Improving Wireless Amplifier Performance with BiASIC™ Technology

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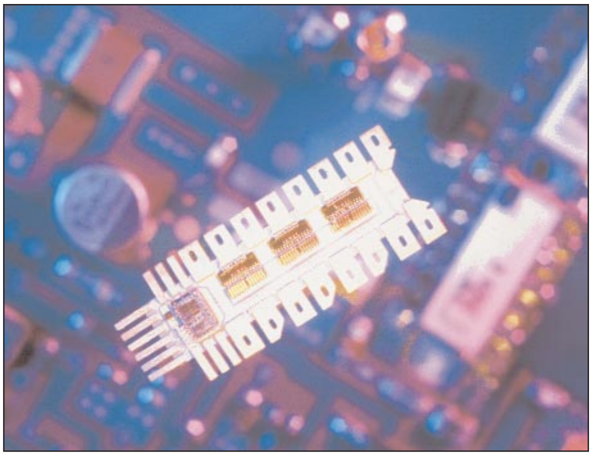
Every day, all over the world, millions of people are making cellular or wireless calls and digital data transmissions. Although their languages may be different, the means by which the wireless networks reliably transmit their voices and information are essentially the same. The electronic methods (protocols and coding/modulation schemes) that enable the many subsystems of a wireless network to work properly are changing. Inventions created for defense applications decades ago are becoming commonplace in today's commercially focused world. But one building block remains the same, from tube to transistor, the generation of radio frequency (RF) power.

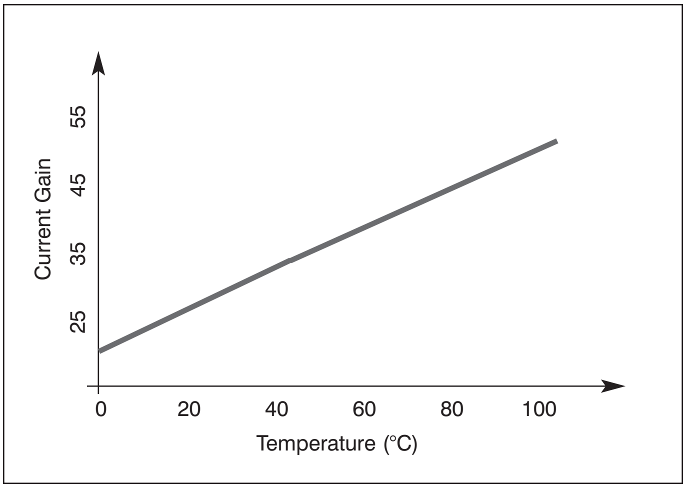
RF power is what allows wireless calls to propagate over the airwaves. Every cellular or PCS phone, or subscriber communications device, is in contact with a base station for connectivity. Base stations' antennae are fed power for the airwaves by RF power amplifiers which in turn are provided low level signals by the radio transceiver equipment. Whether these signals are analog or digital in nature, they are processed at very low signal levels up to the very last stages before transmission. Power amplifiers are used to boost and condition the signal with minimum distortion (static, call bleed over) for transmission through the cell site antenna.

The more linear a high-power amplifier can be, the better the transmission and call quality. The more responsive the amplifier can be to radio signal input characteristics, the more valuable it is to the overall wireless network. Like carefully placed masonry bricks that act as the foundation of a massive structure, high-power linear RF amplifiers serve as a fundamental infrastructure support element, providing a solid foundation for today's and tomorrow's wireless communications networks.

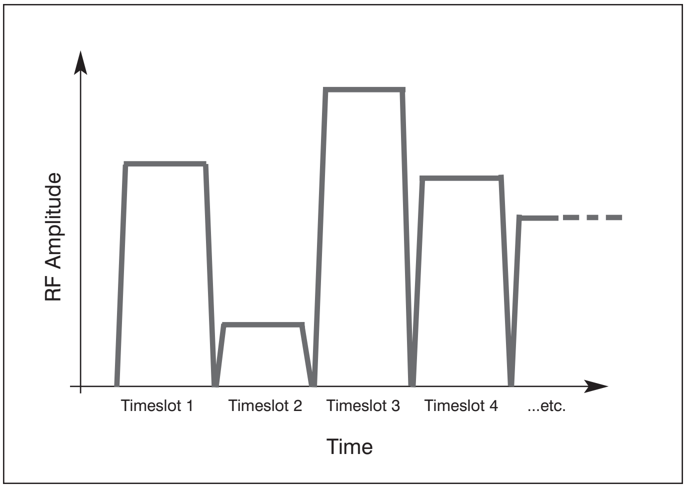


■ **This issue's cover features Spectrian's BiASIC bias control technology described in this article.**

The technology required to deploy effective power amplifiers has changed over the past 15 years. Early applications were simple and did not contain the algorithms and processing capability required to support the evolving digital air interfaces. The key to success in cost-effective and reliable ultra linear amplifiers is thermal and power management within the amplifier itself. As the last link in the chain, the power amplifier must perform the transformation of low level RF to high power RF, and provide enough power to overcome the inherent losses within the remaining transmission chain. Effective control of the RF power generation circuits constitutes the heart of the system. Wireless base station environments continuously expose RF power amplifiers to sudden changes based upon subscriber use patterns, which in turn cause rapid changes in the steady state power demands on the bipolar transistors inside the amplifiers.



■ **Figure 1. Current gain vs. temperature characteristic of a bipolar transistor.**



■ **Figure 2. An illustration of GSM's signal amplitude vs. time behavior.**

Design requirements

Class A/B bipolar RF circuits are the most common technical solution in the generation of high power. These operating modes, which were introduced in the late 1980s as a solution to the opposing constraints of linearity and efficiency, in many cases pose difficult challenges related to the function of bias control for class A/B bipolar transistors. As a result, bias circuits have traditionally required a significant amount of circuit board real estate and co-location with the power transistors to improve performance.

Because of the inherent thermal inefficiencies in high power RF, control circuits require greater attention to thermal tracking between the control and the power transistor. To keep the bipolar transistor thermally stable under varying work load conditions, it is necessary to control and dynamically adjust the amount of quiescent current supplied to the transistor. Without adequate thermal tracking, circuits can experience the thermal run-away of devices as temperature increases, causing long term reliability issues. Unlike older FM systems, new digital modulation schemes have non-constant and rapidly changing envelopes that result in large variation of the RF output power.

Bipolars have a few characteristics that can cause thermal runaway. One such attribute inherent to BJT (Bilateral Junction Transistors) technology is that it has a –2 mV/degree C response characteristic (Figure 1). As temperature increases, the very linear voltage (V_{be}) for a given collector current reduces. If V_{be} is kept constant, collector current increases with temperature. Another characteristic is that BJTs have a propensity towards thermal escalation due to the fact that BJT current gain tends to increase with rising temperatures.

Most high power amplifier designers have learned that thermal tracking must be achieved while providing for instantaneous changes in DC collector current. The typical approach has been to approximate performance points and design to averages. With the advent of digitally modulated RF signals, the problem for present day designers has become an order of magnitude more complex. The characteristics of today's digitally modulated communications schemes — TDMA, GSM, CDMA — demand more of the RF power generation circuits. The varying power levels of GSM are illustrated in Figure 2. Dynamic, non-predictive and rapidly varying digitally-modulated waveforms create fast transitions, which dictates the need for superior bias control of the high-power transistors in order to achieve the required signal distortion performance in base station power amplifiers.

New solutions

Thanks to advanced large-signal RF design and modeling tools, designers of next generation RF amplifiers can now take advantage of integration and silicon advances to obtain a solution for the inherent bias current problem that has been perplexing designers for over a decade. A first in the industry, Spectrian's BiASIC™ is a new Applications Specific Integrated Circuit (ASIC) that tames bipolar devices by performing critical control functions in thermally sensitive RF power circuits. Spectrian engineers developed this novel approach to solve bias current problems. The BiASIC has been developed to address the dynamic performance requirements in new high-power single-channel and multicarrier power amplifiers. Once applied to amplifier power circuits, the BiASIC will provide substantial improvements for bias control regardless of modulation or temperatures in the amplifiers. Engineers expect the device to offer great advantages to amplifiers targeted at the GSM format, where any improvement in gain step accuracy is coveted by system architects.

How BiASIC improves performance

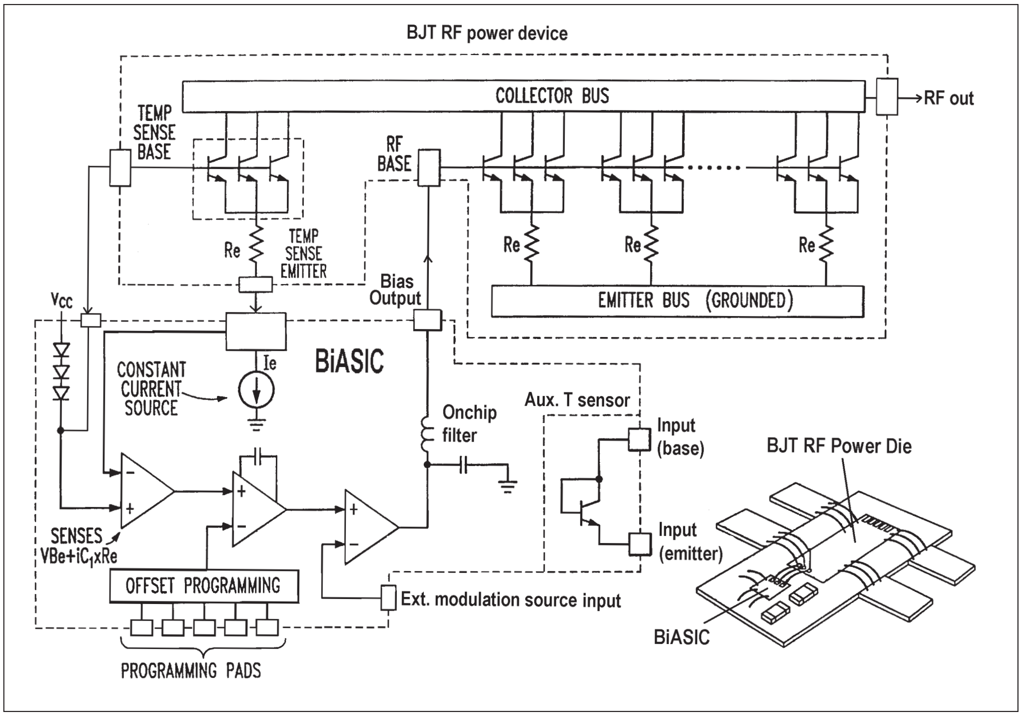
The BiASIC™, for which Spectrian holds a U.S. patent, performs critical control functions in thermally sensitive RF power circuits. After years of experience in implementing discrete bias control solutions in bipolar RF amplifier designs, Spectrian developed the BiASIC to address the size, efficiency, and price/performance pressures facing the entire RF/wireless industry today.

While it has been known that accurate dynamic control of DC bias in the power transistor can improve the linearity of the power amplifier, few have been able to provide a small footprint solution. The BiASIC semiconductor die itself incorporates an internal thermal sensor and an optional input for thermal referencing that, in some applications, could be co-located with the RF power transistor heat source.

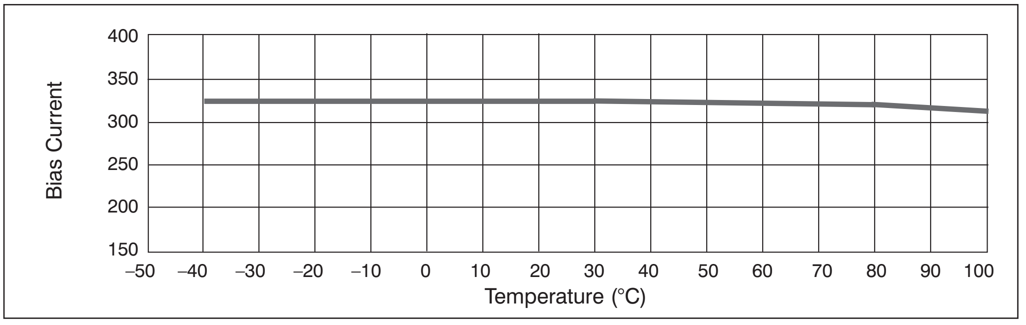
The BiASIC also includes a modulation input to further customize the dynamic bias condition for improved linearity. The circuit is internally and externally programmable, so engineers can adjust it for varying transistor sizes, applications and normal lot-to-lot variation in current gain.

Bias control circuits need to include accurate and flexible temperature sensing, a fast response time, low cost and a compact size. Another crucial design factor is compatibility with a large variety of RF power bipolar devices with varying performance distributions.

Spectrian's BiASIC incorporates all of these requirements. In addition, the BiASIC reduces the allocation of PC board space by as much as 30 times for each power transistor it controls.



■ **Figure 3. Block diagram of the BiASIC device and its control of the power transistor.**



■ **Figure 4. BiASIC performance over temperature.**

Size does matter

Conventional bias circuits have traditionally consumed significant PCB real estate in proportion to the transistors they controlled. The size of the BiASIC is small. Because it is an integrated circuit, it can reduce the complexity of a layout by a factor of 10. What traditionally took ten parts can now be accomplished with one or two, and lower parts count generally means an increase in reliability. The new circuit, if packaged into its own leaded small outline IC package, could reduce the size of this function by 30 times, compared to conventional discrete realizations of similar functions.

Implementations

Designers envision several possible implementations of the BiASIC. The IC could be packaged separately in a surface mount package that can be installed directly on the PCB. The IC could also be included inside the power transistor package, with external leads for in-circuit programming. For specific transistor applications, the invention could be *integrated onto the power transistor die*, programmed internally during semiconductor test, and provided as part of a self-biased transistor.

Conclusion

In order to keep the bipolar transistor thermally stable, it is necessary to not only control, but dynamically adjust the amount of quiescent current supplied to the RF transistor. This must be achieved while providing for the instantaneous changes in DC collector current to support the varying RF signals and characteristics of today's digitally modulated communication schemes. Dynamic requirements of new wireless digital modulation formats demand new solutions for traditional class A/B power amplifier bias circuits.

The new Spectrian BiASIC delivers several performance advantages and is flexible in its application. The design allows for a programmable constant current source and incorporates a programmable DC offset voltage generator.

When it comes to high-power wireless amplifiers, thermal management is the key to performance optimization. Limited spectrum dictates efficient use of resources for wireless carriers and their networks. In the wireless market customers are continuously interested in lower costs, higher performance, and smaller size. The BiASIC delivers this in each of these areas. ■

Author information

David S. Piazza co-invented the BiASIC and is Spectrian's Vice President of Semiconductor Operations. He is responsible for Spectrian's semiconductor product design, new technology development, device simulation and modeling, as well as applications engineering. Piazza earned a bachelor of science degree in electrical engineering from the University of California at Davis, with a specialty in Microwave and Solid State Technology.

Dr. Francois Hebert is Director of Semiconductor technology at the semiconductor design and wafer fabrication facility in Sunnyvale, CA. He and his team are currently developing low-distortion and high frequency bipolar and LDMOS power devices and circuits, for RF power applications in the 500 MHz to 2.5 GHz frequency range. Dr. Hebert earned his B.A.Sc., M.A.Sc. and Ph.D. degrees, all in Electrical Engineering, from the University of Waterloo.

Robert Carl is Director of Communications, responsible for managing Spectrian's public and investor relations functions. Carl joined Spectrian in 1994 as vice president of sales and marketing for its American Microwave Technology subsidiary, where he focused on sales of RF amplifiers to OEMs in the medical and scientific industries.

Bill McCalpin serves as a semiconductor research engineer at the company. A long term Spectrian employee, he joined Spectrian in 1987 as a Design Engineer in the RF amplifier development group. Currently Mr. McCalpin serves in one of the company's remote R&D labs in Boulder, CO. He earned his B.S.E.E from the University of California in Santa Barbara in 1987 and a M.S.E.E. from University of Santa Clara in 1994.

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