 | 28 | per piece | 0 | 0 |
| 56 to 91 | 33 | per piece | 0 | 0 |
| Viton +50% | 50 | ) Enter | 0 | 0 |
| Precoated -25% | -25 | ) 0 for No | 1 | -23.5 |
| Potting +50% | 5 | ) 1 for Yes | 0 | 0 |
| Package Piece/Ext | 5 | per piece | 3 | 15 |
| Aluminital | 3 | per piece | 0 | 0 |
| **Raybraid / Install** | | | | |
| Straight | 3.5 | per metre | 0 | 0 |
| Branch | 5 | per metre | 2.93 | 14.65 |
| Transition Overlap | 8 | per piece | 2 | 16 |
| Bandage | 33 | per piece | 0 | 0 |
| Protection Cap Installation | 5 | per piece | 0 | 0 |
| Marker Sleeves | 4 | per piece | 5 | 20 |
| Protection Sleeves | 1 | per piece | 5 | 5 |
| Wire Cutting | 1 | per wire | 37 | 37 |
| **Unravel / Count Cut Wires** | | | | |
| Common Size | 0.1 | per wire | 37 | 3.7 |
| Mixed Sizes | 0.3 | per wire | 0 | 0 |

Enter 1 to add 5% allowance for QC: 0
Special Requirements (mins): 0
Total Labour Time (mins): 679.67
**Total Labour Time (hours): 11.33**
Labour rate per hour: 0.00
**Total Labour Cost £ 0.00**

Enter 1 to Add Allowances for Prototypes:
20% for Straight or Branched < 4 Ends: 0
35% for Branched 4+ Ends: 0

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MARKER PAGE

**PL1**
**MATES WITH**
**CPU - SK1**

Item:34 Quantity:1
Part Number:TMS-SCE-1-2.0-4
Colour:Yellow Font:10 cpi Standard

**SK1**
**MATES WITH**
**BOX 1 - PL1**

Item:35 Quantity:1
Part Number:TMS-SCE-3/4-2.0-4
Colour:Yellow Font:10 cpi Standard

**MAIN MARKER**
**ISSUE #**
**SERIAL No.**

Item:34 Quantity:1
Part Number:TMS-SCE-1-2.0-4
Colour:Yellow Font:10 cpi Standard

**SK2**
**MATES WITH**
**BOX 1 - PL2**

Item:35 Quantity:1
Part Number:TMS-SCE-3/4-2.0-4
Colour:Yellow Font:10 cpi Standard

**SK3**
**MATES WITH**
**BOX 1 - PL3**

Item:33 Quantity:1
Part Number:TMS-SCE-1/2-2.0-4
Colour:Yellow Font:10 cpi Standard

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CODES OF PRACTICE, FAX-ON-DEMAND AND DRAWING NOTES

**Codes of Practice:**

| Code | Description |
|---|---|
| 251 | End stripping primary wire and cable |
| 254 | Stripping wire and cable jackets |
| 256 | Laying hand laid sections of harnesses |
| 257 | Applying Kevlar binder to hand-laid sections of harnesses |
| 261 | Preparing shielded and jacketed wire |
| 301 | Looping wire gauges 18 and below |
| 368 | Terminating a primary wire to a cable shield using a solder sleeve with a pre-installed lead |
| 361 | Applying a single layer of braid to a hand laid cable |
| 363 | Terminating overall shields formed by single layers of braid at a transition |
| 551 | Installing heat shrinkable tubing |
| 610 | Preparing cable jackets for the installation of pre-coated tubings |
| 359 | Installing Tinel-Lock rings with a resistance heater |
| 366 | Positioning Tinel-Lock rings |
| 451 | Applying Loctite sealants to Raychem adaptors |
| 452 | Torque tightening Raychem adaptors |
| 553 | Installing medium and large transitions |
| 554 | Installing straight lipped boots |
| 557 | Under jacket packing for moulded parts |
| 559 | Installing moulded parts using Unicure adhesive |
| 603 | Preparing cable jackets and adaptors for installing moulded parts |
| 609 | Preparing non-shielded moulded parts |
| 556 | Installing marker sleeves |
| 454 | Checking the retention of pins or sockets within a connector |

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TITLE: BRANCHED HARNESS ASSEMBLY | CREATOR: D Hammond | DATE: 13/03/01 | FILENAME: PicHarn.vsd | Page 8 of 8

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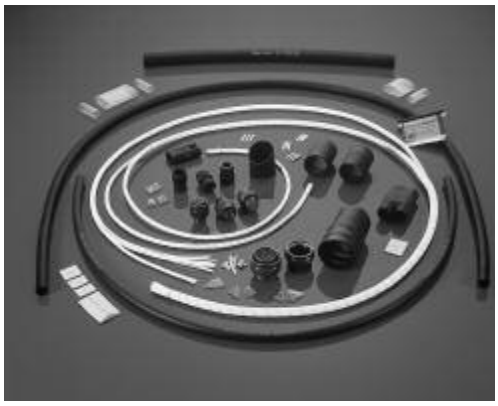
Singapore: 65-4866-151
UK: 44-1793-528171

## Integrated Military Harness Systems for Defense and Allied Industries



Assembled military harness.



Military harness system components.

Raychem integrated harness systems have been developed for a wide range of defense and industrial applications. Each system consists of compatible components, including cable jackets, heat-shrinkable components, and adhesives. Performance of these parts is assured because all components are tested separately and as part of an assembled system (see photo top left).

A typical designed harness consists of seven component parts (pictured at right):

1. Primary wire and cable
2. Heat-shrinkable tubing
3. Backshell adapter
4. Molded part
5. Adhesive
6. Cable jacket
7. Marker sleeve*

Additional components for harnessing systems include the following:

- A wide range of special devices, such as SolderSleeve devices for primary wire interconnection.
- A selection of electrical shielding (screening) options, including braids and termination assemblies.
- Multiconductor (multi-core) cables.
- Specialty adhesives and sealants for complete environmental sealing.**

Table 1 on the next page serves as both a summary of Raychem products for specific harnessing systems and a selection table for harnessing system components. An explanation of how to select components for a harness system follows.

*Tyco Electronics Identification products information available at www.tycoelectronics.com

**Tyco Electronics Sealant product information available at www.tycoelectronics.com



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## Integrated Military Harness Systems for Defense and Allied Industries (Continued)

**Table 1. Raychem Harnessing Systems and Their Components**

| Components | System 10 | System 20 | System 25 | System 30 | System 100 | System 200 | System 300 |
|---|---|---|---|---|---|---|---|
| Wire | 44 | 44 | 44 | 55 | 99, 100A, 100G | 55 | 55 |
| Tubing | Versafit | NT-FR | DR25 | VPB | ZHTM | Viton® | RT555 |
| Adapter material and plating finish chosen for compatibility with the connectors. | | | | | | | |
| Molded part | -3, -4, -71 | -51 | -25 | -50 | -100 | -12 | -55/-125 |
| Preinstalled Rayaten molded part | -35 | — | -25S | — | -100S | — | — |
| Adhesive | S1017, S1030 | S1124, S1048 | S1048, S1125 | S-1125, S-1255-04 | S1030, S1125, | S1125, S1255 | S1255-04 |
| Precoated adhesive | /42, /180 | /164,/86 | /86, /225 | — | /180 | — | — |
| Conductive adhesive | — | — | S1184 | — | S1184 | — | — |
| Cable jacket | Thermorad | NT-FR | FDR-25 | Thermorad VPB | Zerohal | Viton® | RT555 |
| Marker sleeve* | TMS-SCE | TMS-SCE | TMS-SCE | TMS-SCE | HX-SCE | HT-SCE | HT-SCE |

*Tyco Electronics Identification products information available at www.tycoelectronics.com.

### Selection Process

Selecting the components for a harnessing system is a four-step process:

**Step 1:** Select the material system appropriate for the operating conditions and environment to which the harness will be exposed.

**Step 2:** Select the adhesive system appropriate for the material system you select in Step 1.

**Step 3:** Determine the level of EMI shielding required.

**Step 4:** Select the components.

Each step is described on the pages that follow. A selection table accompanies each step. You can also use Harn*Ware* software to design your harness.

### Step 1. Select the Material System.

Detailed in Table 2 on the next page are the major material systems for use in a wide range of operating conditions and environments.

Choose a material system that:

- Has the physical characteristics your harness requires.
- Will accommodate the operating temperature and the fluids and abuse to which the harness will be exposed.

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**Table 2. Material System Selection**

| | System 10 | System 20 | System 25 |
|---|---|---|---|
| Operating temperature | -20°C to +60°C [-4°F to +140°F] | -55°C to +121°C [-67°F to +250°F] | -75°C to +150°C* [-103°F to +302°F] |
| Physical characteristics | • Environmentally sealable<br>• Lightweight<br>• Small diameter<br>• Flexible | • Environmentally sealed<br>• Tough<br>• Flexible<br>• Low profile | • Environmentally sealed<br>• Rugged<br>• Abrasion-resistant<br>• Very flexible |
| Flammability | • Flame-retardant<br>• Self-extinguishing | • Flame-retarded<br>• Self-extinguishing | • Flame-resistant<br>• Self-extinguishing |
| Fluid resistance | • Resists common industrial and military cleaning solvents and degreasers. | • Resists most commonly used military fuels, oils, and greases | • Resists most common military fuels, oils, and greases. up to 70°C [158°F]. |
| Typical applications | • Used in high-performance industrial applications, and in military communication and test equipment. | • Specially suited to military vehicles and engine compartments, low profile shapes save space and weight. | • Specially suited to military vehicles, aerospace and marine applications, and communication and test equipment. |

| | System 30 | System 100 | System 200 |
|---|---|---|---|
| Operating temperature | -55°C to +150°C [-67°F to +302°F] | -30°C to +105°C [-22°F to +221°F] | -55°C to +200°C [-67°F to +392°F] |
| Physical characteristics | • Environmentally sealed<br>• Tough<br>• Flexible<br>• Low profile | • Environmentally sealed<br>• Flexible | • Environmentally sealed<br>• Very flexible |
| Flammability | • Flame-retarded<br>• Self-extinguishing | • Low toxicity index (as defined by NES-13)<br>• Low smoke emission (as defined by NES-711)<br>• Low corrosive gas evolution | • Highly flame-retardant |
| Fluid resistance | • Resists most of commonly used military fuels, oils, and greases. | • Resistant to a range of military fuels, oils, and greases. | • Resists long-term immersion in military fuels, oils, and greases at elevated temperatures. |
| Typical applications | • Specifically suited to military vehicles and engine compartments for higher temperature applications, low profile shapes save space and weight. | • Specially suitable for confined habitat areas in military and civil applications.<br>• Extensively used in surface and submarine vessels and underground railways | • Used where there is prolonged exposure to high temperatures.<br>• Used where a harness may be permanently immersed in difficult fuels, such as in fuel tanks. |

| | System 300 |
|---|---|
| Operating temperature | -55°C to +200°C [-67°F to +392°F] |
| Physical characteristics | • Environmentally sealed<br>• Highly abrasion resistant<br>• Low profile |
| Flammability | • Highly flame-retardant |
| Fluid resistance | • Performs in aggressive fluids at extremely high temperatures |
| Typical applications | • Permanent immersion in aggressive fluids |

*Per VG 95343.



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## Integrated Military Harness Systems for Defense and Allied Industries (Continued)

### Raychem Harnessing Systems and Their Components — NBC Survivable Systems*

New Product 2005

| Components | System 770 | System 780 | System 790 |
|---|---|---|---|
| Wire | 44 | 55 | 55 |
| Tubing | RT-770 | RT-780 | RT-790 |
| Molded part | -770 | -780 | -790/-791 |
| Adhesive | S-1264 | S-1255-04 | S-1255-04 |
| Marker sleeve cover | RT-375 | RT-375 | RT-375 |
| Marker sleeve** | TMS-SCE | NBC-SCE | NBC-SCE |

**Tyco Electronics Identification products information available at www.tycoelectronics.com.

### Material System Selection

| | System 770 | System 780 | System 790 |
|---|---|---|---|
| Operating temperature | -55°C to +125°C [-67°F to +257°F] | -65°C to +175°C [-85°F to +347°F] | -65°C to 200°C [-85°F to +392°F] |
| Physical characteristics | • Environmentally sealed<br>• NBC resistant<br>• Flexible | • Environmentally sealed<br>• NBC resistant<br>• Flexible | • Environmentally sealed<br>• NBC resistant<br>• Flexible |
| Flammability | • Flame retarded<br>• Self-extinguishing | • Flame retarded<br>• Self-extinguishing | • Flame retarded<br>• Self-extinguishing |
| Fluid resistance | • Resistant to NBC uptake and decontamination | • Resistant to NBC uptake and decontamination | • Resistant to NBC uptake and decontamination |
| Typical applications | • Base-line system for NBC resistant applications | • High temperature system for NBC resistant applications | • Extreme high temperature system for NBC resistant applications |

### Adhesive Selection

| Material System | Adhesive Type | Component Adhesive | Precoated Adhesive Designation | Service Temperature |
|---|---|---|---|---|
| System 770 | Two-part Epoxy | S-1264 | — | 150°C |
| System 780 | Thermoset tape | S-1255-04 | — | 200°C |
| System 790 | Thermoset tape | S-1255-04 | — | 200°C |

*Under Development - contact Tyco Electronics for additional information



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## Integrated Military Harness Systems for Defense and Allied Industries (Continued)



### Step 2. Select the Adhesive System.

Two types of adhesives are used to bond heat-shrinkable boots and transitions to tubing or wire jacketing:

- Thermosets, which include epoxies and other two-part systems.
- Thermoplastics, which include pre-coated meltable adhesives applied to parts during manufacture and those applied as meltable tapes during assembly.

Table 3 below outlines the differences between thermosets and thermoplastics.

Table 4 shows which adhesive type is appropriate for each harness material system.

**Table 3. Comparison of Adhesive Types**

| | Thermoset | Thermoplastic |
|---|---|---|
| Method of adhesion | Cures through chemical reaction. | Melts, flows, and solidifies. |
| Application | Two-part types require mixing and application at assembly. | Precoated types require no preparation at assembly. |
| Cure time | Varies with cure temperature. Oven cure usually desirable. | Not required. Adhesive functional when cooled to room temperature. |
| Strength | Retains most strength at elevated temperatures. | Loses strength as melt temperature is approached. |
| Disassembly | Items can be forcibly peeled apart when heated sufficiently. | Items can be separated when heated to temperature of the adhesive. |
| Repair/reassembly | Requires new adhesive or hot rollback to reenter behind connector without affecting adhesive bonds. | Can be reheated to form new bond if sufficient adhesive remains. |

**Table 4. Adhesive Selection**

| Material System | Adhesive Type | Component Adhesive | Precoated Adhesive Designation | Service Temperature |
|---|---|---|---|---|
| System 10 | Thermoplastic | S-1030 | /180 | 80°C |
| | | S-1017 | /42 | 60°C |
| System 20 | Thermoplastic | S-1124 | /164 | 105°C |
| | | S-1048 | /86 | 120°C |
| System 25 | Thermoplastic | S-1048 | /86 | 120°C |
| | Two-part thermoset | S-1125 | /225 | 150°C |
| System 30 | Thermoset Tape | S-1255-04 | — | 200°C |
| | Two-part thermoset | S-1125 | — | 150°C |
| System 100 | Thermoplastic | S-1030 | /180 | 80°C |
| | | S-1048 | /86 | 120°C |
| | Two-part thermoset | S-1125 | — | 150°C |
| System 200 | Two-part thermoset | S-1125 | — | 150°C |
| | Thermoset tape | S-1255-04 | — | 200°C |
| System 300 | Thermoset tape | S-1255-04 | — | 200°C |
| System 770 | — | S-1264 | — | — |
| System 780 | Thermoset tape | S-1255-04 | — | 200°C |
| System 790 | Thermoset tape | S-1255-04 | — | 200°C |



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**Integrated Military Harness Systems for Defense and Allied Industries** (Continued)

**Step 3. Determine the Level of EMI Shielding Required.**

Tyco Electronics offer several methods and technologies for controlling electromagnetic interference (EMI) and noise in cable harnesses. Developed in response to well-established threats in military and other harsh environments, these technologies can be employed in compatible shielding (screening) systems to achieve the level of shielding required for a harness system. Table 5 on page 2-22 outlines the shielding requirements for various types of threat and levels of interference.

**Introduction**

This section is intended as a guide for the use of harness designers who are required to achieve a level of EMI control in their design practices. It is not intended that it should be a definitive statement on all aspects of EMI control for harnesses. In case of difficulty contact us for further clarification or consultancy.

For well-designed EMI control of electrical systems it is essential that a detailed knowledge of the system requirements and susceptibility be obtained. The chosen level of shielding will be dependent on the:

- Susceptibility of electrical system.
- Types of components used.
- Physical layout of the system.
- Equipment practices adopted.
- Anticipated EMI threat.

For the most cost effective design of harnesses, which offer a long-term stability in performance, the system should be designed to achieve a balance of component characteristics. Components should only be used if they are qualified to a minimum level of EMI performance and the performance and test method should be applicable to the design technique being used.

For quality assurance purposes minimum EMI characteristics should always be specified and for critical harnesses the complete performance should be measured. The technique to be adopted should always be specified.

Finally the inter-relationship between harnesses and the protection, termination and grounding of equipment boxes is vital for good system performance against EMI. All components form part of the external shield on the system and therefore should be considered in the overall EMI design process.

Subjects covered in this topic are:

- Harness Types - point to point and branched
- Shielding Levels - calculations

**Harness Types**

Harnesses are divided into two types, point-to-point and branched. The advantages and disadvantages of each from an EMI control standpoint are described below. No attempt has been made to analyze their relative merits in mechanical or installation terms.

**Point To Point:**

The three major components of this type of harness are: connectors, cable, and connector accessories.

**Connectors**

There are many different types of circular military connectors. However, for a well-shielded harness only those connectors having a guaranteed performance level should be used e.g. MIL-C-26482 Series II and MIL-C-38999 series 1 and 2, and series 3 and 4.

**Cable**

Cable used in this type of harness is generally machine made. Hand laid cables may also be used but generally the shields incorporated in these harnesses vary in consistency of performance. In the case of machine made cables all shields should be designed for optimum shielding effectiveness at radio frequency.



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## Integrated Military Harness Systems for Defense and Allied Industries (Continued)

### Connector Accessories

Connector accessories, such as Raychem adapters, are available in many styles and therefore their performance varies with construction. For a level of consistency in performance it is essential that, as with connectors, a guarantee in performance level be achieved. Fittings not specified in this way may significantly degrade the overall system performance.

### Branched

In addition to those components described above, branched harnesses include transitions. This type of harness is usually made by hand and it is therefore difficult to incorporate accurately made machine fabricated shields. The implications of this are:

### Shields

Cable shields may be put on by hand or by feeding through a braiding machine. However, as braid optimization depends on all the constructional parameters of the braid being accurately specified, unless braid is well constructed the shielding performance can suffer dramatically. Reductions in shield performance of 20-40 dB have been measured on badly made branched harnesses. The alternative method is to use pull on braids. If the cable bundle diameter is known the braid may be designed for optimized performance.

### Transitions

Transitions, as with accessories, are very susceptible to performance variability with construction type.

For high performance harnesses these components should also have a guaranteed performance.

In general the use of techniques such as hand soldering or the use of butted tape wraps are not recommended except where only a low performance of less that 40dB is required.

### Shielding Levels and Component Performance

### System Performance

To specify the overall requirements of a complete electronic system in terms of its EMI characteristics it is necessary to consider the performance of the individual components parts. The harnesses form one of the major entry points for interference and this as such can degrade a complete system performance by a significant amount. In general terms, assuming that a shielded harness system is used, with the available components on the market the overall harness system performance and typical applications may be as below.

- 40 to 50 dB Standard shielded systems for insensitive systems.
- 50 to 60 dB Military standard shielded systems for general applications.
- 60 to 80 dB As above but where full threat EMP & TEMPEST protection is required.
- 80 to 100 dB Severe TEMPEST and very sensitive systems.
- Over 100 dB Exceptional shielding requirements only.

Shield performance is specified in two ways, either as a power relationship in decibels (dB) or as an absolute measurement of the shield performance in terms of the surface transfer impedance. Except for very specific low frequency problems it is general to specify the performance at frequencies in the range 0.1MHz to 100MHz.





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## Integrated Military Harness Systems for Defense and Allied Industries (Continued)

### Safety Margins

As with all designs EMI system design should not be performed to the "limit of performance safety margin should always be incorporated when determining the minimum shielding level appropriate for consistent operation of the system.

The inter-relationship of shielding effectiveness measured in decibels and the surface transfer impedance in ohms presents the designer with a conversion difficulty. External harness circuits vary, as do the coupling characteristics and it is therefore only possible to give an approximate conversion. The normal conversion from decibels to ohms and vice versa is to a reasonable approximation:

Screening Effectiveness (dB) = $36 - 20 \log_{10} (Z_T (\text{Ohms}))$

The constant term is developed from the expressions for the characteristic impedance of the line formed by the harness shield and the ground plane and the internal characteristic impedance of the inside of the harness. The translation from shielding effectiveness to surface transfer impedance is shown below in Table 5 for S.E. from 20 to 105dB.

### Connectors

A study of those connector specifications having an EMI test shows that they are generally specified in the frequency band 100MHz to 1GHz. For an assessment at lower frequencies the low frequency performance as dictated by the d.c. resistance of the connector is required. These two parameters enable the EMI characteristic to be made of the complete connector performance. Typical values for standard connectors are 65dB (MIL-C-26482 Series II) and 90dB (MIL-C-38999 Series III) connectors.

**Table 5 - Screening Effectiveness (SE)/Surface Transfer Impedance (Zt) Relationships**

| S.E. (dB) | $Z_T$ (ohms) | S.E. (dB) | $Z_T$ (ohms) |
|---|---|---|---|
| 20 | 6.309 | 65 | 0.0355 |
| 25 | 3.548 | 70 | 0.0200 |
| 30 | 1.995 | 75 | 0.0112 |
| 35 | 1.122 | 80 | 0.0063 |
| 40 | 0.631 | 85 | 0.0036 |
| 45 | 0.355 | 90 | 0.0020 |
| 50 | 0.200 | 95 | 0.0011 |
| 55 | 0.112 | 100 | 0.0006 |
| 60 | 0.063 | 105 | 0.0004 |



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## Integrated Military Harness Systems for Defense and Allied Industries (Continued)



### Cable

In accordance with most common cable specification the shielding performance of a cable is specified at 30MHz. It is also well into the band where inductive leakage is the primary penetration characteristic. For frequencies above or below 30Mhz, approximations, as for connectors, must be made. It should be noted that the performance specified at 30MHz in Table 6 for different cable types is the maximum that is allowed using Tyco Electronics' standard Q.C. values. Actual performance may be up to 20dB better.

### Connector Accessories and Transitions

In constructional terms the performance of the connector accessory includes both the resistive terminations to the cable shield and the connector. However, it is most unusual to specify the performance of an accessory and this is a distinct weakness in the design of harnesses. The reason is that the performance is extremely variable as accessories have to fit a variety of different cable sizes and shapes. Where specified at all the relationship between the test method and the coupling mechanism for the EMI must be considered.

**Table 6 - Cable Performances**

| Type of Screen | Diameter under screen (mm) | Surface transfer Impedance Zt @ 30 Mhz (maximum) |
|---|---|---|
| Single optimized braid | Up to 7.5 | 100 milli ohms/metre |
| | 7.6 and up | 50 milli ohms/metre |
| Double optimized braid | Up to 7.5 | 10 milli ohms/metre |
| | 7.6 and up | 5 milli ohms/metre |
| Superscreened (2 braids + 1 wrap) | Up to 7.5 | 100 micro ohms/metre |
| | 7.6 and up | 50 micro ohms/metre |



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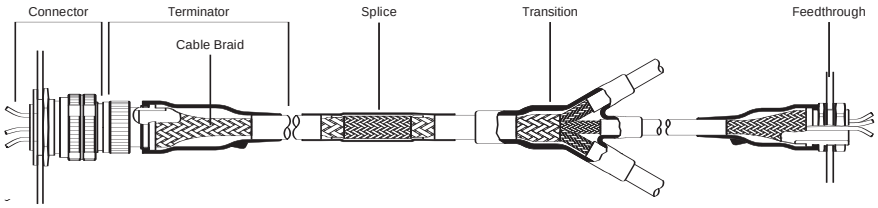


**Complete Harness**

When considering the complete harness the coupling calculations are relatively simple. In general terms they are the addition of all the individual leakages within the system from connector to connector. The analysis route is therefore as follows:

1. Convert all decibel values at the desired frequency to surface transfer impedance.
2. Choose components for a 'balanced' system, i.e. the components should have approximately the same performance.
3. Add the values determined for surface transfer impedance of the components at the frequency chosen.
4. Reconvert to decibels if necessary. (Table 5 can be used for this purpose)

As a guide to the shielding performance that can be expected from a harness that is constructed using Raychem components, Table 7 on the next page has been compiled to help in the product selection process.

For branched harnesses it is necessary to determine whether every branch has the same susceptibility requirements or carries the same signals of power. The performance requirement of each branch is then determined and the matrix for the harness established. This is a more complex subject and not discussed here. System improvements may be achieved by changing either the connectors or cable. In general terms changing from a single to a double optimized braid improves the performance of that component by 20-25 dB. A similar advantage is achieved by changing from MIL-C-26482 Series II to MIL-C-38999 Series I connectors. However, the relative significance, as part of the system, of each component must be considered to determine the true weighting effect. For the optimum in system design a balance of component performances should be achieved wherever possible such that each of the components is of similar performance level.

**General Considerations**

Although cables and harnesses are considered to be the most significant in terms of coupling into systems the construction of equipment boxes can play an important part in the overall EMI performance of a system. With the increasing use of high speed digital circuits and the generation of harmonics having high energy content relatively short printed circuit board tracks can radiate or pick up energy as efficiently as cables. If the boxes themselves are not adequately protected these circuits may constitute an EMI threat. There is a further area of significance in the EMI protection of the boxes and this is the connector/box interface. The junction may be considered to be a part of the harness system and any degradation in it may cause an overall harness degradation.



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**Table 7 - Screen System Guide**

| Harness System Components | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shielding Level Required | Connector | Adapter Styles | | Termination | | Cable Braid (max. length in m/ft) (by cable construction) | | | | | Transition | Splice | Feed-through |
| | | Band Strap | Braided | Tinel-Lock System | Rayaten Assembly | NO | SO | DO | SSS | DSS | | | |
| <60 dB | VG95328<br>VG95234 | ■ | ■ | ■ | — | <2/6.5 | 15/49 | 100/328 | — | — | Shield tape & Solder-Sleeve device | Solder-Sleeve device | Tinel or solder devices |
| 60 to 80 dB | MIL-C-26482 Series 2<br>VG96912 Series 1 | — | — | ■ | — | — | <2/6.5 | 7/22.9 | 100/328 | — | Shield tape & Solder-Sleeve device | Solder-Sleeve device | Tinel or Rayaten assembly |
| >80 dB | MIL-C-38999 | — | — | — | ■ | — | — | <0.5/1.6 | 50/164 | 65/213 | Not recom-mended | Solder-Sleeve device | Tinel or Rayaten assembly |

NO = Non Optimized, SO = Single Optimized, DO = Double Optimized, SSS = Single Super Shield, DSS = (TYCO must provide info)
Note:
1. The cable lengths are to be used as a guide.
   Outside 30 MHz, the lengths that can be used will vary. For specific harness design outside 30 MHz, please consult Tyco Electronics.
2. Tinel-Lock use at shielding levels of 60–80 dB depends on the adapter entry, cable braid size, and design. For further details, contact Tyco Electronics.
3. Connectors commonly used but not mentioned in the table may not have a stated shielding performance in their specification. Contact the manufacturer for guidance.
4. This guide makes no allowance for the possible effects of resonance. Tyco Electronics should be consulted for advice on compensating for resonance.

## Step 4. Select Components

Using the previous sections, you can now select all of the components for an integrated harness assembly.

Please refer to the sections listed for more detailed component information:







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Dimensions are in millimeters and inches unless otherwise specified. Values in brackets are U.S. equivalents.

Dimensions are shown for reference purposes only. Specifications subject to change.

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