Wiring harness design
can a computer help?

by Roger Billsdon and Ken Wallington

Raychem and ADE have developed a computer-aided wiring harness design system to help engineers select the most suitable parts and undertake many of the necessary analysis operations. This article describes some key features of the wiring harness design process and a little of the background on how the system was developed.

Features of the harness design process

Designing wiring harnesses, especially those for demanding applications such as defence and aerospace, is a surprisingly complex business. There are many different parts to select while taking into account various environmental and mating part conditions. There can, therefore, be a large number of potential design solutions to analyse.

The constraints imposed on harness design are also becoming more demanding. For example:

- Weight and space saving considerations are especially important in missile and aerospace applications. With the additional electrical equipment now being added to products such as cars and public transport, the same factors are becoming an issue in these industries.
- Electromagnetic interference (EMI). Harnesses can either radiate interference to, or they can pick up interference from, equipment that is close to any point along the route of a harness. With the increasing use of sensitive electronic equipment in cars, aircraft and military equipment this is becoming a major design consideration.
- Resistance to environmental hazards including high temperature or fire, chemical and nuclear agents. Also in products such as military vehicles, different characteristics may be specified for each area. For example, zero halogen materials in the crew area and materials able to withstand high temperature and resistant to fluids in the engine area.
- Corrosion has always been a problem in electrical systems. Many factors may need to be considered, including humidity, corrosive fluids and temperature cycling which can lead to condensation. 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 on the fault-free operation of electrical systems.
- Repair and maintainability. Some electrical and electronic systems in military vehicles, naval vessels and other products now need to be upgraded or modified several times during the life of the main mechanical platform. There are parts and harness design techniques available to make this work easier to accomplish on harnesses installed in a very integral manner in the equipment.

The harness designer

Harness design is not generally considered to be a glamorous role or one which confers a particularly high status. Nevertheless a particular blend of electrical and mechanical design skills is required and the design tasks demand careful, even grinding attention to detail. Unfortunately the detail is often skimped with only vague attempts at optimising designs to the particular requirements of an application. Furthermore harness design is often left until a very late stage and the resulting time pressures can increase the likelihood of expensive mistakes being made. For example:

- Electrical interference disrupting the gun stabilisation system in a main battle tank is a problem with associated costs that far outweigh those of the wiring harness.
- In civil aviation there have been some recent accidents attributed to such wiring faults as wrong connections or inadequate protection for the operating environment.
- Wiring harnesses are assembled into many products

such as cars and military vehicles, at an early stage, and testing is not possible until the final stages of assembly. It is then extremely difficult to rectify any problems in the wiring harness and again the costs of mistakes can far outweigh those of the wiring harness.

Because of these risks and the somewhat thankless nature of the work, harness designers often tend to be somewhat cautious. They are certainly not susceptible to glib sales patter from computer salesmen and they, quite rightly, demand extensive proof of the capabilities and benefits of using computer design aids before trying such techniques. Moreover, due to the time pressures under which they work, harness designers do not have the patience or forgiveness that many CAD systems seem to expect of their users.

Computer solutions

Given the type of analysis work and volume of detail involved, wiring harness design would seem a natural candidate for computerisation. But there are no standard software packages available, or at least none that provides more than a limited amount of functionality to help the wiring harness designer. This is because, compared with the market for general-purpose 2D draughting, wiring harness design is a highly specialised and small segment of the computer-aided-design (CAD) market. Therefore, we decided to develop our own wiring harness design software for use with a general-purpose CAD system for the drawing work.

The first attempt we made was over 12 years ago and used a CAD system which ran on DEC minicomputers and engineering workstations; Unfortunately the equipment was so expensive as to preclude its use by all but a few dedicated operators. Also in the 1980s only limited means were available for interfacing application software with CAD systems.

We began our second attempt three years ago using low-cost PCs running Microsoft Windows. To provide the necessary drawing functions we selected Visio as it was the only CAD system able to fulfil all our criteria, namely:

- *Affordable:* The standard Visio system costs less than £100.
- *Easy to use:* Unlike many CAD systems, it was designed from the outset to run under Windows and the user interface is familiar to anyone who has used any of the Microsoft Office applications. Ease of use was a major consideration as we wanted to make the system suitable even for engineers who only occasionally need to do some design or to work with designs from their colleagues.
- *Schematic drawing capabilities including connectivity and attribute handling facilities:* The drag and drop Visio drawing system is ideally suited to the schematic style of harness drawings. Connectivity and attribute management facilities are also very well implemented.
- *Programmability:* Object linking and embedding (OLE) automation facilities allow other programs to access the Visio drawing objects, their properties and methods. Visio was one of the first CAD systems to adopt this technology. Previously CAD systems had to be programmed using special purpose macro languages, files containing command sequences or by using calls to subroutine libraries. OLE automation provides a much more flexible and powerful method of integrating custom software which can be written in any of the general-purpose programming languages that support OLE automation.
- *Drawing, text and spreadsheet functionality:* Although Visio is primarily a drawing system, it includes many of the basic functions of a word processor and spreadsheet. This is important because our harness design documents include an assembly drawing, a wiring schematic, parts list, wire list, labour estimate spread sheet and design notes. Also most CAD systems generate files containing single drawings which we believe is too restrictive for harness design documents. The multi-page documents that can be held in a single Visio file mean that all the details associated with a harness design are easier to manage and to E-mail.

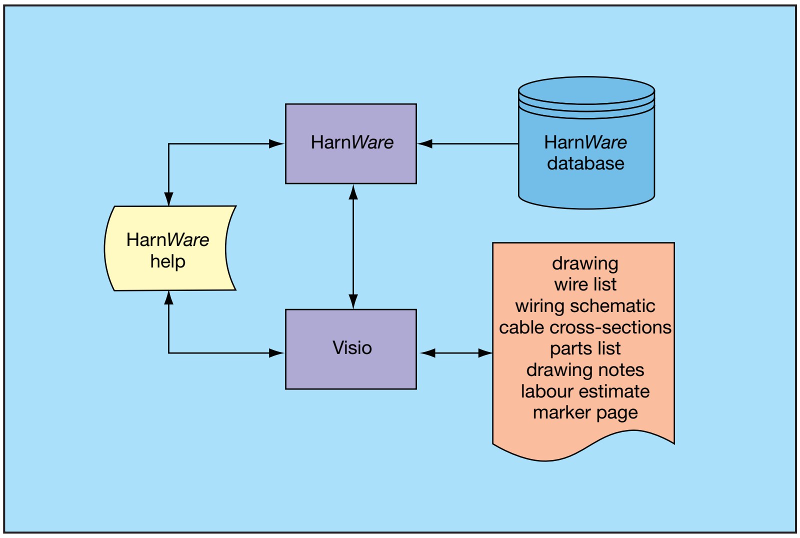

Fig. 1 Harn*Ware* harness design system

Harness design system

Harn*Ware* is the name chosen for the Raychem harness design system (Fig. 1). The software is written in Microsoft Visual Basic and currently comprises about 50 000 lines of code. The design database includes 60 000 Raychem wiring harness products plus many material, finish and other permu-

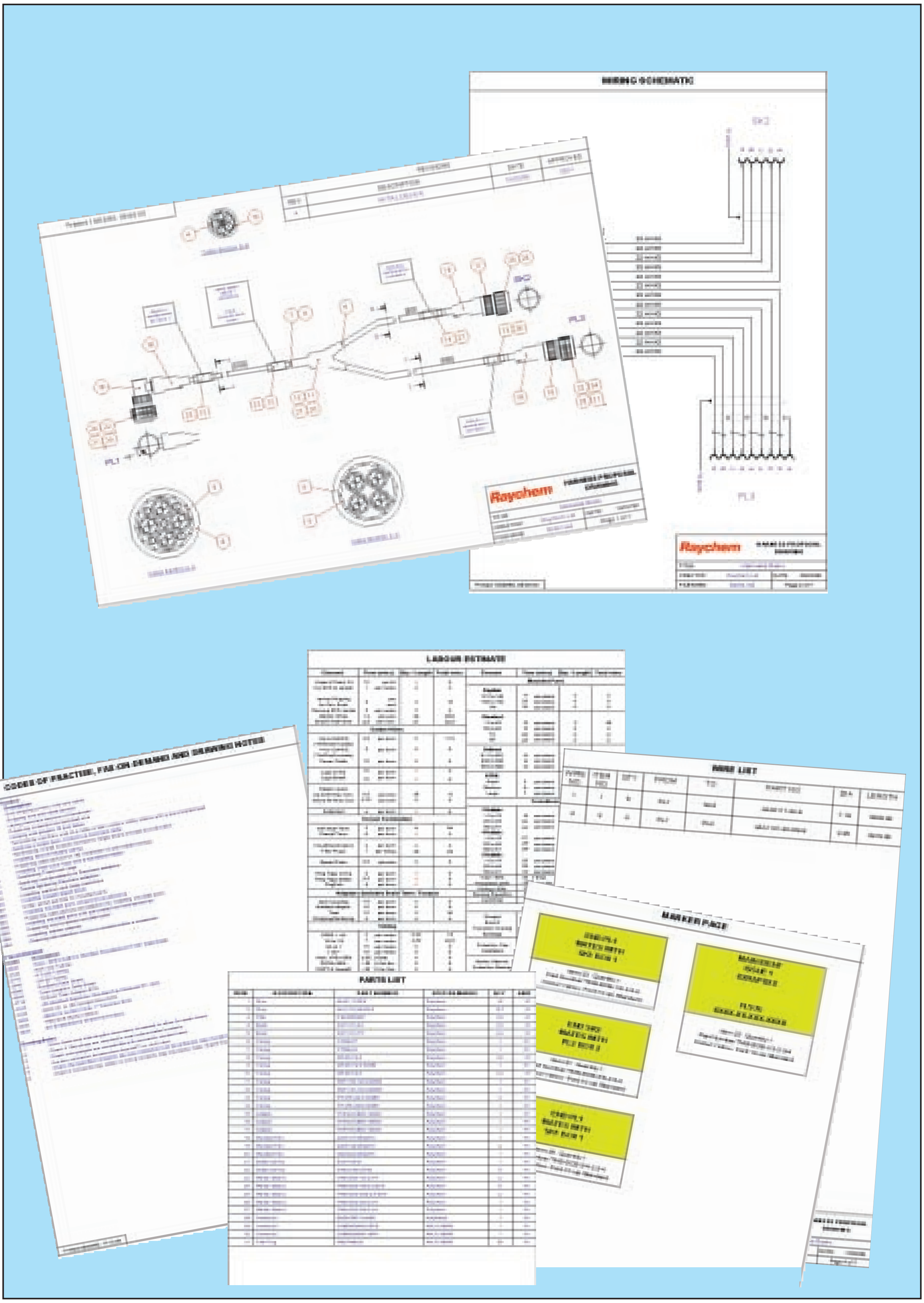

Fig. 2 Some pages from a sample Harn*Ware* document set

tations. Also included is online help for guidance on using the system and on wiring harness design procedures and products.

The starting point for the system is a simple harness assembly drawing. This is created using Visio to drag and drop shapes into the drawing. The shapes automatically snap and glue together, so that it does not take very long to produce a high-quality drawing. Fig. 2 shows some pages from a sample Harn*Ware* document set.

Factors such as minimum and maximum operating temperature and any required Military or Defence Standards are entered. This, along with such information as the need for fire resistance or the need to withstand nuclear agents, is used to narrow down the choice of harness material systems.

A design wizard (Fig. 3) is used to analyse the drawing and to generate a suggested design sequence. When the mouse is moved over the parts listed by the wizard, Harn*Ware* outputs such details as dimensions, materials and connections between parts. By clicking a part in the list the appropriate shape in the drawing is highlighted and the form used for selecting that particular class of part is loaded. For example, the form used to select wire contains options for various types of wire suited to different temperatures and environments. Guidance is also available for choosing the wire gauge most suited to given current loading, ambient temperature and other conditions (Fig. 4).

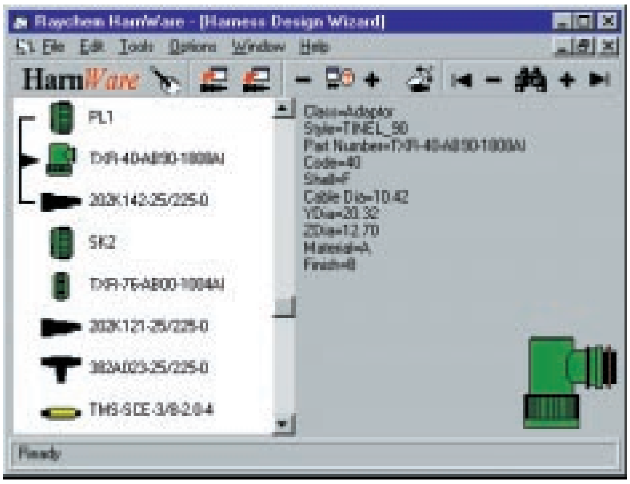

Fig. 3 Harness design wizard

Wire lengths are calculated automatically by tracing routes through the harness and applying allowances for certain parts through which the wires pass. For example, if a wire is routed through a right-angled adaptor a small amount is added to the length to allow for the wire bending around the corner.

The key steps in selecting the optimum part to use in a particular harness design situation include (Fig. 5):

- On clicking the part in the drawing or design wizard, Harn*Ware* obtains design data from the shape and those with which it is mated in the assembly drawing. For example, in the case of a Raychem boot, the style of part is determined by the drawing shape and the required diameters are obtained from the mating harness leg and adaptor.

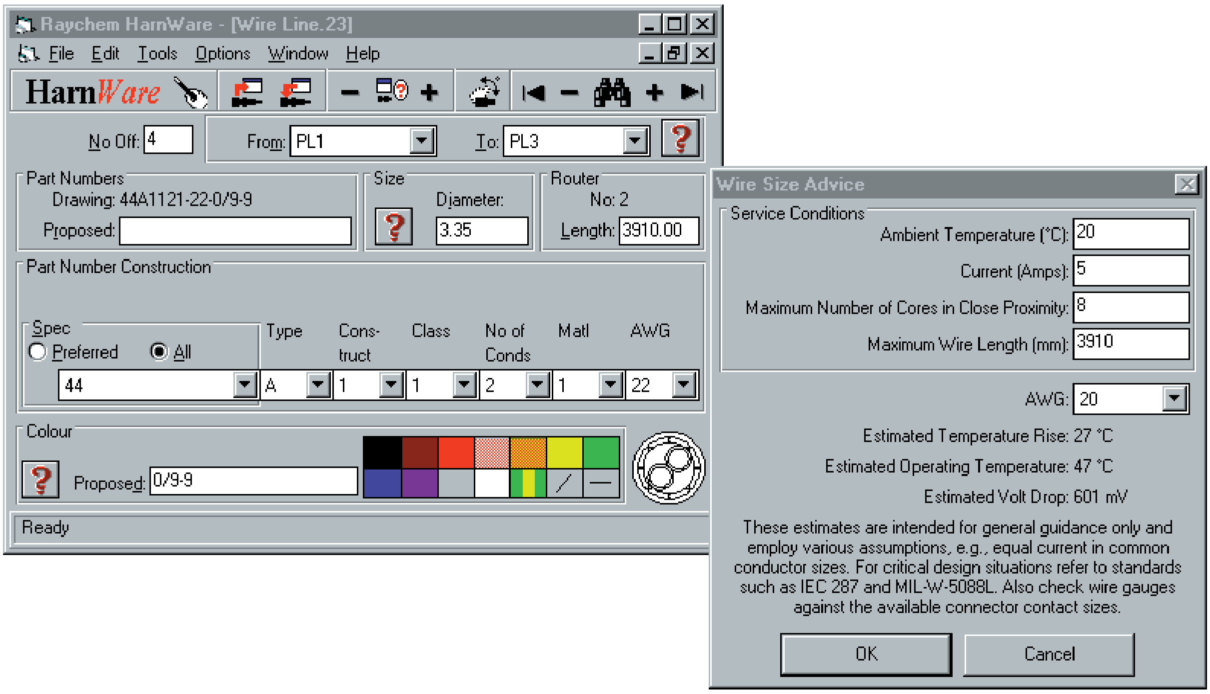

Fig. 4 Guidance on choosing wire type and wire gauge

- The database is then searched for parts which are suited to all these dimensional, material and other constraints. In many cases several parts that could satisfy the constraints are found and are listed in order of preference.
- Information on each part is output and the designer is free to choose any of the parts listed. Therefore, when for example space is limited the designer may choose a smaller part than the one that would normally be preferred.

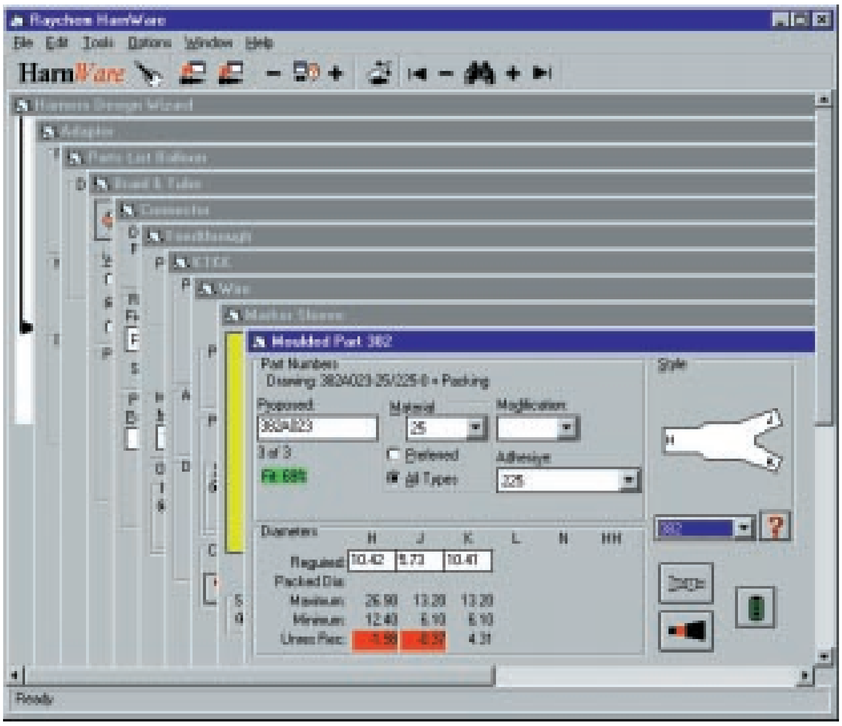

Fig. 5 Route to selection of optimum part

Five more examples of the various analysis options are:

(i) The design checker analyses the contents and structure of a design against a set of rules. Where potential problems or deviations from 'best practice' are found, the drawing is flagged with warning messages. These messages are each linked to the online help system which contains additional explanations and details of the problem.

(ii) The labour estimator analyses the parts contained in the design and certain aspects of the structure of the harness. The results are automatically inserted into a spreadsheet containing standard assembly time synthetics. 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.

(iv) 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.

(v) Alternative lays of cables containing mixed diameter wires can be automatically analysed to identify the smallest diameter and most even construction.

Benefits achieved

Harn*Ware* was originally intended for in-house use by Raychem engineers. But even during the first year when the system was at an early stage of development, a number of customers expressed an interest in using the system. It is now used by many companies in countries around the world including Europe, the USA, Japan, Israel, South Africa and Australia. We have recently added a mechanism for translating harness design phrases included in Harn*Ware* documents into other languages, including those such as Japanese, Korean and Taiwanese that use extended character sets.

One of the key features of the system is that it is used interactively. The choices and calculations can always be modified by the engineer in order to suit specific requirements. It is also easy to modify the design constraints and to analyse alternative design solutions.

Users of the system have reported benefits in four key areas:

(i) Selection of preferred parts to ensure best delivery and price.

(ii) More detailed and accurate designs and better quality documentation.

(iii) Faster designs and quotations, in some cases up to 20 times faster.

(iv) Increased confidence that each part is compatible with the intended service conditions and with the mating parts.

We believe we have proved, even to the most sceptical harness designer, that computers can help to produce better designs more quickly.

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