Jim Andrews & Tektronix Connections

Tektronix of Beaverton, Oregon was for many years the world's leader in oscilloscopes. My initial contact with them was as an electrical engineering student at the University of Kansas in the early 1960s using their o'scopes in the EE labs. Then as a graduate student, my professor at KU was Dr. Norris S. Nahman. Dr. Nahman's specialty was very fast pulse measurements. His nick-name was Nano Second Nahman from his initials NSN. He had come to KU from NSA where he worked on instrumenting the performance of very fast NSA computers. He brought along from NSA a large grant of money to establish Project Jayhawk to do fast pulse research. One of Norris's early graduate students was George Frye. Upon graduation, George took a job with Tek. There at Tek, George became the chief design engineer for the Tek sampling oscilloscopes in the 560 series which were introduced in the mid 60s.

In 1966, the USA National Bureau of Standards (NBS) had realized that they needed to start supporting the new growing digital electronics industries of computers and telecommunications. Prior to then, NBS' Electricity & RF divisions had only supported standards for DC and AC (sine waves). The NBS labs in Boulder, Colorado thus decided to start a new program for Fast Electrical Pulse Measurements. They did a search for the best experts in the field. As a result, they hired Dr. N.S. Nahman from KU as a Senior Scientist. Norris took the job, but told NBS he also wanted to bring along some of his Ph.D. graduate students to form the nucleus of the new program. As a result, I along with Bill McCaa and Charlie Manney, moved in 1967 from Lawrence, Kansas to Boulder as new NBS employees. At NBS, Norris assigned us all different projects which also resulted in becoming our Ph.D. dissertations. Charlie was assigned to study the pulse propagation characteristics of unconventional, non-uniform, coaxial transmission lines, such as Heliax. Bill was assigned to study the pulse propagation characteristics of super-conducting coaxial cables. I was assigned to design, analyze the theoretical performance and build a 10 GHz bandwidth, traveling wave CRT oscilloscope [1, 2]. All three of us worked on these projects and then received our Ph.D. degrees from the University of Kansas around 1970. We also had some other NBS engineers in our new group working on other related projects.

Part of our early pieces of test equipment at NBS for our new pulse program included 12 GHz sampling oscilloscopes from both Tektronix and Hewlett-Packard. From Tek it was the 560 series. From H-P, it was the 1430 series. We also had their ultra-fast risetime (30 ps), tunnel diode pulse generators. George Frye had designed the Tek generator. We also had a higher amplitude, but slower pulser (10V, 200ps) from E-H Labs in Oakland, California. Plus we had some really fast mercury wetted mechanical switch pulsers.

As part of my NBS o'scope project I needed to do a theoretical analysis of the traveling wave deflection structure used in the CRT. I also needed to design from scratch the auxiliary o'scope circuits of trigger, CRT blanking and horizontal sweep. This was a very high voltage (50kV) CRT and it was extremely insensitive. No amplifiers were then available with 10 GHz band-widths. The CRT used direct deflection, no amps. The horizontal deflection sensitivity was also quite low. It required that I design a sweep circuit to ramp up from 0 to 1kV in 1 ns [3]. I did this using a high power, microwave transmitting tube. I also needed several 100 volts for the unblanking circuit. For this I used a stack of avalanche transistors. For the trigger circuit, I used tunnel diodes. I also needed to have a test signal source to evaluate the new o'scope. I thus also designed a very fast risetime, high voltage, step pulse generator using an avalanche transistor.

As I was about to finish my Ph.D. in 1970, Janet & I then started considering relocating and taking a job elsewhere than at NBS. Among the companies I contacted were Hewlett-Packard, E-H, and Tektronix. H-P was not interested. Both E-H and Tek invited us to visit their plants in Oakland and Beaverton. At Tek, George Frye was our host. I then did receive nice job offers from both E-H and Tek. But they offered no more than I was earning at NBS. Staying at NBS thus made sense as it kept us closer to our families in Kansas City. Thus, my first major connection to Tek was a job offer. We have lived in Boulder, Colorado ever since, dating back to 1967.

Shortly there after, NBS sent Janet & I, plus our two preschool sons, Scott & Steve, on a one year (1971-72) assignment to France. There I worked in the French national telephone labs (CNET) [French equivalent of Bell Labs]. It was in Lannion, Brittany, on the English Channel. At CNET I worked on the early research of fiber optics. I studied the pulse degradation of laser pulses as they traveled through fiber cables. To accomplish this, I designed a 100ps wide laser diode pulse generator. Work done there at that time proved the feasibility of using lasers and fiber optics for telecom.

Tektronix fans will not be pleased to hear, but in our research at NBS in the late 60s and early 70s, we had come to the conclusion that the best, most accurate, oscilloscope was not from Tektronix. It instead was the HP-1430. In the late 60s it was their 1430A model with 12 GHz band-width (30 ps). By the early 70s, HP came out with an improved version, the HP-1430C with a higher band-width of 18 GHz and faster risetime of 20 ps. We thus adopted the HP-14030C as our national standard which we used for our pulse generator fast risetime calibration service. Another new graduate student of Norris', Sedki Riad, was assigned to model and do a theoretical analysis of the pulse/transient response of the HP-1430C sampling head. Still another guest worker from CNET, Michelle Guillume, was assigned to study mathematical deconvolution with Norris to then be able to process the recorded data from the o'scope. He incorporated the Fast Fourier Transform (FFT) which had just been developed at about the same time.

At this same time, working with Bill McCaa and John Shafer, we were developing the first Digital Oscilloscope [4]. We used an A/D to digitize the analog recorder output from the HP-140 o'scope. We also used a computer driven D/A to drive the X axis sweep of the sampling o'scope. The first generation interfaced this equipment to a time share computer. The second generation, we used our own DEC mini-computer. The automated digital sampling scope became the heart of our NBS fast pulse calibration service.

But, at NBS we did not ignore Tektronix's contributions to sampling oscilloscopes in the late 60s and early 70s. Tek offered some unique features not available from H-P. First was the Random Sampling Time Base concept (Tek 3T2 time base). Second, was their infinite persistence, storage CRT, (Tek 564 main frame).

It was one thing to be able to measure fast rep. rate pulse signals which also had pre-triggers available. All our o'scopes needed to be triggered, then wait a brief (10s to 100s of nanoseconds), until the horizontal sweep circuit could be started. In conventional o'scopes, this meant that a delay line had to be inserted in the signal path before the signal was allowed to hit the CRT deflection plates. With high bandwidth, sampling oscilloscopes, we used an external delay line with typically about 70ns of delay. A trigger signal for the o'scope was picked off from the input to the delay line. Delay lines introduce band-width limitations. One way around the BW limits of ordinary coax cables used as delay lines was to build an equalizing network which was essentially a high-pass filter to compensate for the skin effect loss in the coax. Another approach, which Bill McCaa studied, was to use extremely low loss, super-conducting (liquid Helium), coax cables. I later used it routinely at NBS [6].

The Random Sampling technique developed by George Frye and Tektronix got around the requirement of needing a pre-trigger ahead of the pulse to be measured. This was implemented in their Tek 3T2 Time Base plug-in. By taking random samples in time both before and after the pulse edge to be measured and then storing them indefinitely for later display on the Tek 564, we were then able to reconstruct after some data acquisition time a reproduction of the signal, including before and after the fast pulse edge.

To enable NBS to take advantage of Tek's random sampling, but still use the HP-1430C sampling head, I thus in 1971 designed an Inter-Face box [5]. The 1430 was connected to it and the output of the box used a Tek sampling head extender cable which plugged into the S series slot on the Tek 3S-2 sampling vertical plug-in.

However, there were some limitations in the 3T2. It only worked with high rep. rate signals. There was a whole class of super-fast pulse generators which used mercury wetted, mechanical relays. These only operated at up to line frequencies of about 60 Hz. The 3T2 couldn't handle these low rep. rates. So, starting in 1972, I started to design a new random sampling time base which would work at extremely low rep. rates. I designed it as a direct replacement plug-in for the 3T2. It did in fact work and allowed us to measure 60 Hz, fast rise pulse from mercury switches. Only one prototype was ever built. [7]. I gave a talk about it at an IEEE I&M conference [8]. After my talk Howard Vollum, Tek founder, came up to me and congratulated me on the fine work.

The next Tek connection was in 1975-76, when Bob Lawton and I invented at NBS a new type of high band-width sampling head using a totally different technology [9, 10]. Instead of using a diode bridge as the sampling gate, we used a photo-conductive switch strobed by a short laser diode pulse. We were actually awarded a US patent for the idea [11]. The patent was assigned to NBS. I heard later that Tek was interested in the idea and actually had assigned a couple of their engineers to investigate it further. No Tek product resulted however.

By the mid 70s, Hewlett-Packard dropped out of the sampling oscilloscope market. By then, Tektronix had begun to dominate the sales of sampling o'scopes with their 7000 series, still using the old S series of plug-in sampling heads. (7S11 vertical & 7T11 horiz.) The Tek S4, 25 ps risetime sampling head plugged into the 7S11. Nothing more was done with sampling by Tek for the next ten years. Tek coasted on its 7000 series offerings.

In the meantime, I had a mid-life crisis and left NBS. In 1980-81, I started my own company, Picosecond Pulse Labs (PSPL). The company was first just me and my dog working in our basement at home. The first products were some fast impulse and step generators, similar to ones I had designed at NBS. I used avalanche transistors to generate 50 Volt, 300 ps risetime pulses. I then added even faster pulsers using SRDs. Because HP had dropped out of the sampling o'scope market, they had also discontinued their super-fast risetime (20ps) tunnel diode pulser, model 1107. So seeing a market opportunity, I then developed my own similar tunnel diode pulser and called it my TD-1107. I also designed a much improved, very stable driver, my model TD-1110. Sold them for at least 20 years there after.

Over the next 35+ years, PSPL had working relationships with four of the world's major oscilloscope manufacturers. They included: Iwatsu (Japan), Hewlett-Packard (then Agilent later), Le-Croy and Tektronix. They included OEM deals with PSPL making products for them with their name & logos on them.

In the early 80s there were other engineers who regretted HP leaving the sampling o'scope market, with the only option left being to buy Tek o'scopes. They included the folks in the nuclear test community at Los Alamos labs. So they, via E G & G, Los Alamos, commissioned me to design and build a new sampling head, hopefully better than the Tek S-4, and with similar performance to the old HP-1430. In 1982, I delivered to them both single channel and dual channel sampling heads I called my model S-1430. Unfortunately, they didn't have as high a band-width as hoped. They ended up being DC-10GHz, 35 ps risetime, but with a better overall transient response than the Tek S-4. I designed the S-1430 so it would work interchangeably with either an HP or Tek main frame. The S-1430 is documented in reference [12].

By the mid 80s, things began to move again in the sampling o'scope field. The Japanese company Iwatsu was the first to market with a true Digital Sampling Oscilloscope. It was their model SAS-8130A with the SH-4B remote sampling head. It was specified as being a < 30 ps risetime head. Iwatsu lacked a good fast pulser for TDR measurements with their new o'scope. So, PSPL and Iwatsu entered into an OEM agreement where we supplied them with our 20 ps risetime tunnel diode pulser combo TD-1107 & TD-1110, but with Iwatsu model numbers, color scheme, and logo. For the next couple of years Iwatsu grabbed market share for the high end sampling scopes, because they were offering a truly digital scope.

By 1987, Hewlett-Packard came back into the high end sampling scope market with a fury. They introduced their all digital model 54120A main frame and 54121A remote sampling head with an 18 GHz band-width. They soon captured the market and killed off the Iwatsu scope. Tek was now faced with playing "catch-up" to HP. A couple of years later, Tek introduced their own digital sampling scope. It was their model 11802 main frame. They also developed a new line of plug-in sampling heads. The SD-24 was specified to have a 20 GHz band-width.

Over the years, starting in 1986, I did a series of comparisons of the various, then available, sampling oscilloscopes. I published these as a series of PSPL application notes, AN-2 [13]. The most recent one I published in 2011.

During the mid to late 80s, I did have a couple of visits from Tektronix. At the time, Tek was looking into the possibility of buying PSPL. But both times, they got scared away when they realized that we had to hand select the avalanche transistors used in several of our pulse generator products.

In 1990, PSPL entered into an arrangement with Hewlett-Packard. Their 54120 oscilloscope included TDR capability, but their built-in TDR pulser was considerably slower than the risetime of their sampling head. Thus, they were limited to 35 ps resolution. They asked us if we could develop a companion pulse generator with a much faster risetime to enhance their TDR. I thus developed our model 4015 which had a 5 Volt step pulse with a super-fast 15 ps falltime. Then using the HP "normalization" (i.e. deconvolution) math processing built into their scope, we were able to achieve an effective 10 ps risetime TDR. HP then agreed to advertise in their hard cover catalog our pulse generator along side their o'scope. We also shared marketing leads. It was a win-win situation.

Almost from the very beginning in 1981, PSPL also was making a line of broad-band coaxial components. The original purpose was the need for a broad-band Bias Tee with a perfect transient step response and flat frequency response from a few kHz to many GHz. I needed them as internal components in my own super-fast pulse generators. I was unable to find suitable ones to buy on the open market. Thus, I designed my own. I soon realized there would be a market for them. This got us into the component market. I soon added amplifiers, transformers, etc. to the component line. It eventually accounted for 1/2 of our sales.

By the mid 90s, I had developed a design for a "perfect" Gaussian response Rise Time (or Low-Pass) Filter. Perfect Gaussian step transient response, plus No reflections. This caught Tektronix's eye. They soon adopted it to use as an internal component in their Optical Reference Receivers. We were soon selling lots of them to Tek on an OEM basis.

By the late 90s, there was a Fiber Optics Boom going on. Suddenly the telecom industry was moving up to 10 Gbps over long distance fiber cables. Everyone was jumping on the band wagon. Suddenly our component line of ultra-broadband components was in big demand. Especially our 14 GHz BW amplifiers, our 40 GHz Bias Tees, and our low-pass/risetime filters. Sales were booming. I brought in my oldest son, Scott, to manage the growing company. He joined his younger sister, Susan, in accomplishing it. In the 1999-2000 time frame, we grew from a dozen employees to over 140. We hired a lot of bright, young engineers.

At this point, year 2000, Tek also again enters the picture. Not in a way they anticipated however. By this time, both Tek and HP (now Agilent) had developed 50 GHz sampling heads. But were not showing any signs of being interested in going any further. Already the telecom market was talking about rapidly pushing beyond 10 Gbps to 40 Gbps. At 40 Gbps, you couldn't use a 50 GHz o'scope and expect to have an accurate measurement. Your square giga bit data streams would simply look like smeared out sine waves. So, at PSPL, we felt the next market we should address was the very high end sampling o'scope. Our objective was to be a 100 GHz (3.5 ps risetime) sampling head.

Where to get the talent ? We had been contacted by some Tek engineers interested in working for PSPL. So, a recruiting trip to Beaverton, Oregon. We ended up hiring four current and former Tek engineers. We then opened a branch facility in Beaverton and setting up a 4,000 sq. ft. clean room to be able to build our own GaAs devices. The engineers promptly got started designing a 100 GHz BW sampler. We fabricated our own GaAs Schotky diodes for the sampling gate. We also developed a super-fast risetime pulser using our diodes to build NLTLs (Non-Linear Transmission Lines). They were used to create the sampling strobe. We also then built stand alone pulse generators with the NLTLs. The pulser produced +5V, 7 ps risetime pulses.

Once we had working a 100 GHz sampler, we then started looking for an o'scope company to partner with. We first approached both Agilent and Tektronix. No go. They both had the attitude -- "If it is not invented here --Then it can't be done ! " Wrong guys ! Next we talked to LeCroy, the #3 player in the high end o'scope market. They were definitely interested. The result was LeCroy's 100 GHz, digital sampling oscilloscope, their Wave Expert model 100H. PSPL supplied to LeCroy on an OEM basis, a complete line of remote sampling heads for their scope. It was their series SE-XX. The lowest BW was 20 GHz and the highest 100 GHz. We also supplied them with ultra-fast rise TDR heads. PSPL and LeCroy had now beat Tek & Agilent at their own game. And they said it couldn't be done.

By 2001, it was apparent that father and son didn't see eye to eye on how to manage the rapidly growing PSPL. So it was time for Jim to move on. So in Oct. 2001, I retired from PSPL. Janet & I then moved to Maui, Hawaii for our winter time retirement home, spending the summers in Boulder, Colorado. From that time on, my sole role with PSPL was to be a part-time volunteer to develop application notes. My last really major project for PSPL lasted 1 1/2 years developing a computer program to automatically deconvolve out the impulse response of our o'scopes to determine the "true" signal being measured. I then used the programs to characterize and calibrate each and every high band-width o'scope PSPL owned, including Le-Croy, HP/Agilent and Tek. This work was documented in the PSPL app. note, AN-26 "Gold Standard, 4.8 ps, Sampling Oscilloscope Traceable to International Standards Labs", published Dec. 2010.

During the 2000s, PSPL continued to develop even better, broad-band, coaxial components, pushing the upper band-widths even higher. We eventually hit 60 GHz with some amplifiers. We also partnered with Corning to develop some high band-width optical modulators.

In the early 2000s, in addition to opening our own GaAs R&D fab in Beaverton, PSPL also embarked upon an R&D program to develop high data rate (> 1 GHz) pulse and pattern generators which were also programmable. The first pulse/pattern generator was the model 1601/1602 capable of up to 1.6Gbps. Soon thereafter, PSPL developed what they called their PatternPro© Programmable Pattern Generator, 12,000 series line. Each succeeding generation upped the ante and the max. data rate. We finally reached the top, state-of-the-art breath-taking speed of 40 Gbps with the PPG4001 generator with 1 V, 11ps (20-80%) rise/falltimes. At the same time, PSPL was also developing a companion Error Detector, also capable of working up to 40 Gbps. The two units working together became what is called a BERT, short for Bit Error Rate Tester. The 40 Gbps pair sold for a cool 1/2 M$!

Around 2010, Tektronix again became interested in PSPL. They desperately needed in their product line high data rate pulse/pattern generators to be able to compete against Agilent. They had nothing to compare with Agilent's. So, they contacted PSPL and asked us to supply them with our 12,000 series of PatternPro generators on an OEM basis with their colors, model numbers and logo. We continued to sell our PatternPro while Tek also sold them under their name for an inflated price over our retail prices.

By 2013, the stockholders and management of PSPL felt that it was time to find a suitable buyer for the company. Several companies were interested, including LeCroy and Tektronix. In the end, PSPL was purchased in Jan. 2014 by Tektronix. Tek then proceeded to move most all of the functions from Boulder to their main plant in Beaverton, Oregon. Transfers to Oregon were offered to the staff, but only a couple of employees opted to move to Oregon. Tek only left a handful of sales and R&D engineers in Boulder. The PSPL web site was shut down and the product line was integrated into Tek's line and catalog. Unfortunately all did not go well integrating PSPL's products into Tek's. They lost critical talent in the process and were never able to easily build PSPL's products in the Oregon factory.

They were constantly flying an engineer or tech from Boulder to Portland to hold their hands in production. Tek did not fund any future R&D in Boulder. As a result, with attrition, the residual engineering staff soon disappeared. The doors in Boulder were eventually permanently closed. Five years to the day after purchasing PSPL, Tek discontinued selling completely all PSPL products. Today, PSPL products are only available on the used equipment market, such as E-Bay.

All was not lost however. Like the phoenix bird, PSPL has once again arisen from the ashes. Five former PSPL/Tek employees have started up a similar company in Louisville, Colorado. It is now called HyperLabs (***www.hyperlabs.com***). Their first product offerings are specializing in very high end, broad-band (up to 110 GHz), coaxial components, similar to those formerly made by PSPL. They are in the R&D phase of also developing high end, very fast pulse test instruments.

Jim Andrews, Boulder, Colorado, 11 Dec. 2023

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