

Introducing the 22FDX™ 22nm FD-SOI Platform from GLOBALFOUNDRIES®

March 2016

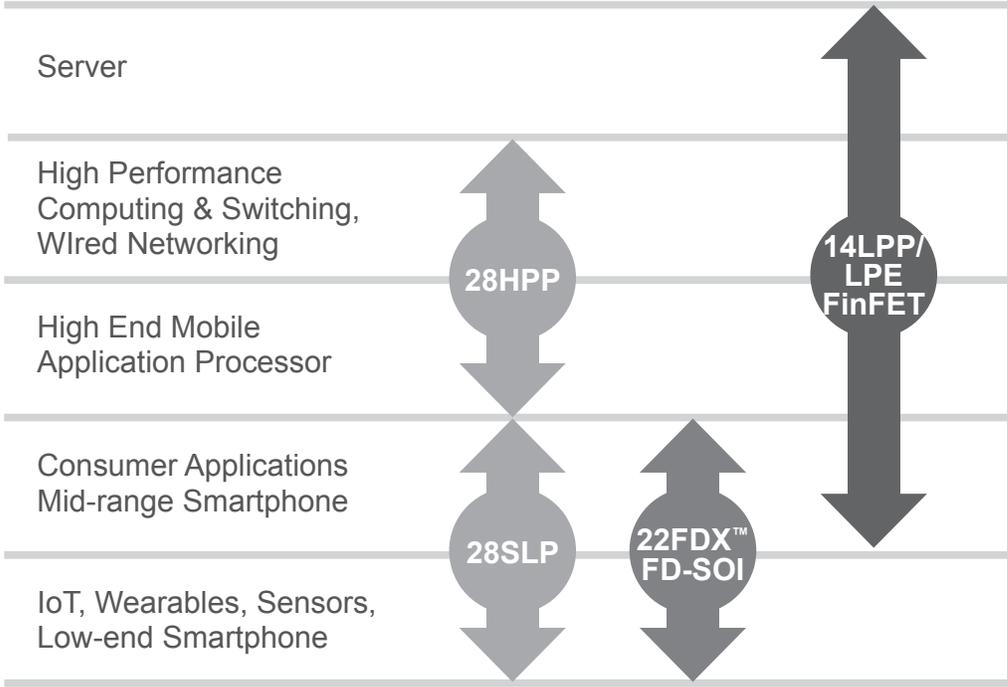


Introduction

Selecting a next generation technology platform for your new product is a critical decision. Product requirements continue the relentless drive for more performance, more advanced features, lower cost, lower power and pervasive wireless connectivity. Unfortunately these requirements are increasingly at odds with each other, and trade-offs are required that will impact your product's success in the marketplace.

What is needed is a process technology that can provide the right balance of performance, power, and cost as well as an entirely new set of product features that allow for product differentiation in an increasingly competitive marketplace. This paper will show that the 22FDX™ platform provides significant opportunities to optimize your design in ways you might not think possible, providing tools so that you can achieve the high performance, low power, low cost AND superior end product functionality your customer requires.

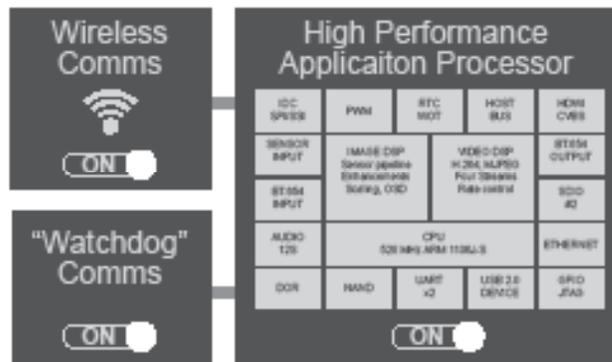
Figure 1: 22FDX and FinFET are Complementary Offerings



Choosing a CMOS Technology Option – FinFET or FD-SOI

As products fabricated using today’s bulk CMOS technologies begin migrating into next generation nodes, the designer has a choice to make. FinFET offers advantages for the highest performance designs that have significant digital content. These designs often show up in high performance computing, server, or premium smartphone applications. In other designs, performance and power are both important and overall processing efficiency and battery life are key. FD-SOI provides significant low power, low cost and processing efficiency advantages for these designs, often found in mainstream mobile application processors, wireless networking, Internet of Things (IoT), wearables and smart sensors. GLOBALFOUNDRIES provides both FinFET and FD-SOI technologies, as illustrated in *Figure 1*, which are uniquely positioned to help you make the right technology platform choice based on your key product requirements.

Figure 2: Example SoC design with requirements for low power, wireless connectivity and advanced data processing capabilities



- Watchdog processor detects motion and wakes image processor
- Processor zooms in and analyzes image
- Wireless comms transmits message

An Example Low Power SoC Design

One way to understand the capability and benefits of the 22FDX™ platform is to look at how it can be used to enhance future low-power SoC designs. This simple example is a low-power image processing application, illustrated in *Figure 2*. This SoC consists of a watchdog processor that requires always-on operation with low activity factors or duty cycles. A high performance image processor analyzes HD images and video in real time, while minimizing power consumption and extending battery life while in the active mode. Finally, to meet the demanding cost requirements of future chip sets, particularly for IoT markets, the design requires integrated RF, such as Wi-Fi or Bluetooth LE. We will come back to this example after we review the features of the 22FDX platform.

The 22FDX™ Platform Description

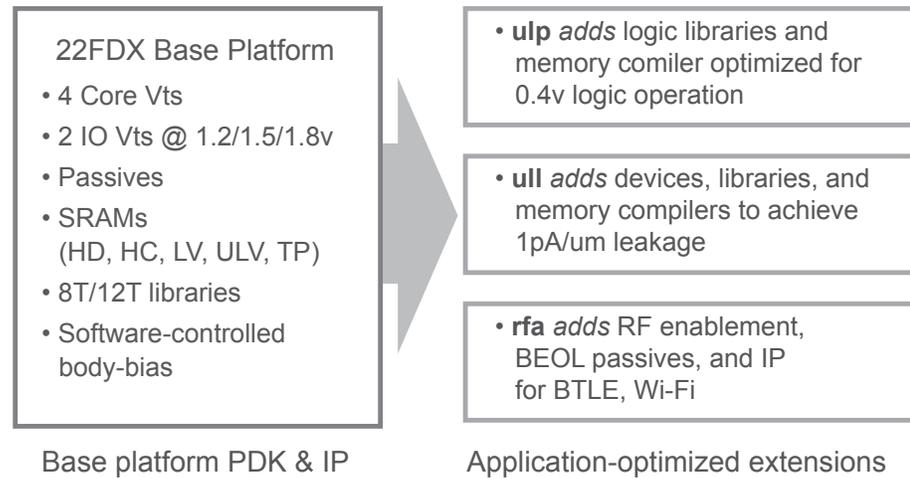
22FDX is the industry's first 22nm FD-SOI platform. Using the 22nm node allows GLOBALFOUNDRIES to leverage our production-proven 28nm tool set, while still minimizing the number of steps requiring double patterning to maintain low cost. It can provide up to 40 percent die scaling relative to the standard 28nm node. 22FDX also provides a second generation FD-SOI transistor, capable of providing nearly 70 percent lower power than 28nm and similar power efficiency to FinFET technology. Thus, 22FDX has FinFET-like performance, ultra-low power efficiency and the cost effectiveness of 28nm.

The benefits of 22FDX provide additional compelling and differentiated capabilities for design flexibility and intelligent control that are not available in any other technology. For example, 22FDX provides:

- A software-controlled transistor body-biasing capability to dynamically tune both power and performance
- Improved transistor architecture with superior electrostatic control, reduced capacitance, and lower variability to minimize standby leakage and active power
- Ultra-low-power 0.4V operation achieved by combining the improved transistor architecture with the body-biasing capability
- RF enablement, superior analog transistor characteristics, and opportunities for novel RF circuit topologies that can reduce RF power by up to 50 percent

22FDX has the features that are required to enable the next generation of products in connectivity, mobile, IoT, wearable, networking, and automotive applications.

Figure 3: 22FDX Extensive Base Platform and Three Extensions



22FDX™ Base Platform and Platform Extensions

22FDX has a very comprehensive base platform, illustrated in *Figure 3*, which provides the key capabilities required by advanced designs:

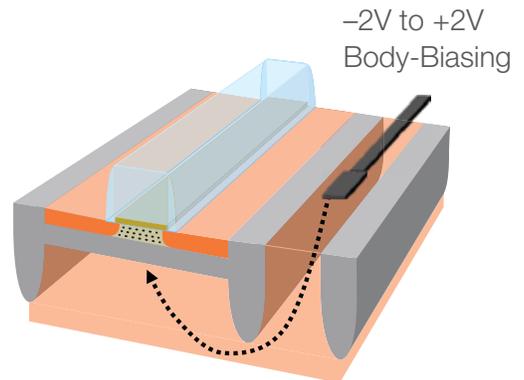
- 4 core Vt offerings (2 w/ forward body-bias and 2 w/ reverse body-bias)
- 2 IO Vt's that can operate at 1.2, 1.5, or 1.8 volts
- Complete set of passive devices
- Broad array of SRAMs spanning high-density, high-speed, low-voltage, ultra-low-voltage, and two-port SRAMs
- High-density and high-speed standard cell libraries
- Foundation and complex IP optimized for mobile, IoT, and RF markets
- Software-controlled body-biasing capability

For designers who want to further differentiate their designs, application-optimized extensions are being developed for 22FDX. These include:

- 22FDX-ulp: ultra-low-power extension that provides logic libraries and memory compilers that are optimized for 0.4 volt operation
- 22FDX-ull: ultra low leakage extension that brings in an expanded device suite capable of achieving one pico-amp per micron leakage
- 22FDX-rfa: RF and analog extension that brings in full characterization and enablement for RF applications, including optimized RF layouts and P cells, BEOL passives, and IP for Bluetooth LE, ZigBee, and Wi-Fi applications

Figure 4: Forward and reverse body-bias dynamic adjustment

- Forward BB (FBB) enables low voltage operation down to 0.4v without speed loss
- Reverse BB (RBB) enables low leakage down to 1pA/micron
- Dynamic body biasing enables active tradeoff of performance vs. power
- Can be used to reduce variability across the die and/or die-to-die



22FDX™ - Architected for effective body-biasing

One of the most differentiated features of the 22FDX platform is that it is architected for effective body-biasing. Body-biasing, as shown in *Figure 4*, applies a positive or a negative voltage to the back gate of the transistor. This allows the transistor V_t to be tuned, either higher or lower, and can be done statically or dynamically under software control. In the case of reverse body-bias, the V_t is increased to reduce the leakage in standby mode operation. For appropriately optimized device architectures, leakages down to 1pA/micron are achievable. In the case of forward body-bias, the switching frequency can be increased and used for a selectable boost or turbo mode to increase performance. Forward body-biasing can also be used to enable ultra-low power or low voltage operation, even down to 0.4 volts, by lowering the V_t to retain voltage headroom and performance while operating at low V_{dd} . There are many other novel ways to use body-biasing, such as process compensation to minimize variability or as a method to mitigate the reliability penalties associated with voltage overdrive conditions.

Figure 5a: Dynamic body-bias optimizes power and performance

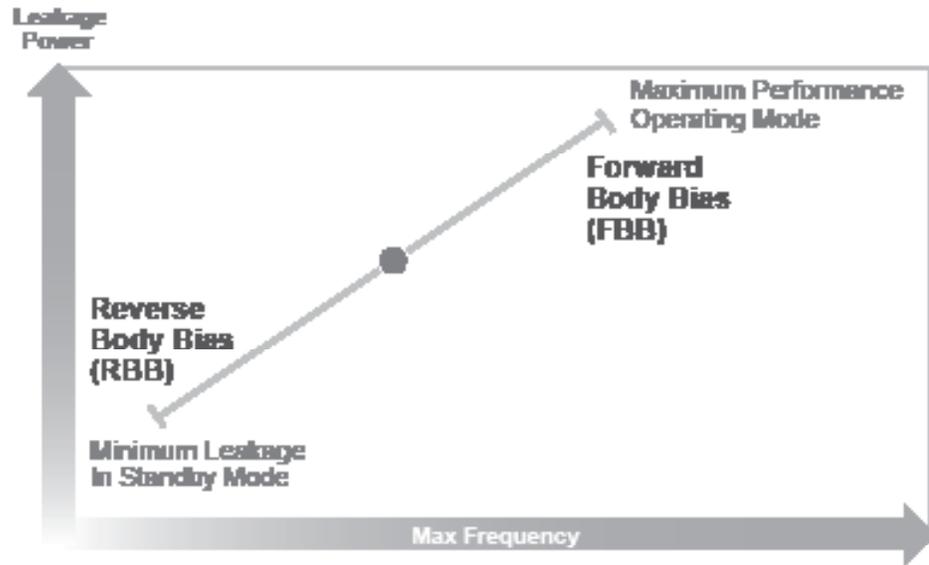


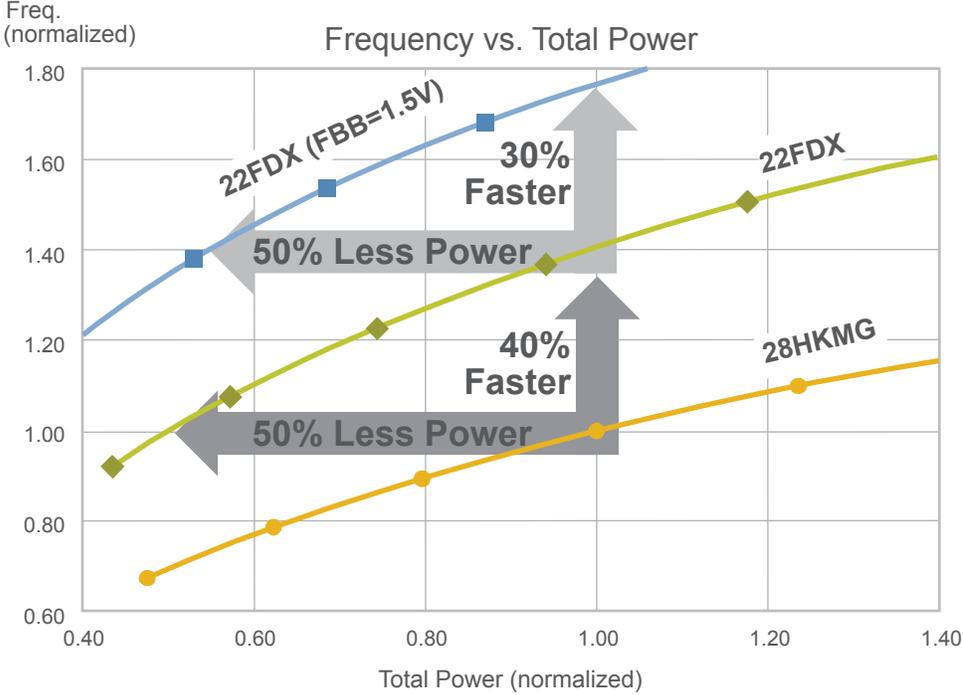
Figure 5b: Dynamic body-bias optimized by system need



Dynamic Body-bias Provides Best Performance-Power Tradeoffs

When body-biasing corners are combined with traditional PVT corners, the designer has access to an entirely new dimension to optimize for power and performance. As illustrated in *Figure 5a*, with the body-bias capability of 22FDX™ you can optimize circuit blocks to maximize battery life with the ideal combination of active or leakage power based on the desired use condition. *Figure 5b* shows the optimal operating points for relative active and leakage power to obtain best performance, lowest total power or best performance per watt. This flexibility enables innovative solutions to the difficult trade-offs designers face when using other process technologies.

Figure 6: 22FDX has less power and more performance when compared to 28nm HKMG



The design point for the 22FDX™ technology definition was selected to achieve performance and power targets that exceed the capabilities of incumbent 28nm process technologies. *Figure 6* shows 22FDX compared to a high-performance 28nm high-K metal gate (HKMG) technology. The base 22FDX process, shown in green, can provide up to 50% less power at the same frequency, or 40% faster performance at the same total power than 28nm HKMG, shown in orange. In addition, 22FDX can be further optimized with forward body-bias, shown on the blue curve, to further reduce the power, or to further boost the speed in a turbo operation mode. This unique capability provides FinFET-like performance and low V_{dd} operation down to 0.4 volts.

In addition to the advantages body-biasing provides, 22FDX™ does not sacrifice any of the power management strategies commonly utilized in Bulk or FinFET technologies as shown in *Table 1*:

Table 1: Power management strategies

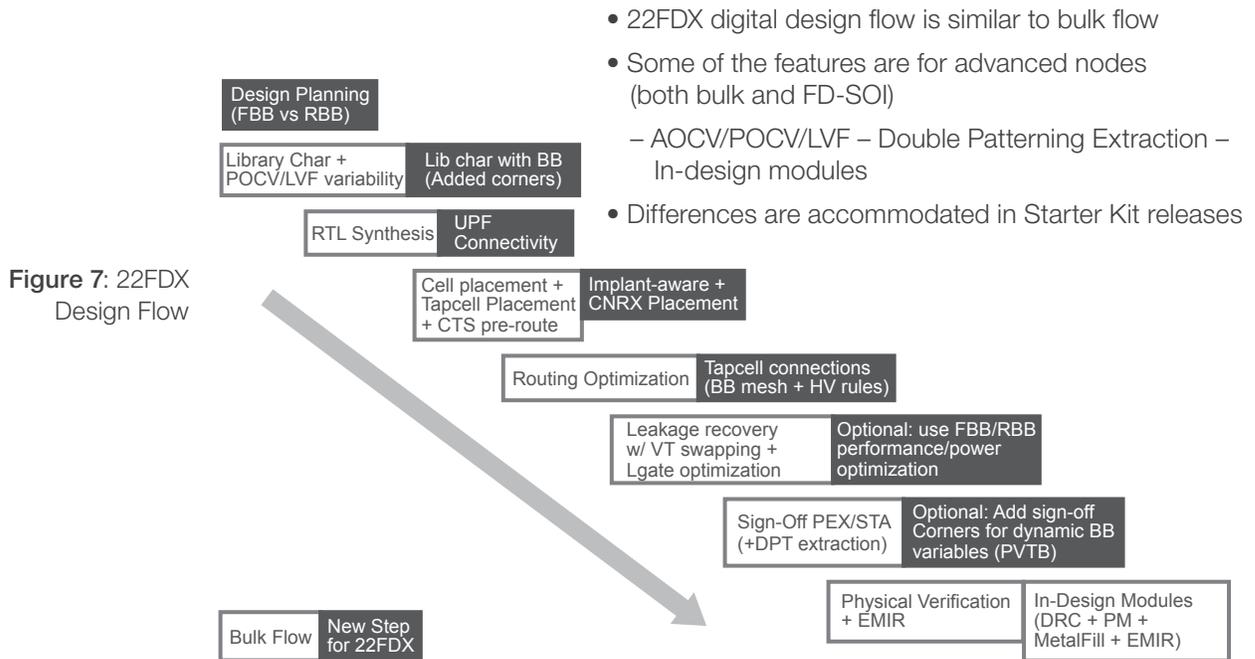
Bulk	FDSOI	FinFET
Multi-Vt • Well • Halo/Extn	Multi-Vt • Back-gate doping • Channel implant	Multi-Vt • Well • Halo/Extn
Gate length sizing	Gate length sizing	Gate length sizing
	Body-biasing • Reverse BB • Forward BB	

From a design perspective, the well and halo/extn mask layers are analogous to the back-gate and the channel implant masks in an FD-SOI technology, respectively. Leakage and performance can be further optimized in 22FDX with multiple available gate lengths and static or dynamic application of transistor body-biasing.

It should also be mentioned that 22FDX transistors have inherent advantages for digital and analog circuits due to their fully-depleted (vs. bulk) implementation (see *Table 2*). Compared to planar bulk technologies, 22FDX transistors have superior sub-threshold characteristics, lower capacitance, and superior transistor mismatch. 22FDX transistors also have higher trans-conductance and lower output conductance which enables higher operating Ft and higher self-gain for analog/RF circuits.

Table 2: Advantages of FD-SOI versus bulk transistors

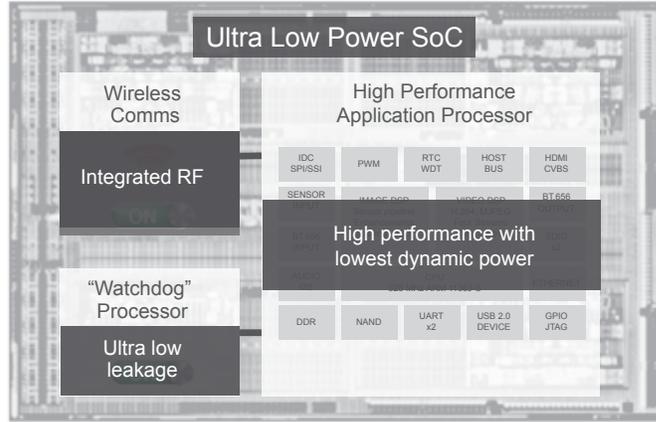
		40LP (Vdd = 1.1v)		22FDX (Vdd = 0.8v)	
		NFET	PFET	NFET	PFET
Electrostatics	DIBL, mV	<199	<205	<89	<92
	SSsat, mV/dec	<97	<104	<86	<90
Capacitance	Cov, fF/um	0.215	0.181	0.186	0.177
	Cj, fF/um	0.378	0.327	0.146	0.146
Mismatch	AVtsat, mV-um	4.45	2.89	1.65	1.61



Design Migration to 22FDX™ from Bulk Node

In order to simplify the transition to 22FDX from bulk CMOS technologies, GLOBALFOUNDRIES has qualified reference flows that are available today to assist in the migration. The 22FDX design flow, illustrated in *Figure 7*, is similar to a bulk technology flow. Because 22FDX is an advanced node technology at 22nm, many of the new features found in the flow are very similar to other advanced nodes, such as 20nm bulk or 14nm/16nm FinFET technology. Many of the new design features that come with 22FDX, such as forward and reverse body-bias connection, continuous RX aware placement, high voltage rules, and signoff for the PVTB (the body-bias corners), are all easily accommodated.

Figure 8: Maximizing design flexibility



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Building Ultra Low Power SoCs with 22FDX™

Let's now look at the example low power SoC design we described at the beginning of this paper to see where 22FDX provides new tools to optimize the design with a minimum of trade-offs (see *Figure 8*). For the watchdog processor 22FDX provides the ability to make devices that have ultra-low leakage, thanks to a fully depleted channel and reverse body-biasing. This results in a 10X lower leakage than the intrinsic device itself, critical when implementing portions of the SoC that are 'always on.' For the high performance image processing core, 22FDX provides intrinsically better variability, good electrostatic control, and the ability to operate with forward body-bias for high performance with the lowest dynamic power. And finally, the 22FDX platform provides complete RF support with the ability to optimize circuit topologies for RF power reduction. Thus, 22FDX provides new and differentiated tools to enable the next generation of ultra-low power SoCs for advanced IoT, mobile, and RF products.

Ecosystem Support

The rapidly expanding ecosystem available for FD-SOI will support a strong, steep design-in ramp. Today, there are multiple foundries and IDMs that are working on developing FD-SOI technology, including 22FDX™ technology from GLOBALFOUNDRIES. The number of EDA and design services providers is also growing very rapidly with five companies announcing partnerships with GLOBALFOUNDRIES on 22FDX. There are also many industry groups working on next generation FD-SOI solutions to grow the FD-SOI ecosystem. Together they provide designers with the IP and support necessary to make 22FDX a part of their next generation SoC design.

22FDX is the Right Solution for Today's Mobile, IoT, and RF Applications

The 22FDX Platform is optimized for cost-sensitive applications that require a better tradeoff of cost vs. performance while still meeting the demanding ultra-low-power requirements for many high growth applications in the global consumer, networking and IoT markets. FD-SOI has been demonstrated to be extendable, down to the next node, while maintaining its many differentiated features. A combination of these key features makes the 22FDX a very capable contender for today's mobile, IoT, and RF applications.

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