

ZigBee® - Make or buy? ***The life cycle cost of a ZigBee HW solution***

Introduction

ZigBee is the only global wireless communications standard enabling the development of easily deployable low-cost, low-power, monitoring and control products and the interest to add ZigBee capabilities to products are increasing rapidly. There are already hundreds of hardware products and software services enabling the market.

Adding ZigBee capability to a product involves designing both the appropriate hardware (HW) and the firmware (FW) including an application. This paper addresses only the HW development of ZigBee solutions.

Because of the cost and risk involved in a chip-based design, many companies are reluctant to add a new feature like ZigBee to their product. The paper will show how adding ZigBee can be done at minimum cost and minimum risk. For companies starting to develop ZigBee end products now, the time to market will also be an important factor.

There are both numerous chips and module available for ZigBee. What difference the modules from the chips is that they contain a small PCB with all necessary components (One piece solution). The RF design and layout (often including antenna) is already done and the module have been manufacturing tested and tested towards conformance to standards.

The final evaluation of make or buy (chip or module) is left to the implementers. This paper will help the decision makers to get the full picture of the cost and other relevant factors, and therefore be able to take a better decision.

The Myth of chip cost

Today a developer can choose between different degrees of integration of the required RF hardware; from a dual chip solution, via single chip solution, to a module solution. Many believe in the myth that basing their design on a single chip always will give lowest cost, but for most applications this is not true. When starting to calculate the life cycle cost of a ZigBee HW platform one will see that the “single-chip” itself is only a fraction of the total cost. Even so-called single-chip solutions require several handfuls of carefully chosen passive components, critically specified crystals, antenna including its matching, shielding can etc., in addition to a very careful layout on a high-frequency board or substrate to give the promised performance.

Cost

The cost of the ZigBee hardware is divided between the bill of material (BOM) and the engineering cost associated with the development, manufacturing and testing over the products life cycle.

The BOM of a ZigBee HW solution is not the same as the chip cost. In addition to the ZigBee chips (RFIC and MCU, or a SoC) there are crystals, antenna, balun, shielding can and a handful of passive components. Depending on the solution it might also include flash, EEPROM, power amplifier, low pass filter etc. Adding all this can make the BOM cost 50-100% higher than the pure chip cost.

In addition to this, there will often be handling cost associated with each component. This will include shipping, logistics, etc. and will give a small cost increase per component.

Development cost

The development can be divided in the pre-study phase and in the engineering phase. The pre-study includes specifying the performance and functionality the ZigBee HW shall have. The pre-study will also include making a component survey. Which components are available, what is the critical performance, what is the size etc? When datasheets are hundreds of pages, this work can be time consuming. In addition a purchasing engineer is needed at this point to collect price offers and negotiate prices.

The engineering phase will include schematic, RF layout, prototype manufacturing (including component purchase), and qualification. In this phase the RF competence of the engineers will determine success or failure. At 2.4 GHz every line width, pad size and distance to ground matters and the layout should not be left to layout engineers with a pure digital design background.

In the qualification phase good RF instrumentation is also important. Companies without RF experience and RF instruments often end up developing the ZigBee HW at an external design centre.

The work of the design engineer is not over when the product is in mass production. There will be support activity towards production that includes: evaluate new and cheaper second source components, analysing yield, process changes etc. This will not be a full time job, but still a cost to be reckoned with.

Development cost is a one time investment and when calculating the development cost per device, one tends to believe that a design lasts forever. As ZigBee is a relative new standard and there are many companies working on new chips, so the lifetime of a ZigBee HW solution should not be expected to be more than 2 years. Today's chips might be available longer, but in two years there will be better and cheaper solutions available.

Testing – the hidden cost

Testing is a cost that often is forgotten when making a radio design. Test cost includes the test development cost, instruments and the actual testing of each device. RF instruments are expensive and will cost \$10k-50k, even if bought refurbished.

For smaller volumes a test engineer can manually test each device, but for large volumes there is a need for an automated test system. The development of such a system can often be as complex as making the ZigBee solution itself. The test times per device should not go above 15 seconds and the test coverage (percentage of errors discovered in test) should still be above 95%. This will require an advanced test jig and also carefully written test program. Many believe that a simple functional test will be sufficient, but this will lead to many products in the market with poor performance.

Chip solution vs. module

Adding all the costs related to making a ZigBee HW solution with the BOM-cost we can compare a chip solution with a module. For a low volume customer the number could be as shown in table below.

	Chip	Module
BOM	~\$ 12 (1k)*	\$ 21 (1k)*
Test cost	\$ 1	\$ 0.2
Yield loss	\$ 0.3	0
Life support cost	\$ 20 000	\$ 1000
HW Development cost	\$ 150 000	\$10 000
Test development Incl. RF instrument	\$ 100 000	0
Total per device(1k)	\$ 283.3	\$ 32.2

* The numbers are based on published internet prices

The same calculation can be done for higher volumes and the relationship between total life-cycle cost per device and volume are shown below.

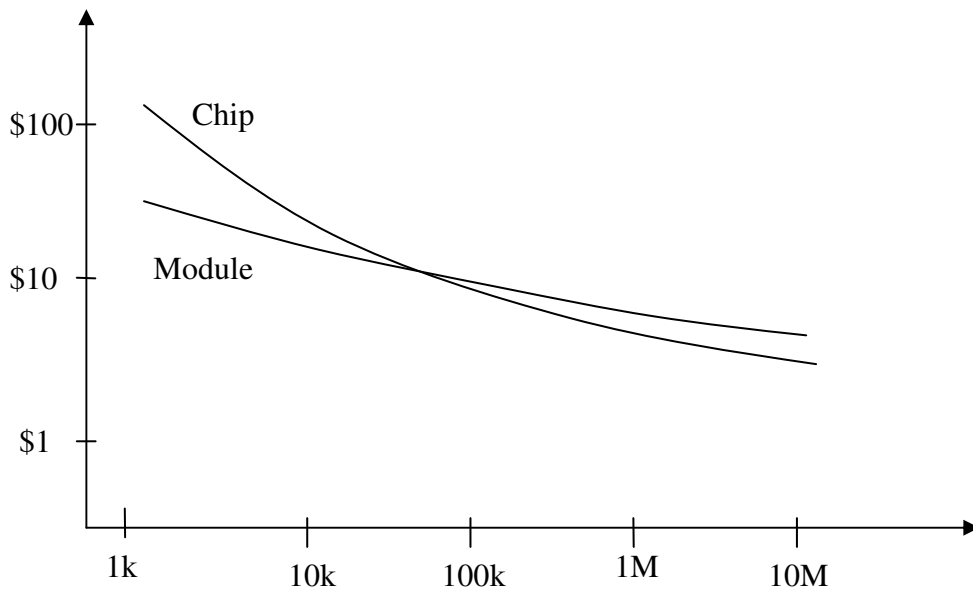


Figure 1 Estimated LCC for chip vs. module solution

A good RF performance

Adding ZigBee hardware to a product does not only involve the risk of faulty functions, but also the risk of poor RF performance. To get the specified range, a good antenna design, a good grounding and a good RF layout must be achieved. If some of these fail, the performance will be poor and the product will not be a success.

It is not only the performance that is critical with regards to the RF design. It's also the conformance to standards. In Europe your device must be according to the R&TTE directive with its underlying EN standards and ERC recommendations. In USA the FCC sets the requirement the wireless devices in the ISM bands. In addition to understanding all these standards, each design must also be verified against them. For FCC-compliance these tests must be done at an approved test house.

Yield is another factor that can influence the life cycle cost. Analogue designs and components have an inhabited variance and the higher the frequency, the more difficult is this variance to control. If the radio design doesn't deal with this tough variance simulation, analysis and appropriate margins, the result might be that the number of unit that fails during test is high.

If one of hundred units fails in test, the fault must be identified repaired and the unit retested. If this operation cost \$50, a 50 cent extra cost is added per unit.

Based of the above factors the importance of getting a good RF and antenna design can not be overstated.

Time to market

A short time to market is a critical factor in order to be successful in this business. Developing RF hardware is an activity with risk and a long lead time. An RF design with development and prototype manufacturing and testing will often take 6 months or more. If the performance is poor additional reruns might be needed. Such a long design time might be the difference between market failure and becoming a market leader. One extra week in the development process means 1 less week presence in the product market.

RISK

All HW developments have risks associated with them. Will the RF performance be as good as you specified? Will the design conform to the standards? Have you chosen the right chip? In addition to this there is the business risk of your own product: Will the new product with ZigBee functionality be a market success?

These factors might leave a manager reluctant to use a large amount of money to add ZigBee into the end product. When faced with this risk, it might be more appealing to the manager to add a ZigBee module into the product with much lower initiating cost (<10%) and lower risk.

Making your own module

When a company introduce ZigBee capability in their products, it is usually not only one single product, but a line of products involved. It is inefficient to do the ZigBee HW design with critical RF-layout more than once. They want to do this part once and reuse the design in several products, also for certification reasons. And the best way to do this is by making a module that can easily be copied from product to product. Therefore companies often end up with their own module, even if they initially decided to make a design based on single chips. The argument that the module level adds to the cost, does therefore not apply.

Business models

Starting with a module does not prevent changing to a chip solution at a later stage. When the new end product has been successfully introduced to the market and the sales are increasing, then it is the time to look at optimizing unit cost. By employing this strategy the best from both modules and chip-based solution can be achieved: Low risk and development cost from modules and still getting the lowest cost for large volumes.

But optimizing cost will not necessarily mean throwing out a module and starting from scratch. Working together with the module provider still might have strong benefits. By

continuing to work with the module manufacturer when entering high volumes there are several paths that might give the best overall solution:

- High volume discounts
 - o When you have an established product in the market and the prospects of high volume arise, modules with volume discount might give the lowest total cost.
- Design-in of the module on your board
 - o This would include copying the module design onto your board and adjust the design. This could dramatically reduce development time and cost, but would normally require some sort of module design licensing
- Optimized custom module
 - o Adjusting the functionality of the module to best fit the application
- Design buy-out

Conclusion

This paper has investigated the LCC cost of a ZigBee hardware solution. It has shown that the cost of the single-chip itself is only a fraction of the total cost and that for low and mid volumes a module would give the best solution with regards to total cost, time-to-market and risk. This paper has also shown how modules could ease the market introduction even for high volume (>100k) customers without compromising cost per unit.

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