PAUL POENISCH | X-FAB
paul.poenisch@xfab.com

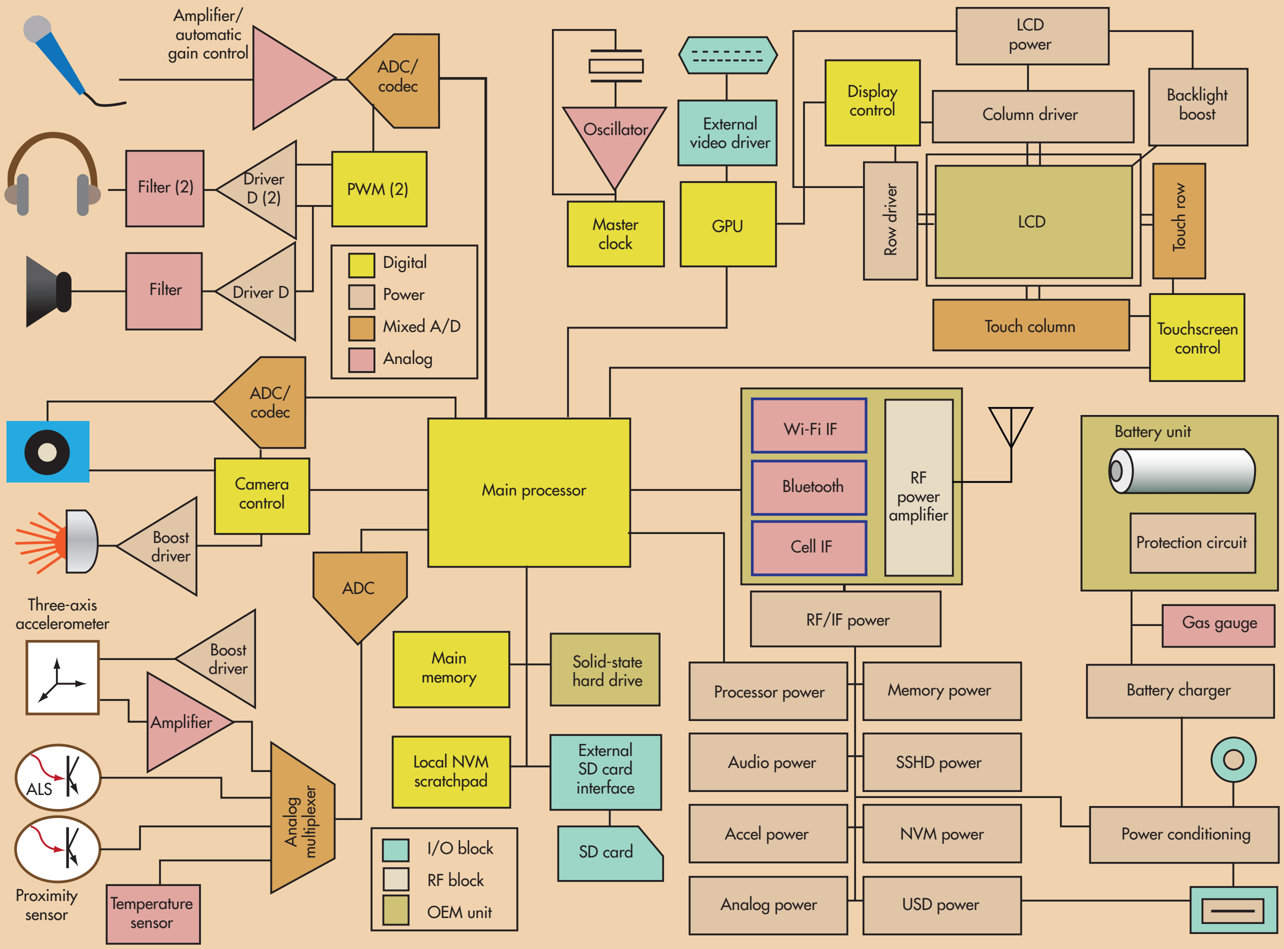
Create Custom "Housekeeping" Chips To Consolidate Functions

Some of the latest foundry processes combine digital with mixed-signal and memory capabilities to allow system designers to "sweep up" many functions into a single chip, with few additional mask steps and little or no third-party IP.

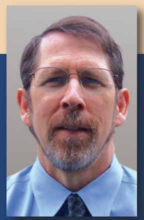
Successive generations of portable consumer products create new headaches for system and chip designers as speed, functionality, and I/O functionality escalate. Moore's Law continues to meet the required jumps in digital processing capability.

Added peripheral and memory functionality often requires a corresponding increase in system components, though, increasing the size, mechanical complexity, weight, and power requirements across the system, raising costs, and reducing margins.

To counter this trend, it's necessary to improve the integration level in the product. But there's a catch. How technically advanced or how easy a semiconductor process used to implement this integration makes it for the system designer doesn't matter if the resulting product is too expensive to sell to the end customer or if the end product is intro-



1. A typical tablet computer challenges the designer with its functional complexity. There is a huge number of digital blocks, analog blocks, and blocks that regulate, condition, or pass power that must be crammed into a small area.



PAUL POENISCH is a senior applications engineer at X-FAB Silicon Foundries, responsible for working with customers to find solutions to their design problems by using X-FAB technology and IP blocks. This activity includes recommending which X-FAB process is best suited for an application and recommending specific devices for circuit requirements and circuit approaches to solve application problems.

duced to the customer too late for the market window. Even reducing the bill of materials (BOM) may not be sufficient to counteract the cost of adding features.

Here’s an approach to consolidating as much new functionality as practical into a single custom IC while maintaining core functionality across generations. Processes such as X-FAB’s XP018 make it practical *(see “Creating A Flexible, Modular Process,” p. 82)*. This approach makes it possible to combine types of devices that previously were available only in separate specialized processes, such as high-voltage, low-$R_{(DS)on}$ transistors with nonvolatile memories.

DESIGN APPROACH

Tablet computers offer a prime example of the challenges of complexity. They add new features every year, leaving the designer with the dilemma of how to incorporate all of this extra functionality in the same footprint *(Fig. 1)*.

The latest functionality embraces the touchscreen with haptic feedback; a stereo audio system with internal speakers, an internal microphone, and possible external microphone jacks; and a camera. The tablet must be Wi-Fi-enabled to network with other electronic devices. And, tablets often have Bluetooth capability and may need to access cell-phone networks.

The operating system and many applications require the device to sense its orientation and even acceleration. Additionally, the system needs to be sensitive to ambient light and to internal and external temperature. It also must be able to inter-

TABLE 1: COMPONENT FOOTPRINT (FROM FIGURE 1)

Block	Quantity	Component	Manufacturer	Part number	Package	Size *	Area †
Microphone amplifier/ACG Audio ADC/codec	1	Codec	Nuvoton	WAU8822	32-QFN	5 × 5	36
Audio amplifier	1	Class D	Texas Instruments	TPA2001D1	16-PDSO	5 × 6.5	45
Camera control	1	Custom IC	Custom	Custom	16-DFN	3 × 4	20
Flash driver	1	White LED driver	ON Semiconductor	CAT4137	5-TSOT	2.9 × 2.8	14.8
	1	Switch	Many	Many	3-MLP	2 × 2	9
3D accelerometer power	1	Boost	National/Texas Instruments	LM4510	10-LLP	3 × 3	16
Accelerometer resonator	3	Custom IC	Custom	Custom	10-LLP	3 × 3	16
Analog multiplexer	1	Eight-input multiplexer	ON Semiconductor	MC13051B	16-TSSOP	5 × 6.4	44.4
Temperature sensor	1	Temperature sensor	Analog Devices	TMP35	23-SOT	3 × 3	16
ADC	1	16-bit ADC	Linear Technology	LTC2380-16	16-DFN	3 × 4	20
NVM scratchpad	1	64-kbit E^2PROM	Atmel	AT17LV65	8-LAP	6 × 6	49
SD card interface	1	CDC interface	ON Semiconductor	NCN6000	20-TSSOP	6.4 × 6.4	54.8
Oscillator	1	50-MHz XO	ECS	ECD-2018	Custom	2.5 × 2	10.5
Master clock	1	PLL clock driver	Texas Instruments	CDCVF857	56-BGA	4.5 × 7	44
Touchscreen controller	1	Capacitive touchscreen controller	Atmel	QT5480	44-QFN	7 × 7	64
Analog power	1	Buck	Texas Instruments	TPS62061	8-PWSON	2 × 2	9
Processor power	1	Buck	Linear Technology	LTC3445	24-QFN	4 × 4	25
RF/IF power	1	Boost	STMicroelectronics	ST8R00	8-DFN	4 × 4	25
USB power	1	Buck	Texas Instruments	TSP65021	40-PVQFN	6 × 6	49
Audio power	1	Buck					
SSHD power	1	Buck					
NVM power	1	Buck	Texas Instruments	TSP65021	40-PVQFN	6 × 6	49
	1	Buck					
Memory power	1	Buck					
Battery charger	1	Charger/power management	Maxim	MAX17085B	40-TQFN	5 × 5	36
Power conditioning	4	NMOSFET	ON Semiconductor	NTD381N	369AA	6.5 × 10	82.5
Gas gauge	1	Charging monitor	Maxim	MAX17050	9-CSP	1.3 × 1.3	5.3
LCD power	1	Buck	Linear Technology	LT3970	10-DFN	3 × 2	12
Backlight power	1	LED driver	Fairchild	FAN5343	6-UMLP	2 × 2	9
						Total	761.3

Notes: * All package sizes are in mm. † All areas are in mm^2.

face with a battery charger and deal with removable mass memory.

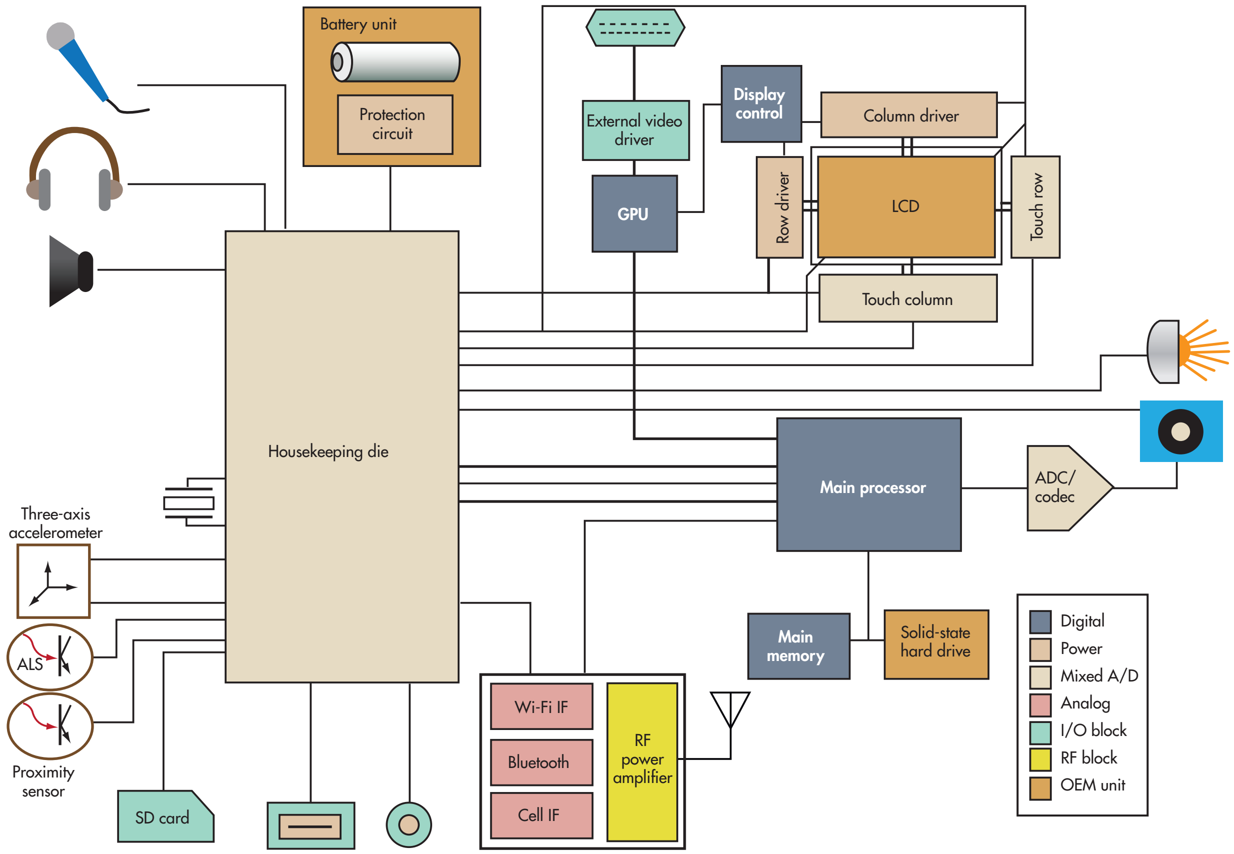
From a circuit standpoint, a typical tablet would include digital blocks, analog blocks, and blocks that regulate, condition, or pass power. Beyond that, any feature the customer sees actually requires several different types of blocks. For example, audio functionality needs analog blocks, power blocks, mixed-signal blocks, and digital blocks just to input and output sound.

BLOCK TYPES

Purely digital elements are blocks with very high density, such as the main processor or main memory, or specialized functional digital blocks that work with one of the computer's particular features. Specialized functional blocks usually don't require the use of a high-density node, but they must be able to interface properly with other types of circuits.

From a process technology standpoint, analog signal elements have special requirements beyond what digital blocks need: a specific operating voltage range; capacitors, resistors, and other devices not normally found on typical digital technology; and well characterized matching and noise properties for the devices.

Power elements have two main specs: the voltage levels they need to deal with,



2. By integrating many of the functional components of Figure 1 into the same IC, it is possible to reduce footprint and bill of materials.

and the currents they must pass. They also have specific internal requirements for the devices, such as low $R_{DS(on)}$, fast switching speed, and low parasitics.

Tablet memory elements include the main random access memory (RAM), a mass storage unit (usually a solid-state hard drive), hardware configurations, software, and peripheral configuration programming, as well as several nonvolatile memory (NVM) blocks for functions such as boot code. Each NVM block has unique density and programming requirements.

REDUCING PARTS COUNT

It's obvious that higher integration means fewer parts and overall lower packaging overhead, physical size, assembly cost, signal delays, and power. But there are two ways to reduce the BOM: individually shrink each subsystem, or review the entire system and reorganize its components according to their technology requirements. The former is reaching the end of its life. The latter is possible, given access to process technology that facilitates the integration of different block requirement types into a single IC process.

HOW PROCESSES DIFFER

Foundries can achieve wider functionality in a process in two ways: merge processes together, or integrate up front when the process is being developed.

In the first case, the foundry might add a third-party eFlash module to the logic process to integrate flash memory. This achieves the integration, but adds seven to 10 masking steps—a very expensive proposition that also typically adds licensing and royalty fees to manufacturing.

The second approach permits process-integration engineers to share process modules and steps, reducing the number of masking operations. And because these modules have been integrated right from the beginning, the intellectual property (IP) blocks that are associated with the modules generally are supplied by the process provider foundry at substantially reduced prices compared to those supplied by third-party IP providers.

RATIONALIZING FUNCTIONAL CONSOLIDATION

How might a designer apply the second approach to a tablet computer? Define a die that gathers as many components as possible into a single component—a housekeeping die—reducing the BOM. For example, using the XP018 process, power conditioning blocks can be included in this housekeeping die as long as their maximum voltage does not exceed 60 V.

Housekeeping die components also can include the Class D drivers and the boost blocks necessary for certain peripherals. They can include the battery charger, power conditioning blocks, and NVM blocks as well. Boot code resides in eFlash, the hardware configuration in one-time programmable (OTP) memory, and software and peripheral configuration information in nvRAM.

CREATING A FLEXIBLE MODULAR PROCESS

X-FAB'S XP018 IS A MODULAR 0.18-µm CMOS process with 1.8-V logic capability, 5-V I/O, and high-voltage transistors ranging from 5 V to 60 V. It allows you to add features as needed for each individual design, paying only for those required for a particular design, rather than for all features. XP018 also offers several nonvolatile memory (NVM) options, isolated low-voltage transistors, analog passive and active components, a variable number of metal layers, and, if required, optical components.

The process is designed so the high-voltage transistors, the NVMs, and the isolated low-voltage modules all share module steps and masks, allowing modules to be added with a minimum of additional process steps. X-FAB provides digital libraries, I/O libraries, memory block IPs, high-voltage and electrostatic discharge (ESD) libraries, and analog block libraries.

TABLE 2: COMPONENT FOOTPRINT (FROM FIGURE 2)

Block	Quantity	Component	Manufacturer	Part number	Package‡	Size*	Area†
Housekeeper	1	Custom	X-FAB/OEM	Custom	144-BGA	13 x 13	196
						Total	196

Notes: * All package sizes are in mm. † All areas are in mm².
‡ Chosen package is an estimate of the required functionality.

ANALOG SENSOR SIGNAL-CONDITIONING BLOCKS

Continuing that approach, it's possible to integrate all of the analog sensor signal-conditioning blocks, including blocks for the audio section, accelerometers, temperature, ambient light, and proximity sensors.

In addition, the analog blocks for the crystal oscillator and battery gas gauge can reside in the housekeeping block. In some cases, it may even be possible to integrate the optical sensors and some or all of the intermediate frequency (IF) blocks.

Of course this is only possible if the junction-isolated devices available in the process provide good noise isolation between digital blocks and sensitive analog blocks. A foundry should supply full matching and noise models to facilitate analog block design.

Now for the tricky parts. Some sensors such as the three-axis accelerometer require specialized drive circuits. If the process provides high-voltage and floating analog capabilities, they can also be integrated into the housekeeping die.

Many of the peripheral functions in a tablet computer require small dedicated digital blocks, such as the camera, the audio's Class D pulse-width-modulated (PWM) amplifier, the master clock, the external secure digital (SD) card reader, and the touchscreen controller. This integration requires digital libraries that include high-density, low-power, low-noise, multi-voltage, and junction isolation features.

Tablet computers often must supply many different voltages to their various components and features. Many of these voltages are required by one or two OEM components with requirements that are different from everything else in the system. By integrating many of these components into the same IC, it's possible to eliminate some of these voltage requirements, reducing the BOM by several passive components the power subsystem needs for supplying the voltage needs of the computer *(Fig. 2)*.

EXAMPLE

A housekeeping die takes the place of a lot of the blocks in the long list. The designer then can put a larger battery in the system and make it last longer—a huge benefit for customers.

Table 1 lists devices that could be used to fulfill the functional requirements of the blocks for a hypothetical tablet computer design. Such devices could be used for these functions. (The set has not been optimized in this example.) The footprint area of each device is assumed to be 1 mm larger in X and Y to allow for placement margin.

Table 2 shows an example custom design IC using a process such as XP018 to meet the same functional requirements. Using a highly integrated process for these functions reduces the area needed for the required functions by almost a factor of four. This area now can be used for additional functionality, reduced product size, or increased battery volume.

LOOKING AHEAD

As time goes on, portable electronic devices will continue to increase in functional complexity. No matter where you are on the functional complexity path, you will need to figure out how to integrate more components into a fixed size to stay in the market. Also, you'll need to figure out how to keep costs from going through the roof!

The only practical way of consolidating components in portable electronic devices is to merge functional blocks to reduce the total component count. The most cost-effective time-to-market approach is to use a process in which multiple features can be added or subtracted at low cost. Eventually, portable electronic products likely will consist of a digital core, a housekeeping ASIC, and a handful of specialized real-world I/O components. ed