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Six Hidden Costs in a 99 Cent Wireless SoC

Considerations when choosing between a wireless module and a wireless SoC

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What you don't know about dropping a wireless SoC onto the board could delay your product.

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So You Want to Save Money by Using a Wireless SoC?

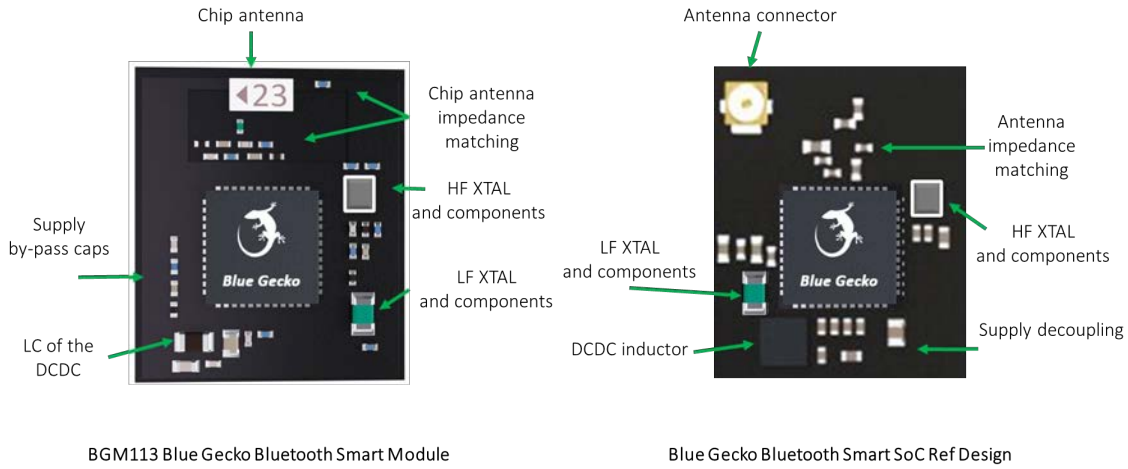
There are two main options:

Option 1: Use a wireless system-on-a-chip (SoC) on the product printed circuit board (PCB). It's small and cheaper than a wireless module. But designing with it may be costly.

Option 2: Use a wireless module with Option 1's SoC inside. A majority of the design is already done including a fully-characterized PCB with RF optimization and antenna layout, shielding, timing components (crystals), external bill of materials (BOM), regulatory approvals, and standards certifications. But they are generally more expensive and larger than the SoC.

Silicon Labs Announces Blue Gecko *Bluetooth*® Smart Module and SoC

- Blue Gecko Bluetooth Smart BMG113 module pricing = $3.07 in 100,000 unit quantities
- Blue Gecko Bluetooth Smart SoC pricing = $0.99 in 100,000 unit quantities



BGM113 Blue Gecko Bluetooth Smart Module

Blue Gecko Bluetooth Smart SoC Ref Design

Example of a Wireless Module and a Wireless SoC Layouts

So, what is the easiest and most cost effective option? That changes depending on the product, the designer, time to market, and so on. Further, the best option changes with volume.

Breakeven Analysis

Modules cost more than their SoC equivalent, but companies use them widely. Why? And what's the breakeven volume for when to change from one option to the other?

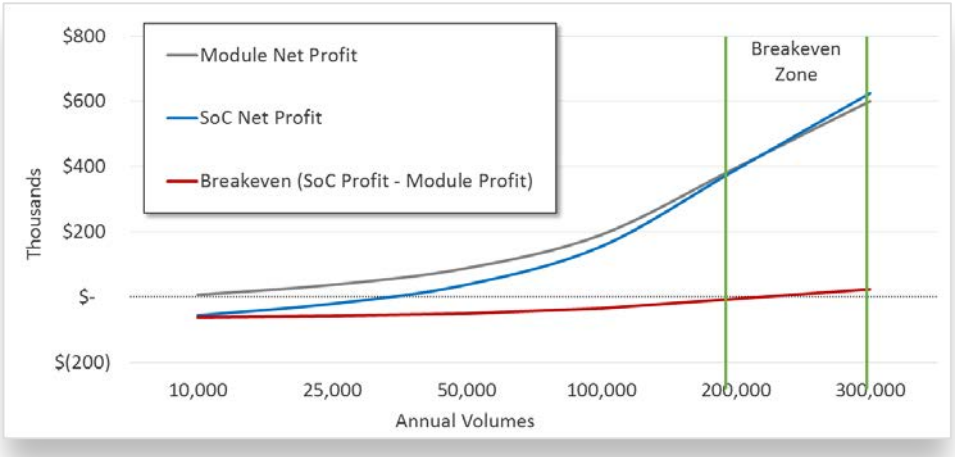
Cost Category (for a single product)	Wireless Module	Wireless SoC
Board design effort (antenna, layout, match, PCB, debug)	Low	High
Resource and lab equipment costs	Low	High
Regulatory certifications costs	Low	High
Standards certifications costs	Low	Med
Time to Market risks	Low	High
100K pricing (in our intro / example above)	$3.07 each	$0.99 each

High-level Cost Comparison of Wireless Module versus Wireless SoC

Breakeven Assumptions

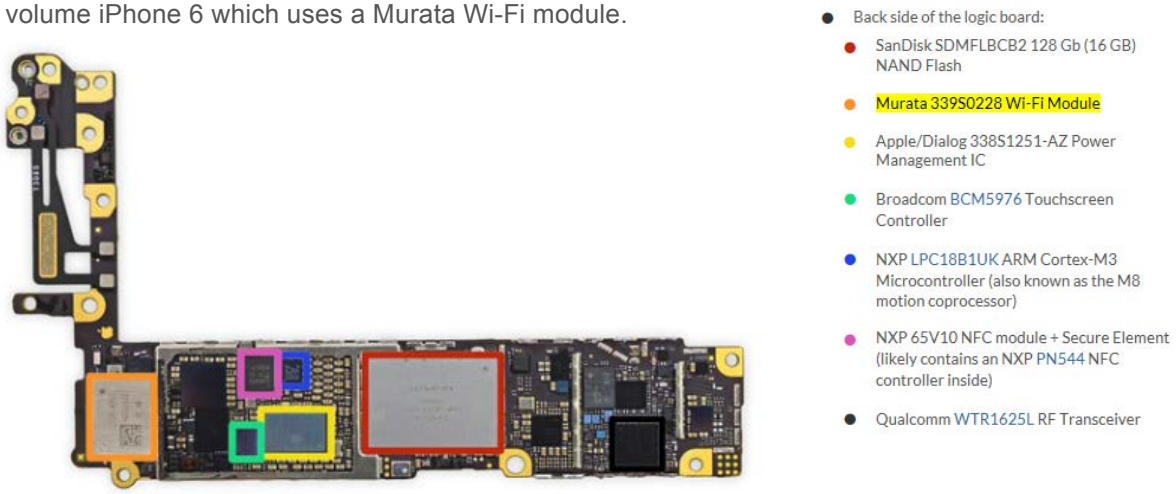
1. Flat $3.07 wireless module pricing between 10K-300K annual volumes;
2. Flat $0.99 wireless SoC pricing between 10K-300K annual volumes;
3. Flat $0.50 SoC bill of materials (BOM) pricing;
   - Module price includes the BOM. SoC does not.
4. Gross Margin = $5.12 or 40% above module price. Assume both SoC and module use this for the sales price;
5. SoC requires 3 months of extra development time due to more complexity in design, certification, and regulatory approvals.

Given the above, the annual breakeven volume falls between 200K and 300K.



Breakeven Example for using a Wireless Module versus Wireless SoC

This breakeven figure may seem high, but it still may not justify using an SoC as seen with the super-high volume iPhone 6 which uses a Murata Wi-Fi module.



iPhone 6 Teardown with Murata Wi-Fi Module

Source - ifixit.com/Teardown/iPhone+6+Teardown/29213

So why is a breakeven on this so complicated? Because modules remove unknown risks of designing with a wireless SoC, and unknown risks are, by definition, hard to quantify in dollars or weeks.

Hidden Cost #1: RF Engineers and Design

An RF engineer is required for an SoC design. Or, at a minimum, access to RF engineering expertise from the SoC supplier. RF engineers can be expensive. The Glassdoor.com RF Engineer salary is $80-152K/year, unloaded, which does not account for overhead (office space, benefits, etc.). In the US, this typically adds about 33% on top of the salary.

Hiring an RF Engineer = $80K-152K/year + 33% overhead = $100K-200K/year.

RF Application Notes – Not Always as Easy as 1, 2, 3

SoC suppliers provide application notes (AN) like Silicon Labs AN930 to help RF layout. These include recommended antennas, traces, board recommendations, and matching networks to maximize performance while minimizing cost and footprint.

However, since every design is different, the recommendations are always—*always*—hard to implement. In fact, industry experts will attest that it is very common for product designers to follow an application note's recommendations "exactly" and still have performance issues compared to the datasheet specifications and/or product expectations.

Module companies charge more for their products partly because they are already RF-optimized within a small footprint and low BOM. The whole "system" can be placed on the product board in a matter of hours if not minutes.

Of course, it is "never always" easy. But in the base case, putting a module on the board is measurably easier than putting down an SoC. See the table below for some issues that affect RF performance.

RF Performance Factor	Potential RF Impact
Antenna type, supplier, and placement	Antenna placement, type, material composition, manufacturer, and cost can change signal gain to the matching network resulting in mismatch and poor performance.
Antenna trace shape and length	Minor variations in length and shape can change the expected signal energy and therefore the recommended matching network.
Board manufacturer	Differing distances or insulation material between layers, PCB via materials, trace widths, screw holes, etc. can have effects.
Component suppliers	Different suppliers' components can behave differently and result in different performance. This can result when designers use "the ones they have on the shelf" versus the recommended supplier, or save a few pennies with a cheaper alternative.
Component types	Different component technologies can affect received power and voltage (e.g., wire-wound capacitors vs. thin-film).
Plastics and screw location	Screw placement can have coupling effects for both radiated and received energy.
Battery location	Battery location and technology can affect signal power. A charging battery can also be an unknown player.
Display location	Like batteries, displays can create interference on the antenna.

RF Layout Challenges and Effects

Hidden Cost #2: Lab Equipment and Facilities

RF engineering requires special equipment, software, and facilities to debug RF designs.

Lab Equipment	Cost to Own	Cost to Rent/Day
Calibrated traceable gain horn antenna	~$2,500	Included in a single day rental at test facilities. This is generally $1,000-$3,000/day.
Bi-conical antenna	~$2,000	
3D positioner	~$2,000	
Spectrum analyzer	~$6,000	
Wireless testing software with desired modulation	~$1,500	
RF isolated, anechoic room (5m x 5m)	~$20,000	
Wireless standard emulator, sniffer, and debug	~$20,000	

Wireless Lab Equipment and Facilities

Hidden Cost #3: PCB Layout and Antenna Selection

How hard can it be? Many engineers believe it should be easy to follow an application note for layout. While that can be true in some cases, antenna application notes are often complex.

AN930, the Silicon Labs Blue Gecko Bluetooth Smart (BLE) 2.4GHz antenna application layout guidelines, provides some good examples of the nuances involved. It is designed to provide detailed RF help so customers can get close to a "perfect" layout on their early tries.

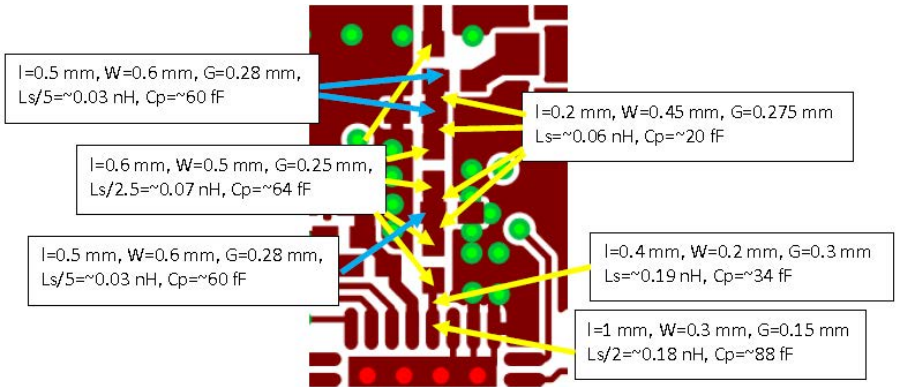


Image from AN930 on Blue Gecko Bluetooth Smart antenna matching

But there is still a good chance the PCB will need tweaks to optimize antenna performance. These take time—a few days to determine what needs to be tweaked and a week to turn the board at a local PCB manufacturer. Two weeks adds up when a typical development can take 16 to 20 weeks. As mentioned before, wireless modules can generally be successfully placed on a product board with very simple guidelines. It is still necessary to test a design's RF performance, but it will likely be much more unpredictable.

Hidden Cost #4: Regulatory Approvals and Wireless Standard Certifications

Products that operate in the unlicensed frequency bands require regulatory "type approvals." Many also require a wireless standard certification (e.g., Bluetooth).

Some wireless modules come pre-certified for type approval and wireless standards. Adding them to a product brings these approvals and certifications along, although the product designer must apply for membership in the standards bodies and conduct some product-level regulatory testing. Wireless SoCs do not carry product type approvals or pre-certifications.

Certifying Body	Estimated Cost	Module Pre-Certification Applies (Yes / No)	Wireless SoC Certification Applies (Yes / No)
FCC	~$7,900	Yes	No
IC (Canada)	~$7,900	Yes	No
ETSI / CE (Europe)	~$7,900	Yes; some limited testing/re-testing required	No
South Korea	~$4,500	Yes	No
Japan	~$8,600	Yes	No
Bluetooth®	~$8,000	Yes; Add'l membership fee required	No; Add'l membership fee required
ZigBee®	~$4,000	Yes; Add'l membership fee required	No; Add'l membership fee required

Regulatory and Certification Estimated Costs

Regulatory testing costs and type approvals vary by country. Some countries will accept others' approvals. For example, the United States FCC Part 15 approvals and paperwork are accepted by Canada without the need for further testing, but require separate application, approval, and certification mark.

Every wireless standard requires certification and paid membership in the standards body. Each certification body is independent and will not accept others' certifications. There are consulting companies for the approval and certification processes. They understand exactly what's required, how to test, how to correctly complete reports, and when an approval or certification is required. Appendix 3 provides a list of certifying bodies, guidelines, estimated costs, and consulting companies.

Hidden Cost #5: Reduced Product Revenue from TTM Delays

One of the biggest hidden "costs" in using a wireless SoC versus a module is the risk of missing the market window due to incremental time to design it in, test it, debug it, type-approve it, and certify it.

Every day the product is not on the market is a day of lost revenue. This can range from a few weeks to a few months. As we saw above with the iPhone 6, removing risk of time to market is a key reason why some very large volume companies still use modules even though they cost more.

Hidden Cost #6: Supply Management and Assurance

For companies with low-volume production runs, modules can mitigate supply risk. A module supplier bargains for SoC supply in their modules on behalf of its entire customer base. Therefore, they consolidate demand and insulate small companies from potential line-down if there is a shortage of SoCs. Sourcing a single module is also simpler than sourcing all the components to put an SoC on the board.

Moving from Wireless Modules to Wireless SoCs

When a company using modules decides to move to wireless SoCs, the question becomes how to reuse the software they have developed with the module. Module companies generally provide a unique software application programming interface (API) for their modules. This serves their customers with an easy-to-use API that allows them to transition between different modules for different SoC versions and/or wireless standards.

It also helps the module company retain the module customer as a result of their software investment; the customer won't want to port their code from the proven, hardened, and mature wireless module to a new, unproven, and unfamiliar wireless SoC.

Single Source for Wireless Modules and Wireless SoCs

Some suppliers sell both modules and SoCs. As such they may support software migration between modules and SoCs.

Silicon Labs is one example of such a company. The company has a 20-year legacy of pioneering wireless SoCs, and a long history of working with module companies. Recently, the company acquired two strategic module providers: BlueGiga, a company specialized in designing, certifying, supporting, and manufacturing Bluetooth and Wi-Fi modules, and Telegesis, a leading provider of ZigBee and Thread modules.

Silicon Labs has become a one-stop-shop for both wireless SoCs and wireless modules, delivering common software, stacks, support, and development tools.

Conclusion

The answer of whether or not to use a wireless module or a wireless SoC has a high degree of associated complexity that depends on volume, time to market urgency, risk tolerance, and available resources.
By choosing a single supplier who can deliver both modules and SoCs while protecting software investment, the migration from module to SoC is simplified if and when the breakeven analysis warrants the move.

Check out Silicon Labs Wireless Solutions

Check out Silicon Labs Bluetooth Solutions

Appendix

Appendix 1: Breakeven Calculations

	SoC Costs	Module Costs
Wireless Standards Body Certification (Single)	$ (4,000)	$ -
Wireless Memberships (Single)	$ (4,000)	$ (4,000)
Reg. Approvals (US, IC, EU, Korea, Japan)	$ (36,800)	$ (5,000)
Lab Equip or Rental for Development (3 months prorated for SoC dev	$ (15,000)	$ (5,000)
RF Expertise (3 months for SoC design and debug)	$ (20,000)	$ -
RF, Dev, Cert & Govt Approval Cost	$ (79,800)	$ (14,000)
SoC TTM Difference vs. Module (3-6 months)	3	-

	100KU Pricing
Module Cost (BGM113)	$ 3.07
SoC Cost (EFR32 32 QFN w/ 256 Flash)	$ 0.99
SoC BOM Cost	$ 0.50
SoC Total Cost	$ 1.49
SoC Savings vs. Module	$ 1.58
Product Retail ASP Wireless Premium @ 40% GM on Module Price	$ 5.12

Annual Volumes	10,000	25,000	50,000	100,000	200,000	300,000
Total Revenue	$ 51,167	$ 127,917	$ 255,833	$ 511,667	$ 1,023,333	$ 1,535,000
Module Dev Costs	$ (14,000)	$ (14,000)	$ (14,000)	$ (14,000)	$ (14,000)	$ (14,000)
Module Costs	$ (30,700)	$ (76,750)	$ (153,500)	$ (307,000)	$ (614,000)	$ (921,000)
Module Net Profit	$ 6,467	$ 37,167	$ 88,333	$ 190,667	$ 395,333	$ 600,000
SoC Dev Costs	$ (79,800)	$ (79,800)	$ (79,800)	$ (79,800)	$ (79,800)	$ (79,800)
SoC TTM Lost Revenue	$ (12,792)	$ (31,979)	$ (63,958)	$ (127,917)	$ (255,833)	$ (383,750)
SoC + BOM Costs	$ (14,900)	$ (37,250)	$ (74,500)	$ (149,000)	$ (298,000)	$ (447,000)
SoC Net Profit	$ (56,325)	$ (21,113)	$ 37,575	$ 154,950	$ 389,700	$ 624,450
Breakeven (SoC Profit - Module Profit)	$ (62,792)	$ (58,279)	$ (50,758)	$ (35,717)	$ (5,633)	$ 24,450

Appendix 2: Costs of Designing a Wireless SoC onto a Product Board and Going to Production

Cost Category	Module Cost	Confidence Level (%)? Comment?	SoC Cost	Confidence Level (%)? Comment?
Selecting antenna	Zero	100%	Med	50% – The supplier likely has a list of recommended antennas. Even so, picking one with confidence can require careful analysis.
Laying out antenna	Low	90% – As an all-in-one system, a module is hard to mess up. However, there may be restraints on module placement and "keep-out zones" that *could* get messed up. It's also likely that the module package probably includes shielding to account for these eventualities and so the probability of these issues is really low.	High	90% – Very high likelihood of trial-error-tweak-repeat cycle. Even highly experienced RF engineers spend weeks optimizing antennas for Rx/Tx performance *and* low BOM cost. This includes rigorous attention to keep-out zones, effectively isolated inductive loops, component selection and placement, etc… Also likely to need RF expertise, lab equipment and an RF-isolated testing environment.
Optimizing antenna layout	Low		High	
Reducing interference to antenna inputs	Low		High	90% – Very high likelihood of coupled noise into RF front end from unanticipated and/or unintentional radiators.
Reducing interference to antenna output power	Low		Med	50% – Very likely that suboptimal layouts will degrade output performance; unintentional interferors will also degrade output power.
Pinout complexity	Standard	Module companies mask SoC pinout changes by accommodating them in an unchanging module footprint.	Standard	SoC pinouts may change between alpha and production silicon. Likewise they may change with subsequent releases.
Software complexity	Low / Med	50% – It's likely that module companies have an "SoC abstraction layer" development software and API. It varies from supplier to supplier.	Low / Med	50% – Depending on the SoC company's design philosophy, their software APIs may be super easy or super hard. It varies from supplier to supplier.
Regulatory certifications Standards certifications	None / Low	100% – Modules can come pre-certified for various regions and wireless standards. There may be some product-level certs required that the module supplier cannot provide, driving some incremental cost here.	High	100% – Each product must be certified in each desired regulatory region and for each supported wireless standard. This is a time consuming and expensive task, and not always successful the first time resulting in "redos."

Appendix 3: Regulatory and Wireless Standards Certification Cost Estimates

Certification Body	Link / Comment	Estimated Costs	Module Applies (Yes/No)
Regulatory			
US FCC, Parts 15B and 15C for unlicensed radios	https://en.wikipedia.org/wiki/Title_47_CFR_Part_15 This page provides an easy-to-read guide.	~$7,900	Yes for Part 15B
Industrie Canada (IC)	http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01698.html Guidelines for testing: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01130.html FCC Part 15 certification applies for IC certifications with written reports stating cross-country compliance.	~$7,900	Yes
Europe ETSI and CE	Covers Europe, Africa, Middle East and parts of Asia. http://www.etsi.org/standards/looking-for-an-etsi-standard/list-of-harmonised-standards EN 300 328, EN 301 489, and EN 60950 are all important for unlicensed radios.	~$7,900	Yes
South Korea	http://rra.go.kr/eng2/cas/introduction.jsp	~$4,500	Yes
Japan MIC / Telec	http://www.tele.soumu.go.jp/e/sys/equ/tech/	~$8,600	Yes
Sub-GHz / Proprietary wireless	Generally only require regulatory compliance.		Yes
Bluetooth®			
Membership fees	https://www.bluetooth.org/en-us/members/membership-benefits	$0 - $8,000 (or higher)	No
Qualification overview	https://www.bluetooth.org/en-us/test-qualification/qualification-overview		Yes
Qualification fees overview	https://www.bluetooth.org/en-us/test-qualification/qualification-overview/fees	$4,000 - $8,000	Yes
Qualification FAQs	https://www.bluetooth.org/en-us/test-qualification/qualification-overview/listing-process-updates		
ZigBee®			
Membership fees	http://www.zigbee.org/zigbeealliance/join/#levels http://www.zigbee.org/Join/HowtoJoin.aspx http://www.zigbee.org/Join/MembershipFAQ.aspx	$4,000 - $9,000 (or higher)	No
Qualification overview	http://www.zigbee.org/zigbee-for-developers/zigbeecertified/		Yes
Qualification fees overview	Per test house	~$4,000	Yes
Qualification FAQs	https://docs.zigbee.org/zigbee-docs/dcn/05/docs-05-3594-04-0zqg-zigbee-certification-testing-faq.pdf		
Helpful sites			
Northwest EMC	http://www.nwemc.com/		

TUV	http://www.tuv.com/en/corporate/business_customers/product_testing_3/product_testing.html
NTS	https://www.nts.com/services/certification_services
7Layers	http://www.7layers.com/#!/type-approval/

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