The 11400 Story

ET struggled from the chaos of reorganization, conflicting visions, market research and false starts in the Fall of 1982 as Tek's first raster display digitizing oscilloscope. Four years of difficult development followed as we created a totally new digital scope architecture climaxing in a spectacular introduction in the fall of 1986. ET set many new standards and expectations for digital scopes, such as live operation, high accuracy and resolution, self-cal, multiple channels, and a sexy human interface.

ET had always been a controversial project; this is typical whenever one is leading in new directions. ET was a necessary bold step to thrust Tek into new thinking about the future of oscillography; almost as a bonus, it was also a successful product in the market place, having the highest ramp-up rate of any new Lab Scope ever introduced! There were mistakes, to be sure, but overall Tek is better because of it. Already, many of ET's concepts and experiences are providing benefit to other products throughout Tektronix.

Overview

ET took its name from its descriptor "Equivalent Time", as it was intended to be a general purpose scope primarily for repetitive signals. ET was the Digitizing Scope in a new family that was originally conceived as an extension to 7000 Series called "7K-Plus". In time we came to realize the significance of our new products and the tremendous power beyond 7K, so we adopted a new family nomenclature "11000 Series" (later code named "Pioneer"). Three instrument clusters were envisioned in 7K-Plus: the low end at 150 MHz, the middle at 300 MHz, and high end at 600 MHz. Each cluster contained analog and digital mainframes and were to share common plug-ins. The first wave was targeted at the 300 MHz cluster, since that would address the largest market. ET was nomenclated 7863, 7853DP, and 11331 before finally becoming 11401/11402 (11402 was an eleventh hour skunk-works effort born out of concern for more bandwidth).

Many of ET's features changed little from inception; others changed dramatically. The 7853DP was to be a 300 Mhz mainframe with 10 bit 20 MS/s digitizer, ROM packs for specific application SW, an optional disk drive for user programs and data storage/transportability, an external keyboard for a "programming language", and color display option. In time, the ROM packs faded away due to lack of sufficient ideas. Disk drive lost favor to the argument that the scope could readily be connected to PCs, which were becoming very common. Color remained in the architecture but was dropped from the first product due to display quality/packaging/cost issues. Color was demonstrated in 1984 to verify the architecture.

There were a number of forces and several key areas of development in the ET program. Major forces included a drive for full product programability, easier and more intuitive operation, 7K compatibility, and architectural modularity....HW and FW. Key areas of development were human interfacing, new scope architecture, software, hardware, diagnostics, self-cal, and manufacturability. The requirement for 7K plug-in compatibility placed serious boundary conditions on some aspects of the design, even though it was eventually dropped; one could equally argue both sides of this requirement.

Human Interface

Initially, the human interface was more or less the traditional wall of knobs and buttons, though mode switches were giving way to direct access of desired functions, with software filtering out the illegal combinations. In the winter of 1982-83, a group of engineers and marketing people studied the entire concept of human interfacing to suggest new directions. The goal was a simplified interface that was not so intimidating as the 7854's 250 knobs/buttons! Their study resulted in a thorough understanding of the nuances of human operation, and many clear recommendations. However, we were hung-up on the "input device" (mouse, track ball, finger, light pen, knobs/buttons, etc.). An intensive workshop at Otter Crest eventually led us to the touch screen approach; it was software based (flexible, reliable) and direct: a user only had to touch whatever he wanted without fussing with locating something physical. The touch screen had its skeptics (as did all approaches), but as a team we agreed to give it a fair chance. We also agreed to a dynamic shallow-depth menu structure: the idea was to use FW to present only valid and meaningful functions when appropriate. This was to reduce front panel clutter, and allow for a reconfigurable interface; two knobs were considered more convenient than the industry trend towards zero or one. The use of "pop-up" menus provided a flexible means for presenting additional selection menus with only temporary clutter, and a visual presentation of the complete menu path. We realized that a truly "expert" user would probably prefer the direct access approach offered by the single layer wall of controls, but we believed that such expert users were becoming less common in deference to casual users who preferred a simpler layered appearance.

By the summer of 1983, we had a simulation of the human interface running on an Apollo workstation. This provided a vehicle for us to evaluate the concepts and do some tuning long before the actual software and hardware would become available. Less known but probably at least as important, the simulation provided a means to politically sell the project and keep it alive while we worked with great fervor to get something "real" working.

By the end of the summer, the fundamentals were well established, although we certainly had some intense moments of "fine" tuning afterwards. We found the menu touch targets to be too small for many fingers, and ended up doubling their size and changing to a larger CRT in order to spread things more apart. We agonized over icon symbols and words. Speed and location of commands were frustrating, as well as flexibility, user inputing, and reconfiguration for different plug-ins and probes. Even today, some warts still exist (such as the manner of exiting menus not always being consistent), but it is quite usable.

Architecture

One of the first precepts was that the architecture would have multiple microprocessors with loosely coupled functional modules. This was a fairly strong notion we developed from our work on the 7854, whose single microprocessor really slowed things down at times, occasionally to the point that the instrument looked dead for extended periods while the processor was doing something invisible to the user. Therefore, ET's multi-processor concept seemed to be well accepted early and wasn't too controversial. Toward the end of the project however, we could think of some reasons that we should have had only one processor (primarily simplicity). It is probably not possible to make a strong objective argument favoring one approach over the

other based on the available technology; it may be years before a clear distinction can be made. However, the multiple processor architecture does give us some important advantages which have already helped us in the market: faster operation, live display, faster throughput rates, and the ability to do several things at one time; this architecture also gives us the opportunity to develop follow on products faster with common modules (if we can exercise sufficient wisdom). The down side of multiple processors is the overall system complexity and the tendency to being architecturally committed for a longer time.

The architecture was broken into four major modules, each which had its own microprocessor, operating system and ROM: Plug-ins (analog front end signal conditioners), Digitizer (A/D conversion, time base), Executive (central memory, main processor), and Display. These modules were relatively independent in their local operation, though obviously worked together to make a scope (via dedicated parallel interfacing). The modules were intended to be individually changeable for our own purposes of making other products: for example, other digitizer modules could be used to provide higher sampling rates and/or bandwidth; a color display could be offered; or application SW could be added (FFT).

Firmware

FW was tremendously impacted by the human interface and architecture, being yanked mercilessly in one direction or another every time we decided to "fine tune" something. But it had its own problems, too. LID had never done a large scale FW program. We had no internal talent and experience. We ended up building the team from scratch with 100% outside hires, many straight from college. "Wetness behind the ears" combined with the frequent question "...tell me again, what's an oscilloscope?" would normally mean disaster for any project; and while it almost did for us, the sincerity and fundamental strength of our people prevailed through endless difficulties. Our success is the highest tribute to these people.

FW was to be developed in a high level language and have a high degree of commonality between the analog and digitizing products. This latter management guideline soon proved unreasonable, as analog and digital scopes are too different to share very much (although we have had good leverage of ET FW to follow on digitizing scopes). In addition, the FW group inherited much of a pre-determined architecture, including the microprocessor family. That alone had major problems in that we had to make major changes because the vendor could not deliver promised development tools.

We had very serious system level problems with communication protocols and self-cal issues between ET, RT and the plug-ins: each had their own interests to optimize. Self-cal was originally conceived to occur in <100 ms every time a new setting was made; this way, the scope is always "spot on" (to quote one fearless leader)! In the end, we were barely able to make the scope calibrate itself at all, as we were tuning it right down to first customer shipments, and have continued to make improvements since.

Hardware

We purposely tried to control our appetite for fancy new hardware, since project risk was already very high; we could always come back and add the

neat stuff later, after the basic architecture worked (in essence, that's what's happening with subsequent projects). Thus, the digitizer is a modest 20 MS/s, the display is monochrome, no disk drives, and so forth. But we still had our hands full with difficult hardware issues: dual time bases with versatile functionality and precision timing measurements, multiple access shared memory, and high resolution vertical raster display system.

In spite of our bias to minimize new components, we still had to develop a number of new ICs for performance and/or cost reasons: VRS, DAG, Channel Switch, MMU, Time Base, Time Interpolator, SDI. For the most part, these went very well due to the skill and careful execution of each engineer. We even impressed ourselves!

The most difficult area was the acquisition system: sorting out where all the points go, which waveform they belong to, and not losing any or mixing them up. These problems tended to manifest themselves as holes or spikes on waveforms. Complicating factors included multiple channels, two time bases, hold-off, variable record lengths, equivalent time vs. real time modes ... this is one reason we don't have variable time/div!

Diagnostics

We emphasized self-test and diagnostics from the beginning. Our reasons were to save time in the plant and field towards verifying proper operation and repair, and to utilize less skilled technicians. We did not achieve the complete coverage for which we hoped due to other problems that had to be solved before the diagnostics could be completed. The acquisition system is most notable. We did the best we could and subsequent products are going further in those areas. A recent comment from a service center technician expresses our success: "The 11400's are boring to fix; they're no fun to troubleshoot because the diagnostics finds the problems so quickly and easily."

An unexpected bonus was that the diagnostics actually saved considerable time in bringing up the prototype instruments, particularly in B-Ø. Only the "old timers" will remember how difficult this used to be!

Competition

We dominated the high end digitizing scope market in 1982 with the 7854 and 7D20. There were a few products with good ideas from small companies, but none of them really posed much threat to us (e.g., Data Precision 6000, Austrian Trace). Even HP's 1980 was no match for our well accepted products.

But this is a very tempting market, and HP took another run at it in 1984 with the 54100, proving that they were still in the scope business. While we felt that we had a generally superior product, we were two years behind, and were deficient in a few key areas. They had 1 Ghz bandwidth vs. ET's 300; we changed to 500 MHz, otherwise being limited by the sampling hybrid and triggering. They had infinite persistence; we added point accumulate. They had a larger screen and were perceived easier to use; we changed to a 9" screen from 7", and simplified our human interface.

With only eight months before product announcement, we decided to go for 1 GHz bandwidth, under considerable pressure from the field and the realization that

they might be right (this was probably the single most important favorable decision made). A skunk-works program to soup-up the sampling hybrid was undertaken, along with porting the 7A29 amplifier to 11K. By now we were willing to compromise that the instrument would not trigger to bandwidth.

By the time we introduced the 11400 Series, HP had well established their product and added some variations: a color version and a 1GS/s version. They have added a sampling version since our introduction. The marketplace is generally reaffirming that our products are superior, but that is of little consequence to us since we're presently running about two years behind. By the time our products are available, their products are established.

Kudos

We should be justly proud of our accomplishments in ET. During a time where less complex projects were failing all around us, we succeeded. ET's initial success is clear; if this product family falters in the market, it will be due to our inadequate follow-up. Our initial efforts were meritorious, and achievable because of the quality of the people on the team. Of course we had our problems along the way, but we prevailed. 11600 and 11800 programs have benefited from our work: many architectural problems have been resolved, and a new crop of trained and experienced engineers have been developed to lead future projects. Our knowledge, experiences and better ideas have already permeated to other parts of Tek, with further improvements as they are applied.

Observations

ET was a long and difficult project for all of us! ... this was probably necessary to some degree, but should be the exception rather than the rule.

There are some important concepts we reaffirmed:

* focus on one or two superordinate goals, then compromise all others to properly scale the project;

* keep projects as simple as possible to meet our customer needs;

* limit the many complex variables in one project at one time (new processes and components, lot's of FW, many new people, ...);

* try to scale a project to fit within 1 - 2 years ... the product has less chance of becoming obsolete, and it's easier to keep morale up.

Once in a while you'll find yourself in a position where it will be necessary to violate one or more of these points ... usually after some bad decisions trap you. When you do, go in with your eyes open, be prepared for a tough grind, and re-evaluate your position occasionally to verify your goals. Be flexible, because more things can change on a longer project. And don't let it happen again!