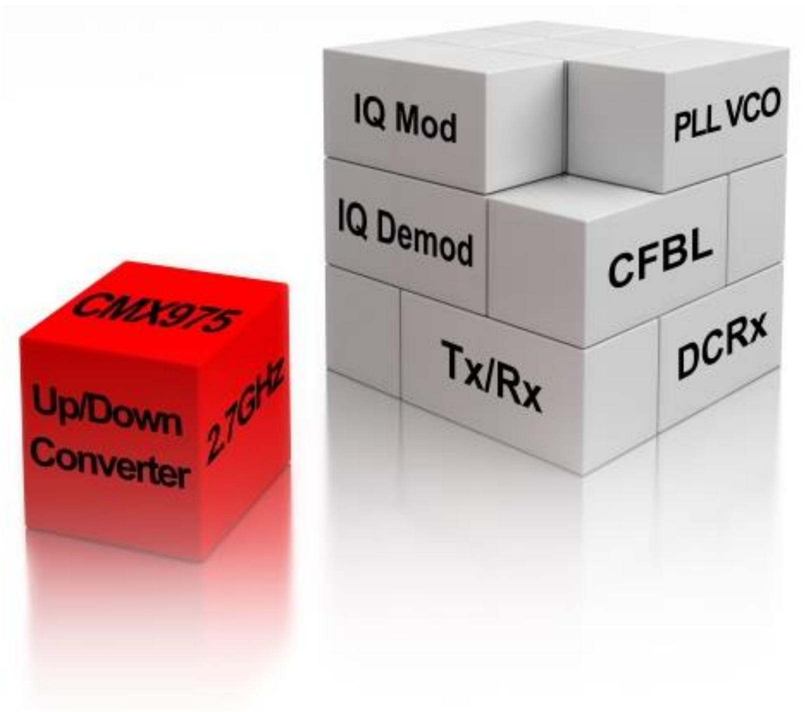
Speed your Radio Frequency (RF) Development with a Building-Block Approach

Whitepaper - May 2018



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Executive Summary and Introduction to CML Microcircuits

In this increasingly connected world, driven by the growing phenomenon that is the internet of things, the need to provide wireless communications is omnipresent in design. From wearables to smart home appliances the range of applications using RF is growing daily. In parallel with this, the number of standards for such radio links is also increasing quickly. Further, there are the traditional professional RF markets of wireless data, satellite communications, avionics and marine, along with a host of other scientific, medical and industrial applications.

Even with the prevalence of 2.4 GHz wireless applications such as Wi-Fi and Bluetooth, the lower radio spectrum is still very much alive with the diversity of HF, VHF and UHF systems, some of which are occupying bands previously used by terrestrial broadcasting. Faced with implementing RF features into a new product design and mindful of the constant pressures of time-to-market, many engineers are finding the task increasingly daunting. The traditional approach of embarking on a discrete design is quickly dismissed, yet the need to deliver connected designs remains.

CML Microcircuits is a world leader in the design, development and supply of low-power analogue, digital and mixed-signal semiconductors for global telecommunications systems.

CML's range of RF products provides a selection of modular building blocks for implementation as part or all of the 'wireless front end'. They are designed to provide the flexible, high-performance ICs required for HF/VHF/UHF designs.

These enable engineers to adopt a building-block method for RF design; an approach that uses versatile, low-power and well-supported RF IC devices to speed the design cycle.

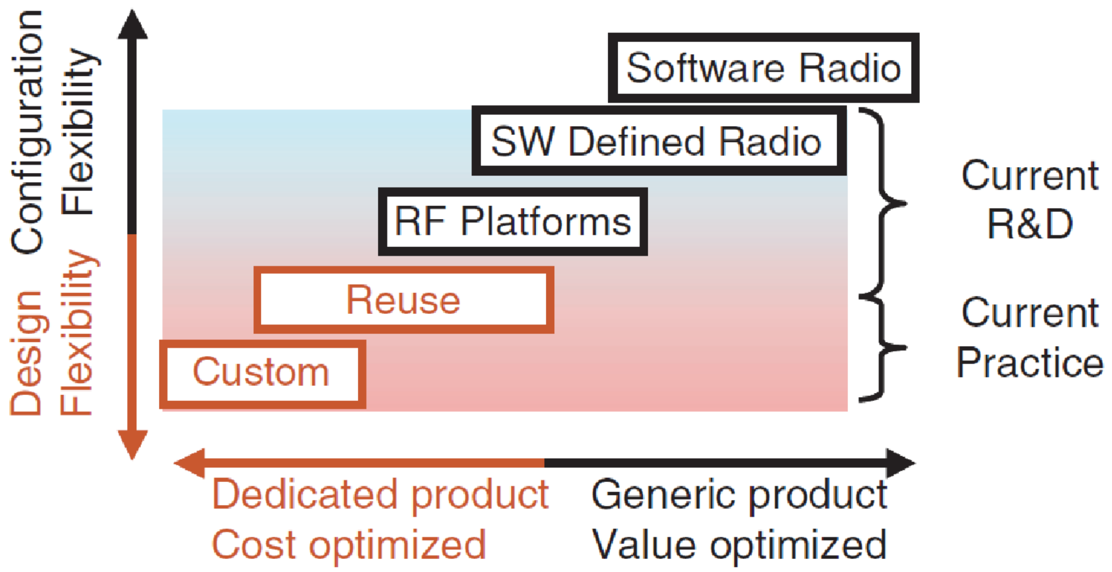

Figure 1. Platform-based RF system design (Source: Peter Baltus – Philips Semiconductors and Eindhoven University).

The RF Design Challenge

It is widely recognised that designing RF applications can be extremely challenging. Some engineers prefer the discrete method for embarking on a design. However, this approach is now at odds with the fast-moving commercial pressures to get products to market before the competition.

These factors are driving tremendous change in wireless applications. As one of the dominant drivers for the semiconductor industry, the wireless evolution towards higher data rate and higher capacities presents numerous opportunities. However, it also introduces many challenges to current design technology, particularly the demanding requirement for (ultra-)low power consumption. The rapid growth of wireless services increases the need for highly integrated and low-cost solutions with very demanding performances. The fast-growing market and heated competition require very short system development cycles. To cope with these demands, new design techniques for wireless systems have become imperative.

Enter a new, better-adapted design approach than the traditional, and arguably more flexible, method of deploying discrete RF devices. Built on the paradigm of platform-based design, it features the adoption of higher levels of abstraction (building blocks), better reusability and early consideration of system performance.

Consider the example of a wireless receiver – a complicated system consisting of RF, analogue and mixed-signal components. Traditionally, system design and discrete circuit design are conducted separately. However, effective interactions between the different levels are critical to obtaining an optimal system. Platform-based receiver system design is presented from system level down to circuit design..

In the context of the platform or building-block design approach, several challenges in the wireless receiver design are reconciled, including how to improve system robustness, how to quickly estimate wireless system performance, how to build abstracted behavioural models, etc. System-level optimisation is performed using behavioural models and, to preserve fidelity, the models are constrained by the achievable performance of actual circuit implementations. The results show that the required performance can be accomplished in the platform-based design framework.

Designing an RF Application

CML's range of RF products are ideally suited to diverse applications encompassing voice-centric and data-centric markets, covering a wide range of systems.

The diagrams below show examples of typical system architectures for high-integration implementations for: digital/analogue two-way radio (TWR), wireless data (WD) telemetry and software-defined radio (SDR).

The building blocks of such designs typically include the following elements:

- Receiver (Rx) – Each of the various blocks in the receiver chain has some gain (or loss) associated with it, hence the receiver chain has distributed gain. There are several considerations involved in determining how to distribute the gain across the RF, intermediate frequency (IF) and baseband (BB) electronics. In many systems the response of the entire system must remain linear over a wide range of operating conditions including signal level, presence of interference and temperatures.

- Transmitter (Tx) – An RF transmitter performs modulation, up-conversion and power amplification, with the first two functions combined in a modular approach. Tx design requires a solid understanding of modulation schemes due to their influence on the choice of such building blocks as up-conversion mixers, oscillators and power amplifiers (PAs).

- Transceiver (XCVR) – An integrated combination of the above two. The platform-based approach to transceiver design is illustrated below.

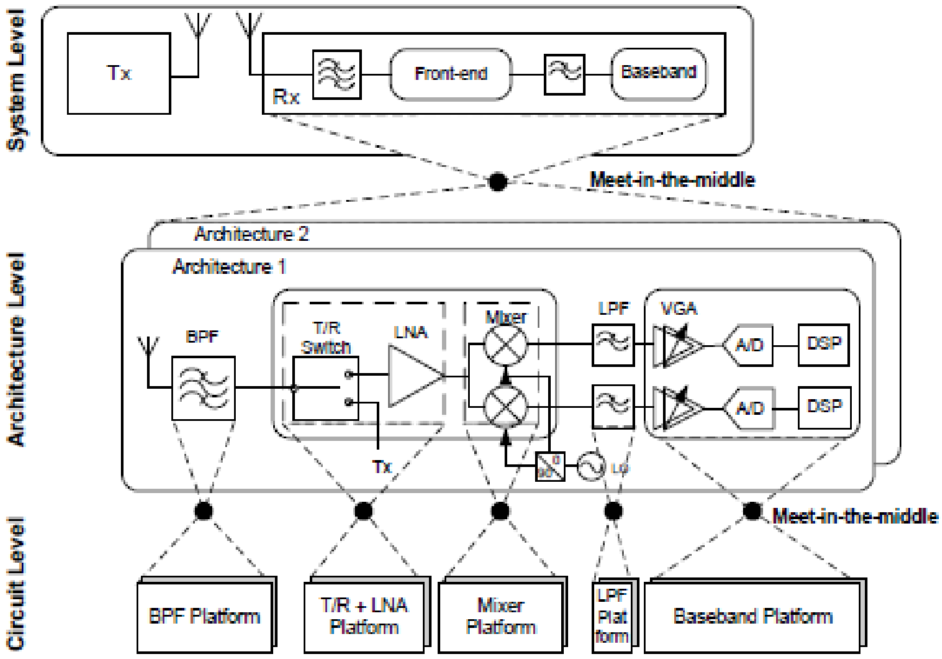

Figure 2. Platform-based approach to transceiver design.

- Power amplifiers – The RF PA is an important component of any wireless transmitter, since it is a key factor in achieving performance, reliability and acceptable cost. RF PA design requires the designer to be aware of the factors that have an impact on the performance of the power amplifier IC: the choice of semiconductor technology, accuracy of the transistor device models, packaging, thermal management and architectural design techniques.

- Mixer – A mixer is a frequency translation device with two prime functions:
    - Convert RF frequency to an Intermediate Frequency (IF) (or baseband) for further signal processing in receivers.

    - Convert baseband signal or IF frequency to a higher IF or RF frequency for transmission.

  Note: mixers usually require appropriate filtering. A mixer will remove unwanted frequencies in transmitters or unwanted responses in receivers.

- Local oscillator (LO) – Oscillators are used in all RF and wireless systems. Oscillation occurs when an amplifier is furnished with a feedback path that satisfies two conditions:
    - Amplitude condition – The cascaded gain and loss through the amplifier/feedback network must be greater than unity.
    - Phase condition – The frequency of oscillation will be at the point where loop phase shift totals 360 (or zero) degrees.

  In modern systems the LO needs to tune over a given range of frequencies depending on the system. To achieve this a Voltage Controlled Oscillator (VCO) can be used as part of a programmable Phase Locked Loop (PLL).

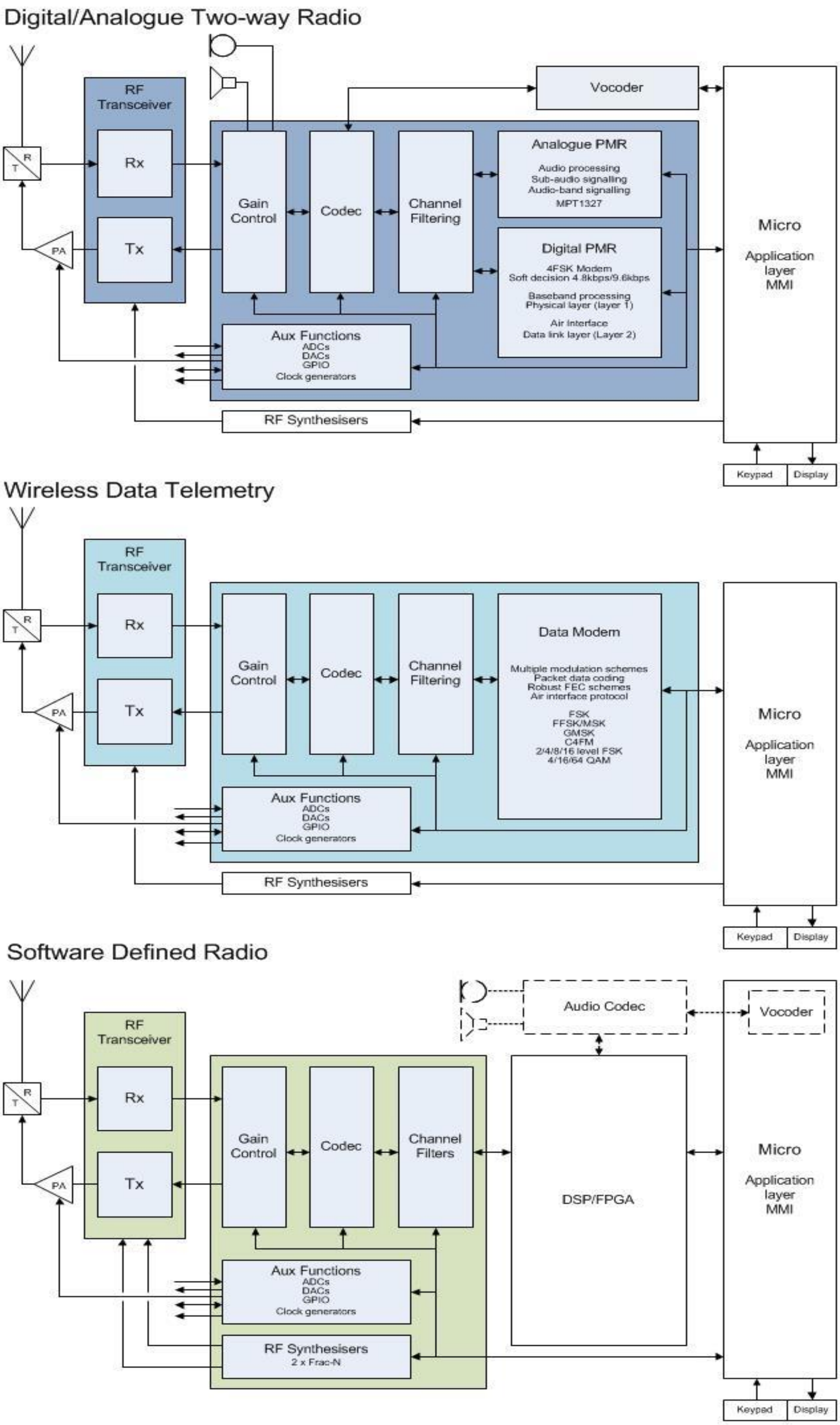

Figure 3. Typical system architectures for building block RF designs.

Introducing the Building-Block Approach to RF Design

Most of the individual functions or components illustrated in the previous section will be required in RF designs, so it makes good design sense to use existing commercial devices for them. CML Microcircuits' CM99x and CM97x series of devices includes integrated receiver, transmitter, transceiver, modulator/demodulator and PLL functions, which will speed the design process and reduce time-to-market. A summary of device specifications is as follows:

- **CMX971** – A high-performance quadrature modulator featuring a wide operating frequency range. Control of the CMX971 may be either by serial bus or by direct control. Programmable features include LO divider ratio (two or four) and optimised operation for noise or linearity).

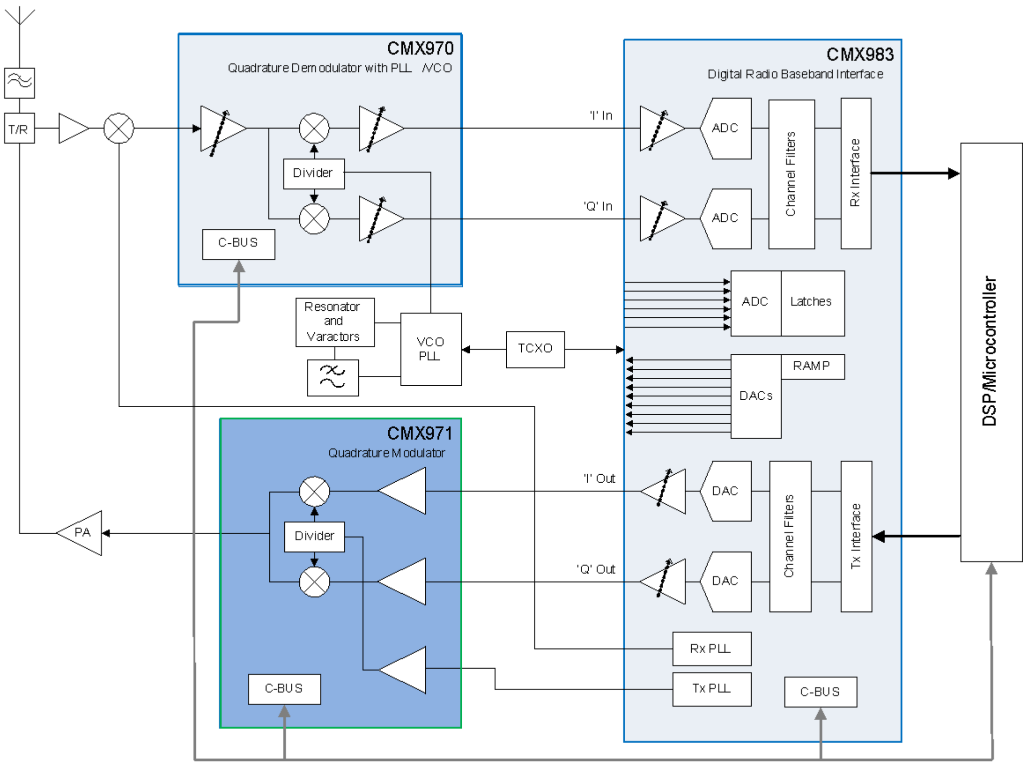

Figure 4. Typical system application utilising CMX971 Quadrature Demodulator, CMX970 IF/RF Quadrature Demodulator and CMX983 Programmable Baseband Interface IC.

- **CMX972** – Features a low-power quadrature IF/RF demodulator with wide operating frequency range and optimised power consumption. The demodulator is suitable for superheterodyne architectures with IF frequencies up to 300MHz, and the device may be used in low-IF systems or in those converting down to baseband. An on-chip PLL and VCO, together with Uncommitted baseband differential amplifiers, provide additional flexibility. Control of the CMX972 is by serial bus.

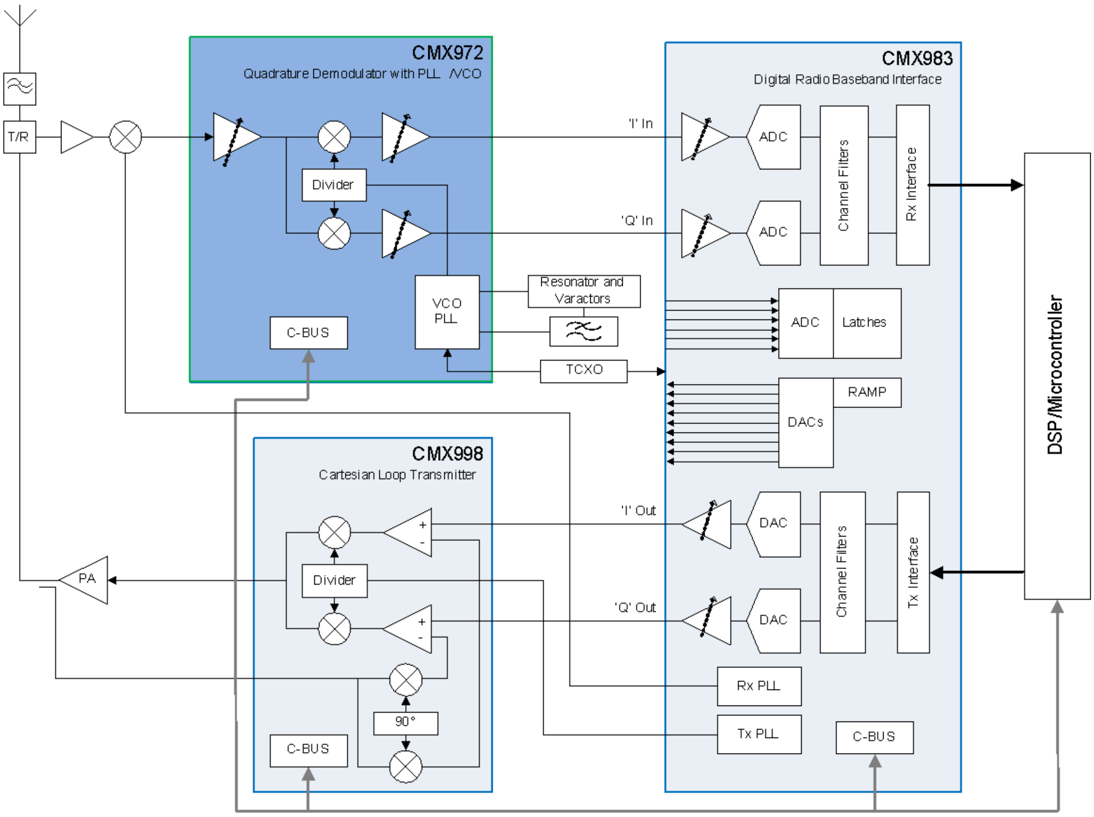

Figure 5. Typical system application utilising CMX972 Quadrature Demodulator with PLL/VCO, CMX998 Cartesian Feedback Loop Tx and CMX983 AFE Digital Radio Interface IC.

- **CMX973** – Integrates a quadrature (I/Q) modulator and a low-power quadrature IF/RF demodulator. The demodulator is suitable for superheterodyne architectures with IF frequencies up to 300MHz and the device may be used in low-IF systems or those converting down to baseband. The modulator converts directly from baseband to the desired transmit frequency up to 1GHz and features quadrature phase correction to achieve excellent I/Q accuracy. An on-chip PLL and VCO, together with uncommitted baseband differential amplifiers, provide additional flexibility. Control of the CMX973 is by serial bus. Like the CMX971 and 972, the

CMX973 is supplied in a small, RF-optimised 32-pin VQFN package, and minimal external components make the device ideal for space-constrained applications.

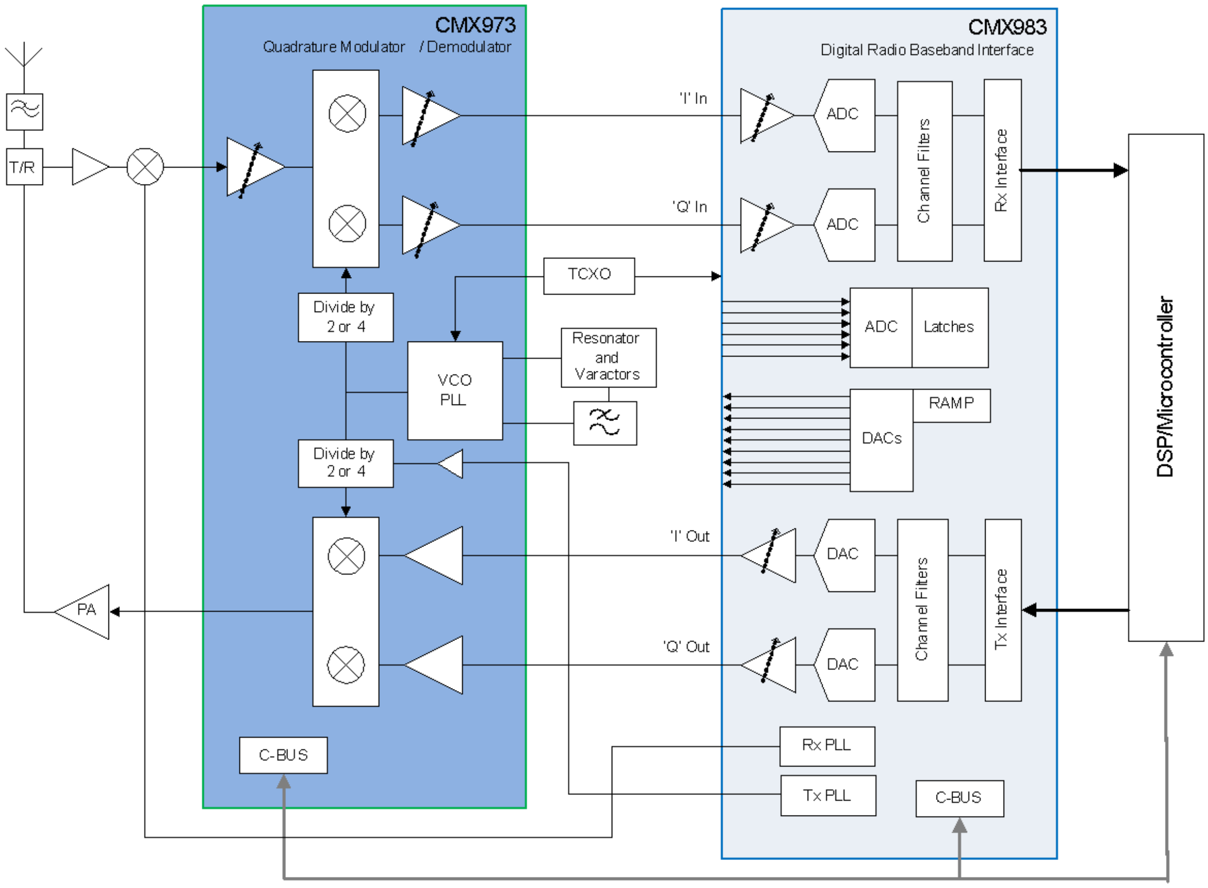

Figure 6. Typical system application utilising CMX973 Quadrature Modulator/Demodulator and CMX983 AFE Digital Radio Interface.

- **CMX975** – An IC that expands the reach of CML's RF Building Blocks by providing multiple functions: RF PLL/VCO, IF PLL/VCO, Transmit Up-convert mixer, Rx Down-convert mixer and LNA. The RF high frequency synthesiser employs a Fractional-N design and operates at frequencies up to 3.6GHz using a fully-integrated internal VCO or up to 6GHz with an external frequency source. The IF synthesiser employs an Integer-N design and will operate at up to 1GHz. It has an integrated VCO requiring only an external inductor to set frequency. The Rx mixer can be configured in image reject or normal mode and the Tx mixer can be configured in sideband suppression or normal mode. The integrated LNA offers 18dB of gain reduction in three steps.

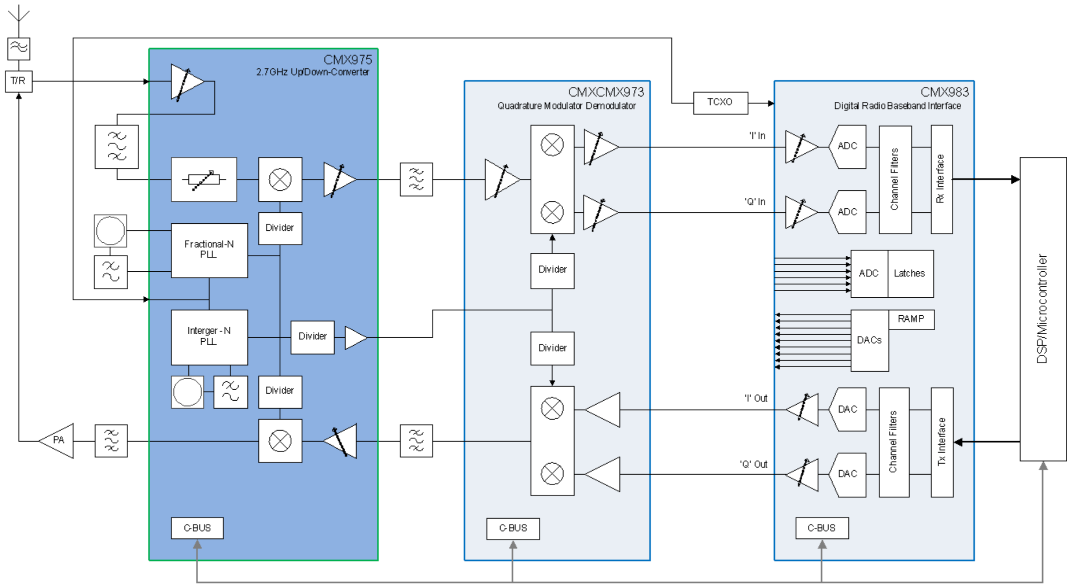

Figure 7. The CMX975 has been designed to work with CML's CMX973 Quadrature Modulator/Demodulator to provide a simple and cost effective high frequency superheterodyne transceiver operating in the range 1 to 2.7 GHz.

- **CMX979** – The CMX979 is a low-power dual-RF (Fractional-N)/IF(integer-N) synthesiser that supports signal generation over a wide range of frequencies. It directly supports both single conversion and superheterodyne radio architectures and minimises the number of external components. The CMX979 provides flexible LO generation in a small 6x6 mm VQFN package. The RF fractional-N synthesiser operates over the range 2.7 to 3.6 GHz with a fully integrated VCO supporting output frequencies in the range 338MHz to 3.6GHz via a configurable output frequency divider. The IF synthesiser is an integer-N type and operates over the range 500 to 1,000MHz. It includes a fully integrated loop filter and a VCO.

- **CMX99x** – The CMX991 Quadrature Transceiver, CMX992 Quadrature Receiver, CMX993/993W Quadrature Modulator, CMX994 Direct Conversion Receiver and CMX998 Cartesian Feedback Loop Transmitter are a family of highly flexible ICs working in the RF frequency range 100MHz to 1GHz, with the CMX993/993W and CMX998 operating down to 30MHz. These ICs, alone or in combination, address the needs of many over-air formats for data and encoded-voice operation in both constant-envelope and linear modulation systems. To reduce savings in the PCB requirement, these low-power products require a minimum in the way of external circuitry and control, and are available in compact VQFN packages. To enable the shortest design-in time, these RF products are well supported by ready-to-use evaluation and demonstration kits along with a range of application information.

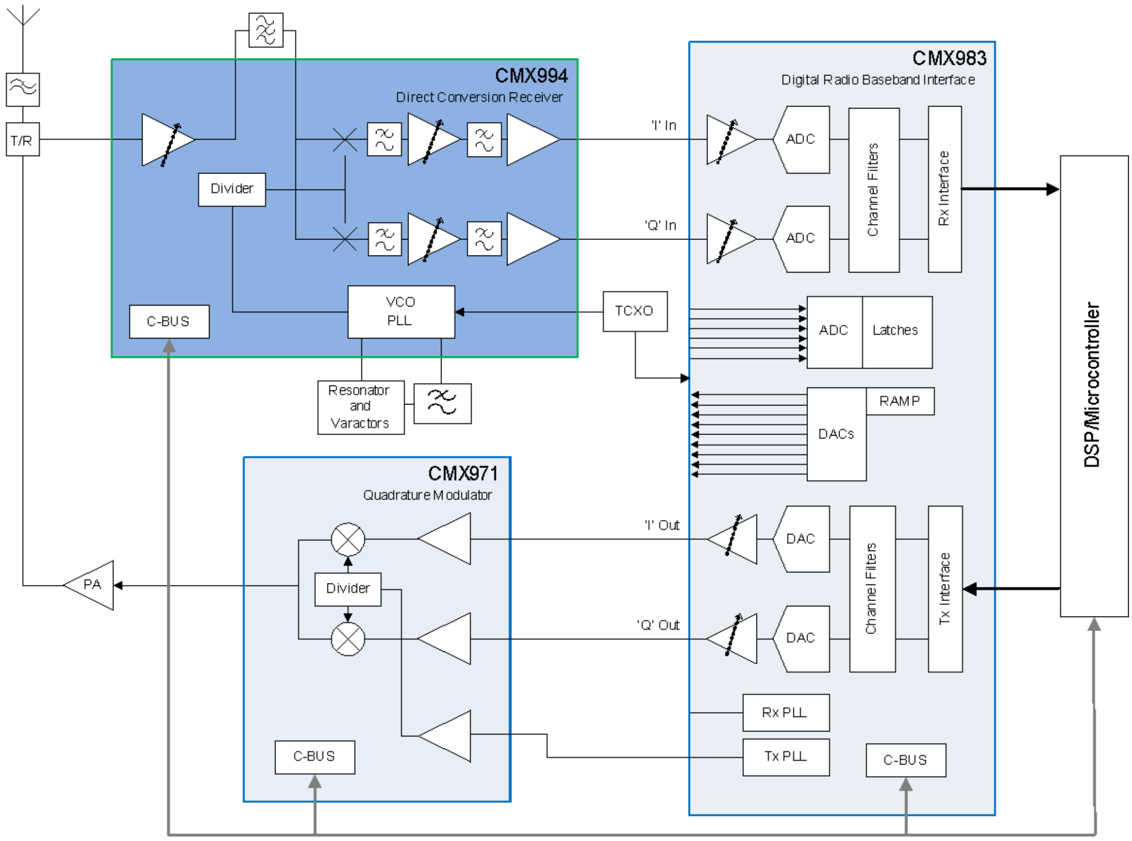

Figure 8. Application example of combined design with CMX971 and CMX994.

Conclusion

We can summarise the following key advantages to using a building-block or modular approach to RF design, as opposed to the use of discrete components and circuits as follows:

- Shorter design cycle.
- Faster time-to-market and reduced time-to-revenue.
- Simpler testing of the finished design.
- Fewer components required to complete the design.
- Higher reliability.
- Enhanced performance and control.
- Greater probability of reuse of the design.
- Lower-cost end products.

While the use of discrete components can offer some applications a greater degree of flexibility, in most cases the use of integrated building will yield some if not all of the above list of benefits. The technology and products delivered by CML are ideally adapted to this approach to RF design.