Product Design for Precision and Purity

by Robert L. DeVries

IN AN INSTRUMENT of the complexity of the 8662A Synthesized Signal Generator, the circuit design is of the utmost importance in achieving a signal of precision and purity to the degree specified. Much careful thought and sophisticated engineering went into the circuit design of the various modules. To provide the proper environment for these complex circuits to perform to expectations under various environmental conditions, a lot of care also went into the product design of the 8662A.

Some of the items given special attention were shielding, modularity, grounding, decoupling, reliability, power consumption, serviceability, human factors, and environmental testing.

Shielding and Modularity

A frequency synthesizer has the general characteristic of having many frequencies present at one time in the various modules. Under some conditions of modulation and/or sweeping these many frequencies are rapidly changing. Unless a good job of shielding, decoupling, and isolation is achieved, there will be some unwanted frequencies at the output along with the desired frequency.

We wanted a shielding system that would give us the necessary shielding, low cost, and a modular approach. As the circuit design evolved we wanted to be able to adjust the volume of the shielded compartments to get maximum use of space without great expenditures in tooling for die-casting changes. As a result we designed a family of interlocking extrusions (Fig. 1). These include full-width, half-width, three-thirds, one-third/two-thirds, and end-plate extrusions. These may be assembled in any combination to best suit the circuit designers' needs and optimize board layout requirements.

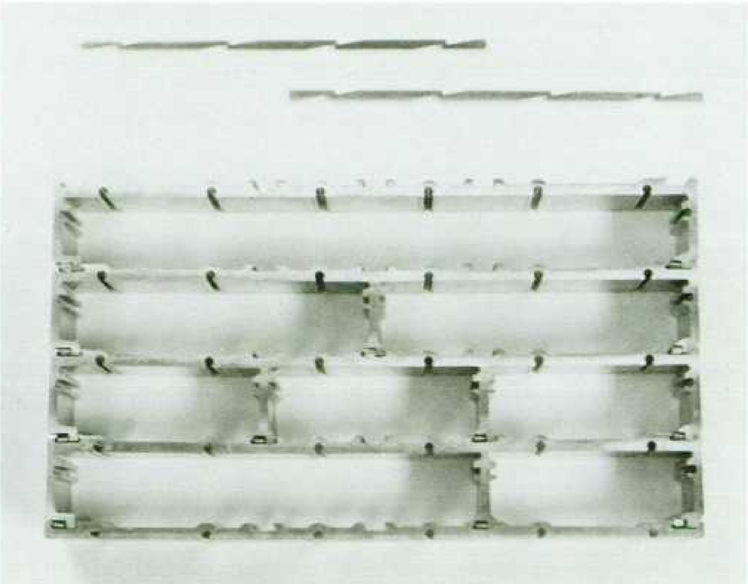

Fig. 1. *Interlocking extrusions provide a low-cost modular approach to internal shielding in the 8662A Synthesized Signal Generator.*

To seal the gaps where the extrusions interlock, we designed a shearing wedge that is inserted into an opening in the extrusion (Fig. 2). Pressure is applied to both ends of the wedge. It shears, wedges, and seals the joint at the extrusion interface. The shielding effectiveness at this joint is as good as if it were cast.

The shielding is further enhanced by using a ground plane on the extrusion side of the motherboard. On assemblies that have greater potential for leakage and radiation the motherboards are multilayer with a ground plane on the extrusion side, a ground plane on the other side, and dc and logic traces sandwiched between.

Along the edges of the extrusions we have a screw every 30 mm to minimize the gap length between the screws and reduce the possibility of leakage from the extrusions. To further minimize leakage we have included copper waffled gaskets at the interfaces between the extrusion covers and the extrusions, and between the extrusions and the motherboards to compensate for any irregularities at these inter-

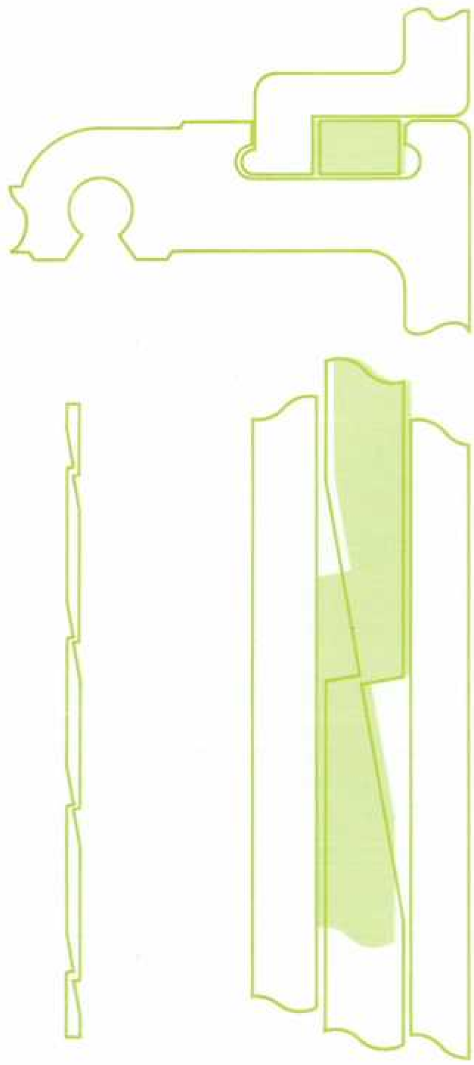

Fig. 2. *Shearing wedge seals the gaps where extrusions interlock.*

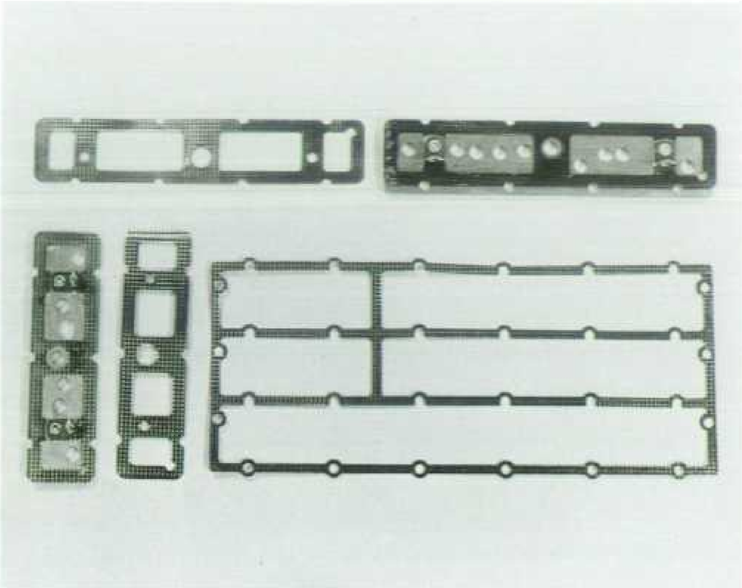

Fig. 3. *Copper waffled gaskets seal the interfaces between the extrusions and the extrusion covers and motherboards.*

faces (Fig. 3).

The motherboards and extrusions covers are extra thick to make them stiff and eliminate any tendency to bow and create gaps between the extrusion screws.

Grounding and Decoupling

In general, the high-frequency signals are routed by coaxial cable to the various circuits and connected at the top cover connectors. The low-frequency or dc signals are routed by means of multiconductor cables or motherboards. The more critical or sensitive plug-in boards get additional grounding by means of spring ground straps secured to two edges of the plug-in boards, which insert into the grooves in the extrusions (Fig. 4). These ground straps provide two important benefits. First they give us an intimate grounding scheme between the plug-in board ground plane and the extrusion wall. Next, they provide a very effective thermal path to carry the heat away from the board, to the extrusion, and then to the outside.

The RF and dc portions of the plug-ins are shielded and decoupled from each other by means of a beryllium-copper shield on the connector end of the board, which covers the decoupling network, surrounds the interface connector, and grounds the shield to the motherboard ground plane when the board is inserted (Fig. 4).

Reliability

Reliability was foremost in our minds throughout the project. High component temperatures generally mean high failure rates. To insure a lower operating temperature we have a cooling system that pulls air in through the rear panel, builds up a pressure through the center of the 8662A to force the air through and around the extrusions, and exhausts out the perforated side covers. The air cooling the power supply comes in the rear, goes past the heat sinks, and exhausts out the perforated side cover.

To insure reliable operation at any combination of line voltage and line frequency we selected a fan that would provide adequate air flow with minimum vibration and noise. To minimize phase noise we gave careful consideration to the vibrations caused by the fan. We shock mounted the fan, the crystal reference, and the crystal filters that are sensitive to vibration. We provide thermal isolation and baffling to the reference oscillator. We intentionally do not cool the oven, since this would waste power and make control of the oven temperature more difficult. To reduce the power dissipated in the 8662A we are using a switching-regulated power supply. A thermal cutout in the power supply turns the instrument off in case of a fan failure or if the temperature gets too high.

Reliability is further insured by using prescreened semiconductors and a more efficient power supply, derating of components, and careful thermal profile evaluation.

Serviceability

In addition to reliability, serviceability got special attention as the product was being developed. For such a complex instrument, the 8662A is easy to service. In addition to the error codes on the front panel and the internal loop-unlocked lights, all the plug-in boards are accessible from the top, test points are provided, extender boards are available, and the front panel pulls out and tilts down for access to the attenuator, filter, and panel components.

The motherboards are in one plane, clearly marked, and very accessible. The major assemblies are removable with a minimum of effort. Each assembly is mechanically independent. The operating and service manual that accompanies the instrument is thorough, complete and comprehensive.

The rear-panel covers are easily removed for access to the power components, fan, VCO, and reference oscillator. Sturdy rear feet are provided for the user who wishes to operate the instrument standing vertically.

Human Factors

The front panel is designed for ease of operation. The sweep and marker functions are on the far left.

Function, data, and increment keys are in the center sec-

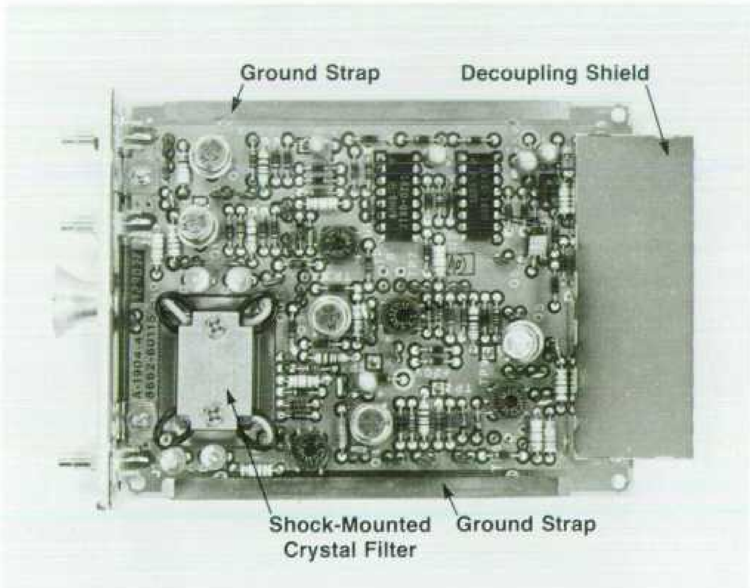

Fig. 4. *Spring ground strap provides additional grounding for sensitive or critical boards. A beryllium-copper shield decouples the RF and dc circuits.*

tion. This section is used most often and is tilted to provide a more natural feel for the user. The connectors are on the far right to keep cables away from the keyboard area. Generally, the operating parameters are input working from left to right across the keyboard.

The rotary pulse generator (large knob on the right) has been included for those users who still like to tune a signal source by turning a knob.

Environmental Testing

The completed instrument is rugged and strong and has gone through repeated vibration, shock, and package drop tests. The tests have included temperature and humidity, environmental extremes, radiated and conducted interference, magnetic radiation and susceptibility tests and many other tests. The switching power supply went through several hundred hours of life tests, on/off cycling, high/low line operation, shorted outputs to ground, shorted outputs to each other, overvoltage and overcurrent testing. The objective of all of this testing and careful design is an instrument that should give the user years of trouble-free service.

Acknowledgments

Throughout the development of the 8662A there have been enthusiastic support and contributions from many departments here at HP. While it's difficult to name all those involved I want to thank them all for their support. Specifically I want to thank Dan Derby, Jim Stewart, and Lynn Beckley for their excellent front-panel marking, layout, and design, Betty Dodson and her coworkers for the careful detailing and layout of the 78 etched circuit boards in the 8662A, Bill West for his well engineered, reliable pushbutton switch which was designed for this product but because of its size, convenience, and reliability is used on many HP products, and Bob Guisto, John Ellis, Walt Weightman and Kress Alexander for their contributions in tool design, extrusion design, wedge design and shielding investigations. Accurate product documentation and preproduction part procurement are the results of efforts of Ruby Miller, Myra Slade, Mary Richards, Bob Cirner, and Hans Voorby. A special thanks to Shirley Flock and Edna Fleck who provided us with many excellent suggestions to improve manufacturability and reliability.

Robert L. DeVries

Bob DeVries joined HP's test department in 1956, after serving as a U.S. Air Force radar technician for four years and a salesman for three more. In 1959 he became a product designer, and in the next 22 years helped design an impressive array of HP oscilloscopes, tape systems, and microwave products, the latest being the 8662A Signal Generator. He is named inventor on a connector switch patent. Bob was born in Spokane, Washington. He's married, has two children, and lives in Palo Alto, California. He enjoys photography, electronics, high-fidelity systems, woodworking, and bicycling.

Verifying High Spectral Purity and Level Accuracy in Production

by John W. Richardson

A PERPLEXING SITUATION usually exists with the introduction of a new, state-of-the-art product such as the 8662A Synthesized Signal Generator. How does one test, with sufficient margin, the various critical performance specifications without losing production line efficiency?

For the 8662A, two critical specifications are spectral purity and output level accuracy. In both cases no existing equipment is available to measure these parameters efficiently with acceptable measurement error. Spectral purity (phase noise and spurious) is difficult to measure without a suitable low-noise receiver to resolve low-level signals near the carrier. Output level accuracy presents a problem because of difficulty in accurately measuring RF power over a 150-dB range. The solution to these measurement problems, along with the solutions for most other signal generator specification measurement problems, has taken the shape of the HP-IB test system shown in Fig. 1.

Measurement of spectral purity requires a spectrally clean, low-noise receiver or spectrum analyzer with noise performance at least equal to that typical of the 8662A. Existing spectrum analyzers have noise performance about 20 dB worse than the 8662A for offsets less than 100 kHz and require a 30-Hz bandwidth to measure the 90-dB spurious specification with sufficient signal-to-noise ratio. Measurement of very low output power levels also requires a receiver or spectrum analyzer with a sensitive, low-noise input. Such a receiver has been incorporated in the HP-IB test system.

The heart of this distributed test system and the key to