

Advanced Complementary Bipolar Processes on Bonded-SOI Substrates Optimize Performance for High Voltage Precision Analog Applications

*Reducing Parasitic Leakage, Minimizing Noise and Avoiding Latch-up
Allows Optimization for High-voltage, Low-Power, Stability and Design Flexibility*

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Application Challenges

For semiconductors, medical and industrial applications often present difficult operating environments with extreme temperature ranges, high levels of ESD, and high sensitivity to electronic noise. These applications demand robust, high-voltage precision circuits for data acquisition and signal processing. The combination of high accuracy, high voltage, and low-noise requirements, plus the need to deploy in harsh operating environments, make it extremely difficult to create precision analog front-end components and circuits that can handle all of the challenges.

These challenges range across a wide spectrum of high-performance applications such as:

- Medical imaging & instrumentation
- Process control (I/O modules)
- Precision instrumentation & test systems
- Spectral analysis equipment
- Thermocouples
- Bio-analyzers
- ATE & Data acquisition

The design of precision analog front-end circuitry can be especially challenging for applications that use high-impedance sensors. These devices are inherently more prone to capacitive and inductive noise pick-up, and typically have higher noise sensitivity, which can make it difficult to achieve repeatability of readings and overall stability of the design. For example, many industrial systems using optical imaging, photodiodes, piezoelectric sensors, piezoresistive pressure transducers, PH sensors or gas meters must be able to provide fast and accurate readings under often very harsh operating conditions for real-time process monitoring and control applications.

As discussed in this article, solving these challenges requires a fundamental bottom-up approach that starts with the use of advanced bipolar processes to design and manufacture products, such as precision Op Amps, instrumentation amps and bandgap voltage references. By leveraging fabrication techniques such as deep trench isolation and lateral device spacing to optimize noise performance and minimize parasitic leakage at the transistor level, this approach enables the designer to create very robust products that have very efficient power-to-bandwidth characteristics and can handle high-impedance inputs with speed, accuracy and low power usage.

Process Methodology Overview

Intersil has developed a new 40V complementary bipolar plus JFET (CBiFET) process known as PR40 expressly for the development of robust products optimized for precision analog circuit applications. The process is fabricated on bonded silicon-on-insulator (BSOI) substrates and uses deep trench isolation (DTI) to build devices with complete dielectric isolation. The process features a core-bipolar foundation and optional device modules that are added as needed to facilitate product-specific, low-cost manufacturing. The PR40 process is currently being used to fabricate a range of low-noise precision Op Amps, Instrumentation amps, Current Sense amps and Bandgap Voltage References for use in industrial, medical and other high-performance applications.

BSOI substrates offer a number of important advantages. These include robust devices with low parasitics that exhibit very predictable device performance characteristics and are free of latch-up in harsh environment applications. BSOI is a convenient isolation method for making complementary bipolar devices with significant area reduction compared to the junction-isolated devices that are typically used in high voltage analog circuits.

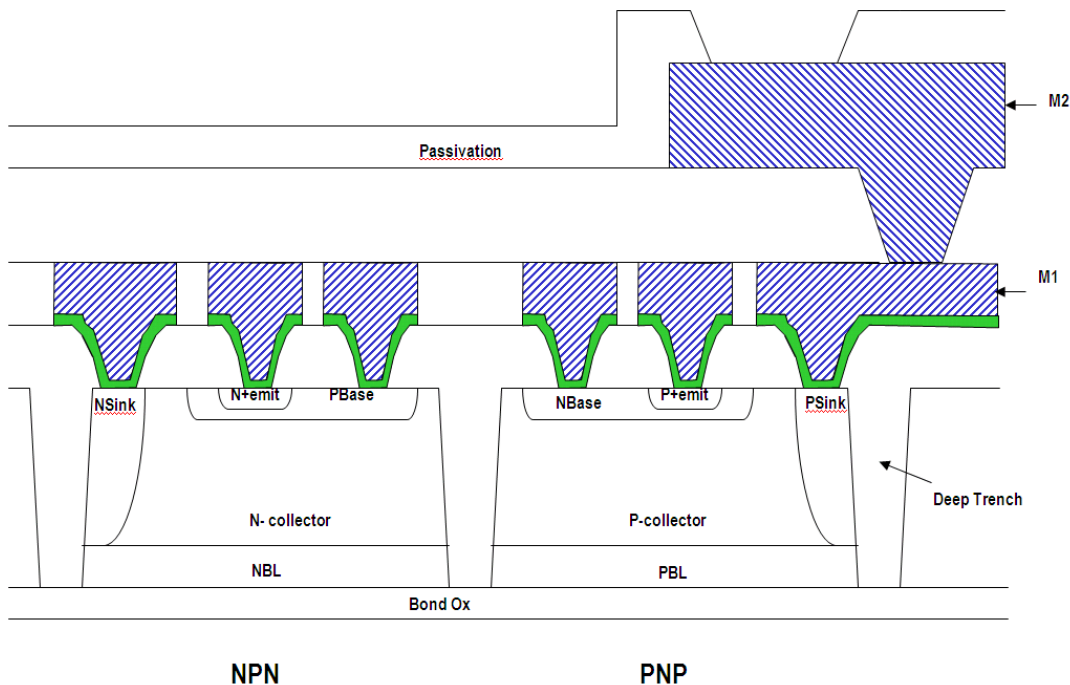


Figure 1: Cross-section drawing of PR40 npn and pnp devices.

SOI uses layers of silicon-insulator-silicon in place of conventional silicon substrates. This allows for lower parasitic capacitance due to isolation from the bulk silicon. Deep trench dielectric isolation provides separation of devices to further minimize capacitance and reduce leakage current associated with diodes, transistors, etc. The reduced level of parasitics allow the designer to optimize power-to-bandwidth efficiency and reduce overall power consumption.

Avoiding Latch-up

Latch-up is one of the most problematic conditions that can result from an inadequate front-end analog design. In essence, latch-up is a particular type of short circuit that results from the inadvertent creation of a low impedance path between the power supply rails of an IC, which triggers a parasitic structure that disrupts the proper functioning of the part. A power cycle is typically required to correct the situation and latch-up can even lead to destruction of the part due to an over-current condition.

The parasitic structure that causes latch-up is equivalent to an unintentional thyristor that is acting across a PNP and an NPN transistor stacked next to each other. Latch-up occurs when one of the transistors is conducting and the other starts to conduct at the same time. Then, both transistors keep each other in saturation for as long as the structure is forward biased and current is flowing through it.

Latch-up can happen at any location where the underlying parasitic condition exists. For example, a spike of positive or negative voltage on an output or input pin of a digital chip that exceeds the rail voltage by more than a diode drop is a common cause of latch-up. Another cause is the supply voltage exceeding the absolute maximum rating, for instance from a transient spike in the power supply.

By using advanced fabrication processes such as BSOI, deep trench isolation and optimal lateral device separation, the PR40 process enables latch-up free circuit operation.

Maximizing Design Flexibility

To maximize design flexibility, the PR40 process features a full suite of precision analog devices including 40V low-noise NPN and vertical PNP bipolar devices, 40V P-and N-channel JFETs, 10V super-beta NPNs, and MOSFETs. In addition, the process offers a high BVebo lateral PNP device with high-beta, a buried Zener, and a well controlled Schottky diode. The process supports multiple levels of metal, as well as Active-Area-Bonding.

The process is optimized to allow for consistent matching of devices, with both the NPN and PNP structures constructed in a similar fashion on a common subsurface base. Thin film resistors provide precision matching in relatively little area. The low temperature coefficient of the thin film makes it possible to achieve tighter specifications over wider operating temperatures. It offers optimized high-density multilayer capacitor that provides additional design flexibility and minimizes die area. In terms of ESD protection, it offers superior ESD structures that easily achieve the minimum 2KV HBM targets and are typically in the 4-6KV range.

These unique capabilities of the PR40 process provide the designer great flexibility for designing high performance precision analog circuits. The exceptional device matching enables the design of very high precision amplifiers with minimal offset trim requirements. The absence of parasitic junction leakage over temperature combined with predictable device behavior enable high impedance input amplifiers with very low and stable input bias current behavior across their specified common mode voltage and

temperature ranges. Deep trench isolation results in very small device footprints enabling very efficient noise and power tradeoffs that result in low power designs with exceptional noise performance. Small devices combined with active area bonding and high density capacitors result in very dense circuits that enable 40V products in small footprint packages such as SOT23, uTDFN and MSOP.

Part #	Primary Performance Feature	Low Noise	Low Power	Low I _{bias}	Single Supply	Dual Supply
ISL21090	40V, Low Noise, Low Power Precision Voltage Reference Best in class noise and power performance	Yes	Yes		Yes	
ISL28110 ISL28210	40V Low Noise, High Slew Rate JFET Op Amp Best in Class I _{bias} over Temperature	Yes		Ultra Low		Yes
ISL28107 ISL28207 ISL28407	40V Precision, Low Power, Low TcVos Op Amps Flat I _{bias} over Temperature Range		Yes	Yes		Yes
ISL28117 ISL28217 ISL28417	40V Low Power Precision Op Amps Outstanding Combination of Precision, Low Power & Low Noise	Yes	Yes			Yes
ISL28127 ISL28227	40V Precision Very Low Noise 10Mhz Op Amp Outstanding combination of Low Noise, Speed & Power	Ultra Low				
ISL28177	40V, Low Cost Precision Op Amp Significantly Improved OP07 performance in SOT23	Yes	Yes			Yes
ISL28325 ISL28425	Low Cost 40V Op Amps Excellent combination of power and noise performance	Yes	Yes			Yes
ISL28108 ISL28208 ISL28408	40V Ground Sensing, Rail-to Rail Output Op Amp Excellent Combination of Low Power and Low Noise		Yes		Yes	
ISL28118 ISL28218	40V Ground Sensing, Rail-to Rail Output Op Amp Excellent Combination of Low Noise, and High Bandwidth	Yes			Yes	
ISL28005 ISL28006	28V Precision High Side and Low Side Current Sense Amplifier in SOT23		Yes		Yes	

Figure 2 - Performance characteristics for Intersil PR40 devices

Robust ESD Performance

Products designed on PR40 are also inherently radiation-tolerant and capable of delivering very robust ESD performance. In most analog front-end devices using conventional fabrication processes, it is very difficult to achieve good ESD characteristics while delivering high performance. Because products created with the PR40 process are fully dielectrically isolated using a mechanical process, any sensitivity to electromagnetic pulses has been completely eliminated. Also the use of subsurface transistors with deep junctions means less sensitivity to ionization radiation.

Figure 3 shows a summary of ESD performance characteristics for Intersil devices that have been introduced using the PR40 process. In all cases, the ESD performance comes out at the top of the scale on industry standards for each ESD category.

Part Number	Description	Human Body Model (HBM)	Machine Model (MM)	Charge Device Model (CDM)
ISL21090	Low Noise Precision Voltage Reference	3000V	200V	2000V
ISL28110/210	Low Noise, Ultra Low Ibias Precison 10Mhz JFET OPA	4000V	400V	2000V
ISL28107/207/407	Low Power, Low Ibias Precision OPA	4000V	500V	1500V
ISL28117/217/417	Low Noise Precision OPA	4500V	500V	1500V
ISL28127	Low Noise 10Mhz Precision OPA	6000V	500V	1500V
ISL28227	Low Noise 10Mhz Precision OPA	4000V	500V	1500V
ISL28177	Low Cost Precision OPA in SOT23	5000V	300V	2200V
ISL28325/345	Low Cost Dual/Quad Precision OPA	4500V	500V	1500V
ISL28108/208/408	Low Power Precision Single Supply OPA	6000V	400V	2000V
ISL28118/218	Precision Low Noise Single Supply OPA	3000V	300V	2000V
ISL28005/6	Low Power Precision High/Low Side Current Sense Amp	4000V	200V	1500V

Figure 3 - ESD Performance for Intersil PR40 devices

The Bottom Line

The use of advanced feature-rich Complementary Bipolar and BSOI fabrication processes, along with deep trench dielectric isolation, provides a very predictable and flexible foundation for designing robust, high-voltage, low-noise, low-power devices for use in precision analog front-end designs. Elimination of internal parasitic structures within the devices and inherent resistance to external ESD or radiation make these devices ideal for use throughout a wide range of industrial, medical and other applications that require high accuracy within difficult operating environments.

In addition, because it is a modular fabrication process with a wide range of features that can be incorporated for specific designs, the PR40 approach also improves both design flexibility, product cost and package size. Critical features needed for specific designs can be predictably modeled and efficiently integrated so as to minimize the size of the design while optimizing its performance for the target application.

The bottom line is that precision analog design will always present difficult challenges, especially for those applications that combine high-impedance sensors, high-voltages, the need for high-accuracy and exposure to harsh operating environments. Intersil has created a way to lessen the difficulty by developing robust products using a device fabrication process that addresses all of these issues from the bottom up.