Integration Trends with RF Silicon Technologies in Mobile Radio Applications

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ABSTRACT

The aim of this paper is to outline the likely future trends in the integration of RF circuits within portable radio applications utilising silicon technology. This will be achieved firstly by examining the historical evolution of RF IC products with a particular emphasis on how a component oriented focus has become system oriented, which in turn is causing semiconductor manufacturers to re-think how existing and future technologies may be applied in more effective ways. In particular as semiconductor companies take control of the development of a greater part of the overall radio, new architectures and techniques are evolving and technologies are being applied in radically new ways.

I. INTRODUCTION

To achieve and maintain rapid growth in the market for portable radio products such as cellular and cordless telephones it is necessary to continually reduce the bill of materials (B-O-M) for the radio whilst at the same time maximising performance. This has lead to increasing levels of integration to minimise the number of external components and improve manufacturability. Careful consideration needs to be taken to ensure that the trade off between integration and external components is optimised if the lowest possible B-O-M and highest performance is to be achieved.

Historically, semiconductor manufacturers have produced standard IC products which could be utilised in a variety of application areas. Examples of such products are: Operational Amplifiers, Low Noise Amplifiers, Mixers, IF strips, frequency synthesisers, regulators etc.

These components would typically be optimised for a given specification rather than any particular application.

However, to achieve rapid growth in certain market segments such as cellular radio, it was necessary to obtain components that were optimised for the application, thereby achieving a more efficient implementation of the final product. This was achieved by producing components dedicated to the application, so called Application Specific Standard Products or ASSPs. As integration levels grew, these ASSPs became true sub-systems forming a major part of the final product. As a result, semiconductor manufacturers supplying components to producers of such equipment could no longer consider small sections of the radio when defining products. Rather a complete appreciation for the whole system became necessary before effective judgements of how best to apply silicon technology towards the objective of minimising the cost and space of the final radio product could be made. This had to be done without compromising either performance or flexibility.

To that end therefore, semiconductor companies must now consider themselves as system integrators as opposed to just manufacturers of components.

II. CELLULAR AND CORDLESS APPLICATIONS

Two examples of where a system oriented approach by semiconductor manufacturers has assisted in the rapid market acceptance of new products are GSM cellular telephones and DECT cordless telephones.

1st generation products for both systems typically utilised either off the shelf standard product, discrete components, ASICs, or a combination of all three. As a result, these early products tended to be bulky, expensive and gave relatively poor performance. The architectures that these systems employed were largely defined by the performance of the various ICs and components that were available “off the shelf”.

Second generation products were typically more integrated and much of the ICs used would have been ASSPs produced specifically for the system in development. However, the architectures will have been conventional and based upon the first generation product. Also, the semiconductor supplier would not necessarily have taken overall responsibility for defining the radio architecture and in particular at which point the analog / digital interface lies.

By the time that the third generation products were being developed, semiconductor suppliers, seeing the commercial possibilities, were developing complete RF chip sets, with the aim of obtaining the maximum revenue potential whilst at the same time reducing the cost and increasing the performance of the overall solution.

To achieve this, a full system level initiative was required as providing an external ‘work around’ to performance shortcomings with a highly integrated solution was either problematic or impossible.

The stage has now been reached where ‘single chip’ RF solutions for both GSM and DECT handsets are becoming available. These solutions will typically integrate all of the RF functions with the exception of the power amplifier, filters and critical oscillator components.

Illustrations of what a single chip RF solution for both DECT and GSM might contain are shown in figures 1. and 2. [1], [2]

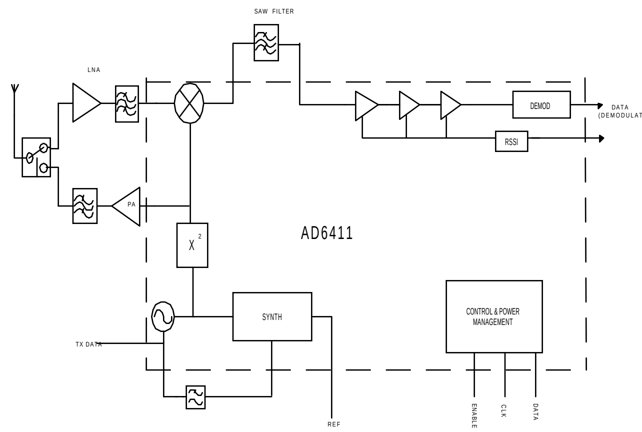

Fig. 1 Typical single chip DECT RF

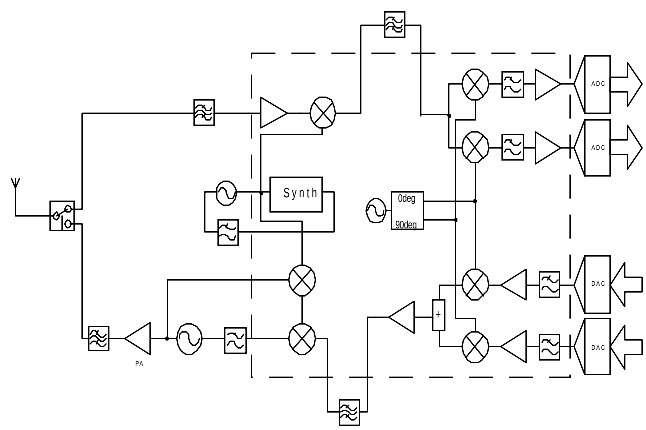

Fig. 2 Typical single chip GSM RF

These solutions in many ways represent what is really close to the ultimate in level of integration that may be achieved using both conventional silicon, packaging technology and radio architectures. However, these solutions do in themselves give us an insight as to what silicon technology may achieve in the future. In particular, it is noteworthy that in many GSM radios, the SAW filters give insufficient selectivity to meet the overall dynamic range requirements of the radio. The shortfall, is made up by digital filters in the baseband ICs that follow the conversion to the digital domain. This means that the ADCs have to have sufficient dynamic range to handle multiple

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channels. Another important observation is that these RF functions have to co-exist and support multiple modes of operation and numerous digital interfaces.

These two points demonstrate that precisely where the digital interface lies in a modern radio system is no longer clear cut, and mixed signal ADC technology is tending to push this interface towards the antenna. Indeed, the attributes and performance of modern data converters is more akin to an RF function than a digital one.

Figure 3. Illustrates the type of architecture now being developed for use in cellular base stations. The advantage of this approach is that by digitising the signal at IF, providing the ADC has sufficient dynamic range, the radio could be re-configured for different systems with different modulation types and channel spacing by changing only the software.

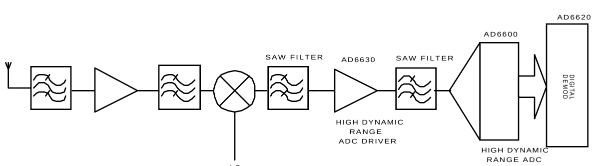

Fig. 3 Flexible base station receiver

It is therefore foreseeable that advances in silicon technology may enable the integration of the data converters and the existing integrated RF functions onto a single silicon substrate. Advances in packaging technology may also allow the PA and the other RF functions to be integrated into a single device, thereby minimising the PCB area occupied by the radio. However, of perhaps even greater significance is the advances in converter and DSP technology that is allowing the implementation of much of the filtering and all of the demodulator functions to be achieved using DSP rather than conventional analog hardware. This radical re-definition of the analog / digital interface opens up the possibility of highly flexible multi-band and multi-standard handsets, where conventional filters are utilised only for RF band pre-selection and anti aliasing. Figure 4. Illustrates the possible architecture that a future multi-band / standard handset might employ. The key will be achieving the necessary dynamic range in the ADCs and DACs at acceptable levels of power dissipation for hand portable products.

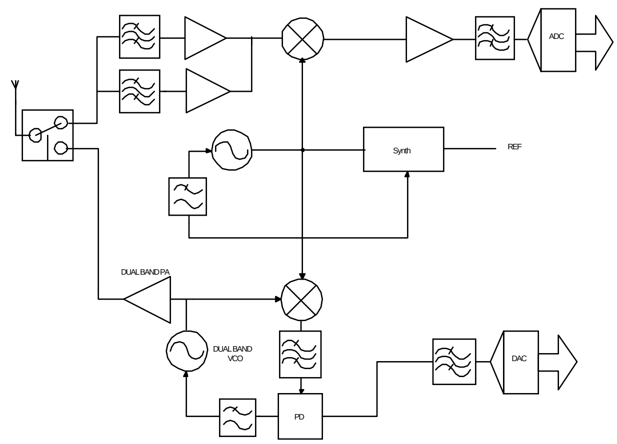

Fig 4. Potential multi standard radio architecture

III. SILICON TECHNOLOGY

As already mentioned, the key to flexible radio architectures lies in the development of IC technology that gives adequate performance and, crucially, is cost effective.

Currently the vast majority of current world wide silicon production utilises CMOS technology. As such, there is an increasing desire on the part of semiconductor manufacturers to gain leverage from the substantial investment in CMOS technologies and the economies of scale that that brings.

CMOS as a technology is highly optimised for digital functionality, but deep sub micron CMOS technologies also have properties that make them potentially very useful at RF. Within the last few years, there have been a number of published examples of ‘vanilla’ CMOS being effectively used in low noise RF circuits at 1 or 2 GHz [3], [4], [5], [6]. It may be seen therefore that current state of the art CMOS may not be as good an RF

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technology as Silicon Bipolar, SiGe or GaAs, for many applications it is already adequate.

As an RF technology, silicon Bipolar has tended to dominate in terms of manufacturing volume. However, silicon bipolar processes have been developed now to the extent, where it is difficult to see where any real performance breakthroughs can come from. This is because in terms of vertical scaling, there is little improvement to be gained. In addition, the investment in developing CMOS technology will most probably mean that it will advance at a faster rate than traditional RF technologies that do not benefit from the same economies of scale. As such, we can foresee that architectures and solutions will evolve that effectively utilise the benefits of CMOS, but also compensate for its short comings.

IV. CONCLUSIONS

We have seen that to maintain growth in high volume mobile communications products such as digital cellular and cordless telephones, it is necessary to continually reduce the bill-of-material cost of such products. As the semiconductor content comprises a substantial fraction of the total product B-O-M, great pressure has fallen on semiconductor companies to increase the level of integration to maintain a competitive position in sourcing components into these markets.

To achieve these very high level of integration, semiconductor manufacturers have had to adopt a system level focus as opposed to a component level focus. This approach is rapidly leading to the point that using conventional radio architectures, there is little left to be achieved, and much of what is left to be achieved will occur as a result of packaging development initiatives.

To maintain momentum in terms of cost reduction and in particular the requirement for ever greater levels of flexibility, semiconductor manufacturers are having to re-think how to apply CMOS, which is generally their most cost effective technology. This is in terms leading to a radical re-definition of radio architectures with a much greater emphasis on converter technology, DSP and software.

V. REFERENCES

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