Technical note: RF remote control as a replacement for IR remote control

Nordic Semiconductor's nRD24H1 RF Remote Control Reference Design is the ideal starting point for designers wanting to take advantage of RF's advantages over Infra Red for modern remote controls. The Reference Design integrates all critical functions and is relatively simple to develop into many different remote control concepts. With the hardware design and optimisation done, a remote control design team can focus on the application functionality needed to make their remote better than the competitions'.

IR (infrared) wireless communication is simple to design-in, robust, cheap to manufacture and yields a controller that can run for months on two to four AAA 1.5 V cells. However, IR remote controls were originally designed in the late seventies to replace ultrasonic devices when a greater range of functionality was required and are starting to show their age. For example, IR remotes are inconvenient to use when navigating the complex multi-layered menus typical of today's digital electronics.

Moreover, users have to point the remote directly at the IR receiver on the equipment they wish to control which means they need a clear path unobstructed by people, furniture and walls. And IR is typically a uni-directional communications technology (bi-directional communication is possible, but it's expensive and prone to interference from other light sources). Contemporary consumers demand a user interface on their remote offering intuitive instructions and information about the media they're listening to or watching.

RF remote controls promise to finally match the convenience of IR – namely design simplicity, low cost and long battery life – while providing consumers with wireless connectivity that can support the more advanced menu-based browse facilities now common to home entertainment devices.

IR exposed

IR is electromagnetic (EM) radiation of wavelengths longer than visible light, but shorter than RF spanning three orders of magnitude between 750 nm and 1 mm. IrDA, the Infrared Data Association, champions IR in the electronics sector and most offerings adhere to the organisation's standards, aiding interoperability.

IR remote controls use IR LEDs to emit radiation that's focused by a plastic lens into a narrow beam. Data is encoded by modulating the beam to provide immunity from other IR sources such as fluorescent lights. The receiver uses a silicon photodiode to convert the IR radiation to a current for decoding by the receiver's MCU (see fig.1.). IR doesn't penetrate walls – although it can be reflected by walls and ceilings - and so generally does not interfere with other devices in adjoining rooms.

A simple IR remote comprises a keypad to input instructions, a resonator to provide a reliable clock base, an 8-bit MCU to detect key presses and modulate the IR signal and an LED to generate the IR.

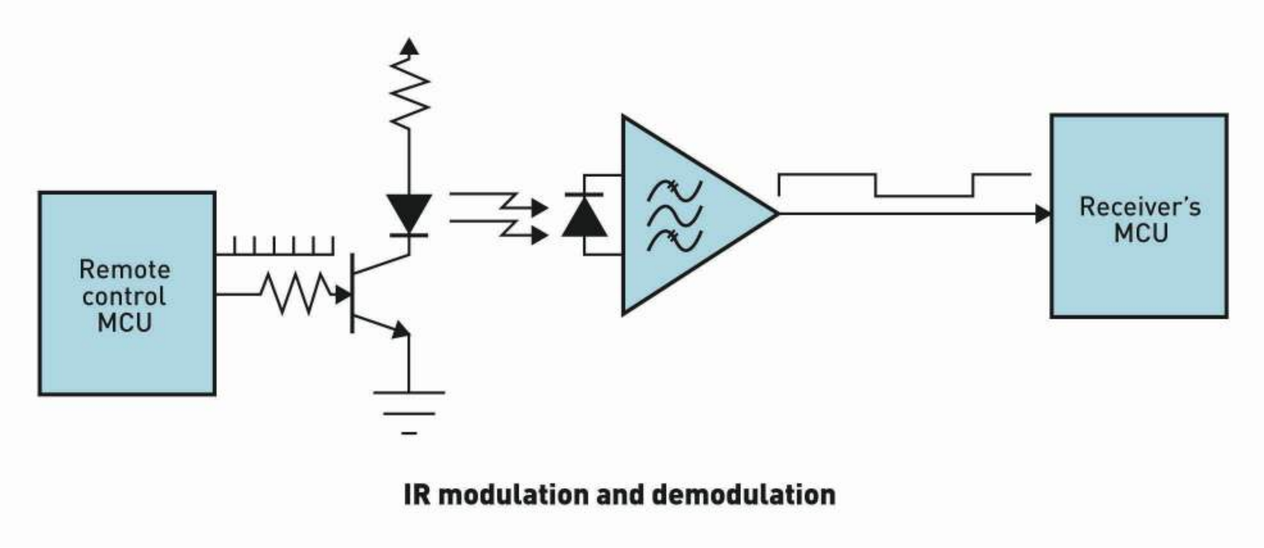

Fig. 1. Schematic illustrating IR modulation and demodulation

There are many modulation protocols but most are frequency or format variations of a few base protocols. Examples include amplitude modulation, frequency modulation or pulse modulation. For example, with pulse distance encoding, pulses remain the same length, while intervals between are either long or short (representing "0" and "1" respectively – see fig.2.). This protocol is favoured by many consumer electronics companies and features a data payload of 8 bits address and 8 bits command, sent twice for reliability.

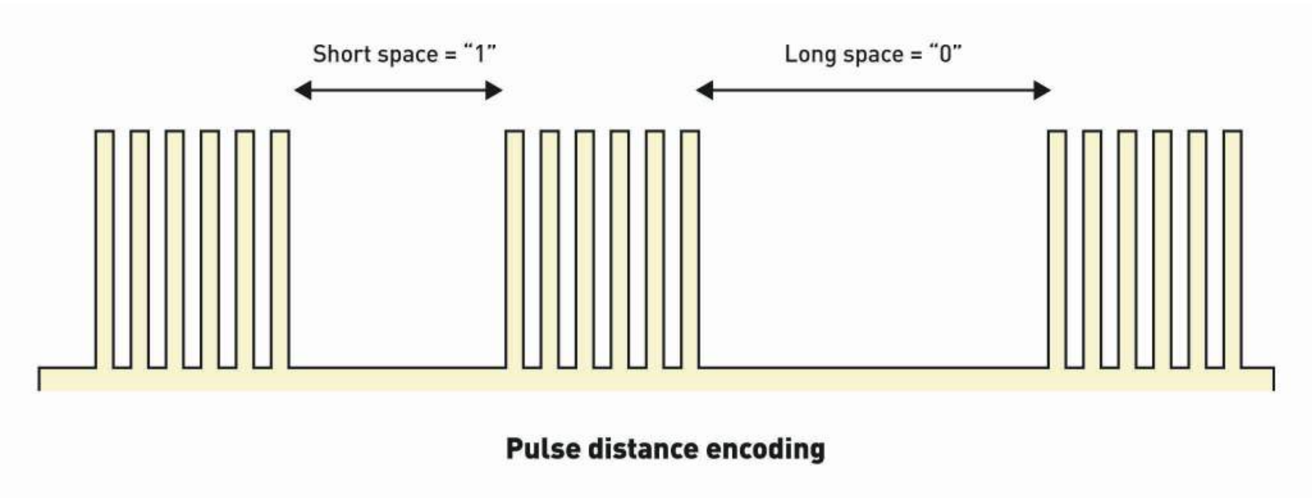

Fig. 2. IR remote pulse distance encoding protocol

In this example, a 9 ms train pulse precedes the data, followed by a 4.5 ms mark, then around 54 ms for the address and command information. IR communication is typically one way. That means the remote has now way of knowing if the signal has been received. The remote will dumbly repeat the command as long as a button is pressed. This example protocol provides repeat frames every 110 ms, meaning the IR remote control is transmitting for perhaps 90 ms during a half-second key press key press (see fig.3.). At, for example, 50 key presses per day, that's a duty cycle of around 0.005 percent.

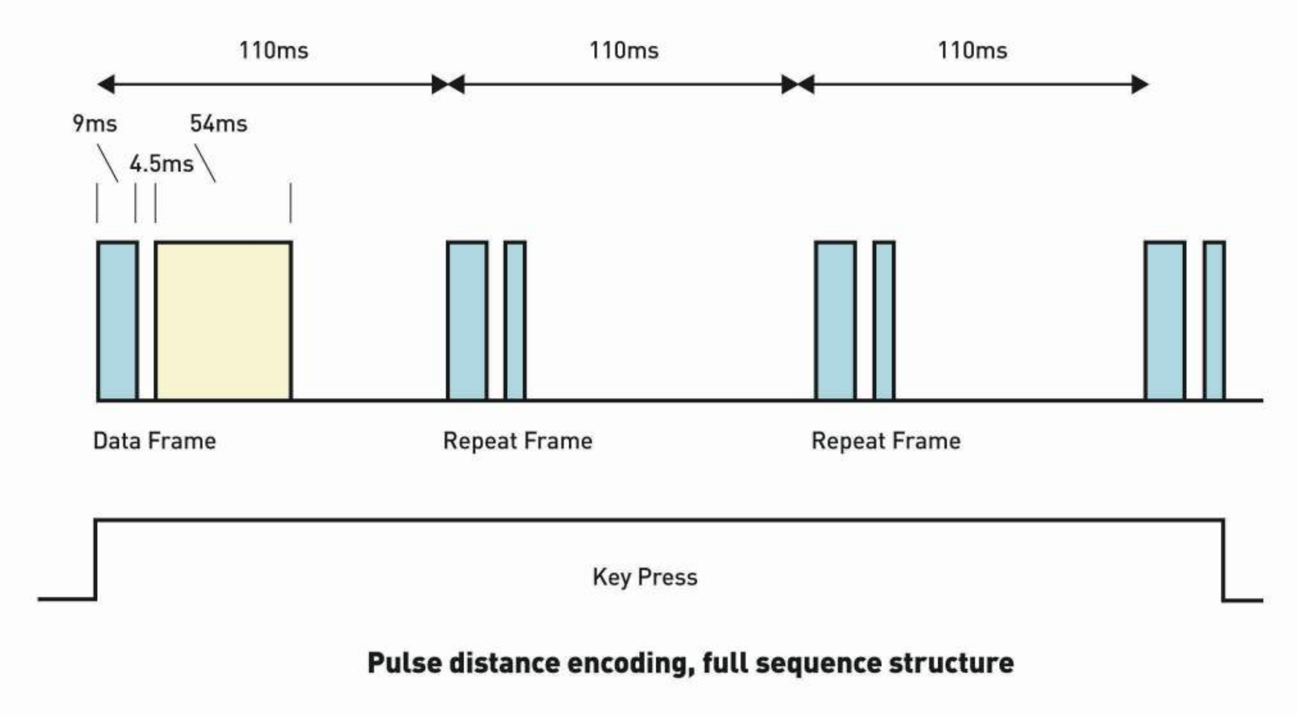

Fig. 3. Pulse distance encoding full sequence structure

While operating at, for instance, 2V, the remote draws around 100 mW. Negligible power is drawn while the remote is in "standby" mode. Two AAA cells connected in series, with a capacity of 900 mAh, provide 2 x 1.5 V x 900 mAh = 2700 mWh. Assuming no DC-to-DC conversion (to keep costs down), and discarding voltage reduction as the battery ages, battery life is 2700 mWh/100 mW = 27 hrs. However, with a duty cycle of 0.005 percent, users would not expect to change batteries for many months or even years.

However, while IR's simplicity, low-cost and low-power consumption has ensured its widespread adoption, the technology is not without its weaknesses.

Consider the consumer of a wall-mounted air conditioner for example; to change the temperature, the user either takes a chance that the IR beam will reflect from surfaces such as walls and ceilings or turns to ensure the remote aims directly at the air conditioner to ensure alignment of IR emitter and receiver.

In a second example, the proliferation of media centers – central PC-based entertainment devices serving as sources of music, video, and other digital files – finds consumers wanting to change volume, channel or website from another room where satellite TV, speakers or monitor are situated. Traditional IR remote controls rely on line-of-sight (or at least direct reflection) and have a range restricted to a few meters.

Third, consumers are increasingly demanding two-way communications. While it is theoretically possible to create two-way communication with IR, real life problems such as (light) interference and low data rate make this a poorly performing system. Moreover, attempting to incorporate two-way communications complicates the remote control's design, adds cost and drains battery power, cancelling out the inherent advantage of the IR remote design.

The RF alternative

RF has been an option for remote control for some time (it was first used over a century ago) but until now the technology's relative expense, design complexity and power consumption have made it uncompetitive with IR for the vast majority of applications. However, the development of a new generation of low power RF transceivers has changed all that.

Nordic Semiconductor's ultra-low power and inexpensive nRF24LE1 2.4 GHz transceiver with Gazell RF communications software is an ideal solution for designers wanting to develop a robust RF system with battery life equivalent or better that that of an IR-based design.

The very mention of RF design is usually enough to scare all but the most confident designer. But while it's true that RF design is not simple, Nordic Semiconductor has worked hard to ensure it's no longer solely the domain of the RF expert. Very high integration in the transceiver, and the availability of development kits and reference layouts, makes it possible for any competent electronics design engineer to incorporate wireless hardware into their latest product.

To ease the design process, Nordic Semiconductor offers an RF remote control reference design, the nRD24H1. The device (transmitter) side of the nRD24H1 is implemented as hardware module fitted on a six-button remote control application board. The module includes a PCB antenna, a 2.4 GHz transceiver and an 8-bit MCU (see fig.4.). The RF module supports up to 49 button inputs plus status LEDs. An alternative layout is fewer input buttons combined with various serial interfaces for display support.

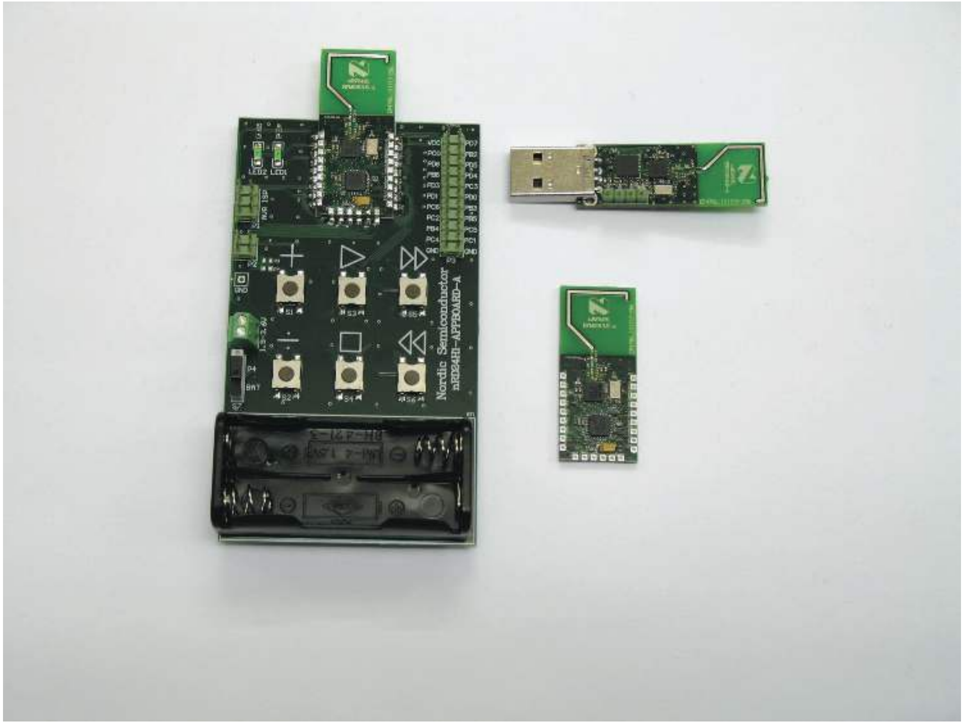

Fig. 4. RF remote control development kit

The reference design's host (receiver) is a production ready, full-speed USB dongle supporting the HID (Human Interface Device) class with descriptors for all commands defined in Windows Vista. A USB compliance certificate is included in the kit and test ID is obtained for USB.org. This means that providing changes to the supplied USB module are limited, USB compliance can be obtained simply by referring to this design.

The nRD24H1 includes all firmware needed to make a remote control. The key part of this firmware is a complete two-way RF protocol stack for remote control applications. The protocol stack is implemented as a standalone software module providing an API (application programming interface) to the application layer. On top of this protocol stack, a simple application layer example, specific to the six button application board, is also included. Consequently, there is no need to get to grips with all the details of the RF protocol stack; programmers can instead focus on modifying and enhancing the application layer code. All the firmware for the reference design is provided as open source ANSI-C code enabling anyone to use it directly or port it to their own microcontroller platform.

The protocol stack provides an ultra-low power two-way communication link with frequency hopping capabilities, dubbed a frequency agility protocol (FAP). This means that one- or two-way remote controls can be implemented without having to worry about RF link up, synchronisation, co-existence with other RF systems or protocol power management.

The protocol offers two modes: Low latency mode and low power mode.

In low latency mode, when a button is pressed the device (the remote control) powers up, transfers the command input to the host (USB dongle) and receives data back if requested. This cycle takes around 500 μs. If the first communication attempt is not successful, the protocol utilises the automatic acknowledge and re-transmit features of the nRF24LE1 to re-try communication on several frequencies. This feature avoids loss of data due to multi-path fading or interference from other 2.4 GHz RF systems. (See fig.5(a).) Lab tests at Nordic Semiconductor have shown that in the typical domestic environment the system will need to re-transmit 4 to 5 times giving an average latency (including RF power on and link up) from button press to data acknowledgement by the USB dongle of 2.5ms. If the remote is in the presence of a strong Wi-Fi (802.11g or 802.11n) interference, this latency increases on average to 3.5ms.

In this low latency mode, the nRF24LE1 in the host (USB dongle) is permanently on (with an RF current consumption of 12.5mA). This current consumption is usually not a problem if the receiving apparatus is mains-powered (for example TV set or a computer). However, if the host side is battery-powered or power consumption is a restriction for other reasons, the protocol can be set in a low power mode. (See fig.5(b).)

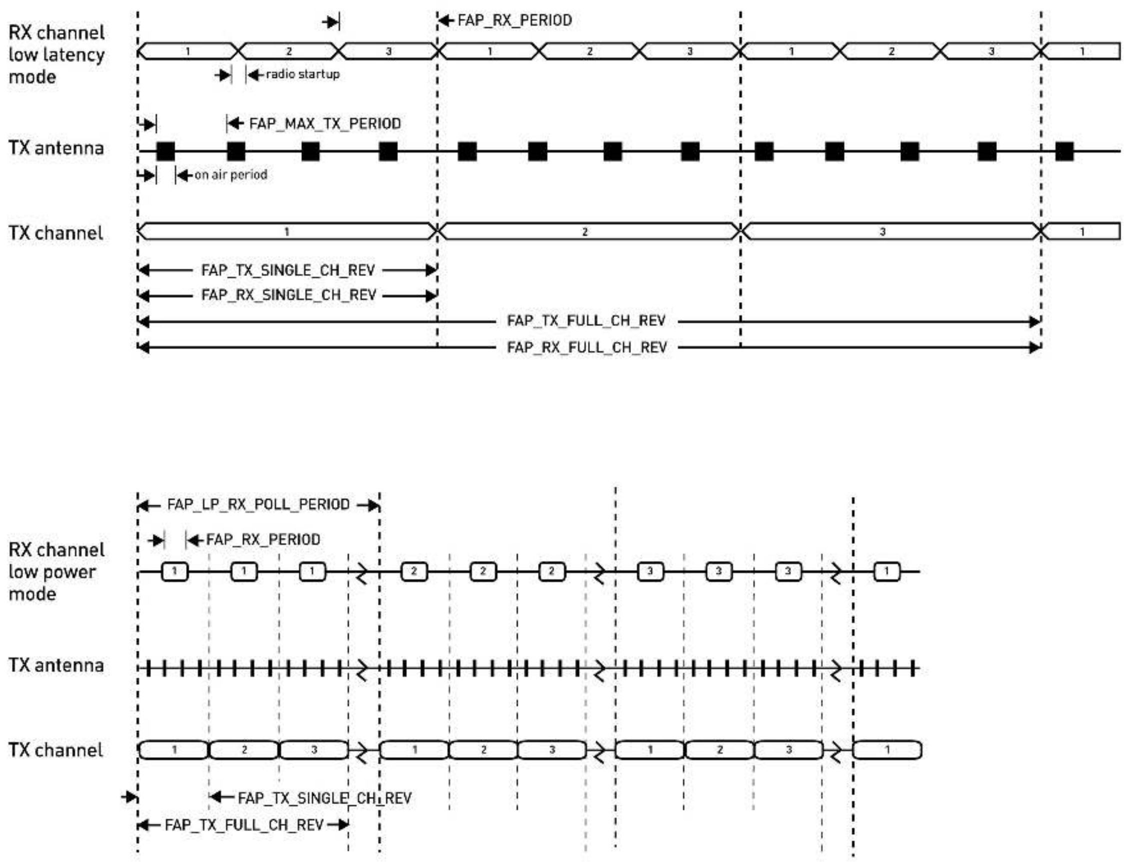

Fig. 5(a) and (b). Low latency and low power frequency agility protocol

In lower power mode, increased latency is introduced to reduce the average current consumption on the host side. This mode can be used to meet low power requirement such as ‘suspend mode’ on an USB bus (implemented in nRD24H1) or ECO requirements in other remote controlled applications such as TVs or stereo sets. The average current consumption (and hence latency) can easily be controlled by input parameters to the protocol stack and the latency will vary from a few milliseconds in the low latency mode up to 30 to 50 milliseconds when operating in the low power mode. This helps the design to meet ECO requirements ($I_{average}$ of two to four mA) and less than one second in the case of waking a suspended USB bus (USB dongle total $I_{average}$ < 0.5mA).

In other words, latency can be chosen based on key design criteria, but in any case, the RF remote’s speed of communication is inherently a lot faster than an equivalent IR remote. In low latency mode the latency is around 2.5 ms, in low power this increases to 30 to 50 ms. This compares with the 70 ms it typically takes for the IR remote control to transfer its first ‘training’ sequence. Assuming the IR receiver doesn't receive this first command sequence because of interference or obstruction – a likely situation – the minimum IR remote latency is greater than 110 ms (the time to the first repeat frame).

While the benefit of this faster communication may not seem so important when considering only the basic remote command transfers typical today, it becomes increasingly important as the payload to be transferred increases. A good example is a remote control with a display, whereby the command from the remote to the host is short and simple, but the reply from the host comprises the large payload required to update the remote's display. The RF system's low latency ensures frequent refreshes and a pleasing consumer experience.

While Nordic's transceivers are keenly priced, the RF solution's BOM, including peripheral devices is likely to be more expensive than an IR remote control's, but the difference is so low that it's outweighed by the added value of the extra features realised by RF technology.

What's more, as a proprietary product, there's no drawn out ratification process for an nRF24LE1-based product (although you do need to ensure your design meets local governmental regulations such as Europe's ETSI and the US' FCC regulations).