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Interference Control Components

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Case History: Ferrite Assemblies for VDE Specifications

The U.S. manufacturing sector has just come through a 1988 export boom. Forecasts for 1989 predict another 10 percent rate of growth, but there is very little known about the contribution and participation of small companies. The major increase that is expected in our export rate again this year may, in fact, derive largely from a ground swell of exports from small and mid-size companies adapting to a worldwide sales strategy (*Business Week*, January 27, 1989). Current statistics indicate that although there are 100,000 exporters in the United States, only 3,600 are major players and more than 86,000 are just "occasional" exporters. The remaining 10,000 do business abroad more frequently, but not in significantly high dollar volumes.

Small companies typify the supply infrastructure of the RFI products market. To date, most have been content to follow the general growth patterns of the U.S. electronics industry, but now there is a strong tendency to diversify independently into foreign markets. Often, larger companies already have a comfortable overseas business base. For example, Tektronix Inc. of Beaverton, OR, derives 45 percent of its sales of test equipment from overseas.

It is the prevailing viewpoint that marketers of instrumentation, medical equipment, scientific and test equipment and computer-related products have the greatest current export opportunities. Certain problems are unique with overseas sales, and price sensitivity (with shipping costs and tariffs) is the first concern. Pricing concerns are exacerbated by fluctuating exchange rates. Then there are political questions such as protectionism and the increasing coalescence of the European Economic Community. Finally, there are various regulatory agencies to contend with regarding product performance and safety requirements.

VDE Regulations

The West German RFI laws are now commonly used throughout Europe and are known as VDE regulations. The VDE (Verband Deutscher Elektrotechniker) is the Association of German Electrical Engineers. The German equivalent of the FCC is their FTZ, the Fernmeldetechnishe Zentralamt, or Central Telecommunications Office. Importers of products generating radio frequencies between 10 kHz and 3,000 GHz are required to qualify for an individual permit (Class A) or a general permit (Class B). The Class A permit has less stringent requirements but calls for testing by VDE. The Class B permit allows a self-certification process and, for this reason, many companies elect to suppress emissions to meet the stricter Class B specs because this provides for a quicker overall process of getting their products into the European markets.

Recently Biosystems Inc. of Rockfall, CT, became interested in marketing products for the first time in Europe. Biosystems is a leading manufacturer of atmospheric monitoring instrumentation with advanced sensor technology; its products have increasingly incorporated electronic and computer components, culminating in its latest product, "Posi-Chek" (see Fig. 1). The device automatically tests the major functions of self-contained breathing apparatus (SCBAs or respirators) for fire fighters, industrial users, recreational products, etc., by integration of a computer, keyboard and video monitor with a system of pressure transducers and a pressure source. The computer circuit controls all of the tests. The user inputs data in response to prompts displayed on the video screen. Test results are displayed on the screen, and hard-copy breathing resistance curves, along with summary test data, are printed out on a graphics printer. Any type of respirator device can be tested quickly.

Figure 1—Posi-Chek SCBA Tester (Manufactured by Biosystems, Rockfall, CT)

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VDE Testing

Jeff Whynall, Biosystems' director of engineering, assigned the VDE testing to Dragerwerk Ag of Lubeck, West Germany. Testing was performed to VDE Regulation 0871 Class B, which addresses RFI emission limits for industrial, scientific, medical, EDP and similar purposes; and to VDE Regulation 0877, which specifies the measurement procedures. Twelve units were tested, and the standard VDE format was followed: namely, conducted emissions from 10 kHz to 30 MHz; radiated emissions, electric field from 30 to 1,000 MHz; and radiated emissions, magnetic field from 10 kHz to 30 MHz. The results in each area were analyzed and properly addressed.

Of interest to this discussion is the electric field radiation. Test results indicated that Class B limits were exceeded (Fig. 2). Various measures were suggested as corrections for the follow-up testing. One was to be sure that contact areas on the back panel and chassis seams were paint-free and in good contact where the line filter was mounted. Similar care was to be taken where chassis members met, to eliminate slots through which radio frequencies could escape.

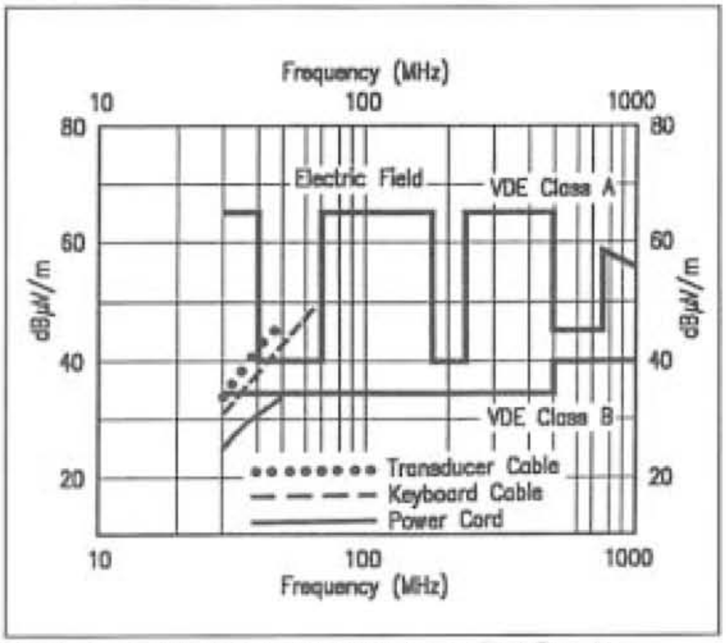


Figure 2—Initial Electric Field Radiation Test Results

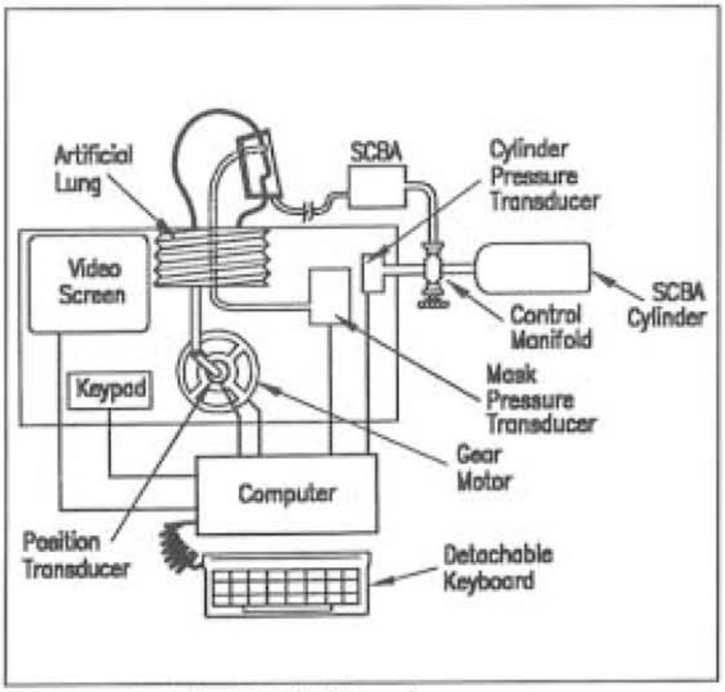


Figure 3—Posi-Chek Cable Network

Because radio interference sources with dimensions of less than one-tenth of the wavelength of the interference frequency usually radiate their RFI power at frequencies above 30 MHz by way of the main cable (which acts as an antenna), the cable network was routinely identified as an area requiring attention (see Fig. 3). Cable measurements can be conveniently performed by using an absorbing clamp, which serves as an acceptable substitute for the field strength method, specified under VDE 0877 part 3 and VDE 0875 part 1/11.84. Using such clamps, tests were recorded for the keyboard cable, the internal low/high pressure transducer cable and the power cord. Most areas were close to, or exceeded, the Class B limits.

It was agreed that corrective measures for each problem area could be performed in the lab on a "quick-fix" basis. The interconnect areas on the chassis members were cleaned of paint overspray, and tight connections were made. But the cable network remained to be addressed. The decision was made to use a split-ferrite assembly inside a plastic encasement with integral mounting capabilities (see Fig. 4). Sample assemblies were available from a laboratory engineering kit already on hand, and they were straightforward to engineer with regard to easy postproduction RF attenuation performance and installation.

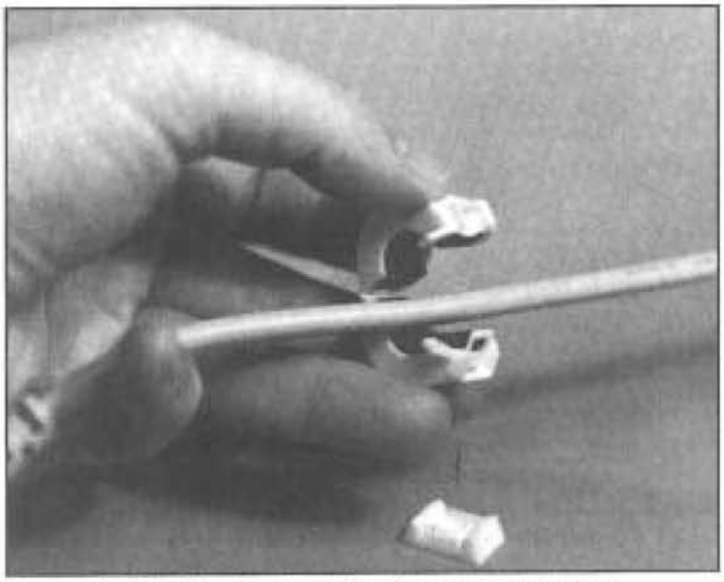


Figure 4—Split-Ferrite Assembly Attachment Method

The transducer network cable, for example, was engineered as follows. By referring to Fig. 2, it can be seen that the frequency where maximum attenuation is required is 48 MHz. At this point, the Posi-Chek measured 44 dB, versus a Class B limit of 35 dB. The characteristic that makes ferrites effective in RFI suppression is their variable sensitivity to frequency. With a ferrite installed as a suppressor, lower frequencies will pass with no significant loss. But above the frequency where $(\tan \delta)/\mu_i$ climbs sharply, the signal couples with the ferrite to create an impedance that is quite high with respect to the rest of the circuit. The offending RFI is immediately and consistently blocked out. The figure (μ_i) in the previous statement is the symbol for initial permeability, which is the most common way of expressing ferrite performance. It is also the property that determines the ratio of magnitude of magnetic induction to magnetizing force.

Ferrite Permeability Formulation

The ferrite permeability formulation that most closely fit the profile of the pattern of frequencies was an 850 μ_i (Fig. 5, A). Although this was on the lower portion of the attenuation performance curve (Fig. 5, B), a higher permeability (for lower frequencies) would tend to drop off quickly with regard to attenuation of any higher frequency harmonics thought to occur in some operational modes.

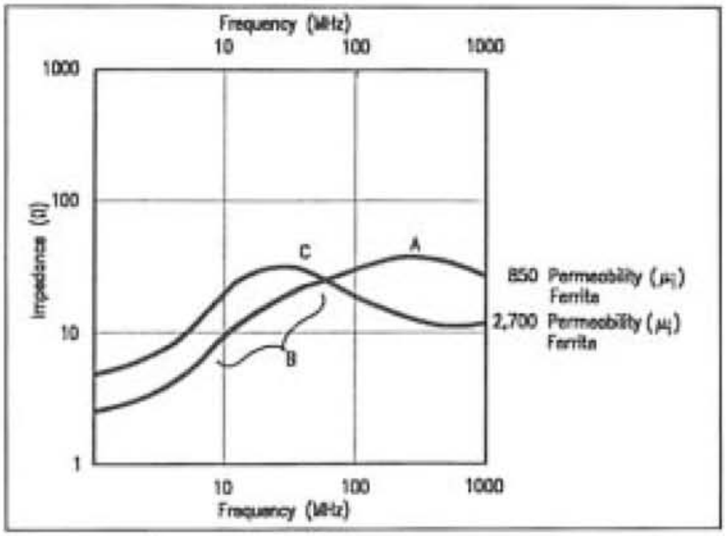


Figure 5—Typical Attenuation Profiles

From a cost-effectiveness standpoint, it was also necessary to consider the ferrite formulation consistency, which directly affects the expected range of variation in attenuation performance. Consistency differs substantially with various manufacturers. However, ferrite performance specifications should be held within ±5 percent of nominal values so that it is not necessary to specify an excessively large and more expensive configuration of ferrite to be assured of proper attenuation and consistent performance (see Fig. 6).

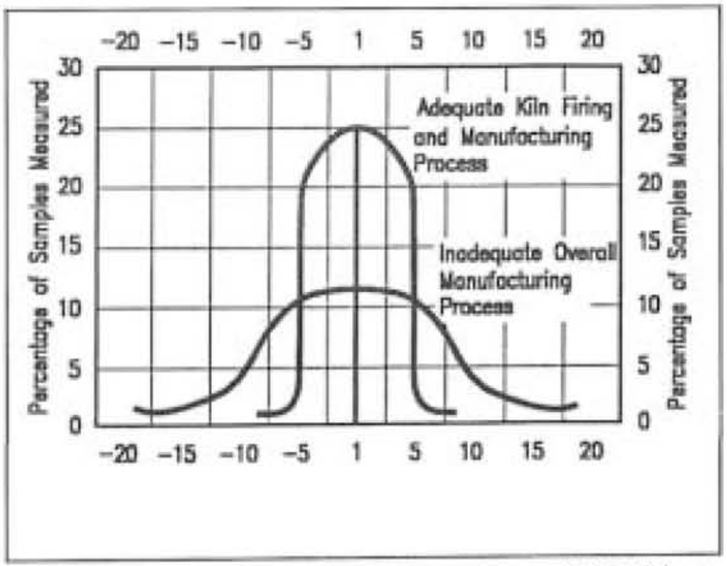


Figure 6—Percentage Variation of Impedance at 100 MHz: 850 μ_i

Once the proper ferrite permeability formulation is determined (along the X-axis, or frequency axis), it is a simple matter to position the attenuation required along the Y-axis by calculating the increasing effects of larger cubic volumes of ferrite as applied to the circuit in question (see Fig. 7). As additional ferrite volume is added, impedance increases almost on a direct percentage basis; for example, by doubling the amount of ferrite, an almost 100 percent increase in attenuation will occur.

Ferrite is more effective if the circuit impedance is low. With a high circuit impedance, or when a slight fine-tuning increase of the impedance is desired, it is possible to increase ferrite effectiveness by increasing the number of turns of the cable through the ferrite (see Fig. 8). This yields an impedance increase within the range shown in Fig. 9, conserves the amount of ferrite required and allows for some adjustment if necessary.

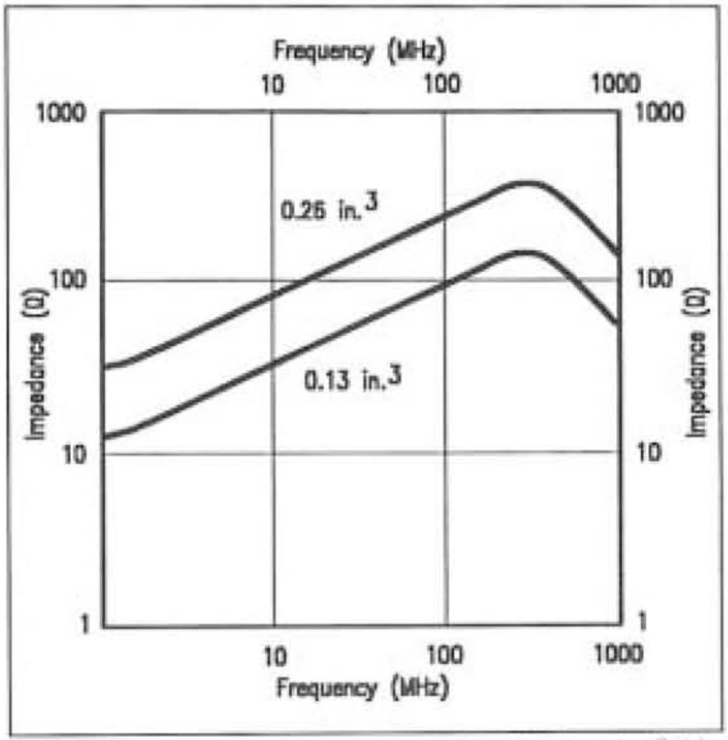


Figure 7—Comparison of Impedance in Relation to Cubic Volume: 850 μ_i

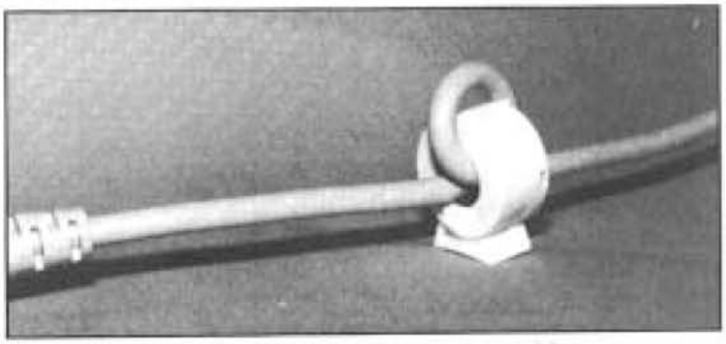


Figure 8—Double Turn through Ferrite Assembly

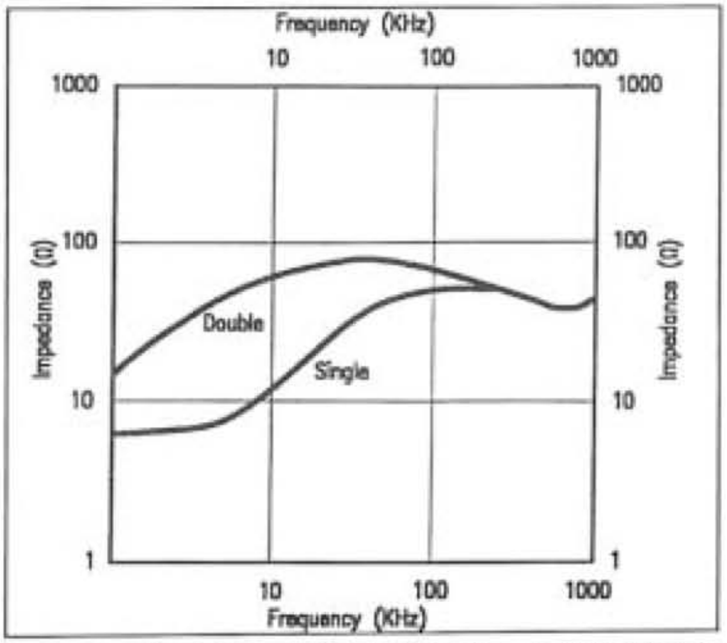
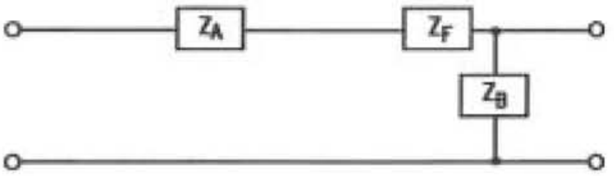


Figure 9—Attenuation versus Single or Double Turns through Ferrite

With the preceding performance guidelines in mind, it is a quick matter to calculate the expected insertion loss, which is the ratio of voltages with, and without, the ferrite filter in the circuit. The voltage ratio is converted to dB by converting the result to $\log_{10}$ and multiplying by 20. For Biosystems' Posi-Chek, a known ferrite design (see Fig. #10) with an impedance of 62 dB at 48 MHz was eventually selected through such a modeling procedure and the expected impedance characteristics were calculated as follows:

$$IL = 20 \log_{10} \frac{(Z_A + Z_B + Z_F)}{(Z_A + Z_B)} \tag{1}$$



where,

IL = insertion loss in dB
Z_A = source impedance
Z_B = load impedance
Z_F = ferrite impedance

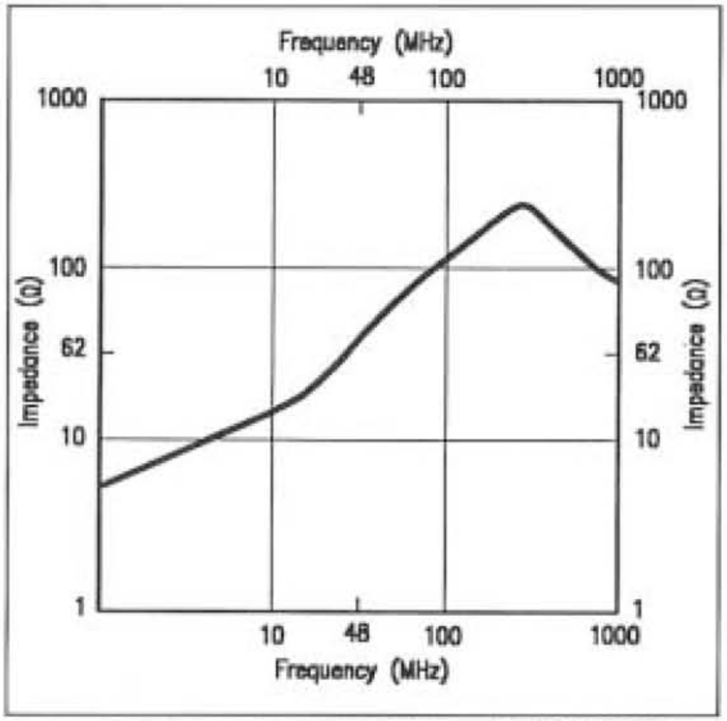


Figure 10—Attenuation Performance Part No. TC28B0937

In the case of the transducer network cable:

$$IL = 20 \log_{10} \frac{25 + 62}{25} \tag{2}$$

$$\begin{aligned} &= 20 \log_{10} 3.48 \\ &= 20\ (0.5416) \\ &= 10.832 \end{aligned}$$

Final Results

See Fig. 11 for final results with the ferrite inserted in the circuit. When compared to Fig. 2 with no ferrite, it can be seen that Biosystems was able to achieve a 10 to 11 dB difference at the highest frequency and a corresponding decrease at the lower frequencies.

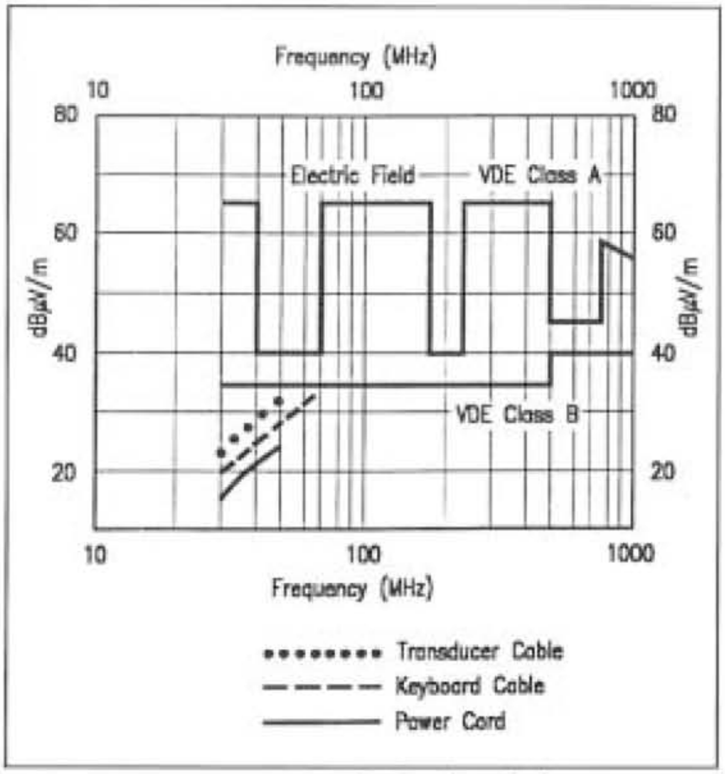


Figure 11—Final Results with Ferrites Installed

Three ferrite assemblies were used in total, one on each cable assembly. Installation was initially a retrofit for the units already built. The split-ferrite and snap-on configuration facilitated the retrofit, and was found appropriate as well for successive production runs for cable installations, since the snap-on ferrite could be installed last and acted as a clamp for routing and packaging the cables. It also provided assured RFI protection (see Fig. 12).

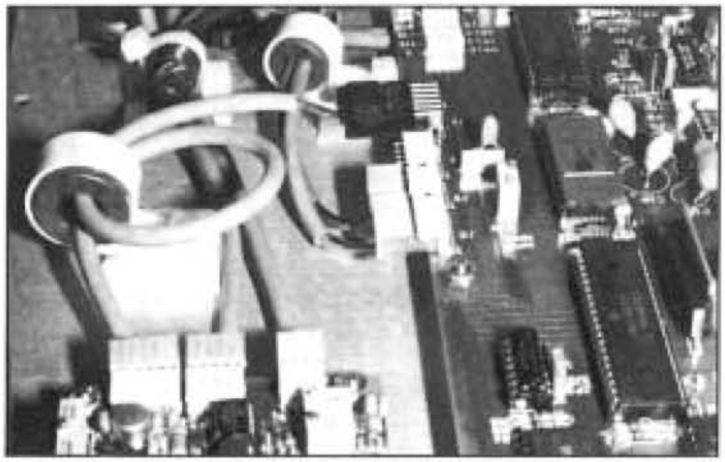


Figure 12—Final Installation

Biosystems has been shipping its Posi-Chek units to Europe in accordance with VDE specifications since the summer of 1988. Marketing executives report that European sales are running well ahead of projections for this product. They admit they were a bit apprehensive about the VDE requirements, and they attribute their unexpectedly easy experience with successful compliance largely to their discovery of snap-on ferrites.