**Richard B. Brown**

**Curriculum Vitae**

University of Utah

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**Education**

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| Ph.D. E.E. | | University of Utah  Dissertation: Multiple-Sensor Chemical Transducer | | June 1985 | |
| M.S.E.E. | | Brigham Young University  Thesis: Logic State and Timing Analyzer | | April 1976 | |
| B.S.E.E. | | Brigham Young University  Cum Laude, Highest Honors,  University Scholar Designation | | April 1976 | |

**Positions at the University of Utah**

College of Engineering Salt Lake City, UT

H. E. Thomas Endowed Dean of Engineering 11/20 –

Dean of Engineering 7/04 –

Electrical & Computer Engineering 7/04 –

Professor

School of Computing 7/04 –

Professor

Biomedical Engineering 4/05 –

Adjunct Professor

**Positions at the University of Michigan**

Electrical Engineering and Computer Science Department Ann Arbor, MI

Adjunct Professor 7/04 - 6/11

Interim Chair 7/01 - 5/03

Arthur F. Thurnau Endowed Professor 7/01 - 6/11

Associate Chair representing EE 10/97 - 6/01

Professor 9/97 - 6/04

Associate Professor 9/91 - 8/97

Assistant Professor 9/85 - 8/91

**Other Positions**

IBM Austin Research Labs Austin, TX

Visiting Scholar, Exploratory VLSI 9/03 - 5/04

Studied low-power circuit techniques in advanced processes while on sabbatical.

Cascade Design Automation Bellevue, WA

Visiting Scientist, Advanced Technology 9/91 - 7/92

Explored advanced electronic design automation concepts and CAD for GaAs technologies while on sabbatical.

Cardinal Computer Division, Cardinal Industries Webb City, MO

Manager Computer Development 1/78 - 9/81

Led team in the development of computers, instrumentation, and printers for process control and elec­tronic weighing applications.

Holman Industries Oakdale, CA

V.P. Engineering 1/76 - 12/77

Designed microcomputer system and dot matrix printers. Directed new product development.

**Research**

Prof. Brown conducts research in two general areas, solid-state sensors and integrated circuits. In the sensor work, he has enjoyed fruitful collaborative relationships with researchers in chemistry and medicine. Brief summaries of the major accomplishments of his research group follow in related sub-areas ranging from sensors to microprocessors. Ph.D. students’ (and post-docs’\*) names are listed with the area most closely aligned to their dissertations to aid in identifying the publications related to each topic.

Chemical Sensors: (H. Goldberg, M. Ger, H. Cantor, G.S. Cha\*, R. Hower, S. Martin, S. Joo\*, T. Strong)

Prof. Brown started working in the area of solid-state liquid chemical sensors in his own Ph.D. research at the University of Utah. Under the direction of Prof. Robert Huber, with Jiri Janata as a very involved member of his committee, he developed a miniature silicon-based chemical sensor array with on-chip electronics. In this project, he developed a junction-isolated NMOS semiconductor process and designed an eight-ion-sensor array using ionophore-doped polymeric membranes, in which the signal from each sensor electrode was buffered by an integrated operational amplifier. This first-of-a-kind smart chemical sensor included digital control circuitry and an analog multiplexor which reduced the number of interface connections needed to seven, which fit on the narrow (1.4 mm) end of the rectangular sensor chip. The junction isolation allowed the sensor chip to be used in solution with only the bond-wire end of the chip encapsulated. The use of integrated electronics improved the signal to noise ratio by more than three orders of magnitude and facilitated the concurrent use of multiple sensors selective to different chemicals. This chip generated all of the data needed to implement chemometrics techniques for reducing errors due to imperfect selectivity of the ionophore-based transducers.

As a faculty member at the University of Michigan, Prof. Brown, and his students continued to solve the fundamental problems in solid-state chemical sensors. They optimized ion-selective membranes for the simple ions based on polyurethane and silicone membrane matrices that had vastly improved biocompatibility and adhesion to the substrate compared to the commonly-used PVC. They developed mass fabrication processes that yielded membranes having precisely controlled dimensions and electrochemical characteristics. They developed a Silicon-on-Insulator (SOI) semiconductor process to give intrinsic encapsulation to these devices that must operate in conductive solution without shorting high impedance signals to the solution. Throughout the sensor research, novel packaging approaches were developed. The SOI process included a p-i-n photodiode that was used to implement an optically-coupled sensor for detecting alcohol and other non-ionic species. A smart sensor chip was fabricated in this SOI process that included an analog multiplexor, a programmable gain amplifier, a 12-bit analog-to-digital converter, digital control circuitry, and a standard serial interface to a computer – the chip contained most of the instrument as well as multiple sensors.

Solid-state conductivity sensors were developed for quantifying hematocrit levels and the ionic strengths of other fluids. Enzymatically- and immunologically-coupled sensors were demonstrated. Amperometric sensors were developed for detecting and determining the concentrations of neurochemicals (dopamine, serotonin, acetylcholine), heavy metals (arsenic, lead), and any of a host of other molecules that have well-defined redox potentials which lie within the water window. With stripping voltammetry, these sensors were able to detect arsenic and lead at levels as low as 0.3 parts per billion. These sensors were also integrated with electronics, this time using commercially processed CMOS circuits as the substrate; post-processing steps developed in Prof. Brown’s lab were employed to form the sensors on top of the circuitry. A model of the full sensor/electronics system was developed to evaluate the noise and optimize the sensor and circuit design. One of the circuits developed and integrated with the sensor was a fully differential potentiostat, which doubled the effective voltage swing available for driving the redox reactions, thereby allowing the electronics to be implemented in modern, fine-featured, low-voltage semiconductor processes. Multiple sensor types were merged onto the same chip to achieve a wide range of sensing capabilities.

With the knowledge and patents generated from this work, Prof. Brown was involved in founding two companies in the year 2000, Sensicore and i-SENS, which commercialized solid-state sensor technology. Sensicore, founded in Ann Arbor, MI, focused on water sensing with a hand-held instrument based upon a single silicon sensor chip that quantified 18 components/parameters of water. More than $30M of venture capital was invested in the company; it was sold to GE Water and Process Technologies in April of 2008.

i-SENS, headquartered in Seoul, manufactures glucose sensors and point-of-care equipment for monitoring blood gases, electrolytes, and biomarkers related to cardiac function, metabolism (HbA1c), infection, renal disease and maternal health. It has factories in Wonju City, the Incheon Free Economic Zone in Songdo, and in Jiangsu, China. Its CareSens product was the world’s first to accurately measure blood glucose in 5 seconds using a blood sample of less than 0.5 uL. In 2019, i-SENS sold more than 1.95M glucometer instruments and 1.65B one-time-use test strips in 80 countries including the US (its largest market). It went public on the KOSDAQ exchange in 2011.

Since being back at the University of Utah, Prof. Brown and his group, with Profs. Cha and Nam from Kwangwoon University, developed several novel reference electrodes that can be miniaturized to sizes comparable to those of the sensors.

Prof. Brown’s latest startup company, e-SENS, is located in Research Park next to the University of Utah. e-SENS mates silicon-based solid-state sensors with microfluidics to automate chemical testing. Its first application will be in culinary water treatment and distribution systems. The fully-automated hand-held instrument communicates with an app on the user’s smart phone, which manages the calibrations and tests, logs locations, times and test results, and both stores them and transmits them to the cloud or a company server. A sensor module containing calibration and rinse solutions, sensors and microfluidics, is used for a month or 100 tests and then replaced. This system reports 24 components/parameters of clean water in about 15 minutes. Tests are being developed for arsenic, copper and lead, but as important, the instrument reports the Ryznar Stability Index and Langelier Saturation Index, which indicates whether water will deposit calcium carbonate scale in pipes or leach lead from the pipes.

Neural Interfaces: (H. Cantor, T. Strong, R. Franklin, S. Kellis)

Prof. Brown’s work in neural sensors started as an effort to apply his group’s chemical sensing technology to silicon-based brain probes which, at that time, detected only electrical signals. Communication between neurons happens through both electrical and chemical means, so adding the ability to identify and quantify the neurochemical concentrations in the vicinity of a neuron, along with the electrical spikes, could greatly enhance the understanding of neuron behavior. Their first design was a silicon-based, microfabricated, passive, *in vitro* array organized in a 4 x 4 pattern, in which each sensor used an electrode for sensing the action potential, and with other electrodes formed a voltammetric sensor for monitoring neurochemicals. Five versions of this array were made, with electrode sizes ranging from 2 to 100 m. The sensor array was packaged in a ceramic integrated circuit pin-grid-array package with lead wires encapsulated, and a small cloning chamber cemented to the sensor chip surface. Human stem cells (hNT cell line from Stratagene) were plated onto the surface over an appropriate matrix, and cultured into neurons. Neurons from this cell line produce spontaneous electrical activity, and secrete acetylcholine and dopamine. Calibration curves for dopamine taken in culture media indicated detection limits for dopamine below 100nM. Neuroelectrical and neurochemical recordings were taken on 24 cell cultures over 75 days. Action potential propagation from neuron to neuron was evident in the data. Electrical spikes and chemical response were correlated in many instances. A cell behavior known as potentiation, in which a neuron fires to prime or activate a particular neural pathway was exhibited in the data; a succeeding pulse causes a larger reaction because of the initial priming. The capture of such events, with multiple action potential spikes in rapid succession followed by a large release of neurotransmitter, highlights the capability of the devices for use in studying the interdependence of neuroelectrical and neurochemical behaviors. This was, to our knowledge, the first case of recording such data without external stimulation. A complete computer model of the sensor’s electrochemical behavior was developed for use in optimizing interface electronics. To improve signal fidelity, CMOS potentiostats were integrated into the sensor using the post-processing approach mentioned in the Chemical Sensors section above.

After returning to Utah, Prof. Brown and his students implemented their neurosensors as *in vivo* brain probes that could concurrently detect neurochemical and electrophysiological signals. They studied various materials as they sought a biocompatible reference electrode for neuroprobes, and eventually developed an activated Iridium Oxide Film electrode with excellent characteristics for use in sensing neurochemicals. Silicon needle probes were designed with Pt and IrOx electrodes on the same shank in appropriate configurations for concurrently measuring local field potentials, action potentials, and neurochemical concentrations. The probes were coated with the perfluorinated ion-exchange resin Nafion to improve selectivity of the platinum sites to more than 100:1 for dopamine over interfering species. The multi-modal probes were implanted in the striatum of urethane-anesthetized rats to examine reciprocal influences of amperometry on neuronal activity, and spatiotemporal characteristics of dopamine effluence vs. local field potential and spike activity following electrical stimulation of the medial forebrain bundle (MFB). The utility of these probes for neuroscience studies was demonstrated as extra-synaptic dopamine overflow in the striatum was correlated with local field potentials and electrical spike activity driven by the frequency and amplitude of electrical stimulation of the MFB. These probes have been made available commercially through NeuroNexus Technologies, Ann Arbor, MI.

Chronic implantation of neural probes is problematic because as the probes move in the soft brain tissue, they see signals from different neurons, necessitating constant retraining of the decoder. Furthermore, biology tries to encapsulate the foreign body, insulating its sensing electrodes from the signals. To achieve better chronic performance of a brain-machine interface, Prof. Brown and his student, Spencer Kellis, in conjunction with neurosurgeon Paul House and Bioengineering faculty member, Bradley Greger, experimented with tiny 40-m micro-electrocorticographic (ECoG) electrodes placed on the surface of the brain. Experiments were conducted to determine whether non-penetrating, high-density microwire electrodes could provide sufficient information to serve as the interface for decoding motor cortical signals. These electrode arrays were implanted over the motor cortex in epilepsy patients who performed reaching movements with a computer mouse while data were recorded. The whole array of 16 electrodes fit in the area normally occupied by a single standard ECoG electrode. It was learned that the electrodes are capable of recording predominantly linearly-independent data if placed 2mm or more apart. Signals from cortical columns, sensed by the micro ECoG electrodes, were filtered into frequency ranges, and the amount of power in each band was monitored. Principle component analysis of the filtered and binned data was used to distinguish between the two movements. The gamma band power at 30-40 Hz increased substantially beginning 500 mS before movement in the contralateral direction; movements in the ipsilateral direction corresponded to a general attenuation in power over the gamma band. The algorithm was able to predict with good accuracy which direction the patient was going to move his arm. While the studies to date involved movement of the arm, the inter-electrode spacing was designed to allow for the decoding of individual finger and hand movements, hopefully enabling the dextrous intuitive control of a prosthetic arm and hand. More detailed studies using both hand and arm movement tasks and more sophisticated decode paradigms will be needed to validate the applications of the non-penetrating electrode arrays. The group’s latest thrust has been decoding spoken words from micro ECoG signals taken from the surface of the brain in the area associated with control of the face and throat. The group reported the first differentiation of spoken words using non-penetrating electrodes at the Society for Neuroscience meeting in October 2009. They are currently able to differentiate between 10 words. The hope is that this technology will lead to an option for locked-in patients to communicate. Prof. Brown’s group also developed a low-power mixed-signal microprocessor to serve as an implanted interface to micro ECoG arrays and for other biomedical interface applications (see below).

Electronic Circuit Clocking: (P. Stetson, A. Drake, F. Gebara, M. McCorquodale, N. Gaskin)

All synchronous digital systems employ a clock to pace the operation of the circuit. In modern integrated circuits, the clock design has a major effect on both the speed and power dissipation of the circuit. Prof. Brown’s group has contributed in several ways to improved integrated circuit clocking. In the mid 1990s, as microprocessors became faster than the clocks that could be distributed on printed circuit boards, phase-locked loops, which multiply the clock frequency, became necessary on-chip modules. The group designed CMOS and Complementary Gallium Arsenide (CGaAs) digital phase-locked loops and delay-locked loops that employed current-steering logic and novel low-voltage circuit techniques to achieve the best phase noise results for a given operating voltage reported to that date. This work included a new simulation technique for analyzing phase jitter. As microprocessor clock frequencies continued to rise, there was a need for ever faster phase-locked loops. Prof. Brown’s group developed a new class of oscillators based on an efficient NOR-gate interpolator. Oscillator frequencies as high as 4.6 GHz were achieved in a 0.18 μm CMOS process, with a 3X tuning range and rms jitter values as low as 0.87ps. These circuits were incorporated into IBM integrated circuits. The group also experimented with a resonant clock distribution system, the first to use the parasitic wiring and gate capacitance of the clock tree as the resonant capacitance in a monolithic harmonic clock oscillator. A method for characterizing the effects of circuit data flow on jitter in both standard and resonant clocks was developed, including a method of extracting the jitter contribution caused by data from time-domain and frequency-domain stability measurements.

While designing a commercial microprocessor as a consulting project, Prof. Brown learned that the quartz crystal oscillators typically used as the time-base for digital systems sometimes cost more than the microprocessor they support. The idea was conceived to develop an all-silicon clock generator that could be integrated on the microprocessor, replacing the off-chip crystal and passive devices required to implement a crystal oscillator. Prof. Brown and his student, Michael McCorquodale, evaluated a number of options, and settled on a harmonic oscillator with on-chip inductors and capacitors and extensive compensation circuitry for temperature and voltage variation. This introduced an entirely new approach to clocking microprocessors. Instead of starting with a stable lower-frequency clock and scaling it up with a phase-locked loop, they generated a very high frequency clock and divided it down to the desired frequency. The crystal-derived clock is very clean because of the crystal’s high Q. The harmonic oscillator’s output is not as good in terms of jitter and stability, but just as noise worsens as the square root of the multiplier in a phase-locked loop, it improves as the square root of the divisor in these circuits, yielding a high-quality clock at the desired frequency. The research involved a sacrificial under-etch to maximize the on-chip inductor’s Q with no added masks or processing steps, so the oscillator could be fabricated in standard, advanced CMOS processes. Major contributions included novel analog circuitry to stabilize the frequency over voltage, temperature and device parameters; fast initial tuning techniques; and packaging solutions to avoid humidity sensitivity. Significant contributions were also made in design methodology for mixed technology (digital, analog, RF and MEMS) systems on chips, and a CAD tool called Newton for MEMS device design was licensed by the University to a third party. The resulting all-silicon harmonic oscillator can be integrated onto a microprocessor or other circuit, entirely eliminating the need for a crystal oscillator in many applications. These all-silicon oscillators have the unique characteristic that they reach stability within as little as 20 nS after power is applied, compared to hundreds of S for a phase-locked-loop to reach stability. This makes fine-grained power cycling to reduce power dissipation practical, thereby significantly extending battery life in portable or implanted electronics. The clock generators are smaller, lower-power, more robust physically, and lower cost than crystal oscillators or MEMS resonant oscillators.

Prof. Brown and his student founded Mobius Microsystems to commercialize all-silicon harmonic oscillators. Integrated versions of the oscillators were implemented on USB interface chips, and discrete versions were sold as pin-for-pin replacements for motherboard clocks and as bare die to be bonded into a package with the primary IC, forming a system-in-a-package solution that makes the part self-clocked. Monolithic CMOS harmonic oscillators are a disruptive technology that is having broad impact on the electronics industry. Top-tier Silicon Valley VCs invested in the company, which was acquired in January 2010 by IDT (Integrated Device Technology, Inc.). At IDT, the frequency accuracy and jitter were further improved to within 20 ppm over the commercial temperature and voltage range. The Mobius technology was sold as the IDT 3LG Family of CrystalFree Solid-state Oscillators. Electronic Products Magazine gave the 3LG Family of Oscillators its “Product of the Year Award” for offering up to 75% lower power than crystal-based oscillators and the UBM/EETimes/EDN ACE Awards named the 3LG product its Analog IC Ultimate Product of the Year. Tens of millions of discrete chips and integrated modules were sold/licensed. Prof. Brown’s group integrated these silicon clock generators onto the embedded microprocessors that they designed, and they explored new applications for the basic technology, ranging from ultra-wideband radio transmitters to position sensors.

**Circuit Design:** (K. Wu, P. Parakh, C. Gauthier, K. Das, R. Rao, J. Sivagnaname, M. Guthaus, A. Ghosh)

The design of circuits underpins all of the areas addressed by Prof. Brown’s research group, so there is overlap between some of the activities in this and the other sections.

As electronics became ubiquitous, harsh environment applications, such as on jet engines or under the hood of cars grew. Prof. Brown’s group and researchers from the GE Corporate Research and Development Center significantly raised the operating temperatures of bulk CMOS circuits by using a thin epi substrate, higher doping levels, and refractory metal interconnect. They increased 300C latchup holding voltage by 4X and holding current by 30X over an equivalent bulk CMOS process. High-temperature design rules were developed that assured latchup-free operation at 200C. A transistor model that accurately represented the space charge at high temperatures (by solving the Poisson's equation and two-carriers' current continuity equations instead of assuming the depletion layer approximation) provided insights into circuit operation at very high temperatures. For example, it became clear that silicon circuits can never operate at high speeds and high temperatures because, in addition to the mobility degradation, the small-signal capacitance equivalent depletion-layer width becomes very small at high temperatures, significantly increasing the parasitic capacitive load.

While microprocessor clock speeds increased during the 1990s at a rate of about 40% per year, off-chip signaling rates improved more slowly, at about 14% per year. Concurrently, the number of transistors on chips increased according to Moore’s Law (doubling about every 18 months) but the number of package pins increased at only about 12% per year. Despite the development of more latency-tolerant architectures (multi-level caches, prefetching, stream buffers, etc.), these effects led to a significant bandwidth bottleneck between processor chips and off-chip memory. Prof. Brown’s group developed a switched-current transceiver with an active current mirror receiver that achieved Gb/s/pin operation in a 0.5 m CMOS process (current technology at that time). This cascoded switched-current signaling architecture was also implemented in CGaAs and compared to Gunning Transceiver Logic, large-buffer voltage signaling, and differential signaling. The switched-current interface was found to be four times more power efficient than similar source-synchronous interfaces. Claude Gauthier, who did this research in his Ph.D., is co-founder and CTO of OmniPhy, a leading provider of interface IP.

Prof. Brown pioneered the use of commercial CAD tools in university courses and research, but when a design automation capability they needed was not available in the commercial tool suites, his group sometimes developed it, always building on top of the best available commercial tools and making the new tools compatible with commercial tool flows. Examples of such contributions were the tools for high-performance gallium arsenide (GaAs) circuits and multichip modules. They developed circuit design techniques and CAD tools that guaranteed process tolerance in the circuits; SRAM compilers that optimize the design for the desired power-delay product; a tool that optimally places modules on a datapath; an automatic block placement tool that minimizes routing congestion; an area-I/O place and route tool for flip-chip packaging; and software that guides engineers through the cost-benefit analysis for nonlinear process scaling. On a sabbatical, Prof. Brown worked with Cascade Design Automation to develop a commercial GaAs circuit compiler that incorporated many of these capabilities. In work that was related to clocking, statistical design, and process parameter variation, his group developed a CMOS clock tree optimizer that correlated both clock and data-path parametric sensitivities to make designs more robust. A quadratic programming heuristic was introduced that was able to realize this improvement without sacrificing deterministic skew. The resulting trees have an average improvement of 16.3% in expected skew with the addition of only 2% to clock power. In a project aimed at making the performance of synthesized circuits approach that of custom circuits, the team developed a logical-effort-based transistor sizing tool, coupled to a cell synthesizer that generated physical, logical and simulation views (years before commercial tools offered this capability), and datapath tiling for wirelength minimization and predictable loads. The on-the-fly library generator enabled studies of circuit performance vs. library size. When the group needed embedded benchmark programs that were not readily available, they developed and published the MiBench suite, which is now widely used in industry and academia for benchmarking embedded processor architectures. According to Google Scholar, the original paper has been cited more than 4,660 times, and there are more than 32,000 references to it on the internet. Prof. Brown’s group saw a need for a library of digital and analog circuit modules that university students could use in class and research projects, so they developed the University of Michigan Intellectual Property Source (UMIPS), and populated it with circuits from their own projects. This resource facilitated collaboration and the reuse of circuits, so that designers could focus on the modules that were unique to their projects. Users from around the world have tapped this resource.

Working closely with the IBM Research Labs, Prof. Brown and his students developed circuit techniques for partially-depleted (PD) and fully-depleted (FD) Silicon-on-Insulator (SOI) technologies. Most of this work had a theme of reducing power dissipation at a given circuit speed. Prof. Brown spent a sabbatical focused on low-power circuits in SOI in the Exploratory VLSI group of the IBM Austin Research Laboratory just before moving to the University of Utah. Because of SOI’s superior short channel effects and better scalability, device technology has since moved to a form of SOI called FinFET. As semiconductor process dimensions and film thicknesses were scaled, subthreshold source-drain leakage and gate-source leakage increased to the point that the leakage power in ICs threatened to exceed dynamic power dissipation. New gate insulators and other process techniques were important parts of the solution, but good circuit techniques were also critical. Prof. Brown’s group developed circuits that mitigate the parasitic bipolar effect and timing uncertainty in PD SOI. They studied and refined multi-threshold CMOS (MTCMOS) for PD SOI, improving the gate delay by as much as 45% and the standby leakage by a factor of eight. Similar techniques were shown to be effective in dynamic logic, as well. Design automation tools were developed to guide the design of SOI circuits and implement the new circuit techniques. An optimal header/footer tapering algorithm was developed for FD SOI; it reduced standby leakage by a factor of 20 over that of conventional MTCMOS. A dynamic logic scheme for FD SOI circuits was developed that reduces leakage power by a factor of 10 to 30 while speeding up the circuits by 15% over a conventional domino logic scheme. All of the new techniques were evaluated in terms of their effects on power rail bounce. Prof. Brown’s group was first to study power-performance trade-offs of SOI circuits taking gate leakage into consideration. CAD tools for efficiently estimating gate leakage were developed, and efficient methods for determining the lowest-leakage data vectors to be applied to static combinational circuits in standby mode were developed. Circuit reorganization schemes were developed for both static and dynamic circuits that reduced gate leakage by 75% and total leakage by 40%. Power dissipation in data buses was reduced through the development of skewed pulse buses, which achieved a 20% reduction in active mode leakage, an order of magnitude reduction in standby leakage, and a delay improvement of 20%. Leakage was studied as a function of process parameter variation, and a model was developed for determining the optimal supply voltage for parametric yield optimization. Analog circuits in SOI, such as a body-compensated current mirror that is stable in the presence of gate leakage, and comparators that employ offset cancellation through body biasing, were also designed, fabricated and tested.

In light of the emergence of SOI technologies and effects that have come with aggressive scaling of electronic devices (short channel non-idealities and leakage), Prof. Brown’s group took a fresh look at unipolar logic families, using datapath blocks from their PowerPC-architecture PUMA Processor for realistic evaluations. They showed that pseudo-nMOS circuits could reduce standby leakage current by a factor of five, and that these circuits could be designed closer to the maximum performance point, since the load bias can be easily adjusted to compensate for process parameter variability. They also developed two variants of dynamic logic, controlled-load limited switch dynamic logic (LSDL), and hybrid limited switch dynamic logic, which offer better immunity to noise and charge sharing than basic LSDL. Wide implementations of CL-LSDL were shown to reduce power by as much as 50% over conventional CL-LSDL circuits, and H-LSDL improved delay by 30% over basic CL-LSDL. These logic styles are well-suited for high clock rate, high switching activity circuits such as digital signal processors, memory decoders and datapath circuits, and they can be freely mixed with other logic styles.

Among the greatest challenges in modern semiconductor technologies, where the gate oxide is only a few atoms thick and edge roughness of physical features makes a significant difference in transistor dimensions, is the variability of device parameters. Prof. Brown’s group has developed a technique for detecting parameter variation and compensating for it, so that circuits can be designed for the desired operating point, rather than needing to be over-designed to tolerate large parameter variations. Other parameter detection schemes are based purely on a representative circuit’s delay; they function properly only if the parameter variations of the p- and n-transistors are shifted in the same direction. The approach developed in Prof. Brown’s group uses delay, but also considers rise and fall times of signals in the representative circuit, thereby providing independent information on parametric shifts in the NMOS and PMOS transistors. With this information, the overall circuit speed can be adjusted by tuning the power supply voltage, and the gain for each transistor type can be adjusted independently using substrate bias to drive the operating point back to the desired position. This detection and compensation approach is in fact a low-power circuit technique because it minimizes the power wasted in circuits designed to operate with broad parameter variation, and it balances the gain of the p- and n-transistors, forcing the circuit to the most efficient operating point. This technique for forcing transistors to the optimal operating point may be even more useful in analog circuits than in digital circuits. The approach has also been successfully employed by Prof. Brown’s group to monitor PMOS devices for negative bias temperature instability and to compensate for this transistor-aging phenomenon. As in all of the research in Prof. Brown’s group, the circuits are not only designed and simulated, but are also fabricated, tested, and demonstrated in realistic applications.

IBM Research Labs hired seven of the Ph.D. graduates of Prof. Brown’s group, and many of the circuits described in this section were incorporated in IBM products.

High Performance Microprocessors: (J. Dykstra, A. Chandna, T. Huff, M. Upton, T. Basso, S. Gold)

The late 1980s and early 1990s were times of exploration of various semiconductor technologies for the fabrication of microprocessors. With DARPA funding, Prof. Brown’s high-speed circuits group designed three gallium arsenide microprocessors in E/D MESFET technology, three in CMOS, and one in complementary heterostructure-insulated-gate FET technology (CGaAs). Prof. Brown was a proponent of holistic design and multilevel optimization; the research group’s activities covered many facets of high-performance processor design, including process technology, circuit design, packaging, CAD tools, architecture, and the architecture’s relationship to software compilers. In 1993, they presented at the International Solid-State Circuits Conference, a MIPS-architecture GaAs microprocessor that operated at speeds as high as 200 MHz with 24W power dissipation. That clock speed was exceeded only by an ECL processor presented later at the same conference, which was clocked at 300 MHz, but dissipated 115W. Close working relationships developed between this university group and Vitesse Semiconductor, Motorola, MIPS Computer Systems, Cray Computer, Tera Computer, IBM, Green Hills Software, and Cascade Design Automation. The results of their exploration of very large-scale digital circuits in GaAs influenced technology directions taken by Vitesse and Motorola, and paved the way for Tera Computers to build a GaAs supercomputer.

Prof. Brown’s group developed a number of MESFET circuits which demonstrated novel ideas at the gate level (e.g., the patented current-mirror memory cell and power-rail logic); module level (e.g., high-speed modified Ling adder); and microarchitecture level (e.g., decoupled superscalar architecture and partially-decoded instruction cache). They were the first group to implement dynamic circuits in complementary GaAs. They also contributed to advanced packaging technologies for high performance computing (multichip modules, fine-pitch flip-chip gold bonding, and area-array I/O). They optimized the PowerPC microarchitecture for implementation in a small transistor-budget, and demonstrated a radiation-hard CGaAs microprocessor that operated at 86 MHz and 2W. Prof. Brown’s research group has been one of only a few at universities that had the capability of prototyping modern microprocessors.

Intel and AMD hired Ph.D. graduates from this group, who contributed to the design of their fastest microprocessors.

Mixed Signal Microprocessors: (K. Kraver, F. Gebara, R. Senger, E. Marsman, N. Gaskin, O. Novak, B. Redd)

Working with colleagues at Michigan, Prof. Brown brought his sensor and integrated circuit research areas together through the design of the MS-8 mixed-signal microprocessor which served as a single-chip interface instrument for the solid-state chemical and physical sensors that he and others developed. The MS-8 included voltage, current and capacitive sensor inputs, an accurate on-chip temperature sensor, an analog multiplexor, bandgap voltage reference, programmable-gain instrumentation amplifier,  analog-to-digital converter, a complete 8-bit microprocessor, on-chip memory, a 16x16 multiply 40-bit accumulate MAC for signal processing, a variety of counters/timers, and serial and parallel I/O modules. The microprocessor instruction set and modified Harvard architecture were original to this project and aimed at sensor-interface needs; they included bit test and set instructions, a fast interrupt response with 32 priority levels, and ultra-lite direct memory access. It was fabricated in a 0.35 m digital process.

Prof. Brown was one of five faculty members, led by Ken Wise, at the University of Michigan, who wrote the proposal for the Michigan Wireless Integrated Microsystems Engineering Research Center. This ERC proposal, focused on microsystems for remote environmental sensor and biomedical implant applications, referenced the MS-8 as evidence that the proposers could implement fully integrated systems. Prof. Brown was the thrust leader for Micropower Circuits in the ERC until he moved to become Dean of Engineering at the University of Utah. He continued to be an active researcher in the Center, participating in weekly administrative meetings (by video conference), industrial advisory board meetings, retreats, and annual reviews, through the ERC’s sunset.

Low power circuits were a focus of the ERC, since both of its testbeds required operation on battery power. Four microprocessors were designed in the WIMS series. They share a custom 16-bit RISC architecture with a 3-stage pipeline and windowed register file, on-chip memory, a loop cache, several peripheral communication interfaces, and the all-silicon harmonic oscillator described above. Efficient methods were developed for measuring the energy expended in the execution of each instruction, and a power-aware C compiler that uses this information was developed for the WIMS instruction set architecture by Prof. Scott Mahlke’s group at Michigan; feedback from the compiler studies was used to optimize the architecture. The Gen 1 processor, implemented in a 180 nm CMOS technology, was aimed at remote environmental sensing applications. It incorporated a full analog front-end that pushed the limits of low-voltage, low-power analog design in advanced digital processes. The nominal process operating voltage was 1.8 V; to accommodate the voltage change as a single battery cell falls from fully charged to its end-of-life potential, the analog circuits were designed to operate on any voltage between 1.8 V and 900 mV. Weak inversion biasing was used extensively to reduce the need for voltage headroom, to reduce transistor noise and power, and to increase amplifier gain. A second-order  modulator was employed in the analog-to-digital converter. When driving a 10 k, 150 pF load, the opamp achieves a DC gain of 80 dB, a unity gain frequency greater than 1.3 MHz, and a phase margin of 60°; the opamp draws a quiescent current of 128 A. The sub-1 V  modulator is enabled by a dynamically biased pseudo-differential integrator. This integrator supports low-voltage operation by employing the reset-opamp technique, thus avoiding the need for high-swing switches. Correlated double sampling curtails the effects of 1/f noise, a more serious problem in fine-featured processes.

Gen 2, also implemented in a 180 nm CMOS process, was designed as an implantable cochlear prosthesis controller. In addition to the processor core, memory and peripherals, it included a digital signal processor block consisting primarily of cascaded 1st, 6th and 4th order infinite impulse response filters that implemented the Continuous Interleaved Sampling Algorithm used to drive the electrodes in cochlear prostheses. To provide the required flexibility for patient fitting, all filter coefficients were made programmable by the processor. This chip included clock gating, the ability to modify the clock speed dynamically, and the ability to employ different clocks in the core and in the DSP. Prof. Brown’s group took the lead in implementing the cochlear prosthesis testbed, integrating the Gen 2 processor, application software, and chips designed by other WIMS researchers into a demonstration system.

The Gen 3 processor was designed at the University of Utah and fabricated in a 65 nm CMOS process. It added Direct Memory Access (DMA) instructions and scratchpad memory to the architecture, and was used to study the impact of process scaling on memory power and performance. It included the processor, all-silicon clock generator, memory, and hardware DSP functionality to support brain-computer interfaces. The fully-functional microprocessor core dissipated 350 W running at 10 MHz or 10 mW running at 100 MHz.

The final version, Gen 4, of this mixed-signal microprocessor, also developed in a 65 nm CMOS process, was designed to be a low-power implantable microcontroller that could handle applications ranging from solid-state sensor and actuator interfaces to wide-band neural interfaces. In addition to the 16-bit microprocessor core, all-silicon clock generator and other features from Gen 3, this chip includes 32 KB of on-chip SRAM, a battery charger powered by inductively coupled coils, a sleep-mode timer, a programmable-gain analog front end, two analog-to-digital converters, two digital-to-analog converters, and an all-digital ultra-wide-band radio transmitter that can transmit at 200 Mbps at an energy per bit of 19 pJ. The UWB transmitter had the highest pulse frequency and lowest silicon area of any reported transmitter. This microcontroller chip fulfilled the original vision of the WIMS ERC, to build a fully integrated instrument on a chip.

**Teaching**

**New Courses Taught at U of Michigan**

Title Introduced Taught

EECS317 Solid-State Devices F88 F88, F89

and Digital Electronics W93, W94, W95

Prof. Brown organized EECS317 to have an integrated-circuit orientation. This course gave all EECS students a good introduction to active devices and large-signal circuits, and prepared them for the VLSI course which followed in the senior year. Large-signal circuit models for diodes and transistors were developed from a physical perspective, and circuit analysis with active devices was introduced using digital circuits. The homework assignments emphasized the complementary use of hand analysis and computer simulation.

EECS427 VLSI Design I F90 F90, W96, W97

In 1990, Prof. Brown modified EECS427 so that it was organized around the design of a simple 8-bit CISC microprocessor, the baseline architecture of which was given to students as a starting point for their projects. Working in pairs, they chose an application for their processor and made all design decisions to support this application. Lectures covered topics just in time for students to design the cells which were due each week. This project and general approach to 427 were used through 1995. VLSI Design I was a major design experience before ABET had such a requirement.

In 1996, he had a chance to teach EECS427 again, and renewed and updated it in major ways. The project was changed to a simple 16-bit RISC processor and design teams grew to four members. A num­ber of new CAD capabilities were put into place to reduce design time, to introduce students to important industrial CAD capabilities, and to improve design methodology. At the end of the term, each team had designed and verified their microprocessor.

EECS627 VLSI Design II W86 W86, W87, W88, W89, W90, W91, F92

F93, F94, F95, F96, F97, F98, F99, W01

Prof. Brown developed EECS627, the UM advanced integrated circuit design course, in 1986; it had been taught once before, but was a very different course. Students gain maturity in 627 as they are exposed to advanced VLSI topics in lectures, and have a realistic design experience. In ’86, he introduced CMOS. In ’87, a silicon compiler and other commercial CAD tools were introduced. In ’92, he introduced design entry with the hardware-description language, Verilog. This course has continued to change to include current topics in VLSI and the latest CAD capabilities. EECS627 enabled many research projects and did much to improve the reputation of the Department in the area of VLSI.

In 2003, Intel identified the UM VLSI curriculum as the model curriculum, and funded Prof. Brown and several colleagues to document and disseminate the curriculum domestically and internationally.

**Short Courses and Workshops**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Course | | Location | | Date  Enrollment | |
| Ideal VLSI Curriculum | | University of the Philippines, Manila | | Aug. 9-10, 2005  18 | |
| Gallium Arsenide VLSI  (Instructor) | | Centre Applied Microelectronics  Universidad de Las Palmas  Gran Canaria, Spain | | Nov. 28-29, 1996  35 | |
| GaAs IC Primer Course  (Organizer) | | 1995 GaAs IC Symposium  San Diego, CA | | Oct. 29, 1995  47 | |
| VLSI Digital GaAs Circuit Design  ‘How to Build a 1 GHz Microprocessor’  (Instructor) | | Helsinki University of  Technology  Espoo, Finland | | July 4, 1995  28 | |
| GaAs IC Primer Course  (Instructor) | | 1994 GaAs IC Symposium  Philadelphia, PA | | Oct. 16, 1994  37 | |
| Device Selection and Performance  for High Temperatures  (Instructor) | | 1st Intl. High Temp. Elect. Conf.  Albuquerque, NM | | June 16, 1991  145 | |
| High-Temperature Electronics  Workshop  (Chairman) | | Ford, GE and UM  Ann Arbor, MI | | Sep. 28, 1990  16 | |

**Contributions to Teaching at U of Michigan**

When Prof. Brown arrived at the University of Michigan in 1985, the EECS Department’s National Advisory Committee had just published a report which recommended that the Department strengthen the integrated circuit design area (VLSI). He decided to make this a focus of his teaching effort.

Early in his career at UM, Prof. Brown realized that one could not teach proper design methodology with the CAD tools that were available at universities at that time. With the support of the Department and College, he chaired an ad-hoc committee to evaluate and procure new CAD tools, with the vision of replacing the fragmentary collection of software packages used in the Department with a consistent set of tools that would satisfy their instructional and research needs. The University of Michigan pioneered the use of commercial electronic CAD tools in academia as the major vendors accepted his proposals to donate their software to the University. His interaction with these companies helped them to establish university programs which have benefited many other schools. The Department’s undergraduate circuit and computer courses were restructured to use the commercial design automation software. These tools have been used throughout the undergraduate and graduate curricula at Michigan, and many universities have used the University of Michigan as a model for updating curricula to include electronic design automation.

Prof. Brown’s proposal to add VLSI as a new major area of study for M.S. and Ph.D. students led, with the help of others, to the establishment of a new kernel for graduate students. From both academic and research points of view, VLSI grew into one of the Department’s strong areas. Prof. Brown developed both the introductory and advanced VLSI courses at Michigan. These courses are widely known in industry and academia for giving students realistic design experiences which prepare them well for careers in integrated circuit design. Many universities have used the introductory course as a model. In addition to computing resources and CAD tools, students involved in VLSI courses and research need some specialized equipment to facilitate their work. Prof. Brown acquired for the Department plotters which can produce large color plots of chip layouts, an IC tester with 360 high-speed channels, and other test equipment that has enabled many class and research projects.

Prof. Brown organized a VLSI contest, originally founded by Kent Smith at the University of Utah, in which UM students participated for 15 years. It raised interest in VLSI at UM and served to improve UM’s VLSI reputation with industrial companies and among peer institutions. Companies with an interest in VLSI donated prizes totaling $15,000-$20,000 each year. Judges from the sponsoring companies evaluated the entries from the participating universities. UM students did well in the contest. Mentor Graphics ran a Student VLSI Contest for four years which was patterned after this competition. Here too, UM students typically took the top prizes. In 2000, the Utah/UM contest was merged with a contest sponsored by the Design Automation Conference (DAC); it later became jointly sponsored by the International Solid-State Circuits Conference. The new competition, called the Student Design Contest, gave students national exposure. The winners had their expenses paid to attend DAC and ISSCC, where they presented their designs as posters or in oral sessions, and were honored at awards ceremonies. For the VLSI students, this international contest was like competing in the Rose Bowl. The contest had two categories, conceptual and operational. In the first year of this contest (2000), there were 31 entries from 22 of the top universities throughout the world. UM students took first prize in operational and both first and second prize in conceptual, as well as best paper. In 2001, UM students took first prize in operational and first, second and third prizes in conceptual, as well as best paper. In 2002, UM students won third place in the operational category, first place in the conceptual category, and overall best paper award. In 2003, UM students were awarded first and second prizes in the conceptual category. So ended Prof. Brown’s coaching career.

**VLSI at the U of Utah**

Long before Prof. Brown returned to Utah, faculty at the U of U had modeled their introductory VLSI course after the one he had developed at Michigan. Since his arrival at the U, Prof. Brown has worked with the ECE and Computer Engineering faculty to flesh out the rest of the VLSI curriculum. A new faculty member was hired in the VLSI area, and he established the advanced VLSI course starting with Prof. Brown’s notes. Prof. Brown acquired for the University a Verigy 93000 integrated circuit tester that not only facilitated his own students’ research, but also the course projects and the research of other faculty members. The VLSI program at the University of Utah has become a strong program with a large number of students enrolled.

**Graduate Education**

Prof. Brown has graduated 31 Ph.D.s.

**Administrative Service**

Prof. Brown joined the University of Utah as Dean of Engineering in July 2004. Since that time, he has led the development of a strategic plan for the College that has a vision of raising the quality of teaching, research and service to a level comparable to that of the best engineering schools in the world. Its objectives include growing the research enterprise, positioning the College to become a leader in nanotechnology, assisting faculty in their career development, increasing the amount of technology transfer, nurturing alumni relationships, broadening the Engineering donor base, strengthening the academic experience and climate for students, and improving recognition of the College. The faculty, staff and students have worked together to bring about significant progress in each of these areas; special credit goes to the associate deans, assistant dean, development group, outreach staff and public relations team.

To encourage higher levels of faculty performance, clear, consistent objectives were established, regular feedback was provided, and incentives were put into place. A uniform annual Faculty Activity Report (FAR) was instigated through which faculty members report on their accomplishments in the same categories considered in retention, promotion and tenure (RPT) decisions. The full spectrum of performance data from the FARs is regularly presented to faculty, and is used in informal annual reviews and merit salary decisions. The FAR data, now entered through a web interface with much of the information pre-populated, feeds directly into the University’s Authoritative Database. The College of Engineering pioneered this on-line version, which has now been rolled out to the rest of the University. Prof. Brown wrote and had adopted new RPT guidelines that restructured the College RPT Advisory Committee and clearly defined expectations for retention, promotion and tenure. The first electronic RPT casebook files were created in the College of Engineering. This approach was adopted university wide.

Dean Brown negotiated a financial model for the College that rewards individual investigators, departments and the college for increased research activity. This has been a huge motivation for growing research volume. He worked with the Office of Sponsored Projects to send faculty members electronic announcements of calls for proposals; this has now been implemented university-wide. He organized industry-faculty interactions with local and national companies, which has led to direct research funding and to joint funding from government agencies. Annual Engineering research expenditures grew from $30M in 2004 to more than $99M.

The College leveraged its current strengths and further expanded interdisciplinary research through the USTAR initiative. Twenty-two USTAR faculty members affiliated with Engineering were hired, most of them world-class senior faculty who are model. This strategic growth has been in the areas of nanotechnology, microsystems, neural interfaces, biomedical devices, computer imaging, animation, and energy. The senior USTAR hires brought with them a standing in their academic communities that immediately benefited the U’s reputation.

The Engineering Initiative, which is aimed at increasing the number of engineering and computer science graduates in Utah, represents a large infusion of funding for the College; these funds have been used almost exclusively to hire new faculty members. The U has organized this state-wide initiative and coordinated the lobbying since its inception; the lobbying is our vehicle for communicating the economic importance of engineering to the legislature and governor. Dean Brown’s industrial advisory board, composed of 29 external members, typically company vice-presidents or presidents, are a great support in this effort. This board meets as a full group five times per year. A Technology Initiative Advisory Board, also composed of industry representatives, divides the funding allocated by the legislature among the eight state universities. The College receives $26.8M in ongoing funds each year and has received $4.3M in one-time funds through the Engineering Initiative. Private and foundation donations have also been critical to growth and progress in the College.

Closely related to the Engineering Initiative is the College outreach program, which coordinates about 40,000 face-to-face interactions with K-12 students per year. College outreach staff, students, faculty, and alumni visit schools or otherwise interact with prospective students. The Engineering Ambassadors, a select group of students, are heavily involved in outreach and recruiting. Many students come to campus for events such as Engineering Day, Meet and Inventor Night, Girl Scout Engineering Night, and summer camps.

To stay engaged with the faculty, Dean Brown invites one faculty member twice a month to present his/her research to the dean, associate dean for research, advancement group, and public relations team. The College PR team, composed of a writer, a graphics designer, a web master, videographer, and social media staff member, have increased the amount of media coverage of U of U Engineering research by many times. The College brand is becoming better recognized through print and electronic newsletters, a research report produced annually, and an excellent web site.

A new faculty orientation is conducted each August to help faculty efficiently start in all of their responsibilities. Junior faculty members are assigned a mentor in their own department, and the department chair takes primary responsibility for guiding the junior faculty. Dean Brown also meets with junior faculty individually, and by cohorts twice per year, to discuss all aspects of building a strong academic career. To complement the university-level teaching support, a teaching seminar is conducted for junior faculty members. A few months after the new faculty orientation, a follow-up research seminar is held. Books on being a responsible faculty member are given to each junior faculty member. Prof. Brown organized a committee of senior women faculty from the College of Engineering, the College of Mines and Earth Sciences, and the College of Science to make recommendations related to women faculty and student issues. This group was very active in the discussion of family leave, and made recommendations for hiring procedures which are followed by the College of Engineering. The College adopted a policy of paying 100% of salary during family leave. He also organized a Dean’s Advisory Council for Women, that mentors women faculty and advises the dean on women’s issues.

Dean Brown has been an advocate for collaborative relations with industry and for commercialization of university research. After hearing from his Industrial Advisory Board about challenges in university-industry relations, he made this topic the focus of discussions with the Engineering National Advisory Council, a group of about 30 of the College’s most successful alumni (and adopted alumni). This group meets twice per year with the deans and department chairs and discusses strategic issues in the college; guest speakers have been governors, senators, the commissioner of higher education, and the university president. A task force from this group wrote a resolution on university-industry relations to Pres. Michael Young that had a large impact on the University. Dean Brown served as co-chair of the search committee that hired the new Director of the Technology Commercialization Office; this hire was the key to an excellent tech transfer climate. IP-related disputes with organizations were resolved and more industry-friendly practices were established in the commercialization office. With TCO, Prof. Brown founded the Tech Titans state-wide entrepreneurial competition. Invention disclosures from Engineering more than doubled to about 100, and College of Engineering faculty have spun out more than 100 companies since 2006. The commercialization office is now called PIVOT.

Dean Brown organized the University of Utah Engineering Alumni Association (EAA) in 2005 with a board that meets regularly and bylaws that provide for rotation of officers and board members. Members of the EAA visit K-12 classrooms as part of the College’s outreach program and help with retention by interacting with current engineering students. They are involved in graduate student recruiting and other ways of helping the College. The EAA web site and electronic newsletters have increased College communication with the alumni, as well as communication between alumni.

The student academic experience was strengthened through the organization of an Engineering Honors Program tailored to fit the engineering curriculum. This program includes the freshman E-LEAP experience, an undergraduate research opportunity and a service component, and it builds the honors thesis on the engineering senior project. Whereas only a few engineering students per year graduated with honors before, now engineering students make up about a quarter of all university honors students. Questions about class climate were added to the engineering course evaluations; consistent improvement has been shown on the answers to these questions. The Engineering Tutoring Center was established to provide free help to lower-division students, and tutoring is now available in all of the departments, helping with retention on many levels. A new Engineering Math sequence was implemented with a focus on applied mathematics, and with recitation sections and in-class remediation for students who are weak in some area. Engineering graduates are developing better communications skills through the College’s CLEAR program, which has been incorporated into curricula throughout the College. Successful ABET accreditation reviews were held in September 2009, 2015, and 2021.

Dean Brown negotiated international student exchange and/or partnership agreements with a number of the top engineering universities throughout the world: Saarland University, Saarbrücken, Germany; Technische Universität, Berlin, Germany, Shanghai Jiao Tong University, Shanghai, China; Tsinghu University, Beijing, China; Seoul National University, Seoul, Korea; Indian Institute of Technology, Kharagpur, India; and Hong Kong University of Science and Technology, Hong Kong, China; and the University of São Paulo, Brazil.

A non-thesis MS degree was implemented in all departments to facilitate the matriculation of Ph.D. students. A Systems Engineering Certificate, available to students across the College, was established. The Nuclear Engineering Program was reinvigorated and a minor in Nuclear Engineering, available to all Engineering and Science students, was approved. Distance education, which has been very successfully delivered to students at ATK (more than 75 have graduated with master’s degrees), has been expanded with a Master of Science degree in Petroleum Engineering, a Master of Science degree in Electrical Engineering, and a certificate in Big Data. The Electrical and Computer Engineering Department developed 2+2 BS degree for the U’s Songdo Campus. The College implemented an on-line graduate application process, mounted a graduate student recruiting PR campaign, and organized a college-wide graduate visitation day to help departments recruit more highly-qualified graduate students. The result was a significant increase in quality of incoming graduate students.

The College of Engineering and the Business School have developed an Engineering Entrepreneurship Certificate at both the undergraduate and graduate levels. It includes courses titled “The Business of Entrepreneurship,” “Launching Technology Ventures,” “Patent Law and Strategies,” and “Emerging Technology & Engineering Entrepreneurship,” a technical writing course, and a capstone project or thesis. Joint Engineering MS/MBA degrees are also available to engineering students.

The College of Engineering is growing. In 1999, we graduated 366 students; the number is now 1,287. Many of the College programs are entering the top 50 in size. As enrollments have grown, student quality has also improved; average ACT scores for our direct-admit students are 31, and average high school GPAs are 3.9. The physical facilities have also improved considerably with the dedication of the 100,000 ft2 John E. and Marva M. Warnock Engineering Building in February 2007. The former Engineering and Mines Classroom Building was completely renovated in 2008 and renamed as part of the Warnock Engineering Building, adding another 60,000 sq. ft. A major renovation was done to the Merrill Engineering Building before 2004, but many lab and mechanical renovations have been done since to prepare space for the newly hired faculty. With a $3.3M lead gift, the Energy and Materials Research Laboratory has been expanded into the Floyd and Jeri Meldrum Civil and Environmental Engineering Building. Dean Brown was intimately involved in the programming, fundraising and design of the $130M, 200,000 ft2 Sorenson Molecular Biotechnology (USTAR) Bldg., which houses the Bioengineering Department, many engineering faculty offices and research labs, a vivarium to support biomedical research, a microscopy and surface analysis core facility, and a world-class nanofabrication laboratory. The most recently completed facilities project in Engineering was the complete rebuilding of the Rio Tinto Kennecott Mechanical Engineering Building, which is a showpiece of sustainable renovation. A third phase of this building, the Stephen C & Lynda M. Jacobsen Tower, opened in 2022. A 250,000 sq. ft. computing and engineering building is in the design stage; groundbreaking is planned for 2023 and occupancy at the end of 2025.

**Grants and Contracts**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Dates | | Title/Participants | | Sponsor | | Total Funds | |
| 1/86 - 7/87  7/87 - 7/91 | | High-Temp. Solid-State Sensor Technology  (grant)  (P.I. & Proj. Dir.; Co-P.I., F. L. Terry, EECS) | | Ford SRL  Ford Fund | | $131,994  $370,000 | |
| 9/86 - 4/87 | | Fabrication Feasibility of Multielectrode Arrays  (SBIR consultant to Integrated Microsystems) | | NIH | | $50,000 | |
| 10/86 - 10/91 | | High-Frequency Microelectronics  (Participant; Proj. Dir., George Haddad, EECS) | | ARO | | $18,000,000 | |
| 3/87 | | Digital Oscilloscope and Plotter  (Equipment Grant) | | HP | | $27,358 | |
| 4/87 - 12/92 | | Integrated Sensors for Water Quality Control  (P.I.) | | Fleck  Controls, Inc. | | $289,084 | |
| 6/87 - 5/88 | | Micromachined Pressure Sensor  (P.I.) | | VP Res.  UM | | $15,119 | |
| 5/89 - 4/90 | | High-Temperature Electronics  (P.I.) | | G.E. | | $20,000 | |
| 9/89 - 7/93 | | Microbiosensor Arrays  (P.I. & Proj. Dir.; Co-P.I.s, M.E. Meyerhoff,  Chemistry, and A.R. Midgley, Medicine) | | NSF | | $574,696 | |
| 8/90 - 8/94 | | GaAs Microcomputer  (P.I. and Proj. Dir.; Co-P.I.s, T.N. Mudge,  R.J. Lomax, K. Sakallah and  W. P. Birmingham) | | DARPA | | $2,776,270 | |
| 7/91 - 11/91 | | High-Speed Digital Tester  (P.I.) | | ARO | | $149,202 | |
| 12/92 - 11/95 | | Rapid Prototyping and Evaluation of  High-Performance Computers  (Co-PI with Mudge (Director),  Davidson, Hayes, Abraham,  Birmingham, Sakallah, and Patt) | | NSF | | $804,076 | |
| 7/92 - 6/97 | | High-Frequency Microelectronics  (Participant; Proj. Dir., George Haddad, EECS) (One student support for 1 yr.) | | ARO | | $5,840,400 | |
| 1/93 - 12/93 | | Solid State Chemical Sensors  (P.I.) | | Motorola | | $50,000 | |
| 2/93 | | Electrostatic Plotter  (P.I. - transferred to gift account) | | HP | | $49,900 | |
| 4/94 - 4/95 | | Evaluation of Polymer Membrane Based  ISMOS-FETS and Characterization  of Same with Respect to Manufacturability  (P.I.) | | Motorola | | $166,667 | |
| 5/94 - 4/95 | | High Speed Design Tools  (Co-P.I. with Pavlidis (Director),  Sakallah, and Katehi) | | ARPA | | $566,279 | |
| 7/94 - 7/95 | | Planar Sensor Fabrication Feasibility  Assessment  (Co-P.I. with M. E. Meyerhoff, Chemistry) | | Mallinckrodt | | $190,487 | |
| 7/94 | | Solid-State Sensors  (P.I., Unrestricted Gift) | | DuPont | | $10,000 | |
| 9/94 - 8/98 | | Design Optimization of a GaAs RISC  Microprocessor with Area-Interconnect  MCM Packaging  (P.I. and Proj. Dir.; Co-P.I.s, T. N. Mudge,  R. J. Lomax, and K. Sakallah) | | DARPA | | $5,002,705 | |
| 5/95 | | Solid-State Sensors  (P.I., Unrestricted Gift) | | DuPont | | $10,000 | |
| 7/95 - 6/00 | | GaAs System Implementation  (P.I.) | | ARPA | | $243,424 | |
| 7/95 - 6/96 | | Solid-State Planar Sensor Technology  (Co-P.I. with M. E. Meyerhoff, Chemistry) | | Mallinckrodt | | $219,739 | |
| 7/97 - 7/99 | | Microprocessor Design Verification  (Co-P.I. with Hayes (Director), and Mudge | | DARPA | | $660,390 | |
| 7/96 - 6/97 | | Silicon-Based Sensor Array for Whole Blood Analysis (P.I.) | | Inst. Labs. (IL) | | $200,281 | |
| 7/97 - 6/00 | | Instruction Stream Compression  (Co-P.I. with Mudge (Director), and Bird) | | DARPA | | $1,183,596 | |
| 1998 | | Mixed-Signal Microprocessor | | National | | $100,000 | |
| 1/98 - 12/98 | | Multi-site Potentio-Amperometric Neural Sensor Array (SBIR with Dr. Hal Cantor of Advanced Sensor Technologies, Inc.) | | NIH | | $100,000 | |
| 1998 | | Analog Circuit Design | | Texas  Instruments | | $50,000 | |
| 1998 | | Silicon on Insulator Circuits | | AMD | | $10,000 | |
| 6/99 - 5/00 | | Low Voltage Analog Front End | | National Semi. | | $100,000 | |
| 1/99 -12/99 | | Low Voltage Analog Design | | Texas  Instruments | | $100,000 | |
| 10/99 - 9/00 | | SOI Circuits | | AMD | | $20,000 | |
| 12/1/99 -  11/30/02 | | Mass Producible Chemical Sensors and Their Measuring Systems | | Kwangwoon Univ., Korea | | $24,000 | |
| 2/1/00 -  1/31/03 | | SOI Circuits for Analog, Digital, and Mixed Signal Applications | | SRC | | $300,000 | |
| 8/00 - 7/01 | | SOI Circuits | | AMD | | $25,000 | |
| 8/00 - 7/01 | | Mixed-Signal Microprocessor | | National  Semiconductor | | $50,000 | |
| 9/00 - 8/05 | | An ERC in Wireless Integrated Microsystems  Kensall D. Wise, Director  Richard B. Brown, Thrust Leader | | NSF | | $29,447,010  my share $500,000/yr.  for first 5 yrs. | |
| 10/00 - 9/01 | | Undergraduate Mentoring Program | | SRC | | $18,000 | |
| 1/01 - 12/04 | | Electron-Relay Enabled Immunosensor  (Co-P.I. with M.E. Meyerhoff, Chemistry) | | State of MI - Life Sciences  Proposal | | $769,589 | |
| 2/01 - 1/02 | | An Optimal Microbial Control System to Enable Environmental Improvement of  Aqueous Fluidic Systems  Steven Skerlos, Richard Brown, Katsuo Kurabayashi, Kim Hayes, Alexa Rihana | | IESET | | $50,000 | |
| 9/01 - 8/02 | | Undergraduate Mentoring Program | | SRC | | $12,000 | |
| 9/01 - 12/01  1/02 - 12/02  1/03 - 12/03  1/04 - 12/04  1/05 - 12/05 | | IBM Faculty Partnership Award:  YR 1: An SOI, DTMOS Resonant-clocked Floating-point Unit  YR 2: Low-Power SOI Datapath Circuits  YR 3: Mitigation of CMOS Gate Leakage  YR 4: Robust Low-Leakage Circuits  YR 5: Embedded Microcontroller to Improve Power | | IBM | | $25,000  $40,000  $40,000  $40,000  $40,000 | |
| 3/01 | | 9 Workstations with Monitors | | Sun  Microsystems | | $142,038 | |
| 9/01 - 9/03 | | Complex Signal Processing ASIC Designs  (P.I.; Co-P.I., Dennis Sylvester) | | DARPA - BAE Systems | | $786,496 | |
| 9/03 - 8/04 | | Sensors for Monitoring and Diagnostics of Bridges (P.I. Andrzej Nowak, Civil and  Environmental Engineering) | | ISI: Infrastruc- ture Systems Initiative | | $85,000 | |
| 2003 | | Focused Ion Beam Workstation  John F. Mansfield (P.I., Materials Science and Engineering, EMAL), R. Brown and others | | MRI | |  | |
| 9/03 - 12/04 | | VLSI Design Curriculum  (Richard B. Brown (P.I.), David Blaauw,  Michael Flynn, Dennis Sylvester) | | Intel  Foundation | | $202,173 | |
| 9/05 - 8/08 | | SST Integrated Particle Counting and Potenti- ometric Sensor Array for Water Quality Analysis  (P.I.; Co-P.I., Henry White, UofU Chemistry) | | NSF | | $299,994 | |
| 7/05 - 6/06  7/06 - 6/07  7/07 - 8/08 | | Feasibility of Measuring Autoantibody  Interference of Physiologically Active Muscle Cells Using a Biological Nanosensor (Co-P.I. with Harry Hill, ARUP Labs) | | ARUP Lab and Dept. of Pathology-UofU | | $15,000  $25,000  $30,256 | |
| 9/05 - 8/08 | | Neural Probes for Electrical and Chemical Sensing (sub-contract with U Michigan) (Co-P.I., Richard Brown; P.I., Daryl Kipke) | | NIH | | $129,371 | |
| 9/05 – 8/06  9/06 – 8/07  9/07 – 8/08  9/08 – 8/09  9/09 – 8/10 | | An Engineering Research Center in Wireless  Integrated Microsystems (sub-contract with U Michigan) | | NSF | | $99,881  $90,000  $90,000  $60,300  $30,000 | |
| 5/09 – 8/09 | | Student Travel Assistance for the Symposium of 35 Years of Chemical Sensors in 215th ECS | | NSF | | $6,000 | |
| 8/09 – 7/12 | | Detection and Mitigation of Hazardous Releases in Infrastructure Systems (sub-contract with U Michigan)  (Co-P.I. with N. Katapodes, director, and A. Stefanopoulou) | | NSF | | $70,114 | |
| 8/09 – 7/10 | | IGERT: Nanobiosensors, Nanomaterials, and Microfluidics | | NSF | |  | |
| 09-11/2013 | | Coagulation Sensor, (Richard B. Brown; P.I.) | | FACTOR 14 | | $15,140 | |
| 09/2014 –  08/2015 | | E-Chem Catheter Project, (sub-contract with University of Michigan) | | NIH | | $45,644 | |
| 03/2014 –  06/2015  01/2017 –  12/2019 | | Prototype Potentiostats for NO-Release, (Richard B. Brown, P.I.)  Advanced Thromboresistant/Bactericidal Catheters via Electromodulated NO | | University of Cincinnati  NIH  UM subaward | | $10,000  $121,942 | |

**Publications *(Prof. Brown’s graduate students’ names are underlined; \* indicates that the person was his postdoctoral student when the published work was done.)***

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Richard B. Brown, “The Utah Story,” Arkansas Innovation Council Summit, Little Rock, AR, Feb. 19, 2019.

Richard B. Brown, “International Collaboration in Engineering,” Chinese Association for Science and Technology Annual Meeting, Salt Lake City, UT, Dec. 2018.

Richard B. Brown, “A Disruptive Technology for Water Quality Testing,” Annual Conference of the American Water Works Association, Las Vegas, NV, June 11-14, 2018.

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Richard B. Brown, Glenn Prestwich, “Faculty Involvement,” 2015 Commercialization Interchange, Session Discussion, University of Utah Technology & Venture Commercialization, Salt Lake City, Utah, October 15, 2015.

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Richard B. Brown, “Helping Meet the Engineering Needs of Hill Field Air Force Base,” Invited Talk, Hill Field Management Awards Ceremony, Hill Field Air Force Base, Layton, Utah, March 4, 2015.

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Richard B. Brown, “The College of Engineering at the University of Utah,” Invited talk, University of Utah, Department of Electrical and Computer Engineering, September 29, 2014.

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Richard B. Brown, “University of Utah College of Engineering,” Invited talk, WECEDHA Meeting, Salt Lake City UT, September 20, 2013.

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**Service**

**Committee Assignments at U of Utah**

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| --- | --- | --- | --- | --- |
| Committee | | Position | | Date |
| Tech. Transfer Office Director Search Com. | | Co-Chair | 8/04 – 5/05 |
| CoE Industrial Advisory Board | | Ex Officio Member | 7/04 – |
| CoE Engineering National Advisory Com. | | Ex Officio Member | 7/04 – |
| CoE Executive Committee | | Chair | 7/04 – |
| Utah Science Technology and Research (USTAR) Oversight Committee | | Member | 7/04 – 9/05 |
| University Academic Senate | | Senator-Deans’ Rep | 8/05 – 5/07 |
| Academic Senate Executive Committee | | Member | 8/06 – 5/07 |
| Presidential Mission Statement Task Force | | Member | 9/05 – 3/06 |
| University Commercialization Advisory Board | | Member | 10/05 – 7/09 |
| Cyber Infrastructure Advisory Committee | | Member | 10/05 – 3/06 |
| Advancement Policy Council | | Member | 12/05 – 3/09 |
| Effort Reporting for Sponsored Research - Steering Committee | | Member | 1/06 – 10/08 |
| USTAR Building - Steering Committee | | Member | 5/06 – 12/11 |
| Disaster Resistant University Advisory Com. | | Member | 8/06 – 10/08 |
| Internal International Advisory Board | | Member | 10/06 – 12/08 |
| Asia Center Advisory Board | | Member | 8/07 – 7/10 |
| Communication, Leadership, Ethics and Research (CLEAR) Advisory Board | | Member | 9/07 – 6/13 |
| USTAR Bldg. Programming Committee  Quadrangle Master Planning Committees  Open Space Committee, Design Committee  NanoFab Subcommittee | | Member | 1/08 – 12/11 |
| Dean College of Pharmacy Search Committee | | Member | 10/08 – 10/09 |
| Mathematics Steering Committee | | Member | 9/08 – 12/11 |
| Endowment Advisory Committee | | Member | 12/09 – 7/11 |
| Assoc VP for Enrollment Management Search Committee | | Member | 12/10 – 7/11 |
| Chief Information Officer Search Committee | | Member | 1/11 – 5/11 |
| Director Technology Commercialization Office Search Committee | | Member | 3/11 – 9/11 |
| Senior Vice President Academic Affairs Search Committee | | Member | 2/12 – 7/13 |
| Operational IT Committee  Songdo Steering Committee  U of U Branding Committee  Budget Principles and Process Working Group  Search Committee Chief Business Officer  Fundraising Working Group  Chair of Search Committee for Dean of Science  College Board AP Engineering Committee  Space Allocation Working Group | | Member  Member  Member  Member  Member  Member  Co-Chair  Member  Member | 2012 – 2015  2012  1/12 – 8/12  2013 – 2014  2013 – 2014  2013 – 2015  01/13 – 04/14  10/13 – 10/14  2013 – 2014 |
| Office of Global Engagement Council | | Member | 2014 - 2018 |
| Chief Information Officer Search Committee | | Member | 7/13 – 12/14 |
| Dean’s Advisory Group to the Provost | | Member | 10/14 – 10/16 |
| USAID Pakistan Water Advisory Board  Faculty Data Services Committee  ARUP Director Search Committee | | Member  Member  Member | 3/14 –12/20  5/15 – 11/15  7/15 – 8/16 |
| TVC Director Search Committee | | Member | 06/16 – 01/17 |
| Campus Budget Advisory Committee | | Member | 01/16 – 6/18 |
| Graduate Writing Committee | | Member | 01/16 – 12/16 |
| Sustainable Funding Models for Learning Abroad and International Student & Scholar Services | | Committee Member | 01/16 – 12/16 |
| Sr. VP’s Institutional Analysis Committee | | Committee Member | 07/16 – 06/17 |
| Entrepreneurial Faculty Scholar | | Faculty Mentor | 10/16 – |
| President’s Leadership Council (PLC) | | Member | 10/18 – |
| Internal Advisory Board (IAB) for Huntsman Cancer Institute | | Member | 03/18 – |
| RPT Content Committee  Rosenblatt Selection Committee  Academic Senate | | Co-Chair  Member  Member | 11/18 – 10/19  3/19, 3/20  8/20 – |

**Committee Assignments at U of Michigan**

(see key below)

|  |  |  |
| --- | --- | --- |
| Committee | Position | Date |
| EECS Ad hoc Circuits Review Com. | Member | 10/85 – 1/87 |
| SSEL Operations Com. | Member | 1/86 – 9/00 |
| EECS Ad hoc Com. on CAD Tools | Chair | 3/86 – 12/87 |
| Solid-State Lab Mgr. Search Com. | Member | 9/86 – 10/86 |
| EECS Computer Policy Com. | Member | 9/86 – 8/91 |
| IEEE Student Chapter Advisor | Advisor | 1/87 – 8/90 |
| SSEL Ad hoc Com. on Document Prep. | Chair | 2/87 – 4/87 |
| EECS Ad hoc Computing Needs Com. | Member | 3/87 – 5/87 |
| EECS Elec. Sci. Eng. Division Executive Com. | Member | 9/88 – 8/89 |
| College Honors and Awards Com. | Member | 9/88 – 9/90 |
| EECS Elec. Sci. Eng. Division Graduate Com. | Member | 9/92 – 8/94 |
| EECS Circuits Advisor | Advisor | 9/92 – 8/94 |
| CAEN Executive Committee | Member | 10/90 – 8/95 |
| EECS Dept. Executive Committee | Member | 9/93 – 8/95  9/97 – 5/03 |
| Solid-State Faculty Search Committee | Member  Chair | 9/96 – 9/99  9/98 – 9/99 |
| EECS Department Chair Search Committee | Member | 11/96 – 9/97 |
| CoE National Advisory Committee | Participant | 11/98 |
| DCO Executive Committee | Member | 9/97 – 9/98 |
| Circuits Faculty Search Committee | Chair  Member | 9/97 – 8/98  9/98 – 9/99 |
| Tauber Manufacturing Institute  TMI Industrial Co-Director Search Committee | Board of Directors  Member | 9/97 – 9/99  9/98 – 6/99 |
| UM Conflict of Interest Committee | Member | 9/95 – 4/01 |
| EECS Administrative Committee | Member | 10/97 – 6/01 |
| EECS Honors and Awards Committee | Member | 9/97 – 5/03 |
| EECS National Advisory Committee | Participant | 3/99 |
| ESE/SSE Curriculum Committee | Member | 9/98 – 6/01 |
| CoE Task Force on Reshaping Graduate Engineering Education | Member | 9/98 – 6/99 |
| EECS Ad Hoc Committee on Undergraduate  Programs | Member | 9/99 – 3/00 |
| EECS Futures Committee | Member | 3/00 – 11/00 |
| EECS National Advisory Committee | Participant | 9/00 |
| CE Undergrad Degree Committee | Member | 10/00 – 7/01 |
| EE/Systems Organization Committee | Member | 4/01 – 8/01 |
| EECS Administrative Committee | Chair | 7/01 – 5/03 |
| ECE Executive Committee | Chair | 7/01 – 5/03 |
| CSE Executive Committee | Member | 7/01 – 5/03 |
| CoE Chair Advisory Committee | Member | 7/01 – 5/03 |
| EECS National Advisory Committee | Organizer | 3/02 |
| CoE National Advisory Committee | Participant | 4/02 |
| CoE Committee on Interdisciplinary Research | Member | 9/02 – 5/03 |
| Medical School Conflict of Interest Board | Member | 9/02 – 2/02 |
| CoE International Programs Committee | Member | 9/02 – 6/04 |
| Arthur F. Thurnau Professorships | Reviewer | 2002  2003 |
| Michigan Society of Fellows | Reviewer | 2002 |
| OVPR Review Committee of Conflict of Interest & Commitment Policies | Member | 2003 |
| Infrastructure Systems Initiative (ISI) Steering Committee | Member | 2003 |

CoE College of Engineering

EECS Electrical Engineering and Computer Science Department

ECE Electrical and Computer Engineering Division of EECS

CSE Computer Science and Engineering Division of EECS

ESE *former* Electrical Science and Engineering Division of EECS

SSE *former* System Science and Engineering Division of EECS

SSEL Solid-State Electronics Laboratory

CAEN College of Engineering Computer-Aided Engineering Network

DCO EECS Departmental Computing Organization

UM University of Michigan

**Administrative Duties at U of Utah**

Organization DutyDate

CoE Dean 7/04 –

**Administrative Duties at U of Michigan**

Organization Duty Date

EECS/CAEN Electronic CAD Application Sector Director 6/88 – 6/04

EECS Department Assoc. Chair 10/97 – 6/01

EECS Department Interim Chair 7/01 – 6/03

**Service to Government and Professional Organizations**

|  |  |  |  |
| --- | --- | --- | --- |
| Type/Organization | | Position | Date |
| **Proposal Reviewer**  NIH  UM Undergraduate Initiatives Grants  State of Michigan Research Fund Proposals  UM Office V.P. for Research Grants  NSF  Department of Energy  NIH Site Visit Special Study Section Panel | Reviewer  Reviewer  Reviewer  Reviewer  Reviewer  Reviewer  Member | 1998 |
| **Journal Reviewer/Editor/Advisory Board**  IEEE Transactions on Electron Devices  Solid-State Electronics  Analytical Chemistry  Sensors and Actuators  IEEE Circuits and Devices  IEEE Journal of Solid State Circuits  IEEE Journal of Solid State Circuits  IEEE Transactions on Reliability  IEEE Transactions on Very Large Scale Integrated (VLSI) Circuits  IEEE Sensors Journal  Proceedings of the IEEE  American Society of Engineering Education | Reviewer  Reviewer  Reviewer  Reviewer  Reviewer  Reviewer  Guest Editor  Reviewer  Assoc. Editor  Advisory Board  Guest Editor  Reviewer | 1995  1999-2002  2001-  2001-2002 |
| **Advisory Committees and Activities**  NSF Workshop on Microelec. Sys. Edu. in the 1990s  ASME Emerging Technologies Com.  NSF Workshop on Rapid Prototyping of ICs  ARPA/ONR Thermal Management Round Table  MOSIS Advanced Technology Advisory Committee  NSF Workshop on Integration of Edu. & Res. in Microelec. Edu.  NSF MOSIS Advisory Council on Education  Engineering Program Review for BYU ECE Dept.  National Advisory Committee for BYU ECE Dept.  SRC Undergraduate Engineering Programs Advisory Board  Hope College Engineering Advisory Board  Utah Technology Council  Utah Technology Council Utah Quality TECH Workforce  Utah Technology Council Public Policy Committee  University of Washington, College of Engineering Visiting Com.  IEEE CS Fellows Evaluation Committee  IEEE Sensors Fellow Committee  Council On Competitiveness  IEEE Sensor Council Fellow Evaluation Committee  Engineering Deans Council Public Policy Colloquium  IEEE Frederick Philips Award Committee  IEEE Sensors Council Technical Achievement Award  College Board AP Engineering Committee Member  IEEE Robert N. Noyce Medal Selection Committee Member  IEEE Robert N. Noyce Medal Selection Committee Chair  Engineering Deans Council Public Policy Colloquium  IEEE Medals Council  IEEE Sensor Council Fellow Evaluation Committee  ASEE Engineering Deans Nominating Committee  Idaho National Laboratory Energy & Environment Science &  Technology Strategic Advisory Committee  Morgan State University Engineering Executive Council | Panel Member  Member  Panel Member  Member  Member  Panel Member  Chair  Member  Member  Member  Member  Member  Member  Member  Member  Member  Member  Member  Member  Committee  Member  Member  Member  Member  Chair  Committee  Chair  Member  Member  Member  Member | 1990  1990  1993  1993  1993 – 2012  1996  1997 – 2012  1999  2000 – 2005  2001 – 2004  2004 – 2019  2004 – 2019  2008 – 2019  2006 – 2021  2006, 2010, 2014  2014  2012-2013  2012, 2013  2014  2011 – 2012  2013 – 2015  2012 – 2013  2013  2014 – 2016  2016 – 2018  2017 – 2018  2016 – 2018  2017 – 2018  2021 – 2022  2022 –  2022 – |
| **Program Committees**  VLSI Education Conference  Advanced Research in VLSI  27th Hawaii International Conference on System Sciences  GaAs IC Symposium  Advanced Research in VLSI  Advanced Research in VLSI Program Chair  Ninth Great Lakes Symposium on VLSI  Microelectronic Systems Education Conference  Advanced Research in VLSI  DAC 2000 (Chair of Student Design Contest)  SPIE'S Int’l. Symp. on Microtechnologies for the New Millennium  Microelectronic Systems Education Conference (MSE) 2003  2004 IEEE Intl. SOI Conference  Microelectronic Systems Education Conference  2005 SOI Conference | Chair  Chair | 1989  1992  1993  1993 – 1997  1995  1999  1999  1999  1999  2000  2003  2003  2004  2005  2005 |
| **Executive/Organizing Committees**  Symposium on Cellular Bioengineering  Instrument Soc. of America, Symp. on Innov. in Meas. Sci.  IEEE/NSF Multichip Module Workshop  IEEE Mid-America Symposium on Circ. and Sys.  1995 GaAs IC Symposium  1996 GaAs IC Symposium  1997 GaAs IC Symposium  1997 Conference on Advanced Research in VLSI (at UM)  Ninth Great Lakes Symposium on VLSI  Microelectronic Systems Education Conference 2001  Public Policy Committee of the ASEE Eng. Deans Council  ASEE Public Policy Colloquium  2014 ASEE Engineering Deans’ Institute  ASEE Public Policy Colloquium  PAC-12 Engineering Deans | Org. Com. Mem.  Session Org.  Org. Com. Mem.  Org. Com. Mem.  Treasurer  Publicity Chair  Publicity Chair  General Chair  Executive Com.  Chair  Org. Com. Mem.  Member  Org. Com. Mem.  State Leader  Organizer | 1987  1988  1991  1993  1995  1996  1997  1997  1999  2001  7/11 – 6/12  2012  2013  2014  2016 |

**Consulting and Industry Board Memberships**

Consulting has played an important role in keeping Prof. Brown current on VLSI and CAD topics, bringing industrial and government funding to his research group, forming critical relationships to aid in his research, and enriching the courses he has taught (e.g., the 16-bit RISC processor which is used as the baseline design in EECS427 is a proprietary National Semiconductor architecture, used with permission). In addition, he has had the exhilarating experience of helping define the next generation of microprocessors and VLSI CAD tools, and seeing some of his research work in several areas have an impact in commercial products.

|  |  |  |  |
| --- | --- | --- | --- |
| Cardinal Industries, Webb City, MO | | 9/81 – 5/93 | |
| Integrated Microsystems, Inc., Ann Arbor, MI | | 9/86 – 12/86 | |
| General Electric Corporate R&D, Schenectady, NY | | 7/87 | |
| Seattle Silicon, Inc., Seattle, WA | | 10/87 – 8/91 | |
| Fleck Controls, Inc., Brookfield, WI | | 7/90 – 3/94 | |
| Cascade Design Automation, Seattle, WA | | 9/91 – 1/98 | |
| DuPont Medical, Newark, DE | | 3/93 – 5/95 | |
| Motorola Semiconductor Prod. Sector, Phoenix, AZ | | 7/93 – 3/95 | |
| Leeds & Northrup, North Wales, PA | | 8/94 | |
| Burns, Doane, Swecker, Mathis, Washington, D.C. | | 2/95 – 6/95 | |
| Idiot Savants, Ann Arbor, MI | | 5/96 – 4/97 | |
| National Semiconductor, Santa Clara, CA | | 5/97 – 01 | |
| Intel Corporation, Santa Clara, CA | | 7/96 | |
| Advanced Micro Devices, Austin, TX | | 3/97 | |
| Giner, Inc., Waltham, MA | | 1/97 – 7/97 | |
| Advanced Sensor Technologies, Inc., Farmington Hills, MI | | 10/98 – 1/00 | |
| Collaboration by Design, Dallas, TX | | 2/99 – 1/00 | |
| Ardesta, LLC | | 12/00 – 6/04 | |
| Maryland Higher Education Commission | | 8/00 – 5/02 | |
| i-sens - Scientific Advisory Board Member\* | | 3/00 – present | |
| Mobius Microsystems Board of Directors\*  Chair of Mobius Advisory Board\* | | 7/02 – 12/05  12/05 –1/10 | |
| V-Spring Capital  e-SENS, Chairman of the Board\*  CoaguSense, Inc., Board Member  University of Arkansas  Arkansas Gov. Hutchinson Innovation Council | | 12/05 – 1/06  12/10 – present  10/16 – present  5/18  2/19 | |

**Honors and Awards** **Date**

Utah Academy of Engineering and Science Founding Member 2021

H. E. Thomas Presidential Endowed Deanship 2020

University of Utah Rosenblatt Prize for Excellence 2018

IEEE Life Fellow 2017

National Academy of Inventors Fellow 2016

Utah Governor’s Medal for Excellence in Science & Technology 2015

Alumni Achievement Award, Ira A. Fulton College of Engineering 2014

and Technology, Brigham Young University

IEEE Fellow Award 2014

Distinguished Alumnus of the Department of Electrical and 2010

Computer Engineering, Brigham Young University

Distinguished Young Alumnus, Electrical and Computer 2003

Engineering Department, University of Utah

Arthur F. Thurnau Endowed Professorship, University of Michigan 2001

Austin Center for Advanced Studies Fellow, IBM 7/01 - 12/05

Distinguished Faculty Award from Michigan Association of Governing 2000

Boards of Universities and Colleges (one of two at University of Michigan)

EECS Department Research Excellence Award, University of Michigan 1995

State of Michigan Teaching Excellence Award (one of 18 in Michigan) 1990

IEEE Student Chapter 1988 Faculty Award, University of Michigan 1988

College of Engineering Teaching Excellence Award, University of Michigan 1987

Member of Eta Kappa Nu, Tau Beta Pi, and Phi Kappa Phi

**Patents Issued**

Richard B. Brown and Noland E. Vogt, “Printer Unit,” U.S. Design Patent D270,732, Sept. 27, 1983.

Richard B. Brown, “Integrated Circuit for a Chemical-Selective Sensor with Voltage Output,” U.S. Patent

4,743,954, May 10, 1988.

Richard B. Brown and Geun Sig Cha, “Solid State Ion Sensor with Silicone Membrane,” U.S. Patent

5,102,526, April 7, 1992.

Richard B. Brown and Geun Sig Cha, “Solid State Ion Sensor with Polyimide Membrane,” U.S. Patent

5,417,835, May 23, 1995.

Ajay Chandna and Richard B. Brown, “High Speed Current Mirror Memory Cell Architecture,” U.S. Patent 5,490,105, Feb. 6, 1996.

Richard B. Brown, Geun Sig Cha and Howard D. Goldberg, “Batch Deposition of Polymeric Ion Sensor Membranes,” U.S. Patent 5,607,566, March 4, 1997.

Hal C. Cantor, Richard B. Brown, Timothy D. Strong, “Microscopic Combination Amperometric and Potentiometric Sensor,” U.S. Provisional Patent Serial No.:60/163,471, July 2000.

Timothy D. Strong, Richard B. Brown, Hal C. Cantor, “Batch Fabrication of Electrodes,” U.S. Provisional Patent, Serial No.:60/163,654, July 2000.

Richard B. Brown and Steven M. Martin, “Laminated Devices and Methods of Making the Same,” U.S. Patent 6,786,708, Sept. 7, 2004.

Robert W. Hower and Richard B. Brown, “Micromachined Device for Receiving and Retaining at Least One Liquid Droplet, Method of Making the Device and Method of Using the Device,” US Patent 6,764,652 B2, July 20, 2004. European Patent EP 01989074.8.

Richard B. Brown, Ching-Te K. Chuang, Peter W. Cook, Koushik K. Das, and Rajiv V. Joshi, “Method of Reducing Leakage Current in Sub One Volt SOI Circuits,” U.S. Patent 6,952,113, October 4, 2005.

Koushik K. Das and Richard B. Brown, “Low-Leakage Integrated Circuits and Dynamic Logic Circuits,” U.S. Patent 6,933,744, Aug. 23, 2005.

Richard B. Brown and Michael S. McCorquodale, “MEMS-Based, Computer Systems, Clock Generation and Oscillator Circuits and LC-Tank Apparatus for Use Therein,” U.S. Patent 6,972,635, December 6, 2005.

Richard B. Brown, Gary D. Carpenter, Fadi H. Gebara, “Ultra High Frequency Ring Oscillator with Voltage Controlled Frequency Capabilities,” U.S. Patent 7,113,048, September 26, 2006.

Michael S. McCorquodale, Richard B. Brown, Mei Kim Ding, “Linearizing Apparatus and Method,” U.S. Patent 7,132,874, November 7, 2006.

Michael S. McCorquodale, Richard B. Brown, “MEMS-Based, Computer Systems, Clock Generation and Oscillator Circuits and LC-Tank Apparatus for Use Therein,” U.S. Patent 7,157,984, January 2, 2007.

Steven M. Martin, Roy H. Olsson, III, Richard B. Brown, Robert K. Franklin, “Microsystem for Determining Clotting Time of Blood and Low-Cost, Single-Use Device for Use Therein,” U.S. Patent 7,291,310, Nov. 6, 2007.

Robert W. Hower, Richard B. Brown, “Microsensor With a Well Having a Membrane Disposed Therein,” U.S. Patent 7,438,851 B2, Oct. 21, 2008.

Henry S. White, Ryan J. White, Richard B. Brown, Hakhyun Nam, Jun Ho Shim, “Nanopore Based Ion-Selective Electrodes,” U.S. Patent 8,123,922, Feb. 28, 2012. International Patent WO 2008030582 A2.

Richard B. Brown and Ondrej Novak, “Sensor with a Membrane having Full Circumferential Adhesion,” U.S. Patent 10,359,391, July 23, 2019. EP3482195, June 8, 2022.

Richard B. Brown and Ondrej Novak, “Microfluidics Chip with Sensor Die Clamping Structures,” U.S. Patent 10,464,063 B2, Nov. 5, 2019.

Richard B. Brown and Ondrej Novak, “Microfluidic Chip with Chemical Sensor having Back-Side Contacts,” U.S. Patent 10,710,068 B2, Jul. 14, 2020.

Richard B. Brown and Ondrej Novak, “Microfluidics Chip with Sensor Die Clamping Structures” U.S. Patent 11,331,664, May 17, 2022.

**Software Developed**

Prof. Brown’s group’s work on GaAs CAD tools resulted in a commercial package that was available from Cascade Design Automation. It included a program for optimizing placement of datapath modules, a phase-checking program for circuits which use two-phase clocking, GaAs DCFL cell generators, delay macromodels, and power estimators.

**Professional Memberships**

Registered Professional Engineer, State of Utah.

Member of ASEE, IEEE and ACM, as well as the following IEEE Technical Societies: Solid-State Cir­cuits; Electron Devices; Education; Computer; and Circuits and Systems.

**Students**

**Postdoctoral Fellows**

Name Ph.D. Received Project Topic Post Doc

Geun Sig Cha 1989 Solid-State Sensor Membranes 1989 - 1991

Segyeong Joo 2006 Novel Chemical Sensors 2006 – 2008

**Ph.D. Committees Chaired**

Name Project Topic Graduation (Co-)Chair

Koucheng Wu High-Temperature CMOS 1990 Chair

Jeffrey A. Dykstra VLSI GaAs DCFL Circuits 1990 Chair

Howard D. Goldberg Integrated Solid-State Ion Sensors 1993 Chair

Hal Cantor Amperometric Endocrine Sensors 1994 Co-Chair (BioE)

Muh-Ling Ger Refractory Metal-Silicide Micromachining 1994 Chair

Ajay Chandna GaAs DCFL SRAM for Embedded Applications 1994 Chair

Thomas R. Huff GaAs DCFL Floating-Point Unit 1995 Chair

Michael Upton Latency- Tolerant GaAs DCFL CPU 1997 Co-Chair

P. Sean Stetson Low Phase Jitter Clock Generation 1998 Chair

Phiroze Parakh Design Methodology for Crosstalk in IC Design 1999 Chair

Todd D. Basso Resource-Limited Superscalar Microprocessors 1999 Chair

Spencer M. Gold Quantitative Nonlinear Process Scaling 1999 Chair

Claude Gauthier Current-Mode I/O 1999 Chair

Koushik Das Low-Power Circuit Design in SOI-CMOS 2003 Chair

Keith Kraver Low-Voltage Analog Front End 2004 Chair

Michael McCorquodale All-Silicon Harmonic Clock Generation 2004 Chair

Timothy D. Strong Solid-State Neural Sensors 2004 Chair

Robert W. Hower Optical Solid-State Chemical Sensors 2005 Chair

Alan Drake LC Clock Generation and SOI DTMOS 2005 Chair

Steven Martin Integrated Heavy Metal Sensors 2005 Chair

Rahul Rao SOI Circuits to Minimize Gate Leakage 2005 Chair

Jay Sivagnaname Unipolar Logic in SOI 2005 Chair

Fadi Gebara Analog SOI Design 2005 Chair

Matthew Guthaus Clock Tree Synthesis with Process Variability 2006 Chair

Robert Senger Low-Power Embedded Microprocessor 2007 Chair

Robert Franklin Electrochemical Brain Probes 2010 Chair

Amlan Ghosh Process Parameter Variation Mitigation 2010 Chair

Eric Marsman Embedded Cochlear Processor with DSP 2011 Chair

Spencer Kellis DSP for Neural Prosthetics 2011 Chair

Ondrej Novak UWB Transceiver for Biomedical Implants 2014 Chair

F. Bennion Redd Embedded Microcontroller for Medical Devices 2015 Chair

**M.S. Committees Chaired**

Name Project Area Graduation (Co-)Chair

Terry C. Huang Solid-State Ion Sensor 1989 Chair

Tri Nguyen Molybdenum Micromachining 1989 Co-Chair

Richard S. Raimi High-Temperature CMOS 1990 Chair

Shailendra A. Save GaAs Circuit Compiler 1990 Chair

David Johnson Verilog to Layout CAD Tools 1991 Co-Chair

Phillip J. Barker GaAs Bus Interface 1993 Chair

Robert G. McVay GaAs Microprocessor Testing 1993 Chair

Thomas A. Hoy GaAs Cell Generation 1994 Chair

C. David Kibler GaAs SRAM Compiler 1994 Chair

David Putti GaAs Load/Store Unit 1994 Chair

Mark E. Roberts GaAs Processor Architecture 1994 Chair

Vince Mazzotta High Perf. Systems 1996 Chair

Michael J. Kelley Dynamic CGaAs Multiply/Acc. Unit 1997 Chair

John Wei Low-Noise Mixed Signal Circuits 1999 Chair

Himanshu Sharma Low-Power Microcontroller 1999 Chair

John Hall Known-Good Die Testing 1999 Chair

Michael E. Poplawski Whole Blood Sensor Array 1999 Chair

Jay Cameron Low-Voltage Analog Design 2000 Chair

Edward Kohler Instruction Compression for ARM 2000 Chair

Brian Larivee Low-Voltage Analog Circuits 2002 Chair

Scott Pernia Low-Voltage ADC 2003 Chair

Yunbum Jung Cell Library Generation 2003 Chair

Daniel Burke Electron-Relay Enabled Immunosensor 2003 Chair

Jeff Campbell Coagulation Sensor 2007 Chair

Nathaniel Gaskin Harmonic Oscillator-based Sensors 2007 Chair

**Ph.D. Committee Member** (since 1990)

Name Project Area Graduation

Chemistry Department – U of U

Mark Mendenhall Glass Nanopore Ion-selective Electrodes 2008

Deric Holden Soybean Agglutinin Sensor 2012

EECE – IIT Kharagpur

Dipankar Das Verification of Multiprocessor Embedded Applications 2009

Sri Ashudeb Dutta CMOS Low Noise Amplifier For Multi-Standard Receiver 2009

EECS Electrical and Computer Engineering Division – UM

Jin Ji Multichannel Intracortical Recording Array 1990

Wei-Tsun Shiau MOSFET Gate Insulator Reliability at High Temperatures 1990

Steven Cho Ultra-Sensitive Silicon Pressure-Based Microflow Sensor 1991

Yibing Dong Instrument for Engine Misfire Detection 1991

Nader Najafi Smart Sensor with Multi-Element Gas Analyzer 1992

Arnold Hoogerwerf Three-Dimensional Neural Recording Array 1992

Mark Nardin Microstimulator with Bi-Directional Telemetry 1996

James Russel Webster Integrated Capillary Electrophoresis Systems 1999

Uk-Song Kang Capacitive Humidity Sensor 1999

Andrew Mason Portable Wireless Multi-Sensor Microsystems for

Environmental Monitoring 2000

Pang-Cheng Hsu Silicon Micromachined Sensors and Actuators 2000

Jeong-Yeop Nahm a-Si:H TFTs Active-Matrix for Liquid Crystal Display 2000

Joohan Kim Active Matrix Liquid Crystal Display Technology 2000

Suhwan Kim True Single-Phase Adiabatic Circuitry for High-Performance,

Low-Energy VLSI 2001

Piu Francis Man Microfluidics for DNA Lab on a Chip 2001

ChuanChe Wang Contamination-Insensitive Differential Capacitive

Pressure Sensors 2001

Yongtaek Hong Active-Matrix Organic Polymer Light-Emitting Display: 2003

Maysam Ghovanloo Wireless Microsystem for Neural Stimulating Microprobes 2004

Pedram Mohseni Bi-directional Wireless Multichannel Microsystems for 2005

Biomedical Recording Applications

Gary O’Brien Angular Rate and Angular Acceleration Sensors 2004

Roy H. Olsson III 1024-Site Multiplexed Recording Array

Mohamed Abdelmoneum Micromechanical Wine-Glass Resonators with 2005

Semi-Automatic Post Fabrication Trimming

EECS Computer Science and Engineering Division – UM

Robert Masiasz Exact Layout Minimization of Static CMOS Cells 1991

Yi-Chieh Chang Load Sharing in Distributed Real-Time Systems 1991

Ayman Kayssi Timing Macromodels for Digital Circuits 1992

James Dolter Multi-Mode Router for Real-Time Systems 1993

Khushro Shahookar Genetic Algorithm for VLSI CAD 1994

Kunle Olukatun Technology-Organization Tradeoffs in Computer Architecture 1994

Rich Uhlig Trap-Driven Memory Simulation 1994

Dan Kaiser Loop Optimization for Multi-Issue Architectures 1994

Joao Paulo Silva Algorithms for Satisfiability Problems in Comb. Circuits 1995

Mickael Batek Test-Driven Transformations in Logic Design 1995

Krishnendu Chakrabarty Test Response Compaction for Built-In Self Test 1995

Michael Golden Branch and Load Hazards in Pipelined Microprocessors 1995

Stuart Daniel Router Architecture for Point-to-Point Networks 1996

Jennifer Rexford Tailoring Routing Architectures to Performance Requirements 1996

I-Cheng Chen Branch Prediction via Data Compression 1997

Chih-Chieh Lee Cache/Branch Prediction Tradeoffs 1997

Bruce Jacob Operating System Issues in a High Performance Processor 1997

James Dundas Data Prefetch & Branch Prediction 1998

V. Chandramouli Timing Models with State Dependency 1998

Hussain Al-Asaad Verification via Testing-Simulation 1998

Michael Riepe Leaf Cell Generation 1998

Hakan Yalcin Timing Analysis 1998

Edward Tom Improving Cache Performance via Active Management 1999

David Van Campenhout Design Verification of Microprocessors 1999

Hyungwon Kim Testing and Synthesis of Systems-On-A-Chip 1999

Jared Stark Out of order Fetch, Decode, and Issue 2000

Charles Lefurgy Architecture/Software Interactions in Microprocessors 2000

Brian Davis Memory Systems Design and DRAM Interfaces 2000

Lea Hwang Lee Pseudo-Vector Machine For Embedded Applications 2000

Marius Evers Improving Branch Prediction by Understanding Branch Behavior 2000

Sung-Whan Moon Quality-of-Service Guarantees in Packet Switched Networks 2001

Gijoon Nam A Boolean-Based Layout Approach for FPGA Routing 2001

Avinoam Nomik Eden Branch Prediction - Stretching the Limits 2001

Victor Kravets Constructive Multi-Level Circuit Synthesis 2001

Hsieu-Hsin Lee Study of Data Cache Accesses 2001

Matthew A. Postiff Compiler Optimizations for Register File Use 2001

Hsien-Hsin Sean Lee Energy and Performance of Data Cache Architectures 2001

Joonhwan Yi High-Level Function and Delay Testing for Digital Circuits 2002

Alejandro Gonzalez Resonant-tunneling diodes in digital circuit applications 2002

Fadi Ahmed Aloul Scalable Algorithms for Boolean Satisfiability 2003

Paul Racunas Reducing Load Latency 2003

Robert Chappell Simultaneous Subordinate Microthreading 2004

Rajeev Krishna Application-specific Processors 2004

Rajiv Ravindran Hardware/Software Optimizations for Memory Power 2007

Bioengineering -- UM

Steve Freeman Digital Signal Processing for Ultrasound Images 1998

Chemistry Department -- UM

Hyoung-Sik Yim Potentiometric Gas Sensor 1993

Dong Liu Solid-State Ion/Biosensor Arrays 1994

Ravi Meruva Gas and Ion Sensing Systems for Biomedical Applications 1997

Bong Oh Electrochemical Nitric Oxide (NO) Sensor 2003

Hairong Zhang Redox Enabled Immunosensor 2007

Physics Department -- UM

Nathan Eddy Analysis of the Top Quark Mass 1998

Eugene Guillian Top Quark Decay Kinematics 1999

**Professional Sketch**

The Department of Electrical Engineering and Computer Science at the University of Michigan was a great place for me to grow up academically. The foresight and efforts of those who went before me provided a world-class solid-state laboratory and computing environment which enabled me to be productive in research and effective in teaching. The Department had the perfect environment for me, and it also had needs which I was able to fill. At Michigan I found excellent role models, a stimulating intellectual atmosphere, a spirit of cooperation among the Solid-State Lab faculty, and able and willing collaborators. I received valuable experience as an academic administrator, and was honored to receive research and teaching awards in the department, college and state levels, a distinguished professor designation, and an Arthur F. Thurnau Endowed Professorship.

The years working in industry before the Ph.D. and my industrial sabbaticals provided a perspective which brought relevance to my teaching. I was pleased to hear from many students that the courses they had with me prepared them well for their careers.

I was able to continue my own Ph.D. research, explore new topics, and manage large projects. My research group developed miniature solid-state sensors for applications in monitoring the environment (water chemistry, heavy metals, nanoparticles) and biological fluids (blood electrolytes and gases, pathogens, neurochemicals). We evaluated and contributed to the development of the most advanced semiconductor technologies, designed some of the fastest microprocessors of their time, some of the lowest power microcontrollers, and some of the most highly integrated microsystems. Our semiconductor clocking technology had a significant effect on electronic systems. The solid-state liquid chemical sensors were commercialized in three startup companies, and the all-silicon clock generators were commercialized in a forth company.

I was able to contribute to VLSI education by developing a much-copied curriculum, and to provide access to chip fabrication for class projects from US universities by raising funds from industry and government as chairman of the NSF MOSIS Advisory Council on Education.

Serving as Dean of Engineering at the University of Utah has been a great opportunity for me. With Engineering Initiative support from the State and the University, private support for facilities, programs and scholarships, and the USTAR initiative, the College of Engineering has been on a steep growth curve in quality and size. Since 2004, the number of Engineering graduates has grown from 484 to 1,287. In 2005, 7% of the U’s freshman class selected a major in the College of Engineering; now more than one in five of the freshmen indicate that they are coming to our college. Engineering-related research expenditures have grown from $30M/yr in 2003 to $106M/yr. Faculty report more than doubling their peer-reviewed publications over the past decade. The quality of our students, both undergraduate and graduate, continues to rise. The demographics of the freshman class have also changed; in 2004, 10% were students of color – now more than 40% are. The number of women faculty has gone from 5 to 43. The physical facilities in the College have improved dramatically, with the new Warnock Engineering Building and Sorenson Molecular Biotechnology Building, and the renovation of the Meldrum Civil Engineering Building, the Warnock Lower Levels, and the Rio Tinto Kennecott Mechanical Engineering Building. In all, we have built or remodeled 1,000,000 sq. ft. of space, and the 250,000 sq. ft. Price Computing and Engineering Building is in design. The College’s social environment has also improved, with the Engineering Alumni Association, Engineering Honors, Engineering Living and Learning Center, Tutoring Centers, junior faculty-dean meetings, faculty research reports to the deans, and more faculty social events. Average course evaluations have steadily improved, and our faculty are advising more than twice as many Ph.D. students. The College of Engineering outreach group has grown the pipeline of students coming into engineering with some 40,000 face-to-face interactions with K-12 students per year, and our Public Relations team is doing more than ever to publicize the accomplishments of our faculty and students. Since 2006, more than 100 companies have been spun out of the College of Engineering. This progress has required resources, incentives, and broad faculty participation. There is every reason to believe that the momentum will continue.