

Multifunction: a Dilemma or Reality?

By Duncan Bosworth

Next-generation aerospace and defense system designers are being pushed to develop advanced, highly configurable systems that combine a range of functions and requirements, integrating functionality that would have historically been implemented by separate standalone systems. Clearly this has the benefit of reducing the number of subsystems that need to be supported by any mission platform, reducing the overall size, weight, and power (SWaP), but with further need to support cognitive and real-time configurability, the challenges can seem daunting. However, a new generation of high performance, wideband components are potentially providing a solution to this challenge, supporting the high performance levels required for each system, but with a broad enough operating range to meet the multifunction challenge.

The ultimate goal for many of these future systems is a completely software determined architecture. This allows for the implementation and mode of operation to be changed dynamically, updated in the field, or factory configured with no, or very minor, hardware changes. The challenge is to support the superset of operational modes that the system may be required to enable. This requires that the underlying single piece of hardware is able to meet the specifications of all the possible modes of operation that may be needed.

An example of such systems in the defense world looking to combine functions are radar and communication platforms. In many cases, these systems look to support multimodes of legacy operation, but they are also starting to incorporate electronic warfare functionality. Radar systems are looking to support electronic support measures (ESM), and communication systems looking to implement signal intelligence (SIGINT) functionality, as well as multimode radar and multiwaveform communications respectively.

In both of these examples, the systems are looking to incorporate wideband and narrow-band functionality, functions that would typically drive very different requirements in terms of linearity and dynamic range, among other requirements. To meet the overarching goal, the designer may have to trade power or size if compromises to the specifications are not acceptable. As an example, consider an X band radar system and an electronic intelligence system (ELINT). The radar system will typically operate over a relatively narrow frequency range, typically hundreds of MHz within the 8 GHz to 12 GHz band. In contrast, the ELINT system will typically require operating over the 2 GHz to 18 GHz range, covering all of the S, C, and X frequency bands. If the assumption is made that both implementations have to be the same size, then compromises to the performance may need to be made to support the wider frequency range and coverage of the ELINT system. Typically in this instance, the linearity or power consumption of the signal chain can be traded for bandwidth.

If this same concept is taken down to the component level, the same issues are observed. For broadband or wideband systems, typically the performance of the component is sacrificed in at least one dimension, whether that be linearity, noise performance, or power. Table 1, as follows, illustrates a typical performance trade-off for wideband and narrow-band phase-locked loop (PLL) with an integrated voltage controlled oscillator (VCO). As seen, the narrow-band device has better typical phase noise, figure of merit, and power, but clearly this is at the expense of flexibility.

Table 1. Comparison of Typical Wideband and Narrow-Band PLLs with Integrated VCO

	ADF4351 Wideband PLL with VCO	HMC837 Narrow-Band PLL with VCO
Output Frequency	0.035 GHz to 4.4 GHz	1.025 GHz to 1.150 GHz
Figure of Merit	-221 dBc/Hz	-230 dBc/Hz
VCO P/N @ 100 kHz (dBc/Hz)	-114	-120
VCO P/N @ 1 MHz (dBc/Hz)	-134	-147
Size	5 mm × 5 mm	6 mm × 6 mm
Power	370 mW	168 mW

Although there will always be some trade-off and some compromise when multiple system specifications are implemented in a single system, the next generation of RF and microwave components, as well as high speed ADCs, will provide some relief to future system designers. Advances in CMOS and silicon-germanium (SiGe) processes, among others, are enabling a significant increase in digital functionality to be incorporated into next-generation devices. Advanced signal processing capabilities are able to provide calibration or digital compensation functionality, in addition to flexibility, enabling the overall system performance levels to be closer to their narrow-band counterparts, while maintaining the ability to be reconfigurable and utilize wider bandwidths for mode of operation as needed.

Figure 1 shows a generic wideband receiver architectural diagram based on a number of the latest RF and microwave components.

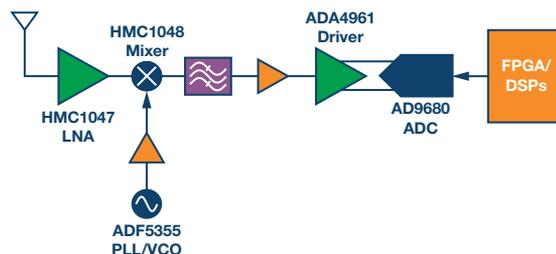


Figure 1. Possible wideband reconfigurable signal chain.

Although in practice the architecture described above may require additional filtering and gain stages to achieve a specific application requirement, the flexibility of the underlying components enables a very wideband surveillance system architecture to be implemented. In addition, configurable digital signal processing functionality has the ability to enable the signal chain to perform more narrow-band functions when needed. Furthermore, the system can support dynamic, real-time mode changing, potentially supporting more cognitive functions in conjunction with further digital signal processing downstream.

The first two stages of the proposed chain, the low noise amplifier (LNA) and mixer are implemented using GaAs technology. While advances are being made with wideband SiGe mixers, the use of GaAs and GaN devices for front-end components is still expected. In both cases, the HMC1049 and HMC1048 offer very wide performance and excellent IP3, which supports both narrow-band and wideband operations. These devices illustrate where process advances enable a single device to meet multiple specifications, without requiring additional digital functionality. The benefit of embedding digital functionality in an RF device can be seen in other elements of the signal chain.

The new [ADF5355](#) PLL with integrated VCO supports RF outputs from 54 MHz to 13.6 GHz and provides a wide range of synthesizer frequencies to be used. Based on SiGe, the device is able to support such a wide range of operation by using four separate integrated VCO cores. Each of these cores use 256 overlapping bands, which allows the device to cover a wide frequency range without requiring large VCO sensitivity, and without sacrificing phase noise and spurious performance. The correct VCO and band are chosen automatically using digital calibration logic integrated inside the device. The device enables the signal chain to support RF scanning from 54 MHz up to 13.6 GHz, as well as fixed frequencies as needed. It does this while maintaining high performance, with typical phase noise levels of -138 dBc/Hz at 1 MHz offset, as required for more narrow-band system operations.

The [ADA4961](#) ADC driver provides wideband performance with excellent linearity. Using SPI and embedded digital control, it achieves 90 dBc IMD3 performance at 500 MHz and -87 dBc at 1.5 GHz. Digital control is incorporated in the device to support gain control as well, with fast attack options enabling the device to be configured, as needed, to provide the optimal performance of the system. The fast attack also increases the flexibility of the system, as it provides rapid gain reduction when the FA pin is driven, typically by the over-range detection output of the ADC, which enables the ADC to remain out of saturation.

The [AD9680](#) completes the chain and is one of the latest high speed converters. Based on 65 nm CMOS, the device supports sampling at up to 1 GSPS at a resolution of 14 bits. Using higher sample rates and the bandwidths of gigasample converters, the AD9680 potentially supports undersampling an IF in excess of 1 GHz. This supports the continued trend of moving the digital conversion point of the system closer to the antenna and increasing the flexibility of the system. The device not only provides industry-leading SFDR and SNR but also incorporates digital downconversion (DDC) signal processing, to provide customizable output bandwidths.

The digital signal processing configurability of the AD9680 ADC enables the device to support wideband surveillance,

as well as narrow-band functionality. With the incorporated DDC disabled and bypassed, it can support an instantaneous surveillance bandwidth in excess of 500 MHz. Utilizing the DDCs, the digital numerically controlled oscillator (NCO) can be set to digitally mix a narrow-band IF to baseband before configurable decimation filters reduce the data rate, supporting output data bandwidths down to 60 MHz when the device is operated at the maximum ADC sample rate. The digital signal processing improves the SNR of the system for the lower bandwidth, again supporting the flexibility needed for a configurable wideband and narrow-band signal chain.

Although the example has focused on the receiver path, similar devices and levels of integration are available for the transmitter side. New DACs are incorporating highly configurable interpolation filters and digital upconversion functionality, and can be used in conjunction with similar broadband RF and microwave components, as previously mentioned.

The example described shows how new generation wideband devices are incorporating increasing levels of digital signal processing and functionality, and how this is enabling future systems to be dynamically configured for multimode operation with levels of performance previously not possible. This contradicts the view that narrow-band and wideband operations cannot coexist. It should be noted that this brief analysis has not included some of the filtering challenges, or an analysis of power. These factors may heavily influence the actual design choices and signal chain architecture. However, with more wideband higher performance devices, and increased levels of signal processing being developed, the future looks promising for highly configurable, cognitive, and software-defined systems.

Finally, and to illustrate the discussion further, integrated RF IC devices such as the [AD9361](#) provide the ultimate level of integration and further demonstrate the disappearing boundary between digital and analog functionality. Supporting a direct conversion architecture, combined with digital filtering and calibration functionality, the AD9361 provides a high degree of flexibility able to support RF input frequencies from 70 MHz to 6 GHz and bandwidths of up to 56 MHz.

The configurability of the AD9361 supports a wide range of applications and uses, including radar, communications, and data links, as well as electronic surveillance and warfare. With digital calibration and processing, the device is able to overcome many of the typical issues found in a direct conversion system, and provides an unprecedented level of integration and configurability, again further supporting cognitive and multifunction systems.

Previously, this level of integration and associated performance was not possible. In addition, many system designers shied away from the use of direct conversion architectures, as the limitations of aspects, such as image rejection over frequency and temperature, could not be overcome. The increased coupling of digital and analog, with advanced calibration and processing now integrated into these devices, provides solutions to these challenges, increasing flexibility without significantly sacrificing performance and power consumption. Although it may still be able to obtain better performance using a more narrow-band, dedicated signal chain using discrete components, the gap is certainly narrowing.

The ultimate goal of a software-defined system, a single RF and microwave signal chain for all applications, would ideally be a single component such as a transceiver supporting multifunction and cognitive applications. In reality, for all systems this may still be some time away, but new advanced developments are getting closer to this goal with ever more functionality being incorporated into each new semiconductor device. In addition to simply improving traditional RF performance, digital signal processing is providing solutions to relieve and overcome some of the multimode challenges. It may not be long before a single solution, using a single device or a cascade of wideband devices, for all applications becomes available and the drive to truly software-defined systems become a reality.



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