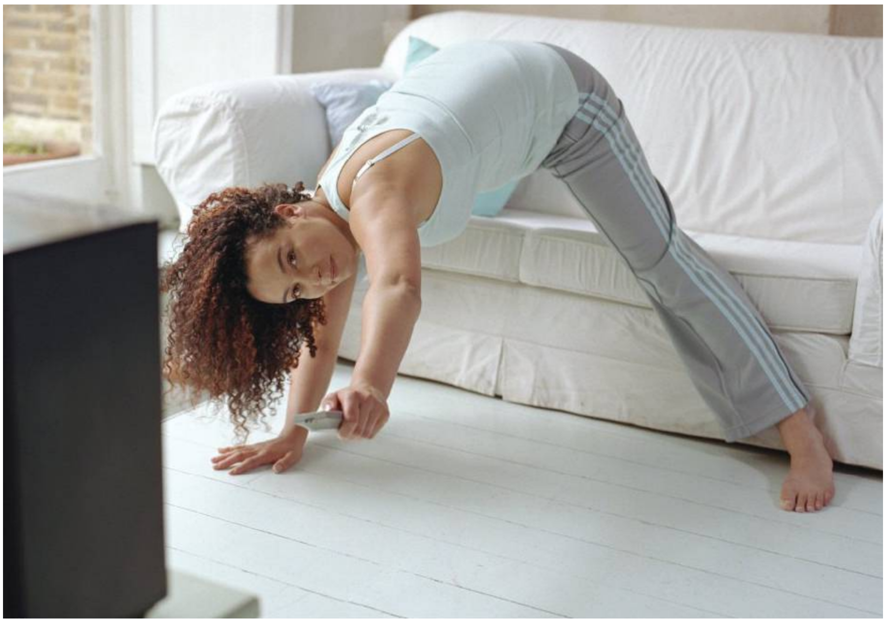
Remote Controls – Radio Frequency or Infrared

Whitepaper by Martin Gotschlich, Infineon Technologies AG, 2010



Content

Introduction

Do you remember those times when you needed to stand up and step to your television set to change channels or tune the volume? Or are you young enough and already grown up with an infrared remote control in your hands? No doubt, the comfort provided by remote controls is essential in our everyday life. Infrared (IR) remote controls have proven being a cost efficient solution for controlling many kinds of electronic devices: Home entertainment, air condition, home lighting. But there are some limitations and disadvantages using infrared light as the medium. During recent years there is a strong trend towards radio frequency (RF) remote controls. Delivering even more comfort for the user, the bill of materials could be shrunk to a competitive level and now being competitive with IR.

In this paper you will read about the differences between IR and RF remote controls not only from the user's view but also from the engineer's view who has to design such remote control systems.

Joint Aspects of IR- and RF-Remote Controls

The remote controller itself, also called transmitter, is a mobile device and has to provide good usability in human's hand. The only reasonable power source is batteries. Regardless of using disposal or rechargeable batteries, AA-cell, AAA-cell, 9V-PP3-block or button cell batteries, minimum power consumption is one of the most important requirements. Not only the active mode supply current directly following a button press is of interest (up to 500mA peak current in IR-emitting diodes). Even more challenging is a low idle current during times when no button is pressed.

The active current is basically defined by the output power of the transmitter and the duration of such a remote command. Different protocols for IR and RF are established, some of them are standards or at least de-facto standards. All of them show a different number of information bits, different modulation and coding, and different data rates. While single-event commands are rather short (e.g. power-on or channel-up) there are also tuning-commands where a button is held down for a longer period (e.g. volume-up). When selecting or defining such a protocol the engineer has to find a tradeoff taking the following parameters into account:

- **Bitlength of command data frame:** The lower the number of bits in a frame, the lower the energy consumption. On the other hand, longer frames allow longer synchronization patterns and more payload information content.
- **Bitrate:** Higher bitrates result in shorter duration of transmission. On the other hand, higher bitrates require faster receiver hardware and higher bandwidth for radio remote controls.
- **Reliability:** Stability of the link may be increased by additional error detection bits in the data frame (e.g. CRC).
- **Receiver architecture:** Depending on the receiver and modulation concept, the protocol possibly must by free of DC-components (see Manchester Coding) and must provide a suitable run-in-sequence giving the receiver the chance to adapt to changing media conditions.

The power-down current is defined by the microcontroller design waiting for a wake-up triggered by a button press. High-end remote controllers may offer additional features which further contribute to the overall power consumption: Illumination of the push-buttons, LCDs, self-learning features and many more.

One interesting topic is the need for security. Depending on the application there may be the requirement for a secure link to avoid misuse of the controlled device (e.g. remote keyless entry for automotive or garage door openers). Suitable encryption algorithms (e.g. AES, XTEA, ..) and rolling-code mechanisms changing the transmitted bit-pattern each button-press are commonly used for security relevant remote controllers. The exchange of encryption keys introduces some additional complexity to the secure system. Furthermore, encryption and decryption are consuming additional power regardless of being implemented in a hardware engine or in microcontroller firmware.

In contrast to the mobile remote controller, the controlled device (e.g. TV-set) is typically mains supplied. But this fact does not relax the demand for lowest power consumption. Being ready to receive commands at any time during stand-by (waiting for power-on command) this is an essential contributor to the electrical energy consumption in households. This “waste-of-energy” is not caused by the receiver circuit itself but mainly by bad efficiency of power-supplies especially when operated at current consumption much lower than its nominal values required for power-on-operation. The European Union has issued regulations limiting the stand-by power consumption of electrical equipment to 2 Watt (1 Watt from 2014 onwards).

IR data communication

Infrared remote controls use invisible light pulses below the visible wavelength spectrum (approx. 950nm). In terms of its radiation behavior it is like any other visible source of light: There must be a line of sight between the transmitter (light source) and the receiver (light detector). Any obstacles between transmitter and receiver will prevent from correct reception. Under good conditions scattered light or light reflected from walls may keep the system working. Having walls between the remote controller and the receiving device will definitely disable the remote control. This obvious disadvantage of IR remote controls simplifies the protocol at the same time. All remote controls for the same device model may use identical coding. There is no need for explicit pairing between transmitter and receiver with dedicated unique codes as the differentiation is guaranteed by optical separation of identical devices.

Practically there is no legal regulation of the maximum emitted light power. This is more limited by power consumption (battery lifetime) and range. Up to 10 meters is the typical range of infrared remote controls assuming perfect conditions (controller physically oriented towards the receiver, no obstacles, and no disturbance of other light sources). To make the infrared connection more robust against any other infrared light sources (e.g. electronic ballasts of fluorescent lamps) the remote control signal is on-off-pulsed at a frequency of approx. 38 kHz. The data information is modulated on this 38 kHz-carrier using on-off keying. The bit information is represented with pulse distance coding or Bi-Phase (Manchester) coding.

The advantages of infrared remote systems are obvious: With a very low bill-of-materials on both, the transmitter and receiver-side, they are widely used in many lowest cost applications. On transmit-side there is just the need for a very simple microcontroller. The number of required input- and output pins is basically defined by the number of buttons on the controller. The IR-LED is simply connected to one of the output pins of the microcontroller directly or in some cases driven by an additional transistor stage. As a time-base a crystal is rather over engineered; most designs rely on a cheap ceramic resonator or even a RC-oscillator with rather poor frequency stability (up to +/-5% may be tolerated by the receiver). Disposal batteries are the first choice for the power supply. As the dimensions of the remote controller case are mainly defined by the number of buttons and ergonomic aspects there is enough space for cheapest AA- or AAA-cells.

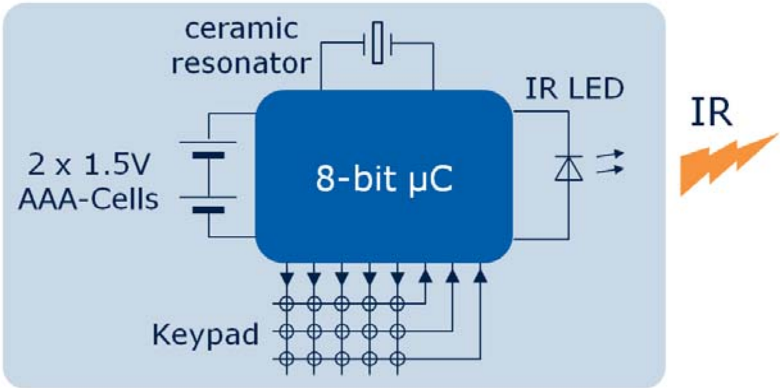


Figure 1: Block diagram of a typical infrared remote controller

On the receive-side the bill-of-materials is basically defined by the infrared sensitive transistor. Today, many designs use an integrated infrared receiver component which not only includes the IR-transistor but also a demodulator and an automatic-gain circuit (e.g. TSOP 1838,TSOP 11xx, SFH 506, SFH 5110). Its output is already a digital signal with clean edges for easy protocol handling by a microcontroller. As the data rate on infrared is rather low (approximately 500 to 1000 bit per second) a microcontroller which is anyway in the receiving device may handle the IR-reception as a side task by simply measuring the time distance between edges using a timer. The real design challenge is the power supply concept since the remote control receiver must remain active even in stand-by mode of the system.

IR protocols

Most IR-protocols contain the following information: A device address which is the same for all devices of the same model type and a command (e.g. volume up). Simple strategies improving the link robustness are commonly used: For example resending of the same bit-pattern in an inverse manner. Comparing the payload received in different versions enables the receiver detecting errors in the received bit-stream. Such frames are simply ignored. Some extended features in IR-protocols are:

- Toggle bits changing their state with each button press enabling the receiver to distinguish continuous button presses from re-presses easily.
- Battery down bits: As soon as the battery charging level of the transmitter falls under a certain threshold this bit will be set. The receiver will signalize this to the user who has the chance to change batteries before a sudden break-down.

Most IR-protocols use one of the following modulation techniques representing one- and zero-bits on the 38 kHz carrier:

- **Pulse distance coding:** The bit information is represented in the distance of edges. Typically, this coding is not free of DC-components. But this is no real issue for IR-receivers. It is rather simple to decode the information in the receiver’s microcontroller by measuring the pulse durations using a timer.
- **Manchester coding:** The advantage of Manchester Coding is that it is free of DC-components. This enables receivers to perfectly adjust the decision threshold between incoming high- and low-levels. Decoding is slightly more difficult in the receiver’s microcontroller since the direction of the edge in the middle of each data bit has to be detected (rising or falling).

Find below the timing diagrams of two typical infrared protocols. The RC5-protocol was initially defined by Philips and SIRC was introduced by Sony. Both are widely used for home entertainment equipment today.

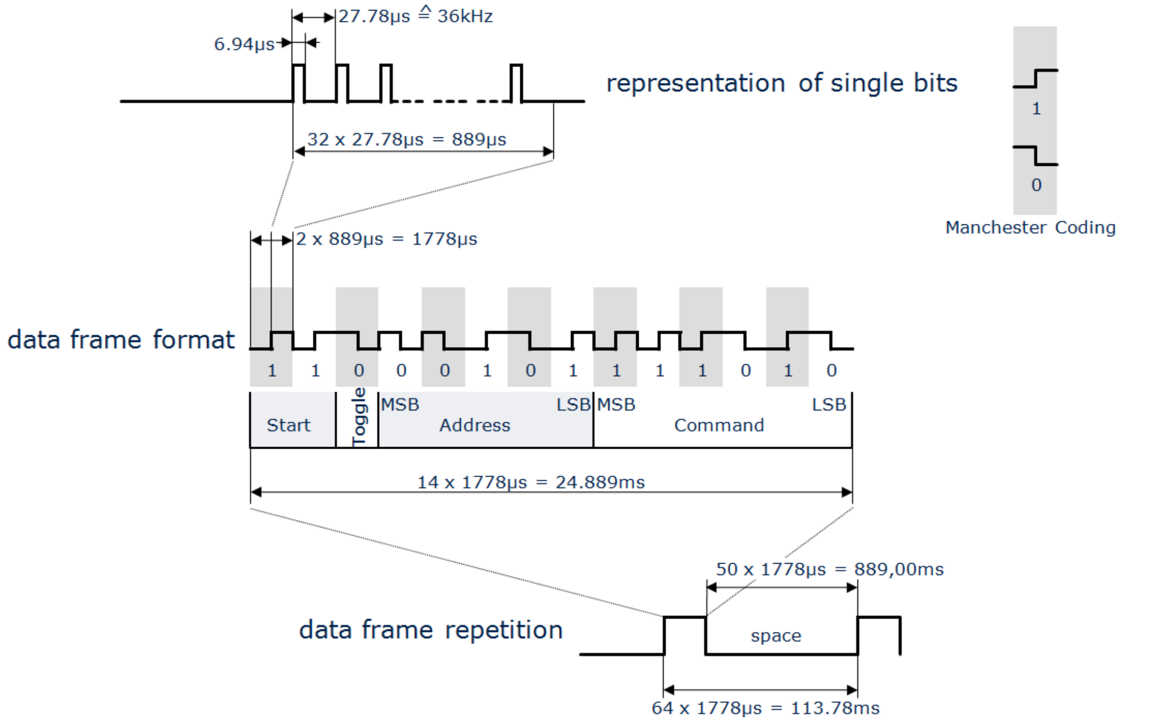


Figure 2: Philips RC5 infrared protocol

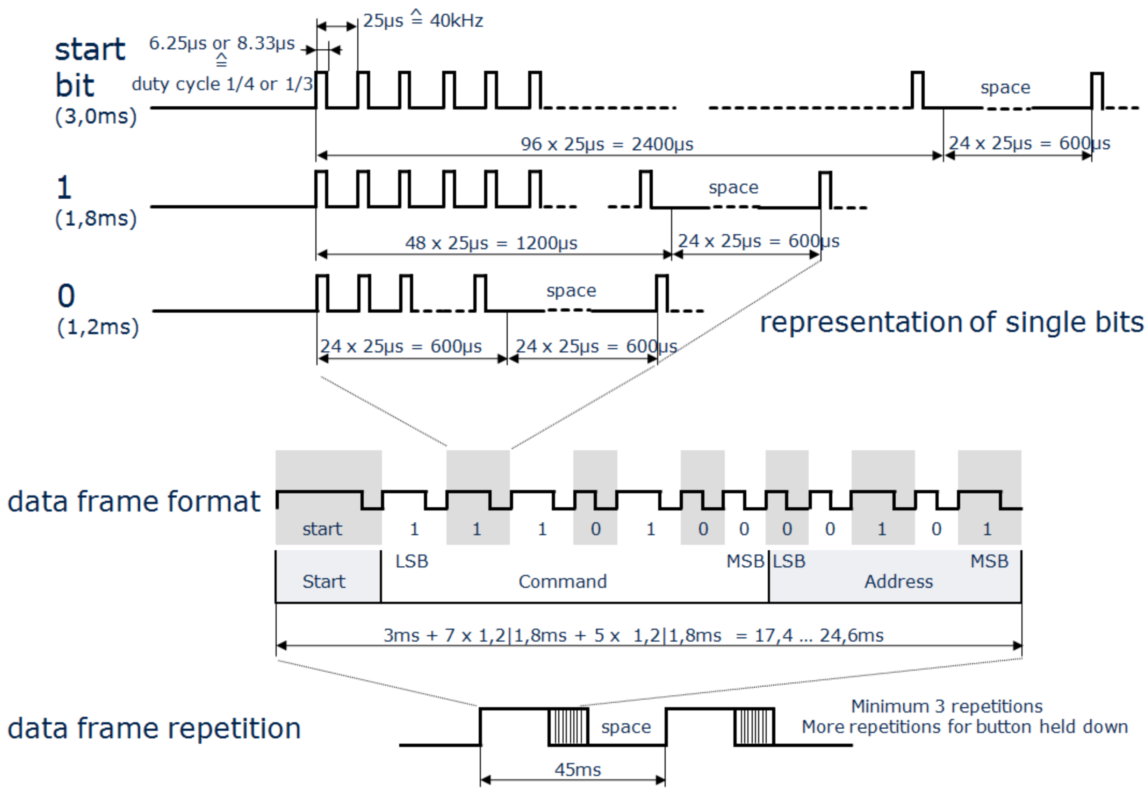


Figure 3: Sony SIRC infrared protocol (12 bit version)

These two protocol examples, RC5 and SIRC demonstrate the typical differences between common IR-protocols. While RC5 is using Manchester-Coding, SIRC is using Pulse-Distance-coding. RC5 transmits most significant bits (MSBs) first; SIRC LSBs first. SIRC is using a reserved start-bit symbol for easier identification of frame start by the receiver. RC5 provides a toggle-bit which enables the receiver distinguishing repetitive button presses from continuous button presses. With each new button press the state of the toggle bit will be simply reversed.

A good source for finding more information about infrared protocols is the Linux Infrared Remote Control project (LIRC): http://www.lirc.org. LIRC defines a description format for all kinds of infrared protocols. Actually, the formats of all IR-protocols on the market can be found on the internet in LIRC-config-file representation (see http://lirc.sourceforge.net/remotes).

RF data communication

Radio frequency communication uses electromagnetic waves as transmission medium. Their propagation properties allow connections of extremely high distances. Electromagnetic waves pass through non-shielding materials to some extent (e.g. concrete walls). This attractiveness demands some limitation enforced by world-wide regulations defined by standardization groups (e.g. ETSI, FCC, …). For all regions of the world there exist binding regulations covering following aspects:

- Frequency bands (spectrum)
- Maximal power of emitted radio waves
- Bandwidth of emitted signal
- Duration of emissions (duty-cycle)
- Purpose of emission (e.g. TV broadcast, mobile phone networks, authority's communication, general purpose)
- License fees

For remote control applications there are some license-free bands available, the so called ISM-bands (industrial, scientific and medical bands). For Region 1 (Europe, Africa, former Soviet Union) the most attractive frequency band is at 434 MHz, for North and South America at 902…928 MHz. Additionally, in Europe the SRD-band (short range device band) at 868 MHz and in the US the frequency band at 315 MHz is commonly used for remote controls. An alternative with world-wide compatibility is ISM-band at 2.4 GHz. Unfortunately 2.4 GHz requires higher power consumption at comparable range and therefore higher cost. Practically, RF remote controls use 315, 434 or 868 MHz as RF carrier frequency.

The payload data needs to be modulated on the RF carrier. Basically, there are two rather simple modulation techniques popular: Amplitude Shift Keying (ASK) and Frequency Shift Keying (FSK). For power consumption reasons, ASK is mostly implemented as On-Off-Keying (OOK). That means, the carrier is simply turned on and off (as this is done for infrared communication described above). Transmitters for both techniques, OOK and FSK, may be implemented as Class-C-power amplifiers resulting in high power efficiency. With OOK there is no need to change the carrier frequency at all. In this case, SAW-based transmitters are the first choice if some frequency tolerance is accepted. Using crystal stabilized PLL-synthesizers allow higher output power as they do not need any safety margins in terms of the regulation's limits. For FSK, SAW-based transmitters may be used only with some limitations and tricks as the output frequency must alternate continuously. Therefore, FSK is preferably implemented with PLL-synthesizers which allow exact generation of both frequencies by digitally switching the divider-factor of the PLL. Generally, FSK provides better robustness against disturbers at the price of higher hardware complexity and slightly increased power consumption.

Some know-how and effort must be spent for the design of the antenna itself and the matching network between antenna and Tx- or Rx-IC. Modern software tools simplify the designer's life in doing this important design step. The challenge is finding an antenna design or concept which represents a perfect compromise between cost and performance. Furthermore, a clean RF design is essential for meeting the radio regulations.

Bi-directional RF Remote Controls

High-end remote controls may be based on bidirectional RF links. In addition to the link from the remote controller to the controlled device there is an additional links backwards from the device to the controller. This backwards-link may be used for several purposes:

- Securing the robustness of the remote link by using handshake-protocols: The controller is waiting for a positive acknowledge that the command was successfully received. Otherwise, it will start a new transmission attempt (maybe with higher output power or on a different RF channel).
- Giving feedback to the user: A display on the remote controller may visualize information from the controlled device (e.g. device status). This may be of special attractiveness when there is no line-of-sight between the user and the remote controlled device.

Bidirectional RF-links are implemented using so called RF-transceiver ICs which include an RF-receiver and RF-transmitter sharing one single PLL and using one single antenna. Infineon's TDA7255V is a typical example of such a RF transceiver IC: http://www.infineon.com/TDA7255V.

RF protocols

Basically, RF remote control protocols have to represent the same information as IR remote control protocols: Device address and command. But, communication via RF demands some additional measures (see chapter **Things to be added going from IR to RF** below). The power consumption of a RF-transmitter is not as high as of an IR-LED and maximum data rates of a RF-link are higher resulting in frames with shorter duration. As a consequence, frames with a higher number of bits and more information content are possible using RF while saving battery life time at the same time. This fact enables some more fancy features for RF remote controls.

Each RF remote control requires a unique ID. This may be compared with the device address of IR remotes. The only difference is that IR uses the same address for the whole series of devices of the same model type whereas RF remotes use real unique IDs meaning that each transmitter world-wide has another ID. Therefore, the bit length reserved for RF IDs is longer (e.g. 32 … 40 bit).

As mentioned above some IR protocols provide a toggle bit for identification of successive button presses. Some RF protocols even implement a counter signalizing how often a button was pressed repeatedly.

For improved robustness of the RF link CRC-values (cyclic redundancy check) are often generated and transmitted as part of the frame (e.g. 8 bit). The receiver may clearly identify any bit-errors by recalculating the CRC-value of the received data frame and comparing it with the one generated before transmission.

The transmitter's battery charging level may be signalized not only by a single bit (battery low bit) but even with a complete 4-bit or 8-bit data-field representing the measured battery voltage.

Additional security may be introduced by rolling codes changing some bits with each button press (e.g. simple 16 bit counter) and encryption of the complete or at least a part of the payload (e.g. AES or XTEA).

Find below a typical example of RF remote control protocol as implemented in Infineon's PMAfob application example (see http://www.infineon.com/PMAfob):

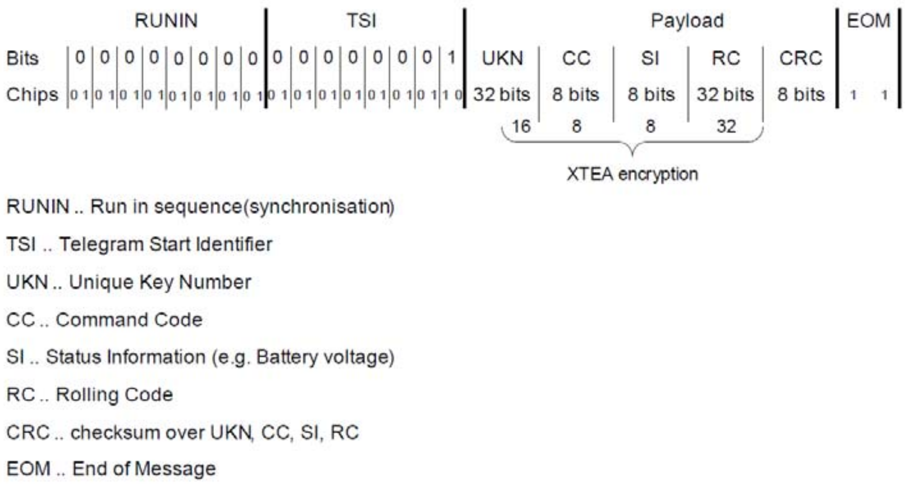


Figure 4: PMAfob RF remote control protocol (XTEA encryption mode)

Differences between IR and RF

Following table summarizes the general differences between IR and RF remote controls:

	Infrared	Radio Frequency
Power consumption transmitter (active during transmit)	20 … 150 mA (sometimes up to 500 mA peak) depending on number of LEDs and range	5 … 20 mA
Power consumption transmitter (stand-by)	Depending on microcontroller idle current (<1 µA)	
Power consumption receiver (stand-by)	Approx. 1 mA	Approx. 5 mA in continuous Rx-operation. Lower than 1 mA when applying a polling scheme.
Range	Up to 10 m Limited by Tx battery lifetime	Up to 50 m at free line of sight Lower room-to-room range inside buildings Limited by regulations (FCC, ETSI)
Bi-directional option	Practically, no (due to power consumption)	Yes (for additional link robustness and extended features, especially for out-of-sight operation)

Bit-length of frame	Restricted by battery life-time (typically max. 40 bit per frame)	Typically, 80 … 140 bit possible. For extended features like security, robustness and additional status information (e.g. battery voltage status).
Datarate	Typ. 500 bit/s … 1 kbit/s	Up to 100 kbit/s
Regulation	No limitations	Regulated in world-wide standards (ETSI, FCC, …). Need for compliance tests.
Expected design effort	Low	Low (using RF-modules), higher when implementing optimized antenna and matching

Things to be added going from IR to RF

The manifold advantages of RF over IR motivate engineers to convert existing remote control systems from IR to RF.

Replacing an IR-LED by a RF-transmitter (-module) and an IR-receiver by a RF-receiver (-module) is not a big deal. Behind this simple sentence there is some considerable design-effort behind. While the IR-hardware is rather simple (an IR-diode as transmitter and an integrated IR-receiver component with a digital output signal as a receiver), RF-hardware is more complex. A simple solution may be the use of RF-modules which comprise all necessary components on a small PCB. The optimal solution is a dedicated transmitter and receiver design. This gives the chance to use specific antenna designs and a suitable antenna matching design.

Anyway, in many cases the effort shall be as low as possible and the changes on transmitter and receiver side shall interfere with the rest of the system to a minimal extent only. The naive idea to keep the IR-protocol basically unchanged and to modulate the same data frame on a RF carrier seems being a smart solution. Unfortunately, this will not work for the following reasons:

Receiver wake-up

As mentioned above, low stand-by power consumption of the receiver is an essential requirement. While an IR-receiver may remain powered at considerable low consumption (approx. 1 mA), an RF-receiver is consuming 5 mA or even more. To overcome this issue a suitable polling scheme may be applied. During polling the receiver is switched on for a short time period to check whether there is a valid signal available. If not, the receiver falls back in power-down-mode immediately. Depending on the polling interval a suitable RF protocol has to be designed. After pressing a button on the remote controller a pre-defined run-in-sequence being long enough must be sent giving the receiver the chance to wake-up after the end of the polling interval.

Synchronization of receiver with incoming data clock

Infrared protocols are very robust in terms of timing accuracy. Even with considerable high clock instabilities it is possible to distinguish zero- and one-bits. RF communication is much more sensitive on clock errors. Therefore, the receiver has to measure the incoming data frame clock before starting payload decoding. Long enough preamble (run-in and sync-patterns) with fixed content (e.g. 000…0001) in the protocol enable the RF-receiver to synchronize with the incoming signal's clock.

Coding

Infrared communication is rather robust against disturbers (e.g. sunlight) using a 38kHz-on-off-modulation. In contrast, RF is much more sensitive to noise. Therefore, RF receivers automatically adjust their zero-one-decision threshold (data slicer) based on the incoming data signal. In order to have a well positioned decision level, zero- and one-bits must be deployed in a balanced occurrence. This is implemented by coding the actual payload with codes being free of DC-components. One of the commonly used codes for this purpose is Manchester coding which represents each bit of the payload with two consecutive unequal chips. The actual bit-information is represented by the center edge in the middle of the two chips. A rising edge relates to a one-bit a falling edge relates to a zero-bit (or vice-versa).

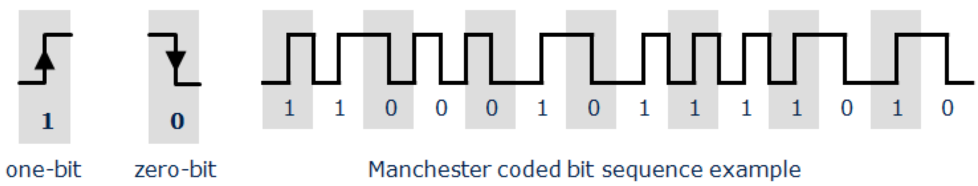


Figure 5: Manchester Coding (DC-free)

One disadvantage of Manchester-coding is obvious: Actually, the number of bits on the channel (called chips) is twice as high then in the payload as each payload bit is represented by two chips. That means that the actual bitrate and bandwidth requirements are twice as high as for uncoded data.

Unique ID and Pairing

As IR communication is restricted on a line-of-sight between transmitter and receiver there is low risk that identical systems in the neighborhood are influenced unintentionally. All models of a given equipment type are using the same identification and their remote controllers are exchangeable. In this sense the higher range of radio remote controls going even through walls turns out being kind of a problem. There is high probability that somebody controls the equipment in a nearby room without intention. As a solution to this problem, RF transmitter and RF receiver have to be paired using a unique code embedded in the data frame. Usually, each RF transmitter provides a hardcoded unique identifier. The receiver has to be paired to each of the assigned transmitters during a pairing procedure where the receiver learns the unique ID of a given transmitter. Typically, the pairing process is introduced by pressing a dedicated button on the receiver unit. The next received ID will be added to the list of paired devices. In normal operation the receiver will accept only data frames with ID codes being learned during pairing procedure before. All other frames with mismatching codes are simply ignored. As a consequence, the receiver requires non-volatile memory (e.g. EEPROM, Flash, …) to keep the pairing list even during power down.

RF2ir Example – RF to IR converter

Following design example named RF2ir perfectly illustrates the differences between IR and RF remote control systems.

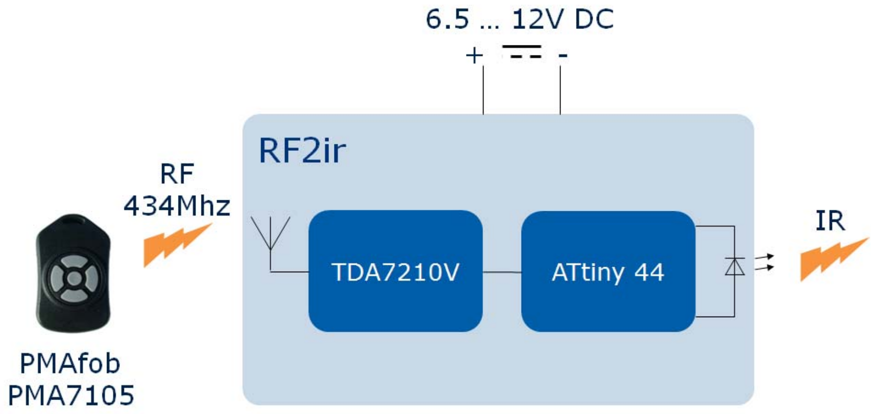


Figure 6: RF2ir block diagram

It represents a converter between the two worlds: Receiving RF-commands and transmitting related IR-commands. On the RF-side it is compatible with Infineon's PMAfob© remote controller. More information about this keyfob design, its internal hardware based on the SmartLEWIS™ MCU PMA5105, the firmware and the protocol is available here: http://www.infineon.com/PMAfob

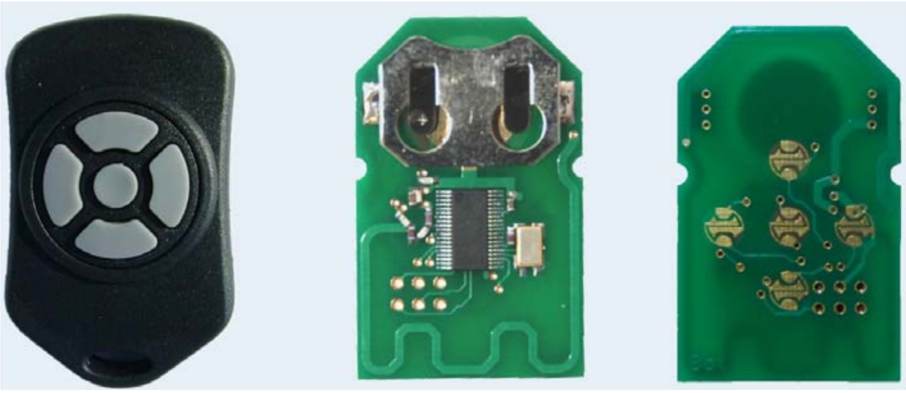


Figure 7: PMAfob - fotos of housing and PCB

For this RF-to-IR-converter there is not any special encryption for the data frame implemented as this is not required for typical home entertainment systems. Infineon's new TDA7210V super het receiver demodulates the incoming RF-commands. This robust receiver provides excellent performance (sensitivity up to -118dBm), does not require any digital register configuration and is perfectly suited for consumer applications with its low size VQFN-package. More information about the TDA7210V is available here: http://www.infineon.com/TDA7210V

An Atmel AVR ATtiny 44 microcontroller is used to reconstruct the received RF data frame (clock recovery, data slicer and decoder), extract the remote control command and to build up an IR data frame with an equivalent command for being sent out via IR. The AVR series is well known in the worldwide embedded systems community. Powerful software development tools are available for free. The firmware for this design example was developed using Atmel's AVR Studio 4 with GNU's avr-gcc compiler. All software used and developed for the RF-to-IR-converter is free under GNU General Public License.

On the RF-side the RF2ir firmware includes a very robust and configurable algorithm which implements the following tasks:

- RF carrier detection
- Clock recovery and synchronization
- Manchester decoding of payload data
- Payload bit-frame extraction

The RF receive algorithm is purely based on time distance measurements between edges of the received digital signal using a 16-bit timer of the microcontroller.

On the IR-side the converter emits commands which can be chosen out of a broad variety of protocols defined by various manufacturers. A comprehensive software library for IR-transmission was published by Frank Meyer under the GNU General Public License and is reused for the RF-to-IR-converter. The homepage of the IRSND-project is located here: http://www.mikrocontroller.net/articles/IRMP#Source-Code_IRSND (German only).

This RF2ir firmware was implemented and verified using a generic ATmega 16 evaluation board connected to a TDA7210V evaluation board. With minimal changes it will be compatible to the ATtiny 44 as proposed above. The source code is published under the GNU General Public License available for download: http://www.infineon.com/RF2ir.

Following microcontroller features are utilized:

- 8-bit timer for generation of the 38 kHz infrared carrier
- 16-bit timer for time distance measurements between edges of the received RF data signal and alternatively as 10 kHz clock for generation of the IR data frame output
- The microcontroller's oscillator with an 8 MHz crystal provide the clock source.

Depending on the configured IR-protocol, the RF2ir firmware example requires a code size of approximately 3300 bytes and uses about 110 bytes of random access memory.

RF2ir - Room for Improvement

Focus during development of the RF2ir design was the illustration of differences between RF and IR. If it comes to a more product focused design there should be some optimization taken into consideration:

The RF2ir example uses two separated crystal oscillators for the TDA7210V receiver and the microcontroller. For the TDA7210V the clock accuracy and stability of a crystal is absolutely mandatory but for the microcontroller an internal RC oscillator may be sufficient. Unfortunately, there is no way to derive a microcontroller clock from the RF-receiver's oscillator.

The infrared-LED is directly connected to one of the microcontroller's general purpose IO-pins. The available current is sufficient for short distances of a few meters. But for a more powerful light source and a wider range a driver stage (one transistor) for the LED is recommended.

In the existing design there was no focus on power consumption. One idea may be adapting the design to the requirements of a battery power source. That means making use of the TDA7210V power-down mode and a polling strategy to wake-up and synchronize the converter just in-time before the payload data is coming in. For such a polling scheme an adaptation of the RF protocol and the run-in-sequence should be taken into consideration.

In this initial version of RF2ir the unique identifier of the transmitter is not evaluated. The receiver reacts on any received frames ignoring the transmitter's identification code. In a productive version a pairing function needs to be added and non-assigned ID codes have to be ignored.

The basic implementation of RF2ir does not care about improved communication robustness and security. A better version of RF2ir may check the consistency of the 8-bit CRC transmitted by the PMAfob transmitter embedded in the data frame by default. Furthermore, encryption of the communicated package (e.g. AES) and a rolling code may prevent from misuse.

Summary and Conclusion

RF remote controls provide multiple advantages for the user compared to IR remotes. Most important is the RF range since the radio signals even pass concrete walls. There is no need for the user to target at the receiver. High robustness of RF links result in increased usability and comfort. On top of that RF communication enables the designer to implement new features and security. Lower power consumption for RF-transmitter allows for smaller batteries which don't have to be replaced for many years of use.

Design effort and bill-of-materials for RF remote controls is already in the range of IR remotes since integrated transmitter- and receiver-ICs simplify the schematic at optimal performance. Comprehensive documentation, tooling and example designs reduce the design-in effort, especially when using components from Infineon Technologies.

Links

IR Remote Controls

Collection of www-links about infrared remote control:
http://www.epanorama.net/links/irremote.html

Linux Infrared Remote Control project (LIRC):
http://www.lirc.org

LIRC-config-files of many devices:
http://lirc.sourceforge.net/remotes

RF transmitters and receivers

General overview of Infineon's Wireless Control product portfolio:
http://www.infineon.com/wirelesscontrol

Integrated microcontroller and RF transmitter SmartLEWIS™ MCU PMA71xx:
http://www.infineon.com/PMA

PMAfob - Design example of an RF remote control based on PMA7105:
http://www.infineon.com/PMAfob

TDA7210V - ASK/FSK Single Conversion RF Receiver IC:
http://www.infineon.com/TDA7210V

RF2ir

Source Code and HW-design example including schematic and PCB-layout:
http://www.infineon.com/RF2ir