

Editorial Director

Gary Breed  
gary@highfrequencyelectronics.com  
Tel: 608-845-3965  
Fax: 608-845-3976

Publisher

Scott Spencer  
scott@highfrequencyelectronics.com  
Tel: 603-472-8261  
Fax: 603-471-0716

Associate Publisher

Tim Burkhard  
tim@highfrequencyelectronics.com  
Tel: 707-544-9977  
Fax: 707-544-9375

Assistant Editor

Katie Landmark  
katie@highfrequencyelectronics.com  
Tel: 608-845-3965  
Fax: 608-845-3976

Production Assistance

Ken Crocker

Business Office

High Frequency Electronics  
7 Colby Court, Suite 7-436  
Bedford, NH 03110

Editorial and Production Office

High Frequency Electronics  
403 Venture Court, Unit 7  
Verona, WI 53593

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Subscriptions

Send address corrections to:  
PO Box 10621, Bedford, NH 03110  
circulation@highfrequencyelectronics.com  
subscribe online at:  
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## It Takes Analog Performance to Make a Digital Radio

Gary Breed  
Editorial Director



New radio designs emphasize digital techniques to obtain operational flexibility—from multi-band/multi-standard wireless handsets to encrypted, frequency-agile military radios. In addition, demand for size and cost reduction has created a major effort to minimize the analog circuitry and replace it with cheaper, smaller digital circuitry.

There are significant benefits from this move to a “nearly all digital” design. Digital circuits can be more complicated than their analog equivalents, but they are numerically precise and easy to manufacture. The analog circuits being replaced may be conceptually simple, but they rely on precise manufacturing for consistent performance, sometimes including laser trimming and tuning.

But the old saying, “You don’t get something for nothing” certainly applies to the conversion of radio functions from analog to digital. As more of the radio back-end becomes digital, the demand for performance of the front-end increases. There are several interrelated issues:

**Bandwidth**—Let’s take the ultimate digital radio: the minimum necessary front-end filtering and preamplification, followed by a sampling detector that drives an analog-to-digital converter. With no IF selectivity ahead of the detector, it must be able to handle the sum of all signals in a wide passband. This is analogous to the performance requirements for a high dynamic range first mixer in a conventional radio.

Because digital radio is intended to handle many different radio services, this input bandwidth will likely be wider than a conventional radio, even one that covers multiple frequency bands. Unless the digital radio employs tunable or switchable front-end filtering, it will require analog front-end performance similar to the very best receivers—as is currently done in military communications, surveillance and countermeasures equipment. This may not exactly be in line with consumer product goals of simplicity and low cost.

**Strong Signal Handling**—The analog-to-digital conversion (ADC) process is different from analog signal detection. In particular, digital circuits do not have the “soft failure” characteristic of analog circuits. Extremely

strong signals may cause distortion in an analog radio, but may not completely disrupt the desired communication channel. On the other hand, once a signal is strong enough to overload the input of an ADC circuit, all digital outputs will go to maximum (e.g. all HIGH bits).

*Dynamic Range*—Certainly, analog circuits can also be saturated to block all signals, but they will handle a much wider range of signals before blocking occurs. At present, there is no practical digital circuit that matches the dynamic range of analog circuits. The best analog radio circuits can handle signals over a 150 dB range; 110 dB of that without generating distortion products.

The range between one bit and 16 bits in an ADC is 96 dB; 20 bits is 120 dB; 24 bits is 144 dB. The latter looks pretty good, but 24-bit ADCs are limited to low frequen-

cies such as audio—it will be quite some time before cheap ADCs with this kind of dynamic range are available for RF applications.

### **Analog and Digital Must Work Together**

For the foreseeable future in low cost consumer and commercial radio equipment, a combination of high performance analog and digital technologies will be required. The most flexible digital radios will have the digital part “close to the antenna.” This will require front-end filtering that is easily tunable and/or switchable. New technologies are being ambitiously explored to accomplish this in smaller size and at lower costs.

The analog portion of the ADC system, whether internal or external to the digital chip itself, must have a dynamic range that significantly exceeds the digital dynamic

range of the ADC. Analog ranging (equivalent to AGC) may be needed to prevent extremely strong signals (desired or interfering) from saturating the digital output and blocking all signals.

In addition, we need to remember that the high-speed digital circuitry itself has characteristics that are similar to RF/microwave analog circuitry. Because of this, more than a few engineers have easily made the transition from traditional microwave engineering to high-speed digital applications.

Digital and analog technologies have more in common than ever, and digital radio is one of the best examples. Each time another traditional analog function is implemented digitally, the performance of the remaining analog circuitry becomes even more important.