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January 2011

Advantages of Energy-Efficient ZigBee Remote Controls

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Foreword

Since its inception, the ZigBee Alliance has worked with a singular focus: create a much needed global wireless language capable of giving voices to the myriad of everyday devices that surround us as we go about our daily lives. This focus has been aimed at the little devices often overlooked in an IT-centric world, such as light switches, thermostats, electricity meters and remote controls, as well as more complex sensor devices found abundantly in the health care, commercial building and industrial automation sectors. As a result, ZigBee Alliance members have created a smart set of wireless standards offering extraordinary control, expandability, energy efficiency, security, ease-of-use and the ability to use ZigBee technology in any country around the world.

Today, organizations use ZigBee to deliver innovative solutions for a variety of areas including consumer electronic device control, energy management and efficiency, health care, telecom services, consumer electronic devices, home and commercial building automation, as well as industrial plant management. By choosing ZigBee, they also benefit from the Alliance's competitive and stable supply chain. With a comprehensive set of attributes, the non-profit, open membership and volunteer-driven Alliance has become a thriving ecosystem with several hundred members. As an ecosystem, the Alliance offers everything prospective product and service companies need to develop ZigBee products and services.

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Table of Contents

1. Overview **4**

2. Battery Life **4**

2.1 Usage Case and Other Assumptions 4

2.2 Traditional Button Remote 5

2.3 Remote Including a Pointing Device 5

3. Other Considerations **6**

3.1 Range 6

3.2 Line of Sight 7

3.3 Interference 7

3.4 Compatibility 7

3.5 Two-Way Communications 8

4. Conclusion **8**

List of Tables

Table 1 - Calculated Battery Life for a Button Remote in Days 5

Table 2 - Calculated Battery Life for a Remote With a Pointing Device in Days 5

Table 3 - Calculated Battery Life for a Remote Also Used For Internet Activity in Days . . . 6

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1. Overview

Remote controls for consumer electronics are ubiquitous and plentiful as consumers manage a world of electronics in their homes: television, set-top box (STB), DVD player, audio equipment and many more devices. STB remote controls in particular can be responsible for a large number of customer calls to customer service centers when a remote control is not operating correctly. Unfortunately, many of those expensive customer service calls can be attributed to a dead battery.

This paper compares the expected battery life of low-power radio frequency (RF) remote controls based on the ZigBee Remote Control standard against that of infrared-based (IR) remote controls. It will show that the expected battery life for remote controls using ZigBee Remote Control is significantly higher than the expected life for a similar IR remote control. Longer battery life not only improves customer satisfaction and reduces mundane call center traffic, but it is also better for the environment because it reduces battery waste.

Additionally, this paper explores other factors that affect remote control operation and the consumer experience, including range, interference and compatibility between vendors. Combined with battery life considerations, the improved effect on the consumer experience can be a compelling reason to use ZigBee for remote controls.

2. Battery Life

For purposes of this paper, we assume that the remote control is primarily intended to control an STB. In addition, the remote control has a secondary function that can turn the television (TV) on or off, change the volume, and other basic commands. Remote controls for other devices and universal remotes in particular will face similar issues and design analysis will reach similar conclusions.

Two types of remotes are considered. The first is a traditional button-only remote control. This remote control would be used, for example, with a traditional program guide that can be navigated with up, down, left, and right button presses.

The second type is an advanced remote control found with new STBs containing a navigation device such as a touchpad or trackball (mechanical or optical) that provides mouse-like cursor control[1]. This type of remote provides a more diverse navigation environment enabling newer, more visually appealing user interfaces. Mouse-pointing capabilities enable multiple system operators to provide a computer-style Internet browser for a richer consumer experience.

2.1 Usage Case and Other Assumptions

The usage model we employed is based upon available customer usage data, with the average consumer watching TV about 8.25 hours per day. The average consumer is assumed to be navigating menus such as the program guide 1.8 times per hour and will watch more half-hour shows but occasionally watching longer programs such as movies or sports throughout their viewing day. The number of commands transmitted during menu navigation varies based on whether the remote is a button-only remote or an advanced remote with mouse-like navigation.

Our usage model also assumes a certain number of button presses for other functions. For example, the model assumes 10 button presses per hour related to TV volume, including mute. Additionally, a remote associated with a set-top box that has a digital video recorder (DVR) function will experience more usage as the user will take advantage of various features such as pause and skip forward.

The power used by the various parts in the remote control will affect battery life. The assumption is that the remote uses AAA alkaline cells wired serially and that the remote ICs can consume 1200 milliamp hour (mA) from the batteries before reaching their lower

1 It is assumed that the remote design includes appropriate power management of such devices. For example when the navigation device is not needed, the remote can turn it off, or at least place is in a deep sleep mode that consumes ~1μA of current.

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voltage limit[2] and ceasing to function.

The remote control's processor is assumed to draw 7.5mA when active and 5 microamperes (µA) when idle. When sending ZigBee Remote Control commands, the remote's transceiver is assumed to draw 27mA and 28mA in receive mode when waiting for acknowledgements. This model assumes all ZigBee messages are acknowledged. In idle/sleep mode the transceiver is assumed to draw 2µA. These currents are typical for the parts that are available today for use in remote controls.

For IR transmission, there is a wide range of current draws as various remote manufacturers try to balance IR communication robustness with battery draw. Additionally, the duty cycles for various IR codes and commands vary. We assumed that the IR current draw is 250mA[3] peak with new batteries and with a duty cycle that is 15 percent on, 85 percent off. These values are in the typical range for IR remote controls[4].

Although the average IR current appears to be similar to RF, there is a significant difference in the total time involved. With ZigBee Remote Control, the transceiver will typically be on for ~1millisecond (msec). Allowing for occasional retries of unacknowledged commands, the average power on time for a ZigBee Remote Control transceiver is <<10msec. In the case of a typical IR command, the IR transmission will take >100msec[5].

2.2 Traditional Button Remote

Traditional button-style remote controls were examined for battery life using the aforementioned assumptions. Battery life was calculated for three types of remote. The first uses IR for all communication with both the STB and the TV. The second uses ZigBee Remote Control to communicate with the STB, but IR to control the TV (because an older TV is only controllable via IR). The third calculation is for a remote that can perform all communications using ZigBee Remote Control. The resulting battery life calculations are shown in Table 1.

	Non-DVR Remote	DVR Remote
IR Only	826	478
ZigBee - STB, IR - TV	1864	1211
ZigBee Only	2575	1476

Table 1 - Calculated Battery Life for a Button Remote in Days

As can be seen from the table, the impact of using IR communication is undesirable. A ZigBee remote has significantly greater battery life than a remote using IR for communication with both the STB and the TV. For the supplier of the STB, there is still significant positive battery life impact to using ZigBee for STB communication even when the remote continues to use IR for controlling the TV.

2.3 Remote Including a Pointing Device

Remote controls that include a pointing device, such as a touchpad or trackball, were examined for battery life using the same usage model assumptions. Battery life was again calculated for three types of remote. The first uses IR for all communication with both the STB and the TV. The second uses ZigBee Remote Control to communicate with the STB, but IR to control the TV. The third calculation is for a remote that can perform all communication with its ZigBee Remote Control link. The resulting battery life calculations are shown in Table 2.

	Non-DVR Remote	DVR Remote
IR Only	596	381
ZigBee - STB, IR - TV	904	688
ZigBee Only	1044	766

Table 2 - Calculated Battery Life for a Remote With a Pointing Device in Days

2 Some designs may not be capable of operating down to a 'drained' level of 0.9V per cell and would therefore not be capable of using as much of the battery capacity. Also there are inexpensive batteries that provide less than 1200mA before the voltage drops to this level. These instances are not considered here.

3 Current draw is a function of battery voltage but a single number was used for simplicity.

4 Typical IR transmit currents are 250-350mA peak although some companies drive their diodes much harder to maintain good range across battery voltage and to overcome interference. Typical duty cycles run from a low of around 10 percent to somewhat above 25percent.

5 Application specific implementations such as 'repeating buttons' can complicate these calculations and were ignored for this analysis.

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By comparing these results with those in Table 1 for a button-only remote, the effect of sending large quantities of data on expected battery life of a remote is readily apparent. However, as with a button-only remote, a ZigBee-only remote will have significantly greater battery life than a remote that uses IR for communication with both the STB and the TV. STB suppliers' remotes will gain significant battery life using ZigBee Remote Control for communications.

As an added feature for consideration on future products, some iterations of the model also assumed that users would surf the Internet using their television and STB. Internet activity was assumed to occur for an average of one hour per day with appropriate amounts of cursor movement and typing for email. The resulting battery life expectations are shown in Table 3.

	Non-DVR Remote	DVR Remote
IR Only	200	168
ZigBee - STB, IR - TV	348	310
ZRC Only	367	325

Table 3 - Calculated Battery Life for a Remote Also Used For Internet Activity in Days

When adding Internet-oriented activity, impact on battery life is significant. The battery life expectation for an IR-only remote is likely unacceptable for everyone in this scenario. A ZigBee Remote Control solution is needed to maintain customer satisfaction.

3. Other Considerations

Beyond battery life, the type of remote control, whether it is IR or RF, affects other aspects of remote control performance. For example, a ZigBee remote will outperform an IR remote for range while avoiding certain IR interference issues. Additionally, ZigBee remotes may have their firmware updated in the field. These performance differences make remotes using ZigBee Remote Control the most robust solution.

3.1 Range

Remote control range is often an overlooked factor by original equipment manufacturers (OEM). However, for a multiple system operator or a satellite provider, range issues drive customer satisfaction or customer complaints.

In a typical IR remote control, the IR-emitting diodes are directly driven from battery voltage. The IR transmit power is designed at a particular level by specifying the current limit resistor value. This will provide a certain IR range with new batteries that will typically satisfy the customer. However, as the IR remote control is used, the battery voltage will drop, eventually reaching about 55-60 percent of the new battery voltage before effectively dying. As the battery voltage drops, the remote's IR transmit power will fall. Users may notice that they must carefully aim the remote at the receiving device, sometimes even requiring physical contortions to avoid furniture interference, to transmit commands.

This type of behavior may be most noticeable for remote controls that are used in large rooms. An IR remote may have plenty of transmit power, but only with new batteries. As the batteries drain, the users may find themselves repeatedly pressing buttons to get the desired action to occur, such as pressing the power button several times in order to turn the device off. Alternately, the remote's reduced transmit power may cause the user to believe the batteries need replacement even when they would otherwise have significant charge left.

However, with a ZigBee remote, the transceiver will typically be operating from an internal regulator. This means that the transmit power will be constant across battery voltages. The remote control range will be identical to new batteries up until the battery voltage drops across the remote's dead voltage threshold. Thus, the user will not need to worry about aiming the remote as the voltage changes and will not experience the need for repeated button presses to execute a command.

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ZigBee Remote Control-based remotes include an additional power management feature related to range. The radios are capable of measuring the quality of a received signal. Therefore, the remote control can automatically turn down the transmit power while maintaining proper communication with the controlled device. This energy-saving technique can be used without affecting the user experience.

3.2 Line of Sight

Since IR remote controls are directional devices that rely on line of sight with the controlled device, they have a number of limitations. Line-of-sight limitations may be mitigated in some designs by using two transmit diodes to broaden the beam. Another common mitigation technique is to use large transmit powers to allow the IR beam to be received after bouncing off objects. While these tactics work, they do so at the expense of battery life and they eventually lose their effectiveness more quickly with reduced battery voltage.

Additionally, the IR-controlled device and the remote control must be in sight of each other. While line-of-sight positioning is not typically an issue for TVs, consumers will often want to place other home theater components such as STBs, DVD players, and surround-sound receivers inside entertainment centers or even out of sight inside a closet or cabinet. These desirable storage locations may not be options for consumers using IR remote controls.

However, ZigBee remote controls are typically designed with omnidirectional radiation patterns. The frequencies used by ZigBee Remote Control-based devices can penetrate the materials used by standard furniture and cabinets and even reach another room. Thus consumers can place their audio-visual equipment out of sight and still maintain control with ZigBee Remote Control.

3.3 Interference

Some of today's modern HDTVs use backlighting that is adjusted to match the room's ambient light conditions. The backlighting is typically modulated in order to control intensity. In some circumstances, the modulation of the TV backlight will cause interference with the IR reception of various devices as the modulation occurs at the same rate that a remote control is modulating its signal.

ZigBee Remote Control products are immune to the interference effects associated with TV backlighting and have been designed to be immune to RF interference as well.

3.4 Compatibility

Amazingly, IR-based remote controls and related equipment do not conform to any set standards, making interoperability between devices difficult. For example, the modulation frequencies can vary from a low of ~29kHz to greater than 400kHz, making it difficult for a basic remote to act as a universal remote control for multiple products since it would require a large database of commands and a more complicated customer set-up to control different makes and models.

A standard such as ZigBee Remote Control, on the other hand, achieves high levels of compatibility with ease. In fact, it is specifically designed to allow standards-based products from multiple vendors to interact seamlessly and without difficult customer set-up.

3.5 Two-Way Communications

ZigBee Remote Control establishes a two-way communication path, greatly increasing the possibilities for new remote control functionality. Actions can be acknowledged locally, an advantage if you are not in the same room as the device. For remotes with displays, playlists can be downloaded or information on programming can be displayed or any number of useful features. The capability can even be used for upgrades and bug fixes. For example, if the remote control is using a flash memory-based processor and is found to have firmware bugs after being shipped to the field,

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it would be possible to upload new firmware[6] without issuing a recall. This concept of sending information to the remote control can be extended into many new areas, leading to improved customer experiences and lower costs to OEMs.

4. Conclusion

In today's ever-complex consumer electronics environment, easily controlling multiple pieces of audio/visual equipment reliably is essential. Achieving multi-year battery life that exceeds IR capabilities, improves customer experience and reduces customer service calls clearly requires an effective RF-based ZigBee solution. Based on an open, global standard, ZigBee Remote Control provides the basis for achieving the high performance levels that consumers demand and the feature support for today's increasingly complex set of home entertainment needs.

6 Features such as this were not included in the models used to generate this white paper.

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