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Fully Depleted SOI Technology for Ultra Low Power Application

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Introduction

Requests on low energy technology for portable equipment are increasing with a background of requirements for high performance such as multimedia capability. Oki has been strategically challenging the lowering of energy by taking up FD-SOI CMOS [1]. Our target is super low power LSI for the portable device market, and focusing on mixed signal LSI that include RF circuits. By adopting full depletion type SOI device structure, we are striving to put to full use the many advantages of SOI which include low leakage current and low voltage high performance when used for digital circuits, improved high frequency characteristics for CMOS analog circuits, and good isolation between circuits in mixed signal applications. OKI succeeded in utilization of FD-SOI for the first time in the world, and development is progressing aimed at achieving analog/digital mix signal system LSI with lowered energy. In this presentation, a development example of FD-SOI CMOS LSI at Oki is introduced.

Digital application

Oki succeeded in volume production of watch-use LSI [2][3] using the FD-SOI CMOS (Fig.1). Watch LSI is consisted of a microprocessor (MPU) block and crystal oscillating circuits (Fig.2). Since operation of the MPU block is intermittent, reduction of power requires suppression of standby power. The selection of high threshold voltage for suppression of off-leak current needs setting up highly power supply voltage for their operation. On the other hand, power supply voltage of the crystal oscillating circuits was set to minimum operation voltage to enable oscillation, for the purpose of power consumption reduction during operation. As a result, in the conventional bulk CMOS process, two power supplies are required to the MPU block and the crystal oscillating circuits for power reduction. By using FD-SOI CMOS technology, the reduction of the S value enables to set a lower threshold voltage than is possible in bulk devices (Fig.3A,3B). Therefore, the MPU block is able to operate with a minimum operating voltage of about 0.7V. Furthermore, this power supply configuration enabled current to be reduced in the level shifter circuit and logic power supply regulator circuit, and also enabled reduction of the charge / discharge current within the MPU block. The FD-SOI CMOS technology allowed a 40% reduction in current consumption. We also developed 32bit micro controller using FD-SOI technology. Figure 4 shows the performance of micro controller by bulk and SOI technology. Power consumption of SOI device is 1/3 of bulk device with same performance. This low power feature of SOI device is fit for battery operation application such as PDA and a portable game machine, and a portable audio.

Analog application

Following development of watch logic LSI, we have developed a long wave time code receiver [3] based on FD-SOI CMOS technology (Fig.5). This LSI receives a long wave standard frequency with a tuning bar antenna then it amplifies the signal to the required level with the automatic gain control (AGC) amplifier.

In order to reduce the current consumption of a transistor amplifier with a resistance load in AGC, it is necessary to increase the resistance load in a reverse proportion to that of the reduction of the operating current. By using FD-SOI CMOS technology, the junction capacitance is small, being only approximately one-tenth that of conventional bulk MOS transistors, by existence of the buried oxide (Fig.6). This makes it possible to greatly alleviate the restrictions on the frequency band due to the raised resistance load of the amplifier. The chip realizes high sensitivity radio reception functionality together with a one third or better reduction in power consumption compared to the existing time code receivers.

Mixing analog and digital application

SOI-CMOS technology also excels in the level of integration of digital and analog circuits into a chip, because transistors are completely isolated from a substrate by an insulation film, which reduces the noise transmitted to analog circuits from digital circuits via substrate (Fig.7). Based on this technology, we also developed industry's first single-chip LSI for radio controlled real-time clock, combining signal receiver, decoder and real-time-clock (RTC) functions onto a single chip (Fig.8). This reduces the chip size of the LSI as well as power consumption, which enables manufactures to develop radio-controlled clocks into embedded equipment in a short development period.

Conclusion

In low power consumption LSI technologies, OKI steadily expanded shipments of SOI-based products for radio-controlled LSI. On the other hand, ultra low-power short-range wireless system will be strongly required in the future ubiquitous computing era. To meet this requirement, we are going to continue develop ultra low-power LSI

based on FD-SOI CMOS technology.

References

[1] F.Ichikawa, et al., Solid-State electronics, No.48, pp.999-1006, 2004.
[2] M. Nagaya, OKI Technical Review, Issue 193, Vol. 70, No. 1, pp.48-49, January 2003.
[3] www.casio.co.jp/release/wva300d_300k.html
[4] J. Yanagihara, et al., OKI Technical Review, Issue 196, Vol. 70, No. 4, pp.36-39, October 2003.

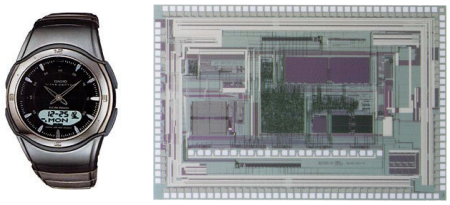

Fig.1 Long wave RF receive solar watch and chip photo of watch use custom LSI based on FD-SOI CMOS technology.

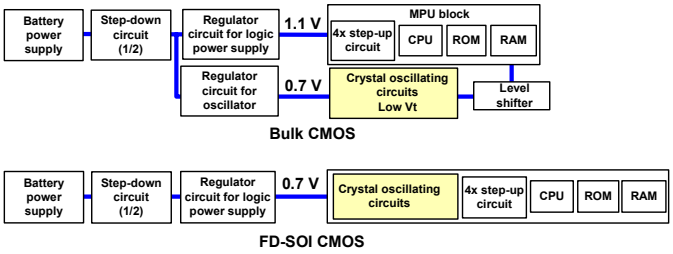

Fig. 2 Power supply configuration of bulk CMOS process and FD-SOI CMOS process.

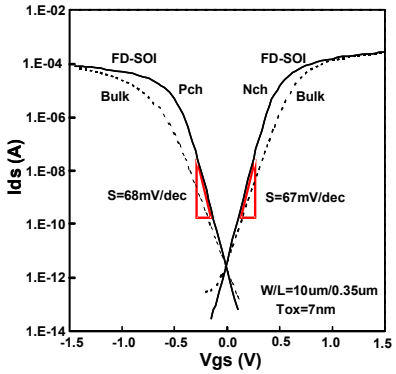

Fig. 3A Comparison of sub-threshold characteristics between bulk and FD-SOI MOSFET.

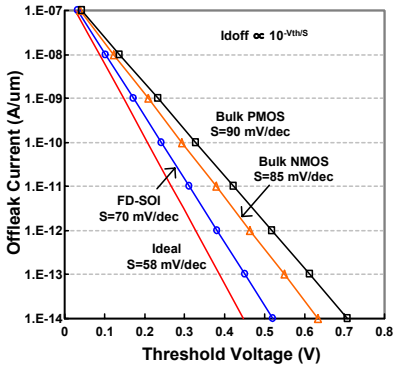

Fig. 3B Relation of threshold voltage and off-leak current in bulk and FD-SOI MOSFET.

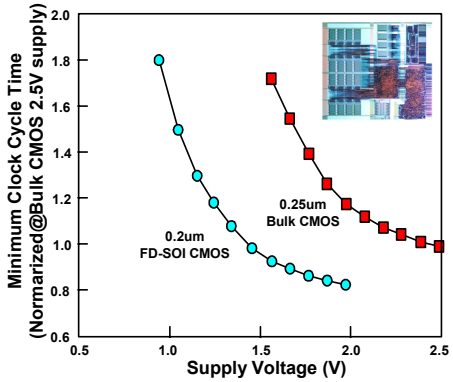

Fig. 4 Comparison of 32b micro controller performance bewteen bulk CMOS and FD-SOI CMOS.

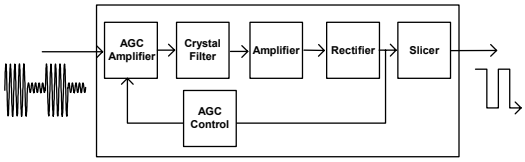

Fig. 5 Block diagram of long wave time code RF receiver LSI.

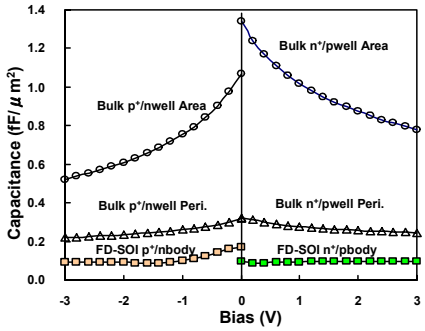

Fig. 6 Comparison of junction capacitance between bulk and FD-SOI MOSFET.

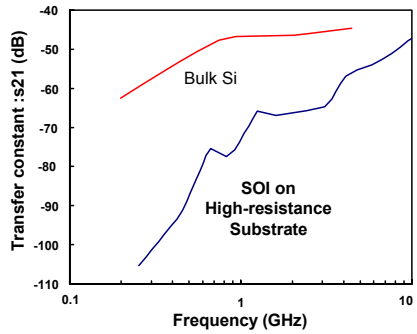

Fig. 7 Frequency dependence of cross-talk characteristics of bulk Si and SOI on high resistance substrate.

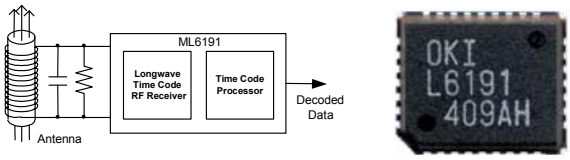

Fig. 8 Block diagram and chip photo of radio controlled real time clock LSI based on FD-SOI technologies.