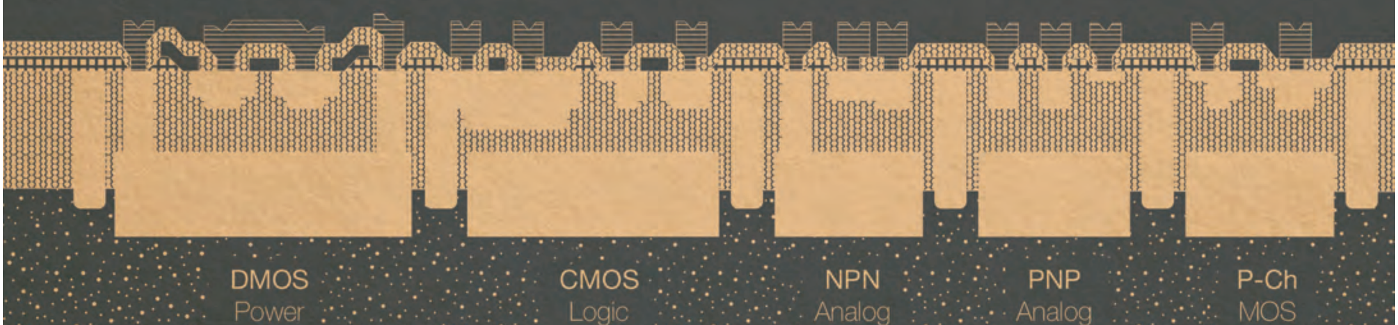
The Elmer A. Sperry Award

For the development of
Power Integrated Circuits
for the transportation industry



Presentation of

The Elmer A. Sperry Award

For 2017

Given in recognition of a distinguished engineering contribution, which through application proven in actual service has advanced the art of transportation, whether by land, sea, air, or space.

PRESENTED TO

Bruno Murari

BY

The Elmer A. Sperry Board of Award

REPRESENTED BY THE

American Society of Mechanical Engineers

Institute of Electrical and Electronics Engineers

SAE International

Society of Naval Architects and Marine Engineers

American Institute of Aeronautics and Astronautics

American Society of Civil Engineers

In recognition of his seminal work and leadership in the development of Power Integrated Circuits for the transportation industry.

At a joint session of the
European Solid-State Device Research Conference (ESSDERC)
and the European Solid-State Circuits Conference (ESSCIRC)
in Leuven, Belgium, September 14, 2017

Bruno Murari

Bruno Murari earned his diploma in electrical engineering from the Istituto Pacinotti, Mestre, Italy in 1955. While beginning his career with SOMIREN (Societa' Minerali Radioattivi Energia Nucleare), he continued his study of Electronics in evening courses at Beltrami Private Institute. Upon graduation, he followed a path typical of men of his age: military service followed by his second work experience.

Since completing his military service, Murari's entire career has been with STMicroelectronics, having joined a predecessor company SGS, in 1961. He has been a leading player in many of ST's most successful ventures, first in the applications laboratory and later in the Company's Central Research and Development group.

ST's Castelletto office, in the Italian province of Milan, has been Murari's second home. In the pioneering age of electronics in the early 1960s, while SGS worked with the trailblazing Fairchild Semiconductor to bring the first operational amplifiers to market, Murari honed his analog design skills. He later moved into R&D and contributed to the development of the world's first mass production power devices for audio applications and the first 3-pin voltage regulators with outputs up to 1.5A.

In this time, Murari and his chief technologist were the first to recognize and develop the idea of band-gap voltage references. These reference voltage circuits have been widely used in the power electronics critical to today's transportation sector. Murari and his team's brilliant analog design skills and creativity used SGS's bipolar power technology to give rise to a whole series of circuits for motor control, audio, TV, and telecommunications. He and his team invented and applied important technology steps in the power process, including Deep Collector Diffusion, Up-Down Junction Isolation, and PNP power components. From this, ST began to build its reputation in analog and power circuits and Murari further built his achievements on the design and implementation of a series of devices that drove the new electronic daisywheel typewriters, in a joint project with Olivetti's typewriter division.

On top of developing valuable silicon chips, Murari and his team began to turn their attention to the importance of dissipating heat from the powerful drivers they were developing for a range of applications. With contributions from ST's assembly technology group, Murari's team was able to design new packages that could dissipate considerable heat and, thus increase the overall reliability of systems.

Of arguably the greatest value to the transportation sector, in this time Murari recognized a number of fundamental limitations of purely bipolar technology. In particular, he was concerned about the very low scalability of power components with the developments in etching and its challenges for building dense logic circuits. From this, he had the insight to mix process technologies combining bipolar components, CMOS, and power MOS (DMOS) transistors to build fully integrated complex systems on a single chip, an innovation later dubbed SoC (system on a chip).

Under Murari's leadership, in 1984 the team began developing a family of BCD (Bipolar-CMOS-DMOS) processes to enable operating voltages between 20 and 700V. These processes, and the ICs that resulted, paved the way for completely new applications in diverse areas, such as automotive, hard disks, gas discharge lamp starters, and high-power car audio. Still today, BCD "Smart Power" technology is among STMicroelectronics's great successes and is today one of several standard platforms in semiconductors, along with CMOS and bipolar process technologies.

Naturally, Murari's creative force found new challenges after starting the ball rolling on BCD. He recognized that in addition to the extraordinary electrical properties of silicon upon which the semiconductor industry had been built, the element also possessed unique physical and mechanical properties and he began efforts to combine these properties with ST's ability to work it with extreme precision to address important problems. Murari assembled a team of smart and enthusiastic engineers and together, they designed and built the company's first MEMS (Micro-Electro-Mechanical Systems) devices. These marvels, suggested more than a hundred years earlier by writers like H.G. Wells, integrate tiny mechanical devices capable of accurately and precisely measuring physical quantities, such as changes in acceleration, pressure, and liquid flow with electronic control and processing systems.

ST achieved its first successes in MEMS with single and three-axis linear accelerometers, rotational accelerometers, and gyroscopes. Moreover, these innovative components allowed ST to repurpose "older" silicon factories, which were no longer well suited for the most advanced digital technologies. In addition, MEMS paved the way to entirely new market sectors. Today, ST gyroscopes and accelerometers, as well as a broad range of other sensors, are used in the most popular mobile phones around the world, in video games, in thousands of other professional, medical and consumer electronics applications, and, of course, in a range of transportation-related applications.

More recently the introduction of a Piezoelectric (PZT) process step on the MEMS Technology Platform has opened another application field where actuation uses piezoelectric material to act as a "muscle." For example, digital cameras can use the technology in the autofocus movement of a lens.

Murari's contributions to MEMS and Sensors were recognized with a Lifetime Achievement Award from the MEMS and Sensors Industry Group in 2014.

In total, more than 200 patents have Murari's name on them and, while "officially" a retiree and no longer an ST employee, he jokingly claims to suffer from "siliconosis," which he treats by serving as an external scientific advisor to ST. In this role he uses his valuable experience to guide researchers.

As the Rector of the Politecnico di Milano, Adriano de Maio, was presenting a second honorary degree in electronics to Murari in 2002 for his contributions to the industry, de Maio said ''Honorary degrees are awarded to three types of people: distinguished scientists, individuals of business, and great professionals. Bruno Murari is all three in one." Earlier, in 1995, Murari had received an honorary degree in Computer Science from Ca' Foscari Venice University.

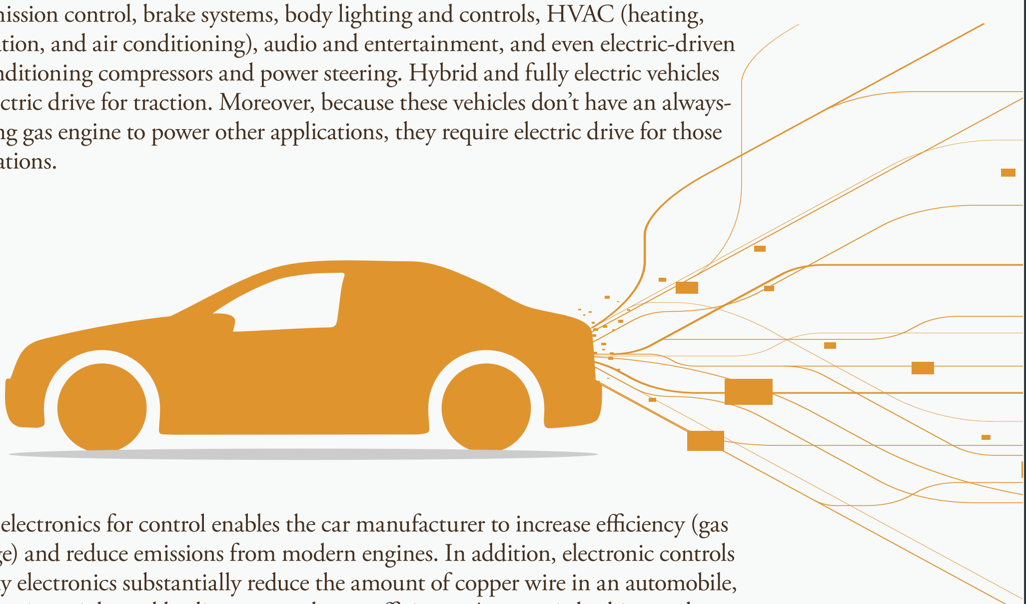
In a feature on Murari, The New York Times wrote "If there is a Lost Tribe of Silicon Valley, it resides here on a broad industrial plain on the outskirts of suburban Milan. And the tribe's leader is … Bruno Murari. …Mr. Murari has passed up many offers to leave Italy and go to the United States, so that he can continue working as a master craftsman in his "Renaissance" workshop and go on cultivating creativity and lateral thinking based on sound technological knowledge."

Automotive Electronics

Early automobiles and engines were all mechanically controlled with very simple electrical systems for the starter motor, lighting, and not much else. As cars evolved, features like fans, windshield wipers, and power seats were added and electrical systems became more complex, but control was still mostly through mechanical switches.

Car radios -- originally tube-type radios -- were the first truly electronic systems in the automobile. Later, it was the radio that became the first car accessory to use solid-state electronics, using discrete transistors in the tuner and power amplifiers. As manufacturers of cars pushed for improvements in performance and reduced emissions, they introduced electronic engine controls and replaced simple mechanical switches to control the ignition timing with electronic ignition-control modules. All of these advances were enabled by the development of semiconductor technology. And much of that semiconductor technology development was driven by Bruno Murari.

Modern automobiles depend heavily on electronic controls. Electronics are an essential — and still increasing -- part of almost all functions in the car, including engine and transmission control, brake systems, body lighting and controls, HVAC (heating, ventilation, and air conditioning), audio and entertainment, and even electric-driven air-conditioning compressors and power steering. Hybrid and fully electric vehicles use electric drive for traction. Moreover, because these vehicles don't have an always-running gas engine to power other applications, they require electric drive for those applications.



Using electronics for control enables the car manufacturer to increase efficiency (gas mileage) and reduce emissions from modern engines. In addition, electronic controls in body electronics substantially reduce the amount of copper wire in an automobile, lowering its weight and leading to even better efficiency. Automatic braking and traction controls greatly improve the safety of vehicles today, too.

While the microcontroller or computer chips are the brains of all of these systems, they need muscles to actuate everything and sensors to interface to the environment. Here the contributions from the Smart Power Integrated Circuit first developed by Murari and his team has played, and continues to play, the major role.

Smart Power IC Development

As integrated circuits developed, they mostly fell into one of two classes: Digital or Analog ICs. By the mid 1970's, microprocessors were common and these were mostly manufactured using Metal-Oxide Semiconductor (MOS) technologies. Most of the analog functions, on the other hand, were manufactured in bipolar technologies. While MOS technologies became the brain and the bipolar technologies provided analog control, both depended on discrete power transistors for the brawn. Bruno Murari recognized the value of combining power transistors on the same device with the analog control. In 1974 Murari's paper on power integrated circuits, "A High-Power HI-FI Monolithic Amplifier," was published in the IEEE Transactions on Broadcast and Television Receivers. Three years later, this paper was followed by "Power Integrated Circuits, Problems, Trade-offs and Solutions," a paper presented at the ESSCIRC '77 and later published in the IEEE Journal of Solid State Circuits in 1978.

Some of the first power integrated circuits were output amplifiers in car radios, like the ones designed by Murari and his team. These devices used bipolar power transistors integrated on an IC with the small-signal transistors for the amplifier. These devices were immensely popular and chips like the TDA2005 and its derivatives were the most widely used audio amplifier in car stereos for most of the 1980's.

Murari also recognized the potential to use the technology for applications beyond basic amplifiers, to integrate smart control into the IC along with the power actuators. With simple bipolar logic and analog for feedback and control, Murari and his team developed Smart Power ICs for solenoid drivers, stepper motor drivers, and fully integrated switching regulators. Although these devices became widely used in printers and industrial applications, the bipolar transistors had significant limitations: bipolar devices had a saturation voltage drop across the output of between 1 and 2.5V. This high voltage drop meant that the devices had high dissipation and modest efficiency and, especially in automotive applications where the power supply is 12V (or less), a 2V loss across the output was far too significant.

Replacing the bipolar transistors, power MOS transistors became common and the DMOS (Double Diffused Metal Oxide Semiconductor) structure was well established in the industry for discrete power transistors. The DMOS devices with a low on resistance could therefore achieve very low voltage drops, in the range of a few tenths of a volt. These low voltage drops substantially lowered losses and dissipation and therefore generated less heat.

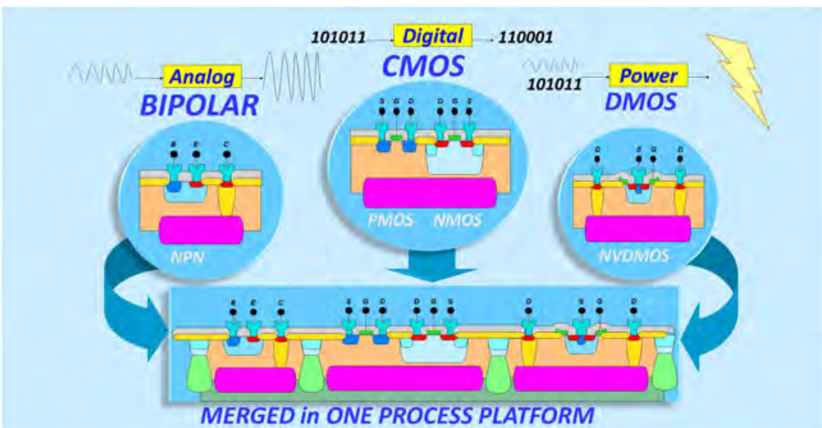
Although MOS transistors had been used in CMOS (Complementary Metal Oxide Semiconductor) logic devices and computer chips for many years, these transistors had limited voltage capability (5V or less) and high on resistances that made them inappropriate for power circuits.

BCD Smart Power Development

Murari wanted a technology that had the high-drive advantages of DMOS for power and analog for control. He and his team of engineers focused their effort on combining the best of the bipolar circuitry for analog, CMOS for logic, and DMOS power transistors. He first demonstrated the resulting process, called BCD for Bipolar, CMOS, and DMOS, in 1984 as a single monolithic device that integrated four 50V power DMOS transistors. Murari and his team had given birth to the modern Smart Power Integrated Circuit. The first commercial product developed with this technology, the L6202, was a full-bridge motor driver for DC or stepper motors.

From this first BCD chip, the technology's advantages were obvious – and quickly recognized. The power DMOS produced much lower losses and less heat than previous-generation power integrated circuits had been able to achieve. At the same time and on the same piece of silicon, CMOS circuits could implement logic control that had not been practical with bipolar circuitry while continuing to make the bipolar technology and its advantages for analog control available.

Integrating the DMOS device onto a Smart Power IC, where engineers could also design the control, was the key to enabling Smart Power actuators for industrial and automotive applications. The lower voltage drop across the DMOS device dramatically reduced power dissipation and produced a higher available output voltage that is critical when operating from 12V batteries, especially in cold-cranking applications where the battery voltage can drop to about 6V.



BCD Smart Power IC elements

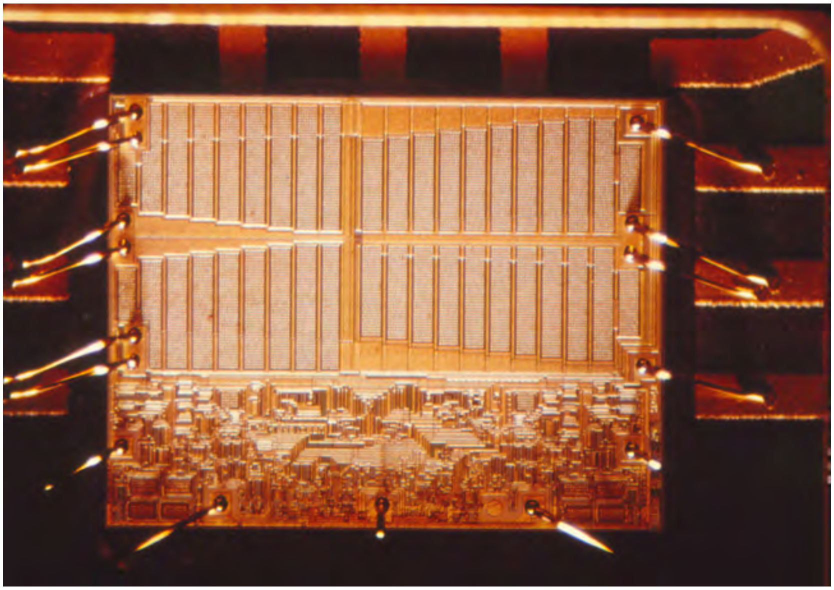
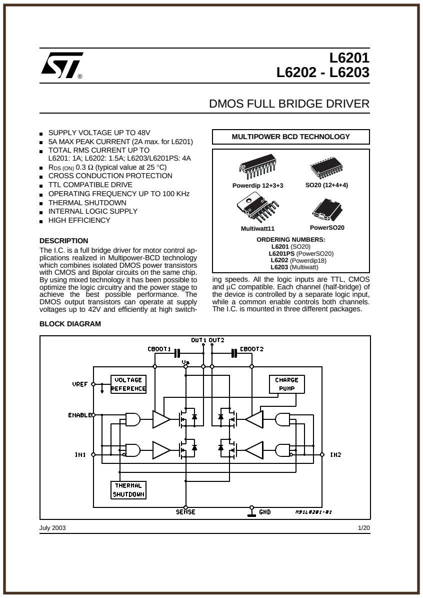


Photo of the L6202 die, the actual size is less than half a fingernail



L6201
L6202 - L6203

DMOS FULL BRIDGE DRIVER

- SUPPLY VOLTAGE UP TO 48V
- 5A MAX PEAK CURRENT (2A max. for L6201)
- TOTAL RMS CURRENT UP TO L6201: 1A; L6202: 1.5A; L6203/L6201PS: 4A
- $R_{DS\ (ON)}$ 0.3 Ω (typical value at 25 °C)
- CROSS CONDUCTION PROTECTION
- TTL COMPATIBLE DRIVE
- OPERATING FREQUENCY UP TO 100 KHz
- THERMAL SHUTDOWN
- INTERNAL LOGIC SUPPLY
- HIGH EFFICIENCY

MULTIPOWER BCD TECHNOLOGY

Powerdip 12+3+3 · SO20 (12+4+4) · Multiwatt11 · PowerSO20

ORDERING NUMBERS:
L6201 (SO20)
L6201PS (PowerSO20)
L6202 (Powerdip18)
L6203 (Multiwatt)

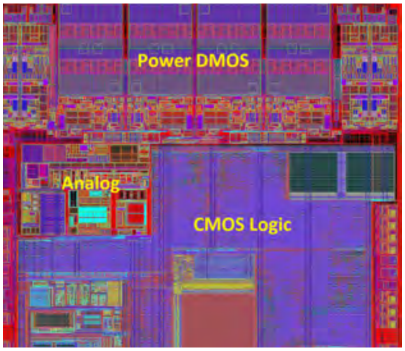
DESCRIPTION

The I.C. is a full bridge driver for motor control applications realized in Multipower-BCD technology which combines isolated DMOS power transistors with CMOS and Bipolar circuits on the same chip. By using mixed technology it has been possible to optimize the logic circuitry and the power stage to achieve the best possible performance. The DMOS output transistors can operate at supply voltages up to 42V and efficiently at high switching speeds. All the logic inputs are TTL, CMOS and µC compatible. Each channel (half-bridge) of the device is controlled by a separate logic input, while a common enable controls both channels. The I.C. is mounted in three different packages.

BLOCK DIAGRAM

July 2003 1/20

L6202 Data Sheet

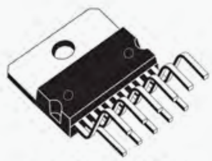


A typical BCD Smart Power device

Smart Power Package Development

In addition to contributing to the development of the silicon technology, Murari recognized the need to improve integrated circuit packages to safely remove heat generated by the power device. The industry's first power IC packages were simply adaptations of the standard power-transistor package that just added extra leads to the package. These packages, like the Pentawatt, were widely used for the original bipolar-based power ICs, especially audio amplifiers. Already comfortable mounting discrete power transistors, manufacturers quickly adapted to mounting the multi-leaded power-IC packages.

Typical package for Smart Power ICs

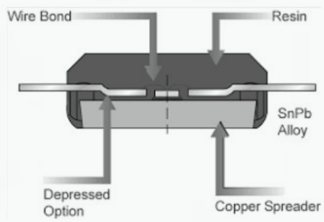


Multiwatt11

Pentawatt

PowerSO20

PowerSO10



As Smart Power devices advanced and the number of connections needed for the more highly integrated functions increased, simply adding pins to what was still basically a power transistor package was no longer practical. Here, Murari also saw the way to solve the problems—and challenged his team's competitiveness to bring it to life. Murari hand-carved models of his package concept and brought them into a meeting with his design team. He threw the models on the table and told the team to look at what their competitors were doing. The team realized only after Murari left the meeting that those models represented the concepts that he was anxious to implement.

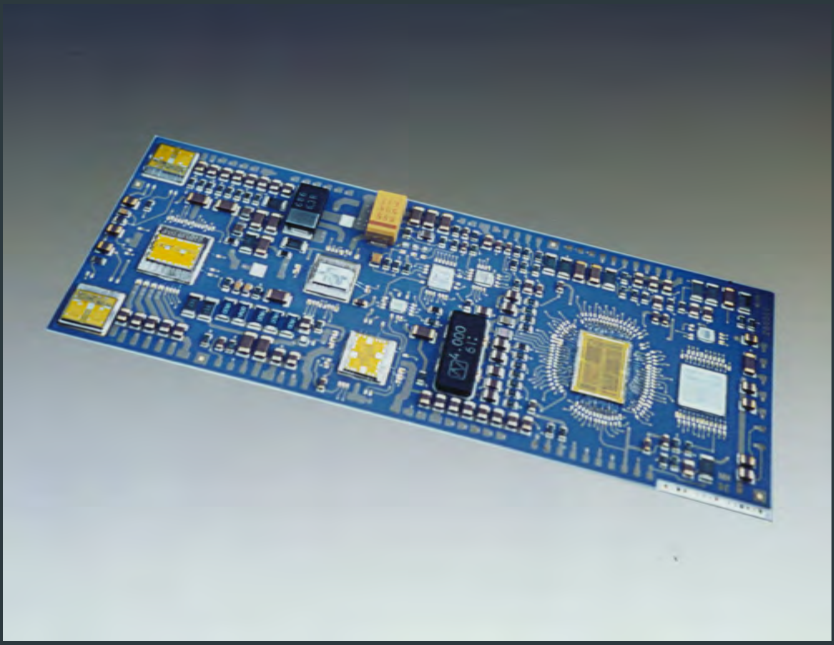
Higher pin-count packages with the ability to transfer heat away from the die were required. Fortunately, in contrast to the higher heat produced by bipolar devices, the DMOS in BCD devices produced less heat and moderated the need for large external heat sinks. As a result, the team developed packages that could be mounted directly on the printed circuit board and used the copper in the board for heat dissipation.

Smart Power Evolution

Following development of the first-generation of BCD technology, Murari's team continued to improve the BCD process. These efforts built on refinements to the semiconductor processes and shrinking CMOS device geometries that allowed ever more complex logic circuits to be implemented in the chips. The team introduced additional process variations to meet specific needs, including higher and lower voltage DMOS devices for specific applications.

In 1990, Murari and his team at ST introduced the first automotive specific BCD devices. By the mid 1990's Smart Power ICs were ubiquitous in automotive control units.

By 1993, ST had implemented an 8-bit microcontroller on the same chip as a 5A 60V power bridge. The cover story in the October 1993 issue of Electronic Design featured the device as a true Smart Power device. Demonstrating its longstanding contributions, thirty years after the introduction of the BCD process, it is still a key technology for the automotive industry.

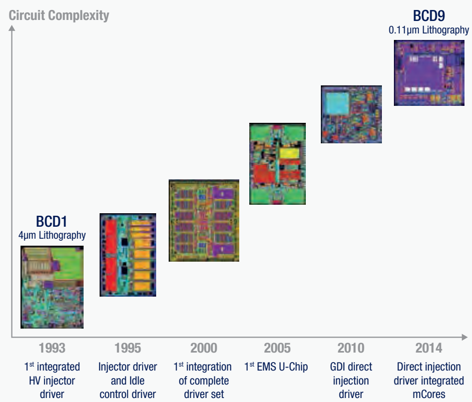


Automotive control board using Smart Power IC

Smart Power in Transportation

Fuel-injection drivers were one of the first applications where BCD technology was used in automotive applications. The first injection drivers included the control and drive stage for a single injection port. As the BCD process has evolved, the Smart Power devices have become more complex, integrating more of the control logic and controlling multiple injection ports.

Today Smart Power ICs are in virtually every car and light truck built in the world. The Smart Power IC enables engineers to economically design complex control and driver devices in small packages. The low dissipation of the DMOS device means there is little or no additional material required for heat dissipation and integrating both the control and power in a single device greatly reduces the size of the control modules. Simply put, without the Smart Power IC, complex electronics could not be economically manufactured.



Uses of Smart Power ICs in modern cars.

Elmer A. Sperry, 1860–1930

After graduating from the Cortland, N.Y. Normal School in 1880, Sperry had an association with Professor Anthony at Cornell, where he helped wire its first generator. From that experience he conceived his initial invention, an improved electrical generator and arc light. He then opened an electric company in Chicago and continued on to invent major improvements in electric mining equipment, locomotives, streetcars and an electric automobile. He developed gyroscopic stabilizers for ships and aircraft, a successful marine gyro-compass and gyro-controlled steering and fire control systems used on Allied warships during World War I. Sperry also developed an aircraft searchlight and the world's first guided missile. His gyroscopic work resulted in the automatic pilot in 1930. The Elmer A. Sperry Award was established in 1955 to encourage progress in transportation engineering.

The Elmer A. Sperry Award

To commemorate the life and achievements of Elmer Ambrose Sperry, whose genius and perseverance contributed so much to so many types of transportation, the Elmer A. Sperry Award was established by his daughter, Helen (Mrs. Robert Brooke Lea), and his son, Elmer A. Sperry, Jr., in January 1955, the year marking the 25th anniversary of their father's death. Additional gifts from interested individuals and corporations also contribute to the work of the board.

Elmer Sperry's inventions and his activities in many fields of engineering have benefited tremendously all forms of transportation. Land transportation has profited by his pioneer work with the storage battery, his development of one of the first electric automobiles (on which he introduced 4-wheel brakes and self-centering steering), his electric trolley car of improved design (features of its drive and electric braking system are still in use), and his rail flaw detector (which has added an important factor of safety to modern railroading). Sea transportation has been measurably advanced by his gyrocompass (which has freed humans from the uncertainties of the magnetic compass) and by such navigational aids as the course recorder and automatic steering for ships. Air transportation is indebted to him for the airplane gyro-pilot and the other air navigational instruments he and his son, Lawrence, developed together.

The donors of the Elmer A. Sperry Award have stated that its purpose is to encourage progress in the engineering of transportation. Initially, the donors specified that the award recipient should be chosen by a Board of Award representing the four engineering societies in which Elmer A. Sperry was most active:

American Society of Mechanical Engineers (of which he was the 48th president)
American Institute of Electrical Engineers (of which he was a founder member)
Society of Automotive Engineers
Society of Naval Architects and Marine Engineers

In 1960, the participating societies were augmented by the addition of the Institute of Aerospace Sciences. In 1962, upon merging with the Institute of Radio Engineers, the American Institute of Electrical Engineers became known as the Institute of Electrical and Electronics Engineers; and in 1963, the Institute of Aerospace Sciences, upon merger with the American Rocket Society, became the American Institute of Aeronautics and Astronautics. In 1990, the American Society of Civil Engineers became the sixth society to become a member of the Elmer A. Sperry Board of Award. In 2006, the Society of Automotive Engineers changed its name to SAE International.

Important discoveries and engineering advances are often the work of a group, and the donors have further specified that the Elmer A. Sperry Award honor the distinguished contributions of groups as well as individuals.

Since they are confident that future contributions will pave the way for changes in the art of transportation equal at least to those already achieved, the donors have requested that the board from time to time review past awards. This will enable the board in the future to be cognizant of new areas of achievement and to invite participation, if it seems desirable, of additional engineering groups representative of new aspects or modes of transportation.

The Sperry Secretariat

The donors have placed the Elmer A. Sperry Award fund in the custody of the American Society of Mechanical Engineers. This organization is empowered to administer the fund, which has been placed in an interest bearing account whose earnings are used to cover the expenses of the board. A secretariat is administered by the ASME, which has generously donated the time of its staff to assist the Sperry Board in its work.

The Elmer A. Sperry Board of Award welcomes suggestions from the transportation industry and the engineering profession for candidates for consideration for this award.

Previous Elmer A. Sperry Awards

1955 To ***William Francis Gibbs*** and his Associates for design of the S.S. United States.

1956 To ***Donald W. Douglas*** and his Associates for the DC series of air transport planes.

1957 To ***Harold L. Hamilton, Richard M. Dilworth*** and ***Eugene W. Kettering*** and Citation to their Associates for developing the diesel-electric locomotive.

1958 To ***Ferdinand Porsche*** (in memoriam) and ***Heinz Nordhoff*** and Citation to their Associates for development of the Volkswagen automobile.

1959 To ***Sir Geoffrey de Havilland, Major Frank B. Halford*** (in memoriam) and ***Charles C. Walker*** and Citation to their Associates for the first jet-powered passenger aircraft and engines.

1960 To ***Frederick Darcy Braddon*** and Citation to the Engineering Department of the Marine Division of the Sperry Gyroscope Company, for the three-axis gyroscopic navigational reference.

1961 To ***Robert Gilmore LeTourneau*** and Citation to the Research and Development Division, Firestone Tire and Rubber Company, for high speed, large capacity, earth moving equipment and giant size tires.

1962 To ***Lloyd J. Hibbard*** for applying the ignitron rectifier to railroad motive power.

1963 To ***Earl A. Thompson*** and Citations to ***Ralph F. Beck, William L. Carnegie, Walter B. Herndon, Oliver K. Kelley*** and ***Maurice S. Rosenberger*** for design and development of the first notably successful automatic automobile transmission.

1964 To ***Igor Sikorsky*** and ***Michael E. Gluhareff*** and Citation to the Engineering Department of the Sikorsky Aircraft Division, United Aircraft Corporation, for the invention and development of the high-lift helicopter leading to the Skycrane.

1965 To ***Maynard L. Pennell, Richard L. Rouzie, John E. Steiner, William H. Cook*** and ***Richard L. Loesch, Jr.*** and Citation to the Commercial Airplane Division, The Boeing Company, for the concept, design, development, production and practical application of the family of jet transports exemplified by the 707, 720 and 727.

1966 To ***Hideo Shima, Matsutaro Fuji*** and ***Shigenari Oishi*** and Citation to the Japanese National Railways for the design, development and construction of the New Tokaido Line with its many important advances in railroad transportation.

1967 To ***Edward R. Dye*** (in memoriam), ***Hugh DeHaven,*** and ***Robert A. Wolf*** for their contribution to automotive occupant safety and Citation to the research engineers of Cornell Aeronautical Laboratory and the staff of the Crash Injury Research projects of the Cornell University Medical College.

1968 To ***Christopher S. Cockerell*** and ***Richard Stanton-Jones*** and Citation to the men and women of the British Hovercraft Corporation for the design, construction and application of a family of commercially useful Hovercraft.

1969 To ***Douglas C. MacMillan, M. Nielsen*** and ***Edward L. Teale, Jr.*** and Citations to ***Wilbert C. Gumprich*** and the organizations of George G. Sharp, Inc., Babcock and Wilcox Company, and the New York Shipbuilding Corporation for the design and construction of the N.S. Savannah, the first nuclear ship with reactor, to be operated for commercial purposes.

1970 To ***Charles Stark Draper*** and Citations to the personnel of the MIT Instrumentation Laboratories, Delco Electronics Division, General Motors Corporation, and Aero Products Division, Litton Systems, for the successful application of inertial guidance systems to commercial air navigation.

1971 To ***Sedgwick N. Wight*** (in memoriam) and ***George W. Baughman*** and Citations to ***William D. Hailes, Lloyd V. Lewis, Clarence S. Snavely, Herbert A. Wallace,*** and the employees of General Railway Signal Company, and the Signal & Communications Division, Westinghouse Air Brake Company, for development of Centralized Traffic Control on railways.

1972 To ***Leonard S. Hobbs*** and ***Perry W. Pratt*** and the dedicated engineers of the Pratt & Whitney Aircraft Division of United Aircraft Corporation for the design and development of the JT-3 turbo jet engine.

1975 To ***Jerome L. Goldman, Frank A. Nemec*** and ***James J. Henry*** and Citations to the naval architects and marine engineers of Friede and Goldman, Inc. and Alfred W. Schwendtner for revolutionizing marine cargo transport through the design and development of barge carrying cargo vessels.

1977 To ***Clifford L. Eastburg*** and ***Harley J. Urbach*** and Citations to the Railroad Engineering Department of The Timken Company for the development, subsequent improvement, manufacture and application of tapered roller bearings for railroad and industrial uses.

1978 To ***Robert Puiseux*** and Citations to the employees of the Manufacture Française des Pneumatiques Michelin for the development of the radial tire.

1979 To ***Leslie J. Clark*** for his contributions to the conceptualization and initial development of the sea transport of liquefied natural gas.

1980 To ***William M. Allen, Malcolm T. Stamper, Joseph F. Sutter*** and ***Everette L. Webb*** and Citations to the employees of Boeing Commercial Airplane Company for their leadership in the development, successful introduction & acceptance of wide-body jet aircraft for commercial service.

1981 To ***Edward J. Wasp*** for his contributions toward the development and application of long distance pipeline slurry transport of coal and other finely divided solid materials.

1982 To ***Jörg Brenneisen, Ehrhard Futterlieb, Joachim Körber, Edmund Müller, G. Reiner Nill, Manfred Schulz, Herbert Stemmler*** and ***Werner Teich*** for their contributions to the development and application of solid state adjustable frequency induction motor transmission to diesel and electric motor locomotives in heavy freight and passenger service.

1983 To ***Sir George Edwards,*** OM, CBE, FRS; ***General Henri Ziegler,*** CBE, CVO, LM, CG; ***Sir Stanley Hooker,*** CBE, FRS (in memoriam); ***Sir Archibald Russell,*** CBE, FRS; and ***M. André Turcat***, L d'H, CG; commemorating their outstanding international contributions to the successful introduction and subsequent safe service of commercial supersonic aircraft exemplified by the Concorde.

1984 To ***Frederick Aronowitz, Joseph E. Killpatrick, Warren M. Macek*** and ***Theodore J. Podgorski*** for the conception of the principles and development of a ring laser gyroscopic system incorporated in a new series of commercial jet liners and other vehicles.

1985 To ***Richard K. Quinn, Carlton E. Tripp,*** and ***George H. Plude*** for the inclusion of numerous innovative design concepts and an unusual method of construction of the first 1,000-foot self-unloading Great Lakes vessel, the M/V Stewart J. Cort.

1986 To ***George W. Jeffs, Dr. William R. Lucas, Dr. George E. Mueller, George F. Page, Robert F. Thompson*** and ***John F. Yardley*** for significant personal and technical contributions to the concept and achievement of a reusable Space Transportation System.

1987 To ***Harry R. Wetenkamp*** for his contributions toward the development and application of curved plate railroad wheel designs.

1988 To ***J. A. Pierce*** for his pioneering work & technical achievements that led to the establishment of the OMEGA Navigation System, the world's first ground-based global navigation system.

1989 To ***Harold E. Froehlich, Charles B. Momsen, Jr.,*** and ***Allyn C. Vine*** for the invention, development and deployment of the deep-diving submarine, Alvin.

1990 To ***Claud M. Davis, Richard B. Hanrahan, John F. Keeley,*** and ***James H. Mollenauer*** for the conception, design, development and delivery of the Federal Aviation Administration enroute air traffic control system.

1991 To ***Malcom Purcell McLean*** for his pioneering work in revolutionizing cargo transportation through the introduction of intermodal containerization.

1992 To ***Daniel K. Ludwig*** (in memoriam) for the design, development and construction of the modern supertanker.

1993 To ***Heinz Leiber, Wolf-Dieter Jonner*** and ***Hans Jürgen Gerstenmeier*** and Citations to their colleagues in Robert Bosch GmbH for their conception, design and development of the Anti-lock Braking System for application in motor vehicles.

1994 To ***Russell G. Altherr*** for the conception, design and development of a slackfree connector for articulated railroad freight cars.

1996 To ***Thomas G. Butler*** (in memoriam) and ***Richard H. MacNeal*** for the development and mechanization of NASA Structural Analysis (NASTRAN) for widespread utilization as a working tool for finite element computation.

1998 To ***Bradford W. Parkinson*** for leading the concept development and early implementation of the Global Positioning System (GPS) as a breakthrough technology for the precise navigation and position determination of transportation vehicles.

2000 To those individuals who, working at the French National Railroad (SNCF) and ALSTOM between 1965 and 1981, played leading roles in conceiving and creating the initial TGV High Speed Rail System, which opened a new era in passenger rail transportation in France and beyond.

2002 To ***Raymond Pearlson*** for the invention, development and worldwide implementation of a new system for lifting ships out of the water for repair and for launching new ship construction. The simplicity of this concept has allowed both large and small nations to benefit by increasing the efficiency and reducing the cost of shipyard operations.

2004 To ***Josef Becker*** for the invention, development, and worldwide implementation of the Rudderpropeller, a combined propulsion and steering system, which converts engine power into optimum thrust. As the underwater components can be steered through 360 degrees, the full propulsive power can also be used for maneuvering and dynamic positioning of the ship.

2005 To ***Victor Wouk*** for his visionary approach to developing gasoline engine-electric motor hybrid-drive systems for automobiles and his distinguished engineering achievements in the related technologies of small, lightweight, and highly efficient electric power supplies and batteries.

2006 To ***Antony Jameson*** in recognition of his seminal and continuing contributions to the modern design of aircraft through his numerous algorithmic innovations and through the development of the FLO, SYN, and AIRPLANE series of computational fluid dynamics codes.

2007 To ***Robert Cook, Pam Phillips, James White,*** and ***Peter Mahal*** for their seminal work and continuing contributions to aviation through the development of the Engineered Material Arresting System (EMAS) and its installation at many airports.

2008 To ***Thomas P. Stafford, Glynn S. Lunney, Aleksei A. Leonov,*** and ***Konstantin D. Bushuyev*** as leaders of the Apollo-Soyuz mission and as representatives of the Apollo-Soyuz docking interface design team: in recognition of seminal work on spacecraft docking technology and international docking interface methodology.

2009 To ***Boris Popov*** for the development of the ballistic parachute system allowing the safe descent of disabled aircraft.

2010 To ***Takuma Yamaguchi*** for his invention of the ARTICOUPLE, a versatile scheme to connect tugs and barges to form an articulated tug and barge, AT/B, waterborne transportation system operational in rough seas. His initial design has led to the development of many different types of couplers that have resulted in the worldwide use of connected tug and barges for inland waterways, coastal waters and open ocean operation.

2011 To ***Zigmund Bluvband*** and ***Herbert Hecht*** for development and implementation of novel methods and tools for the advancement of dependability and safety in transportation.

2012 To ***John Ward Duckett*** for the development of the Quickchange Movable Barrier.

2013 To ***C. Don Bateman*** for the development of the ground proximity warning system for aircraft.

2014 To ***Bruce G. Collipp, Alden J. Laborde,*** and ***Alan C. McClure*** for the design and development of the semi-submersible platform.

2015 To ***Michael K. Sinnett*** and the ***The Boeing Company 787-8 Development Team*** for pioneering engineering advances including lightweight composite wing and monolithic fuselage construction that have led to significant improvements in fuel efficiency, reduced carbon emission, reduced maintenance costs and increased passenger comfort.

2016 To ***Harri Kulovaara*** for leadership in the engineering and design of the most advanced and trend setting cruise ships, ships that integrated "quantum jumps" in cruise ship safety, operational efficiency, features to suit passengers of "all ages," and diverse onboard activities. And, for being the driving force behind the Cruise Ship Safety Forum that brings together owners, builders and classification societies to ensure specific targeted areas of safety improvement are developed and implemented.

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