Service Manual

Solid State switching design

Roundtable Discussion

(Vol. 7 No. 4)

Solid-state switching design was the topic of a letter addressed to Christopher Feiereisen of Manitowoc, Wisconsin. He had inquired as to which kind of system, hard-wired or programmable, would be most widely used in the future. The reply stated that future system design will be determined by the collective actions of organ technicians rather than by the designers or their devices. Following is a summary of that letter, whose author wishes to remain anonymous:

No one could question the functionality of the electro-pneumatic or electro-mechanical devices that have traditionally been used in pipe organs with electric action. They are fairly fast, easy to understand, and made of parts that are easily obtained or duplicated. The switching systems that were produced 60 or 70 years ago can still be restored and will be capable of efficient service for as far into the future as can be seen. Their principal drawbacks are their speed (relay=delay,) lack of flexibility, physical bulk, unreliability and higher maintenance costs resulting from burning contacts, binding hinges and the need for periodic releathering.

Electronic switching systems, by contrast, are faster, smaller, somewhat more flexible and more reliable. They eliminate all moving parts. These systems can be understood, repaired and modified by any competent pipe organ technician. One such electronic unit was even reconfigured for a different organ installation without much trouble. Although a few replacement transistors were difficult to locate, substitutions were made that worked fine since the transistor functions were so basic.

The pace of evolution in electronics is so rapid that a design is nearly obsolete by the time it hits the market. Discrete transistors are now disappearing like vacuum tubes. Basic commodities, such as wood, leather and copper wire, will probably always be available; specific electronic components will not. The more basic an item is, the more likely that it will be available in the future. As you move up the ladder of sophistication, however, the problem grows. Just finding replacements and keeping them in stock is already a problem for a device as simple and diverse as a pilot light. The following story illustrates this point:

About 15 years ago, Bill Zabel designed (brilliantly, for that time) a multiplexed switching system. It is fast, small, and very flexible. Bill's excellent manual, combined with the ingenious idea of using an earphone as a troubleshooting tool, gives the technician a fighting chance to maintain the system. He overdesigned every piece of the system so it is very reliable. He designed it with parts that were at the time so generic that it seemed they would always be available. However, it uses integrated circuits rather than discrete components. Even though the family of parts (4000-series CMOS) seemed so "vanilla" at the time, they are not readily available today. Bill stocks many integrated circuits, and his manual contains other sources for them. He has been updating the design of his system to use integrated circuits that are presently available.

By using a general-purpose computer and general-purpose hardware, it is possible to have the functions (or "intelligence") of pipe organ switching reside in computer memory rather than in a wiring configuration. In a traditional "hard-wired" system, you make changes by wiring in additional switches or by other wiring changes. You control it. The price you pay for that ability is the time and space required for the changes. In a computer-driven "intelligent" system, you change no wiring (except, perhaps, to run a new conductor for a new stop,) but the computer program must be changed. These systems are now built so that configuration changes to the program can be made by the user. These systems are fast, small, very flexible, and have integrated combination action and record-playback functions. Perfect, no?

Not quite. How many technicians or organists want to interact with a computer screen just to use the organ? Further, even though solid-state components will theoretically last forever, heat and voltage surges, like a nice Midwest lightning storm, are their mortal enemies. Sooner or later, something will have to be replaced. Although computer-driven units contain self-test programs, the system itself must run to execute them. What do you do if the system will not run? Are you capable of isolating the bad parts? Once a system is orphaned by its manufacturer, will parts or technical aid be available?

Look at a personal computer that was sold only ten years ago. It looks like an antique. The parts inside are even more rapidly obsolescent. These products are produced with a life expectancy of about five years. I would wager that in only another ten years, it will be impossible to find parts for today's processor-controlled systems. Pipe organs are made with a life expectancy approaching a century. Are you willing to ask a client to replace the instrument's brain with the next hot product when this one fails? That, I think, is the question that you organ technicians will have to answer before you spend your clients' money for today's high-tech systems.

What to do? You have to weigh the benefits against the costs. I am not advocating total abandonment of technology. In balancing the benefits of space, flexibility, and wiring simplicity against the risks of maintenance difficulty and possible obsolescence, I would choose a low-tech electronic approach. I would look for a system that I totally understood, that I could modify myself, and that is maintainable for at least 25 years, even if I had to keep parts in stock for future needs. Low-tech means that the function would probably be wired in so that I could make changes if necessary. Low-tech means a system with only a few types of active components; few enough that I could easily stock replacement parts. The risks that I would be willing to take for my own instrument are far different from those that I would impose on a paying client.

Your question asked where I thought the market was going. It will go where you want it to go. If I were in your position, these are the things that I would consider before recommending a system that so affected my reputation. I hope these thoughts will prompt you to look beyond the hype and consider the long-run effects of the choices you make. It is inevitable that tinkerers will continue to find what they think are better ways to accomplish the switching function. Each year there is something better than last year to do the job. I am afraid, however, that most solutions overlook the longevity and maintainability requirements of the average pipe organ installation. The temptation to take short-term benefits without considering the long-term cost is undeniable.

Readers reply to the above:

Albert Sefl of Novato, California believes that the "diode" relay offers the best combination of reliability and availability of basic replacement parts "with the exception of some output driver chips for units that don't use discrete transistors." He cautions builders to be aware of the added installation time needed for products requiring assembly of components onto bare boards and those with internal wiring connections.

Allen Miller of Glastonbury, Connecticut, an organbuilder whose firm now produces and supports the Z-tronics system discussed in the June issue, elaborated on Z-tronics component availability and the design of other switching systems. His remarks are based on 30 years experience with various types of solid-state switching:

The Z-tronics system was designed around standard TTL 7400 type devices and the 4000-series CMOS, which was very new technology at the time. The 4000 series became very popular and this family of parts is readily available, as is the older 7400 series. Over the years, improvements have been made in the 7400 series designs, and newer versions of these chips are available which operate more efficiently, use less current, and run cooler. Many of these chips are now also available in compatible CMOS versions.

The Z-tronics system remained virtually unchanged for twelve years, at which point two of the boards were modified to accept a different integrated circuit. The new 1488 RS-232 computer serial line driver chip, which replaced the original Teledyne HINIL series 321 chip, is common enough that you can buy them at your local Radio Shack store. The HINIL series 303 was replaced by a TLC556N, also a more common chip. As for the other Z-tronics components, we find as we restock our inventory that sources are competitive and prices are dropping due to the economies of mass usage. We have no reason to fear the demise of the integrated circuits presently used in the system.

Solid-state is here to stay. Relays have progressed from requiring a large room to fitting in a shoe box. Every year, the shoe box gets smaller and new switching features are added. In selecting a system for a particular organ installation, the buyer should focus on the quality of design and construction and look into the history and longevity of the system being considered. Find out if it uses standard parts or if special integrated circuits or operating equipment is necessary. Does the system always come up running when turned on, or does it have to "boot" from a mechanical device first? If a component fails, how much of the organ do you lose: one note, one manual, one stop, one division, one feature? Does the organ stop playing if the combination action malfunctions? How many parts can cause the whole organ to become unplayable? If the system uses a microprocessor, is it, or can it be, properly shielded so that the organ does not emit radio frequencies in violation of FCC standards?

When considering a computer-based switching system, remember that all functions are controlled by proprietary software programs that require special maintenance skills. Switching delays can also be a problem due to the fact that a computer must process information sequentially and can only do one thing at a time. The delays that result when too many keys, pistons or MIDI functions are called for all at once can affect the nuance of a performance, and some systems have been known to simply give up when under the hands of a virtuoso organist.

In contrast with computer-based switching, the "hard-wired" solid-state systems offer a more "nuts and bolts" approach to design and maintenance. The earliest diode-resistor matrix switching designs eliminated the problems associated with moving parts but increased the number of components and solder joints. Some introduced myriad connectors that can (and do) cause periodic failures. One popular system by Peterson Electro-Musical Products has been redesigned several times and is currently in wide use with a present reliability factor far greater than a comparable mechanical system.

Multiplexed switching designs offer the advantage of further reducing the number of internal connections between circuit boards. Unlike computer multiplexing, "hard-logic" multiplexing adds only a fixed 10-millisecond delay, just a fraction of the operating delay caused by chest actions and pipe speech. Z-tronics multiplexing units are sold as completely assembled and tested modules. The organbuilder completes a small series of internal connections to set up any unification and special switching features. While these connections are "hard-wired," they are easily modified by changing a single wire for each stop being altered. I have personally changed or added a custom stop for a specific use in a concert in a matter of a few minutes. By making these board interconnections, the organbuilder usually becomes familiar enough with the system to troubleshoot and maintain it himself. This philosophy has also given Z-tronics a large base of technicians who understand the system. Customers are not completely dependent upon the manufacturer for support.

There will always be builders who will experiment with the latest technology, as there will be those who stick with ancient, time-proven technology. Regardless of the technology being used, remember that any really good system should operate in the background and never require even a moment's thought on the organist's part; and hopefully, very little attention from the technician!