High-Density Packing of UHF-Microwave Devices Using Embedded Die and Integrated Silicon Passive Components

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Abstract

The drive towards smaller, more complex, more reliable and less costly electronic devices is inexorable, and is especially pronounced in the medical implantable device market. This paper will show how the use of Microsemi Corporation proprietary embedded die technology in conjunction with an IPDiA Silicon Integrated Passive Device, has made possible a reduced size, highly reproducible 400 MHz-2.4 GHz transceiver. This transceiver is unique in that the active device is embedded within a PCB, whilst the required RF matching and decoupling circuits having been integrated in silicon, are surface mounted directly above the embedded die. The only components not integrated or embedded are a SAW filter and Quartz crystal, contained within the package footprint.

Introduction

Medical implantable devices represent one of the key innovations of the past 20 or so years in the field of patient care, allowing the improvement and-or lengthening of lives by recovering a non-existent or failed aspect of body functionality. Perhaps the best-known examples of these devices are cardiac rhythm management (pace-maker) devices and cochlear implants, these latter devices having enabled hearing impaired patients to recover some normal hearing function. There are an ever increasing number of functions that can be stimulated or recovered thanks to implanted electronic devices, and millions of people throughout the world now rely on these devices.

As is the case with many electronic devices, implantable devices have seen their power consumption and size reduce and functionality increase, which is achieved with ever increasing levels of integration and software innovation. The most recent devices are not only efficient, but they are able to communicate data –device or indeed patient status, or be programmed wirelessly using highly integrated RF transceivers operating in the MICS-MEDS 402-405 MHz band and-or the 2.4GHz ISM band.

This requirement for increasing miniaturization and functionality forces size reductions in the basic components, including active integrated circuits, memory and devices, as well as the circuit boards required to mount these devices. Naturally, these requirements must be satisfied without compromising battery life or reliability. These are all areas in which the use of an Integrated Passive Device (IPD), in conjunction with Embedded Die Technology (EDT), come to the fore.

Module considerations

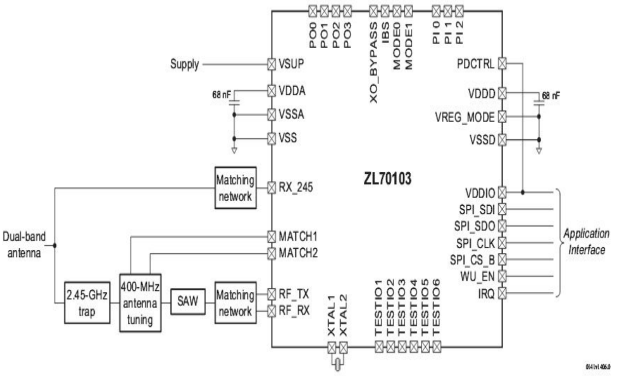

Figure 1: Block diagram of an implantable medical transceiver

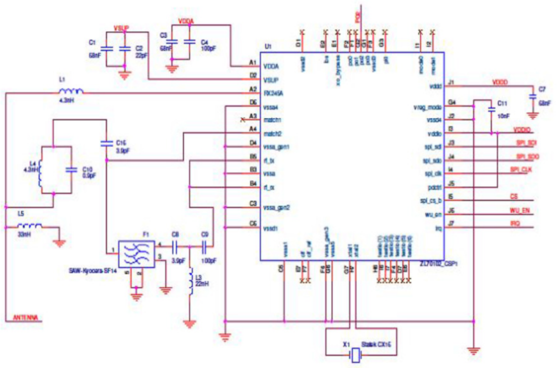

Figure 2: The circuit diagram which realises the block diagram shown in Figure 1

A typical realisation of an implantable transceiver is shown in Figure 1. The Microsemi ZL70103 is the active device which integrates a 400MHz transceiver offering multiple modulation and demodulation schemes at 400MHz, which is based upon a zero IF architecture, has it’s frequency controlled by a synthesiser, and it’s selectivity provided by a suitable SAW filter. At 2.4GHz, only a receive function is required, and responds only to amplitude modulation; this functionality is provided by what is essentially a super regenerative architecture. Overall control is provided by an internal state machine, with overall timing and frequency control being obtained from a suitable Quartz crystal.

By employing standard surface mount techniques, a module such as that shown in Figure 3 is obtained. Here the dimensions are approximately 12.7x8.1x1.5mm, and connections to the various IO functions are made using a grid array on the lower side of the PCB.

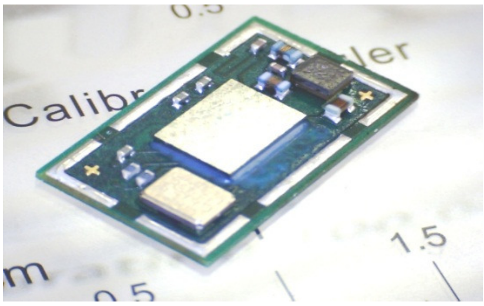

Figure 3: A typical implant module obtained using standard PCB assembly techniques

However Microsemi have a proprietary (patented) technique which allows the active device to be mounted *within* the PCB, in effect giving a zero surface area utilisation by the active device, which results, as indicated in Figure 5, in a package having dimensions of 5.6x3.8x1.5mm; a reduction of over 400% in the occupied surface area, without an increase in the package height. Note that the

construction employs standard surface mount devices and that the required IO connections are made using the edge metallisation. By ‘back grinding’ the active device from a thickness of 500µm to 80µm, an overall module thickness of 1mm to may be achieved.
The use of an IPD does not, in this case, reduce the overall surface area required to implement the required functionality. Essentially the IPDIA PICS™ technology used to produce the IPD used in this application is able to produce resistors with values in excess of 100kΩ, inductors with values of a few 10’s of nH and capacitances of up to 100nF. Of particular interest in this application are capacitors, which show remarkably low thermal and voltage coefficients, combined with a Mean Time To Failure of 4.16×10^6 years at 37°C and high Q inductors. Further, the use of IC fabrication techniques implies that the reproducibility of the module should be excellent. Then this technology provides the possibility of integrating all the passive components to produce a high reliability, highly reproducible module, having a reduced cost of ownership over standard modules.

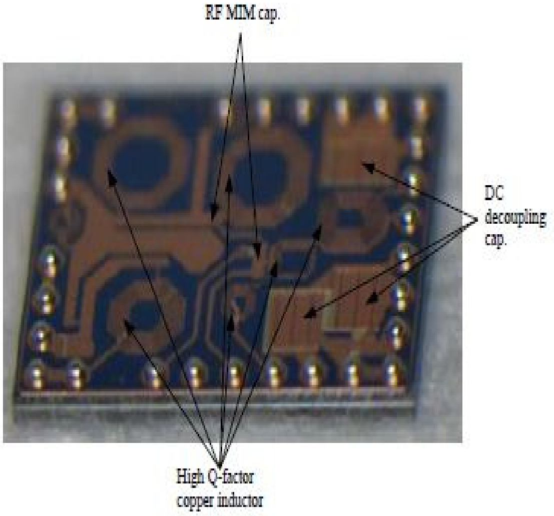

Figure 4: View of the IPD

Figure 5: The final module

Figure 4 shows the final ‘production’ IPD, which includes the necessary matching inductors and capacitors and the required decoupling capacitors, whilst Figure 5 shows the final construction of the module; all passive components with the exception of the SAW filter and the crystal have been successfully integrated.

Measured module performance

The key performance indicators of the module are transmitted power output and receive sensitivity at 400MHz, and receive sensitivity at 2.4GHz. The results obtained for the ‘IPDIA’ modules are compared against two standard products (MiniSim and MiniMics) which serve fundamentally the same purpose, but which employ standard surface mounting inductors and capacitors. 10 IPDIA modules were compared with 10 MiniSim and 10 MiniMics modules using standard production test facilities.

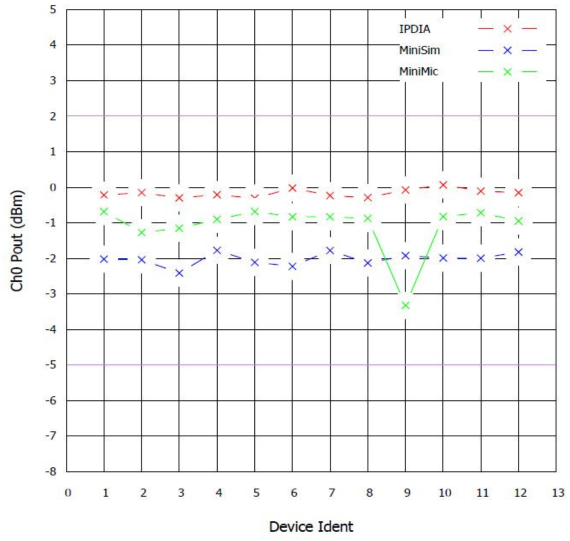

Figure 6: Power output at 400MHz, ch0

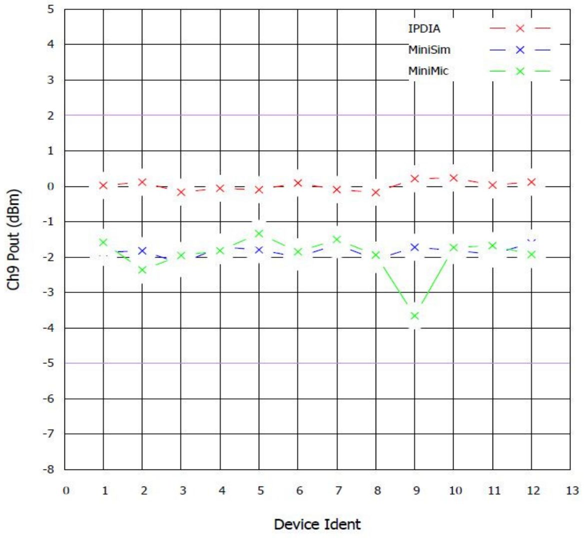

Figure 7: Power output at 400MHz, ch9

The 400MHz frequencies are channelised and Figures 6 and 7 show the results of measuring in the two channels extreme channels. Against either standard module the IPDIA device shows a consistently higher output power, and rather gratifyingly does not show the variation across the band demonstrated by the MiniMics modules. The 400MHz receive sensitivity is shown in Figure 8. Given that a higher RSSI (Receive Signal Strength Indication) value indicates a higher receive sensitivity, with one exception, once again the IPDIA module demonstrates an improved and more consistent 400MHz receive sensitivity. Taken together, the 400MHz performance figures would bode well for system performance.

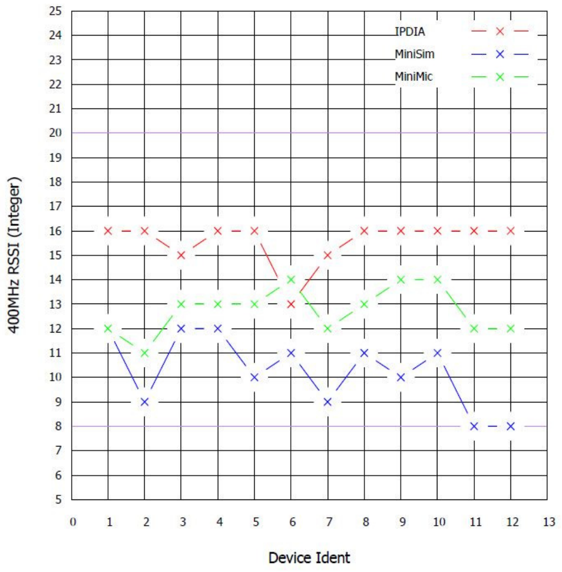

Figure 8: 400MHz receive sensitivity measured mid-band

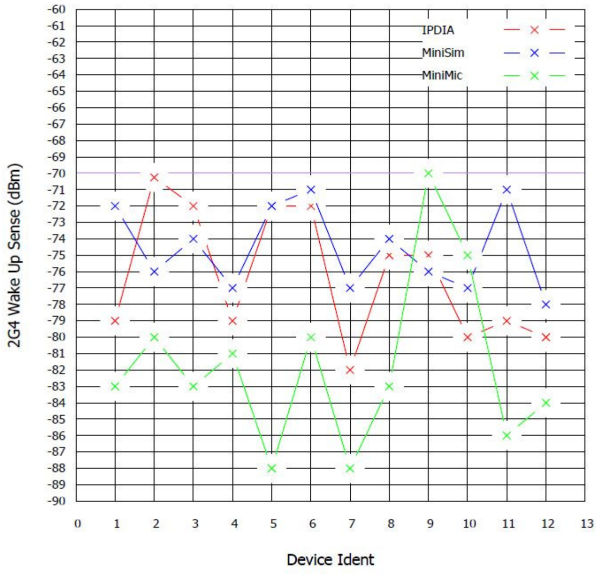

Figure 9: 2.4GHz receive sensitivity

Finally, Figure 9 shows the performance of the 2.4GHz receive sensitivity. This is rather difficult to interpret, given that the circuit is a super regenerative detector whose performance depends critically upon the reproducibility of the test itself. In all cases these units pass the production test with margins of 8dB or better.

Conclusions

It has been demonstrated that construction of modules employing IPD technology is able to offer more consistent performance at low frequencies (400MHz) than construction using standard surface mount components. Further, if considerable care were to be taken in the testing of the 2.4GHz link, there is little reason to doubt that consistently excellent results would be achievable, the variation observed above is typical of a super regenerative system.

Further work is clearly possible. In particular, the integration of the Quartz crystal and the SAW filter would be useful. Whilst the direct integration of these components is not viable in Silicon, it would appear that suitable structures which would replace the crystal are viable, and that if this is the case then in fact it may be possible to integrate a suitable filter structure. Both these options are being persued.