

Strategies for Integrating Bluetooth™ Technology into Mobile Devices

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Bluetooth wireless technology is one of the hottest new concepts in the world of computing and telecommunications. This new standard enables users to interconnect a wide range of computing and telecommunications devices easily and simply—without the use of cables. Devices that can incorporate Bluetooth wireless technology range from notebook computers and PDAs (personal digital assistants) to Internet appliances such as e-book readers and Web pads (tablet-sized computers with a touchscreen that serves as both monitor and keyboard) to wireless headsets and cell phones.

First-generation Bluetooth devices have the wireless technology added after the fact, via a plug-in card. But second-generation Bluetooth devices, which are just now entering the design phase, will have the wireless capabilities built directly into the device. Not only will this approach be more convenient for users, but it will also reduce both the cost of the device and its power consumption requirements.

So what's the best way to integrate Bluetooth capabilities into a computing or telecommunications device? This article begins by reviewing some general design considerations. It then examines three different design approaches and discusses the pros and cons of each.

Starting Point: Device Requirements

Design considerations for a Bluetooth device should begin with the requirements of the device itself. Two particular issues in this regard are the size of the device and the distance over which it must transmit.

Size

The first question that will affect your choice of design approach is: how large is the device? This question has implications both for the availability of PCB real estate and for battery size—which in turn determines any limitations on the device's power requirements.

At the high end of the size range are devices like notebook computers. Notebook form factors range from a desktop equivalent (an A4 form factor), in which features and performance are the most important factors, to thin and light systems (a B4 or B5 form factor) in which size and weight are the primary considerations. In the latter case, even though space may not be plentiful, there is still room to consider a variety of options for Bluetooth integration—and there are fewer restrictions on power consumption than for smaller devices.

At the low end of the size range are devices such as PDAs, cell phones, and wireless headsets. Such devices have the most stringent space and power limitations, making highly integrated solutions the best choice.

Internet appliances, such as e-book readers and Web pads fall somewhere in the middle, with more space and power limitations than the high-end devices but fewer restrictions than the low-end devices.

Transmission Distance

The second basic question affecting your design approach is: over how great a distance will your device need to transmit? This factor, like size, has implications for battery size—and therefore for power consumption requirements.

The Bluetooth spec provides for three classes of devices, each with different distance requirements. Each class incorporates a variety of “profiles,” or specifications on how to apply the base set of standards to a particular implementation, such as file transfer or dial-up networking. The three device classes are:

- **Class III.** Devices conforming to the Bluetooth Class III specification have the shortest transmission distance, typically ranging from 1 to 3 meters. The Bluetooth spec provides for a maximum power output of 1 mW (0 dBm) up to 10 meters for a Class III device, with no specification for minimum power output. An example of a Class III device would be a PDA that incorporates a synchronization profile (so it can synchronize with a desktop computer) or a wireless headset for a mobile phone.
- **Class II.** Class II devices have a mid-range transmission distance—typically up to 10 meters. They have a maximum power output of 2.5 mW (4dBm) up to 10 meters and a minimum power output of 0.25 mW (-6 dBm). An example of a Class II device would be a PDA or thin/light notebook computer incorporating profiles such as file transfer, synchronization, or dial-up to a mobile phone.
- **Class I.** Class I devices are able to transmit over the longest distances—up to 100 meters. They have a maximum power output of 100 mW (20dBm) up to 100 meters and a minimum output of 1mW (0 dBm). An example of a Class I device would be a high-end notebook computer capable of accessing data in the user’s desktop system when the user was in a different room of the building—or possibly even on a different floor.

Three Possible Integration Approaches

Currently, three options are available for integrating Bluetooth wireless technology into a device:

- **Complete module.** This approach involves purchasing a ready-made Bluetooth module and dropping it onto the main circuit board of the device. The module—typically available in a rectangular form factor—contains all the necessary components, including the baseband controller, Bluetooth radio, miscellaneous components (such as bypass capacitors, resistors, and filters), and appropriate substrate materials. From the design standpoint, most of the work is already done for you when you choose this approach. Figure 1 shows an example of a complete module.

[Insert Figure 1 here]

- **Individual components.** This approach, depicted in Figure 2, involves the greatest design effort. You have to select the baseband and RF components, lay them out on the main circuit board within the desired form factor, test the configuration to make sure it works properly, and then send a prototype to a BQTF (Bluetooth-qualified test facility) to complete the Bluetooth qualification process. To significantly reduce the time and effort involved in this approach, choose a component supplier that can provide you with prequalified reference solutions, in which both the components and the layouts have already been prequalified by a BQTF.

[Insert Figure 2 here]

- **Hybrid approach.** With this option, illustrated in Figure 3, you select the baseband controller and its associated components and lay them out on the main circuit board, but purchase a module containing the Bluetooth radio, along with required external components such as resistors, capacitor, and filters. The hybrid approach involves more work than simply purchasing a Bluetooth module, but less work than selecting and laying out all the components individually.

[Insert Figure 3 here]

It should be noted that several companies, including Silicon Motion, are working to integrate the baseband controller and Bluetooth radio into a single chip—an approach that will both simplify the overall design effort and reduce the cost. Such chips are currently sampling in the field and should be in production in time for the third-generation Bluetooth designs.

Factors to Consider in Making Your Choice

The decision as to which of the three current approaches will be best for your application depends on your requirements in four key areas: time to market, power consumption, interoperability, and cost. Let's take a closer look at each of these issues.

Time to Market

The question here is how quickly you need to get the device into production:

- **As quickly as possible.** If time is of the essence, the module approach is your best bet, as the work has all been done for you. The components have been selected, laid out, and tested to make sure they all work together. All you have to do is insert the module onto your main circuit board.
- **Time is less important than other factors.** The individual components approach, in general, will involve the most engineering effort and therefore will require the longest time to market. When working with individual components, you have to first choose the components that best fit your design criteria (for example, those with the lowest power consumption or smallest form factor); then figure out their placement on the main circuit board; and finally test the configuration to make sure it works properly. You can significantly reduce your layout and test time, however, by working with a supplier that provides a prequalified reference design for the components that meet your design criteria. You may also want to consider choosing baseband and RF components that feature a BlueRF interface. Although BlueRF is not yet an official standard, it is moving in that direction—and devices that use this type of interface are generally simpler to connect and require less glue logic than devices that use a proprietary interface.
- **Time is a medium priority.** When time is an important factor, but not necessarily the most important, you might choose a hybrid approach, which involves more design work than purchasing a complete module but significantly less than working with individual components. That's because the bulk of the external components are in the radio portion of the design, which typically has 25 to 60 discrete components—as opposed to the 5 to 10 discrete components generally required for most baseband controllers. Since with the

hybrid approach, you're purchasing the radio as a predesigned module, much of the design work is already done for you.

Size

The question here is how much space is available on the PCB for Bluetooth circuitry:

- **Smallest size possible.** The best solution for devices that must be kept as small as possible is the individual components approach, with components laid out directly on the main circuit board. The flexibility provided by this approach lets you achieve footprint savings of 50% or better over that of a module. For instance, you can save space by choosing a baseband controller that can load program code from a system or peripheral bus (e.g., PCI or USB) rather than from a flash memory chip (which is what modules typically use). Again, to reduce the added design effort involved in working with individual components, choose a supplier that can provide you with a prequalified reference design—as well as layout guidelines aimed at minimizing the layout size.

Another step that will help you keep the size of your device as small as possible is to minimize the number of external components. As pointed out above, this factor depends most heavily on the radio device you choose.

- **Size isn't critical.** If you're not working under tight space constraints, you'll be fine with a complete module—but be aware that this approach will take up more space than any of the other options. A typical size today for a Bluetooth module is 33 mm x 17 mm or about 560 mm². That can result in major design challenges for situations where space is at a premium.
- **Size is a medium priority.** The hybrid approach can typically provide a 30% space savings over the complete module approach. As with the individual components approach, this space savings stems from the flexibility offered by the hybrid approach—such as the ability to choose a baseband controller that loads program code from a bus rather than from flash memory. Because the space savings aren't as great as those achieved through the individual components approach, however, the hybrid approach is most suitable for applications where size is a factor but not the primary factor—that is, those for which there is no need to keep the device's size to the absolute minimum.

Interoperability

Interoperability is a key consideration with Bluetooth wireless technology—both for making sure that the various components work well together and for ensuring that the device can connect seamlessly with other Bluetooth-compatible systems. If you design your Bluetooth device without regard to interoperability, you may find that your baseband controller and radio component need an interface that's difficult to design—or one that requires significant external glue logic—before they will work together. Or your Bluetooth components may work fine with each other but may not work well with other vendors' solutions. With Bluetooth devices, external interoperability is just as important as internal interoperability because the application will generally involve communicating with devices made by other manufacturers (as when a notebook computer is used to access files on a desktop system—or a PDA is synchronized with a PC).

You will need to have the interoperability of your design verified through the Bluetooth qualification process before you can ship it. Your job as a designer will be much easier if you start with a prequalified solution—but there are several ways of achieving this goal:

- **Prequalified module.** If you purchase a modular solution, choose one that's already completed the Bluetooth qualification process. The qualification process involves testing the baseband controller and radio both as a unit and with other devices and verifying that it means the minimum Bluetooth interoperability standards. (Note, however, that these standards are changing every few months—so a solution that was prequalified last year may not have the same interoperability as one that was prequalified more recently.)
- **Prequalified reference design.** If you build your own Bluetooth solution with components, choosing a component supplier that can provide you with a prequalified reference design will make it much easier to ensure interoperability. While using a reference design may give you less flexibility than if you created your own design from scratch, you can choose one oriented to your specific design requirements (e.g., small size or low power consumption)—and you'll still have more flexibility than you would with a modular or hybrid approach. Furthermore, the reference design will save you money and time over doing the entire design yourself and will simplify the Bluetooth qualification process.
- **Prequalified RF module.** If you use a hybrid solution, be sure to choose a prequalified RF module to minimize the risk of incompatibility between your device and other Bluetooth devices.

In any case, watch out for Bluetooth components that use a proprietary interface. You're better off making sure that both your baseband controller and RF chip are compatible with the emerging Blue RF interface standard.

Cost

As you might expect, the cost of a Bluetooth solution is inversely proportional to the amount of design work it requires—so the approach that will get your device to market the quickest is also the highest-cost approach. Cost considerations are as follows:

- **Low cost is critical.** The lowest-cost approach is to work with individual components. You won't have to pay for an extra circuit board or connectors; you'll be doing the design work yourself; and you can choose lower-cost components if you are creating a lower-end application that doesn't need all the capabilities of the more expensive components. In addition, you'll be eliminating the manufacturing and test costs of the module. With this approach, your costs will be at least a third less than what you would pay for a complete module.
- **Cost is less important than other factors.** A Bluetooth module, which is in effect a predesigned solution, has the highest cost of the three approaches. When you buy a module, you're paying not only for the components but for the design time that went into creating the module. In addition, you're paying for an extra circuit board that has to be mounted on your device's main circuit board—and for the connectors that you need to connect it to your main board. A typical module solution costs around \$25 today.
- **Cost is a medium priority.** In the case of the hybrid approach, you have some cost flexibility in choosing your baseband components, but you'll be paying more for the radio module than if you took the individual-component route. This is not only because the radio module involves a second PCB, but also because it may include a specialized LTCC (ceramic) substrate that has the necessary resistors and capacitors built in to save space. In addition, with the hybrid approach, you're paying for the design effort that the supplier put into the radio module—although you're also saving time by eliminating the work of designing it yourself.

Flexibility

A final difference between the three approaches is the amount of flexibility they provide in terms of choosing components and vendors. Your choices here are:

- **You need as much flexibility as possible.** The individual components approach offers the most flexibility. For example, if power consumption is a key factor, you can choose the components that have the lowest power consumption—or choose a prequalified reference design that minimizes power consumption. Similarly, if size and shape are critical, you can choose the components or reference solution that best fits into the space and footprint available on your main circuit board. You also have more choice of vendors with this approach, so you can choose the vendor that offers the best pricing, has the components you need ready to ship today, offers the best design support, or already has a strategic relationship with your company.
- **Flexibility is not a key factor.** The modular approach has the least flexibility, since it ties you to whichever components are provided on the module.
- **Flexibility is of medium importance.** Again, the hybrid approach falls somewhere between the other two. It locks you into preselected components for the radio module but gives you complete flexibility in choosing the baseband components.

Which Choice Is Best For You?

As you can see from the preceding discussion, there's no single best solution for everyone. You'll need to evaluate your requirements in the five key areas of time to market, size, interoperability, cost, and flexibility, and then make the choice that is best for you.

A general recommendation, if you're going with either individual components or a hybrid approach, is to choose a supplier that can offer you prequalified reference designs that take into account the factors that are most critical for your application. By using a prequalified design, you can achieve cost, size, and interoperability benefits while mitigating design effort and time-to-market factors.

And here's one final thought for those who are not quite ready to move to wireless technology today but expect to do so in the future. For example, say you're working on an MP3 music player or a digital recording device that currently uses a power cord, but you hope to come out with a wireless version soon. Think about designing in a DSP (digital signal processor) that not only can provide the voice and music functions you need today, but also can be upgraded later by adding baseband processing software. In addition, leave space on your circuit board to add either individual RF components or an RF module later. This approach will be much less expensive than adding a complete Bluetooth module at a later point—and it will also buy you the time you need to figure out exactly what you want in the way of wireless technology.

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