Circuit Seed™

Planting the Future of Electronic Designs

Circuit Seed Overview

Circuit Seed is family of inventions that work together to process analog signals using 100% digital parts. These are digital circuits and components that are configured and modified to provide the same functionality as transistors, capacitors and inductors with better performance and without the analog limitations. They include digital designs which provide precision without precision parts, eliminating the requirement for current mirrors and matched pairs.

Traditional analog or mixed integrated circuits are complex to design and manufacture. The geometry is an important part of the design. They are usually implemented as a mix of analog and digital circuits with components for both. Analog components are typically 20% of the overall circuit. However, the analog design takes 80% of the time and takes two to three times longer to debug.

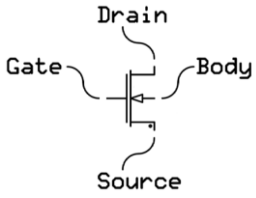
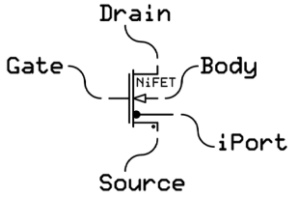
Both analog and digital circuits have design rules and performance characteristics that apply to each. All of the issues that apply to digital circuits apply to analog circuits.

Analog circuits often require matched pairs of devices with identical electrical properties – but there is always some process variation between the devices which causes errors. The mixed signal (analog and digital) integrated circuits cannot perform on smaller than 40nm process nodes, and they can't operate at low power without severe limitations.

In contrast, Circuit Seed circuit design process analog signals using 100% digital components which means they are only subject to the limitations of digital design rules and not the analog design rules. Further, the principles of the Circuit Seed design and the configuration of the circuits overcome many of the deficiencies of analog circuits. Mixed signal circuits require a transistor, capacitor, or an inductor to travel off the integrated circuit to the analog component and then back to the digital process. However, Circuit See circuits, once converted from analog to digital, remain on the integrated circuit eliminating many of the analog circuit issues.

Circuit Seed circuits are much simpler, faster and less expensive to design, test, manufacture and support. They have a wide frequency range making them suitable for many applications; they occupy less real estate, reducing physical size and weight; they consume less power, reducing heat and enhancing reliability while reducing battery size or extending battery life.

Here is a comparison of the Circuit Seed CiFET™ and a regular FET that will help show the differences of the fundamental principles of the designs.

	FET **Field Effect Transistor**	CiFET™ **Complementary Current Field-Effect Transistor**	**Observations**	**CiFET™ example**
Symbol	 Discovered in 1960's	 Developed in 2015	Simple modification to the MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) can yield very important and desirable results and a remarkable functionality with an additional current port input (iPort).	Simpler circuit designs - Less time to develop - Less time to test - More reliable products
Control Input	Voltage controlled – gate terminal	Charge controlled– Port terminal	Charge controlled port provides a bidirectional current sink/source without analog extensions required.	Charge control port
Impedance	High	Low	New low-impedance charge port enables an entirely new set of analog design methods.	It allows easier communications to other components such as transmission lines or antennas to the system.

Transfer function	Trans-conductance (g_m)	Trans-resistance (r_m) (Trans-impedance)	Regular FET operates with a high input impedance, the output current is the result of an input voltage (control input). $g_m = i_{out}/v_{in}$ The Charge Port controls the low impedance terminal where the output voltage is a consequence of an input current (control input). $r_m = v_{out}/i_{in}$	Ultra-linear signal transfer functions that are consistent over an ultra-wide dynamic range (27 bit accuracy). A smartphone, a sensor, a wearable device could function in very extreme conditions and not subject to temperature variations
Output	Current	Current and voltage	Conventional FET designs have a linear change in output signal. With a small current injection into The Charge Port (iPort), there is a substantial, exponential change in output voltage.	Extremely useful for very small weak input signals to be amplified at logic speeds (unlike traditional technologies). Load independent design.
Self-Bias	No	Yes	Conventional FETs requires multiple bias-currents (higher power dissipation). The CiFET™ swings around the sweet-spot (analog-zero reference) between the power supply rails, where it is free of power supply induced noise (self-calibrated).	Less power dissipation and simplified circuitry.

Noise	High	Immune	High resistance channel means higher noise. While operating with current, the CiFET™ is not affected by the internal parasitics (extremely small capacitors).	High noise immunity, suitable for low voltage applications.
Matched components	Yes	Not required	Multiple matching of devices is needed for accuracy in conventional designs (FET). Not required for CiFET™ designs.	Significant area reduction with new designs.
Current mirrors	Yes	Not required	Extra biasing from current mirrors or complicated circuitry is needed for traditional technology.	Smaller and simpler designs with less power consumption.
Power Supply Voltage	Limited by threshold voltage	As low as 10mV (millivolt)	New and revolutionary design that operates all the way down to near zero power supply voltages.	Operates well below 1V supply voltages (extend battery life).
Limited by threshold	Yes	No	CiFET™ amplifiers are not slaved to the threshold voltage stacking that prior art amplifiers are.	Suitable for low power analog and digital circuitry.
Limited by external parameters	Yes	No	The CiFET™ is not impacted by external parameters or conditions such as temperature and humidity which have a huge impact on the circuit output characteristics.	Circuit designs that operate under extreme conditions.

Precision without precision parts	No	Yes	The conventional approach is costly and not available in small integrated circuits for traditional technologies. CiFET™ technology is enhanced to operate internally in a high-precision logic speed without any precision parts required.	Smaller footprint on SoC (Systems on Chip). Designs suitable for VLSI (Very Large Scale Integration) designs.

So, why would a manufacturer want to adopt Circuit Seed circuit designs?

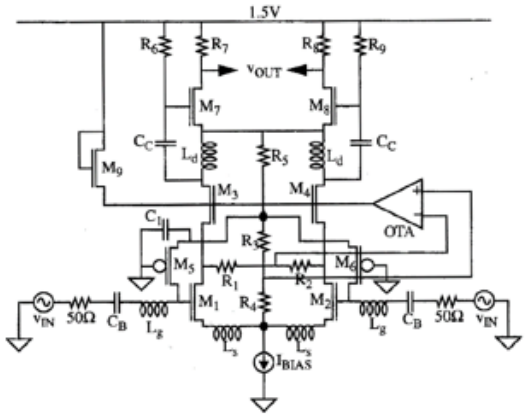
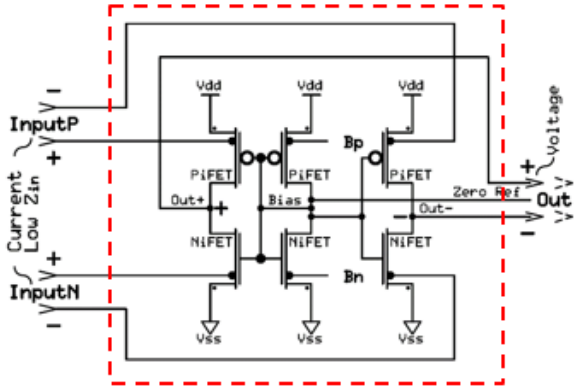
We believe that these designs are the only ones that will scale to very low power (< 100 mv) and work on integrated circuits smaller than 40nm. The fundamental fact is that the designs are 100% digital and much simpler, easier and faster to design, manufacture and support than mixed signal circuits with much better performance. It's that simple. The upfront costs to design new products are growing while the product life of these products is shrinking. Any reduction in cost and increase in reliability will give a company a significant competitive advantage.

Where are the bottleneck and performance issues of your circuits? Most likely, your analog components.

Below is an example of a Low Noise amplifier. The Circuit Seed is 100% digital components. Which one would be the easiest to design and build? Not convinced? Look at the performance specifications.

Grey & Meyer, Analysis and Design of Analog Integrated Circuits, Wiley Textbook, 4th Ed, pg. 482

Circuit Seed™

	
Components: • 12 Resistors • 5 Capacitors • 6 Inductors • 9 Transistors (CMOS) • 1 OTA (Operational Transconductance Amplifier) Benefits: • Gain of 80 K • Operates at 10% of the power supply • Adjusted bias • Operates at 1.5 GHz	Components: • 6 Transistors (CMOS iFET) Benefits: • 100% digital workflow components • Single silicon chip • Gain of 100 M • Better than 100 times faster • High stability • Self-bias (continue measurement) • Operates at any frequency • Fewer components (cost reduction) • Easier to port to other platforms