APPLICATION NOTE

SMART POWER TECHNOLOGY EVOLVES TO HIGHER LEVELS OF COMPLEXITY

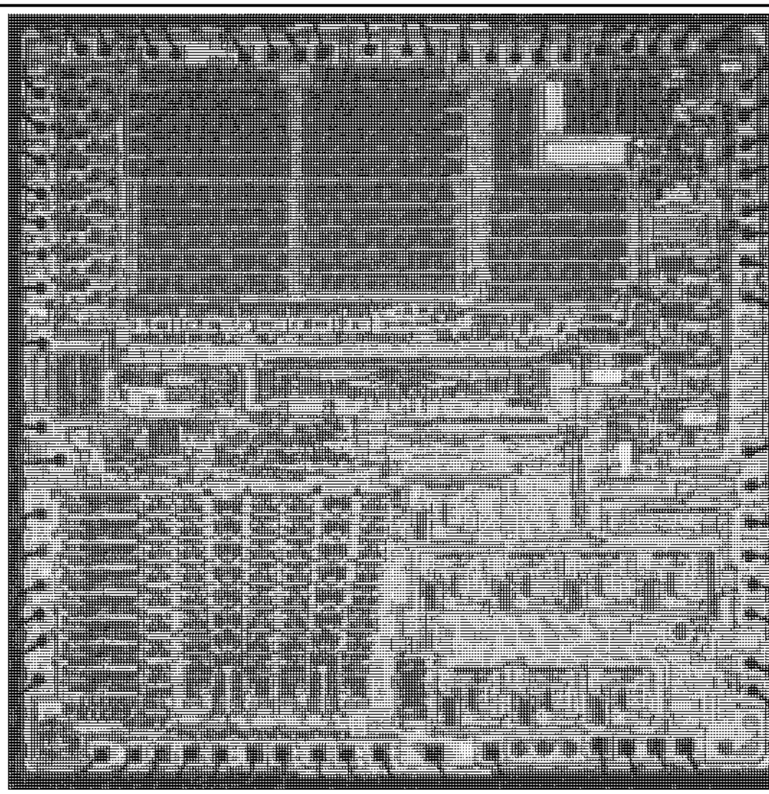
by Bruno Murari

Smart power devices are the shooting stars in power semiconductors, because it's possible to integrate digital and analog functions together with multiple power stages on the same silicon chip. The trend towards higher density will continue.

Since it was first introduced in 1986, mixed bipolar/CMOS/DMOS smart power technology has evolved rapidly, extending voltage capability and integrating highly complex subsystems on single chips containing thousands of transistors.

Integrated circuit fabrication technologies that combine bipolar, CMOS and power DMOS structures on the same chip have had a significant impact on "smart power" integrated circuit design. Since the dissipation of power DMOS stages in switchmode operation is very low it is possible to produce ICs capable of delivering substantial power to the load without the usual heatsinks, cooling fans and so on. Moreover, because it permits the integration of high-density CMOS and multiple DMOS power stages the traditional constraints on complexity are removed and circuits containing complete subsystems have been produced. An example of this is shown in figure 1 -- a custom IC that integrates a motor control system,

Figure 1: An example of the complexity now possible in smart power ICs. This custom LSI device developed by SGS-THOMSON for a computer peripheral application that integrates a servo positioning system, DC motor controller/driver and various other "glue" functions" not integrated in the other ICs on the board.



servo positioning system, a step up converter, microprocessor interface and other circuits.

BCD TECHNOLOGY

A power IC technology combining bipolar, CMOS and power DMOS was first introduced by SGS-THOMSON in 1986. Called Multipower-BCD, this was a 60V process created by merging a conventional junction-isolated bipolar IC process with vertical DMOS technology. The result is a process requiring 12 masks in the standard version -- no more complex than modern bipolar technologies.

Where this process departed significantly from previous smart power processes is that it employs isolated DMOS power devices. The significance of this is that designers are not limited to a single power DMOS transistor per chip, but can have any number (hence ”Multipower”) and connect them in any way. Thus it is possible to integrate any power stage configuration (low side, high side, half bridge or bridge), or even to have several complete power stages on the same chip.

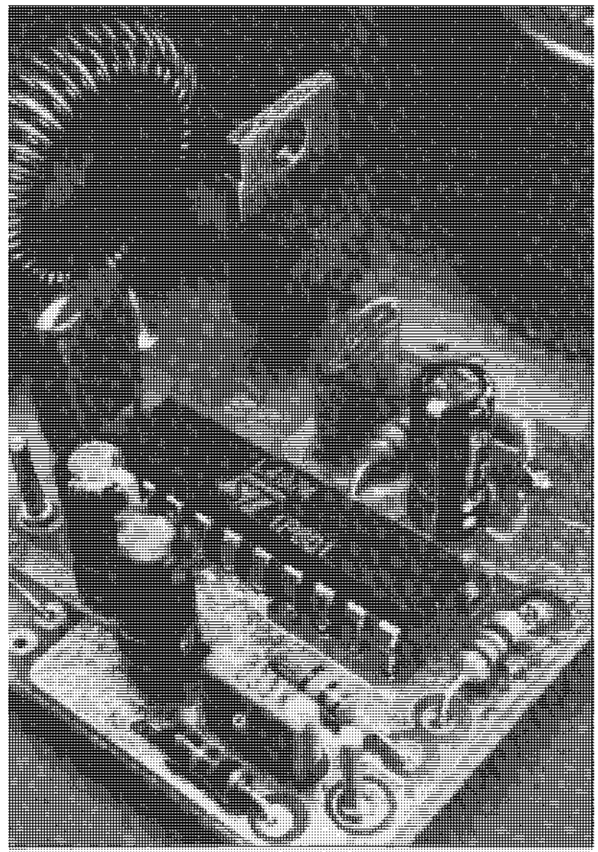
Clearly the combined BCD process gives circuit designers the possibility of choosing the optimal technology for each circuit function: bipolar is the first choice for linear functions where high precision and low offsets are required; CMOS is best for complex analog and digital signal functions because of its high density; and power DMOS is ideal for power stages.

It is the possibility of integrating power DMOS stages that gives BCD technology its greatest advantage: low dissipation. Unlike bipolar power transistors, power DMOS devices need no driving current in DC conditions and operate very efficiently in fast switching operations.

This low dissipation can be exploited to increase the amount of useful power that can be achieved with a given package. For example, both SGS-THOMSON's L296 bipolar power switching regulator and the functionally similar L4970 BCD type are assembled in the Multiwatt package, but the bipolar version delivers up to 160W while its BCD counterpart delivers up to 400W.

An alternative way to profit from low dissipation is to use less costly low power packages in place of high power packages. Very often a bipolar power IC in a power package can be replaced by a BCD part in a DIP, or even PLCC or SO, package. This can bring substantial savings not only because power packages are more costly, but also because they are more costly to mount on the board and are not well suited to automatic assembly. For example, a 4A bipolar switching regulator IC in the Multiwatt package can be replaced by a BCD switching regulator in a DIP package (figure 2) which delivers almost the same current.

Figure 2: The low dissipation of power DMOS can be exploited to make power ICs in low power packages, which are less expensive and easier to mount. This DIP-packaged switching regulator delivers 3.5A, replacing a Multiwatt packaged bipolar IC.



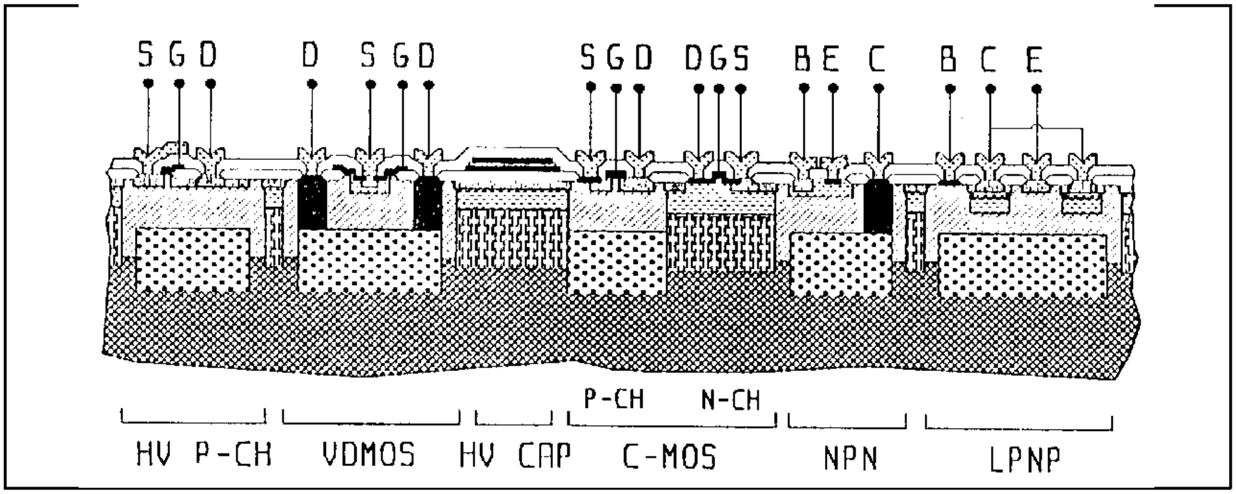
Recently SGS-THOMSON has introduced a ”shrink” version of the original BCD process -- called BCD-II -- which greatly increases the circuit and current density that can be achieved (figure 3).

The original Multipower-BCD process family used 4 micron lithography.

In the BCD-II versions this is reduced to 2.5 microns.

Consequently the current density and component density are approximately doubled. In the case of the 60V version, the shrink increases signal component density from 650 transistors/mm^2 to 1500 tr/mm^2; at the same time the R_{ON}.Area is reduced from 0.9 ohms/mm^2 to 0.5 ohms/mm^2.

Figure 3: A shrink version of the Multipower-BCD technology has now been introduced. Called BCD-II, this version doubles the component density, making high complexity devices much less expensive.



STANDARD BCD PRODUCTS

The first BCD chips to be marketed were the L6202 and L6203 DMOS bridge driver ICs -- actually the same die assembled in DIP (L6202) and Multiwatt (L6203) packages. Both of these devices have an ON resistance of 0.3 ohms, which gives a maximum continuous current of about 1.5A (DIP version) and 3A (Multiwatt version).

These were followed by a variety of power ICs for computer peripheral, industrial and automotive applications. Typical examples include switching regulator ICs, lamp drivers for automotive applications and motor drivers of various types.

All of the early chips and many introduced more recently are standard devices in the sense that they are normally used in various end products, like standard linears or standard logic. In the late eighties, however, designers began to apply BCD technology to make power ICs with a complexity that can truly be called LSI.

LSI COMPLEXITY IN POWER ICs

We have seen that BCD technology allows an arbitrary number of complete power stages on one chip and the dissipation of each is low enough to ensure that the cumulative dissipation of these power stages is within the limit of practical packages. Moreover, high density CMOS allows signal level circuits of LSI complexity to be added on the same chip.

An interesting consequence of these factors is that BCD technology allows the IC designer to build complex systems on a single chip. Moreover, the technological limit on complexity is beyond the complexity of a wide range of end products.

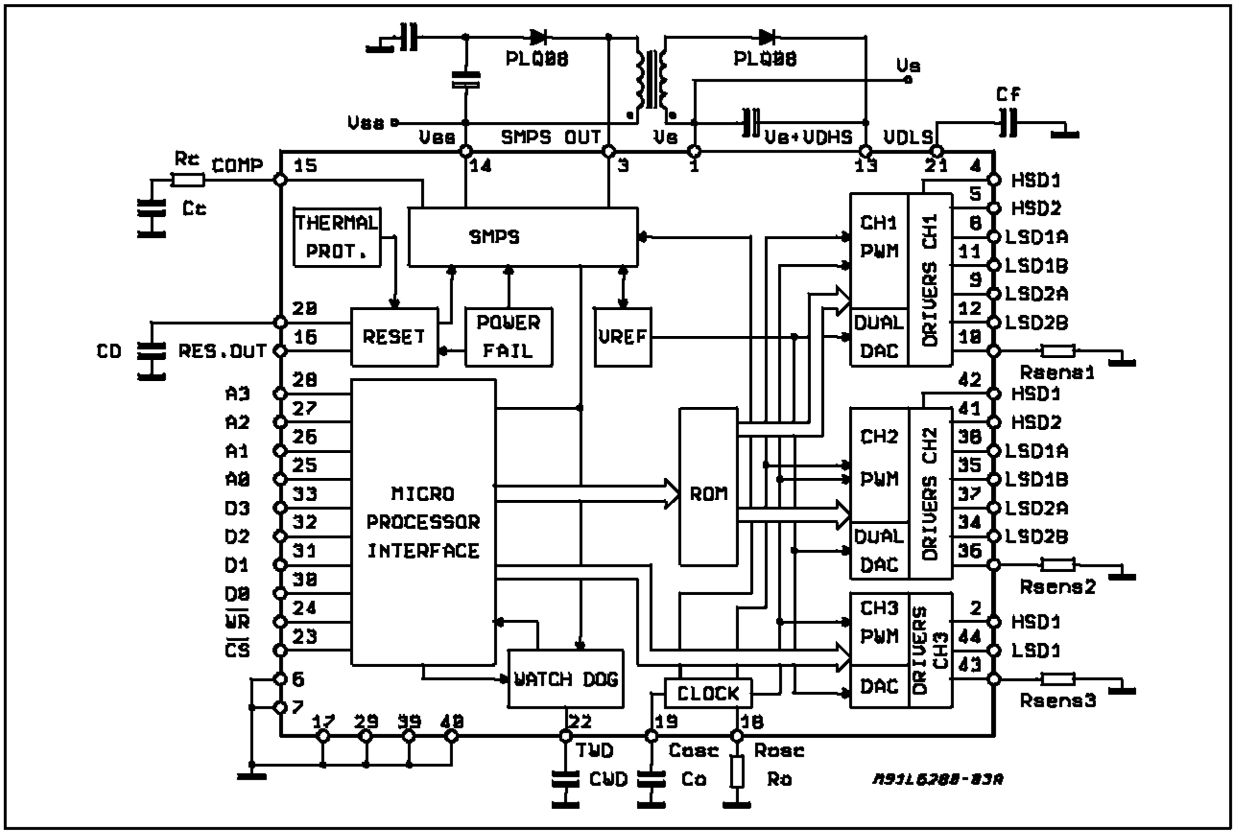
The first example of a circuit that exploits the possibilities of LSI smart power is the L6280, a device introduced in 1989 for a portable typewriter application (figure 4). This IC integrates two 1A motor drivers, a 3A solenoid driver, a 5V/1A SMPS and microprocessor interfacing circuitry -- all of the power subsystems of the typewriter. The L6280 behaves like a microprocessor peripheral, latching commands from the bus. All of the functions can be controlled by software -- even the output stage configurations.

Surprisingly, perhaps, the overall dissipation of this complex IC is so low -- less than 1.5W -- a power package was not needed. In fact the L6280 is assembled in a PLCC 44 chip carrier, though the 11 pins on one side are all connected together and used to conduct heat to the PCB tracks.

Since then the same approach has been applied to other applications of comparable or greater complexity. One example is a custom chip designed for a computer peripheral application (figure 1) that integrates a motor control circuit, a servo positioning system, a step up converter, a microprocessor interface and various other glue circuits needed on the board. There are 12 power transistors and roughly 4000 other transistors in this IC. Such a solution is extremely effective because of the increasing trend towards very compact solutions.

BCD technology can also be applied in areas where the emphasis is more on "smart" than on power. An example of this is the telephone set. Using Multipower-BCD technology it has been possible to realize a single-chip telephone that includes a pulse/tone dialler, voice circuit, ringer and monitor amplifier. Modest power capability is needed for the ringing transducer and the monitor loudspeaker, but half of the chip is occupied by the complex CMOS logic. A total of 16,000 transistors are integrated in this circuit.

Figure 4: Designed for a portable typewriter application, the L6280 integrates two motor drivers, a solenoid driver, a power supply and complex control logic.



The introduction of the shrunk BCD-II technology both increases the amount of logic that can be integrated at a reasonable cost. This improvement in microlithography also allows an improvement in current density of the power DMOS transistors -- an interesting advantage over bipolar technology where current density depends on emitter area and cannot be improved in this way.

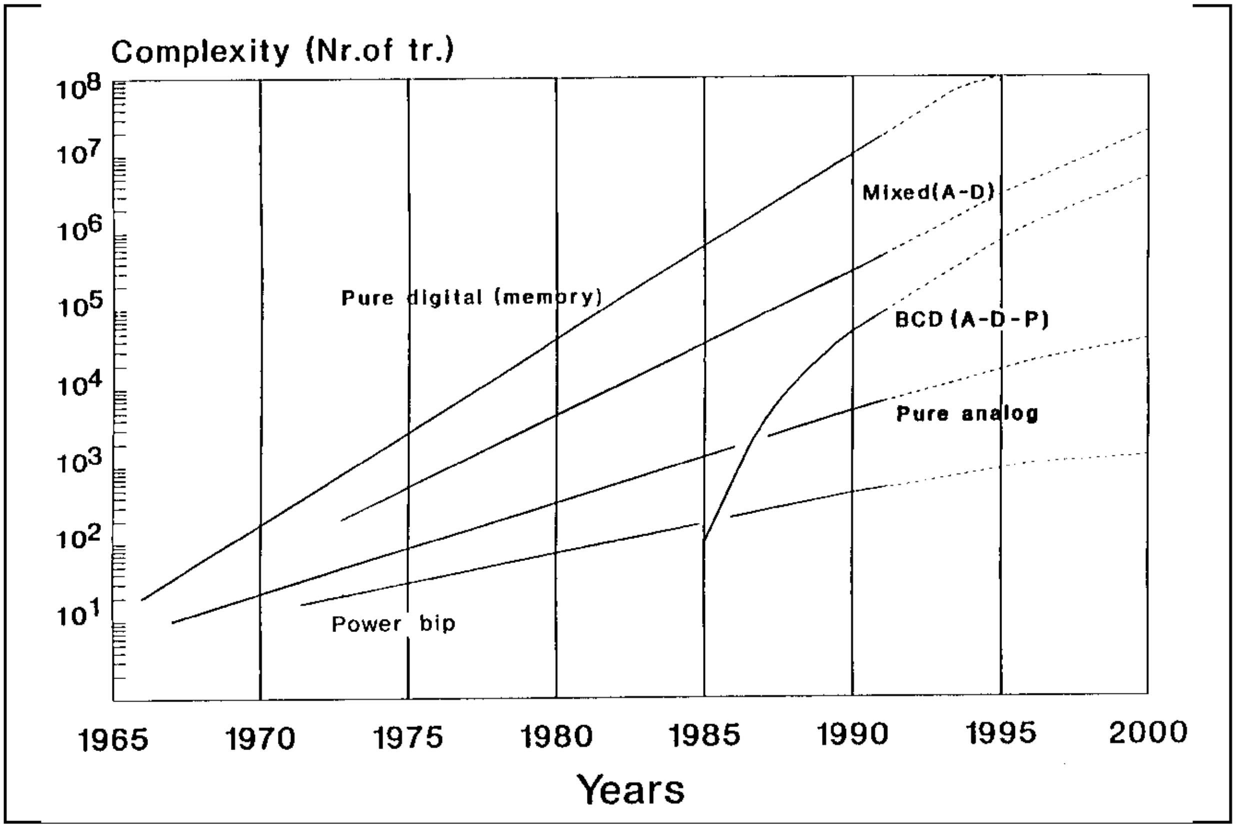
It is also interesting to compare the potential complexity increases for various technologies (figure 5). Clearly there has been a much greater increase in the complexity of pure digital circuits (about eight decades) than in analog circuits (four decades). In fact pure analog ICs containing thousands of components are extremely rare. A consequence of these curves is that there is a tendency to use digital techniques whenever possible because it allows a greater reduction in area. The possibility of having dense digital circuits on a BCD chip allows designers power IC designers to take advantage of this trend.

At present the capabilities of the technology in terms of complexity generally exceed the demands of system designers, few of which have learned to exploit fully the level of integration now possible. Another important consideration is that LSI smart power devices will invariably be full custom and developed for a specific end use with IC designers and system designers working together; at this level of complexity standard products are unlikely.

To create a complex smart power IC the system designer has to understand the capabilities and limits of IC technology and consider a highly-integrated solution from the outset. With today's level of certainty in power IC design this is not a risky choice.

Given the need to embody system knowhow in silicon it is evident that some system designers would prefer to do their own design, using a cell library approach. SGS-THOMSON uses such a design technique in house but we believe that it is too early to offer this on the market because the design of power ICs is not as mechanical as low power ICs and the silicon design experience of a skilled designer is very important. The main difficulty lies in avoiding unwanted interaction between power sections and signal sections -- where a power IC designer really earns his salary. Another non-trivial complication is that there is a difference between designing a circuit which works and designing one that can be produced and tested in large volumes. Often, in fact, the development of testing hardware and software can be more troublesome than the design of the IC itself.

Figure 5: BCD technology allows power IC designers to take advantage of the much greater level of integration achieved in digital technology. Analog functions are replaced by digital equivalents in complex circuits.



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