Utilizing a Vishay IrDA Transceiver for Remote Control

Table of Contents

Remote Control with IrDA Transceivers

An infrared remote control unit is used to control many common consumer electronic products such as TV's, DVD players, VCR's and CD players. When a button is pressed on the remote control unit, a signal is sent from the unit, and received for example by the TV. The remote control unit contains an infrared emitting diode (LED) that transmits the signal and the TV contains an infrared receiver that receives the signal. This signal "commands" the TV to perform a function like Power-On/Off, Sound-Up/Down, and Channel-Up/Down. The signal contains the TV's address and the command code. Each function will have a different command code. The signal is encoded and transmitted using a modulated carrier wave in the frequency range of 30 kHz to 56 kHz.

There are many different coding systems used for remote control. The most common codes are the RC5®, RC6®, and RMM® codes from Philips and the NEC code. Different products may use different coding systems. For example, your old TV remote control unit may not work with your new TV because they use different coding systems. For products using the same coding system, each product will have a different address to avoid performing a command meant for another product. Figure 1 in the Remote Control Data Formats section provides an example of a remote control signal using the Philips RC5 code when the channel "3" is pressed. For more information about remote control codes, please refer to this section and the document "Data Format for IR Remote Control".

Design engineers of handheld devices such as mobile phones and PDAs are faced with the challenge of combining multiple functions in a single device. Among the new features being integrated into handheld devices is TV remote control. Most of these devices feature a Vishay IrDA transceiver used for short-distance wireless communication. **The transceiver's emitter can be used to transmit remote control signals**. This eliminates the need to design-in an additional discrete LED emitter. At no additional cost or board space, this is an excellent solution.

The remote control signal can be generated by software or by the combination of hardware (Baud Rate Generator or Timer) and software. Remote control applications generally include many of the available coding systems. For handheld devices, it is best if the application supports a "teach" function where the handheld device learns the codes from the remote control unit. The detector of the IrDA transceiver receives the emitted signals to be stored in the handheld application.

18802

Figure 1.

By integrating the remote control application with voice recognition, PDA and mobile phone manufacturers can offer their customers a very attractive capability: while in the process of answering a call, the user can simply say "Mute" to mute the TV. Convert the spoken word into an infrared remote control signal.

Hardware - Interface Schematics

The same hardware interface can be used for Vishay's IrDA transceivers whether used for IrDA communication or remote control. No additional components are required for remote control. The following is a general interface block diagram for IrDA and remote control (RC) using Vishay's new generation transceivers (figure 2).

There are two output signals (IRTXD and SD/Mode) from the controller and one input signal to it. To use the same output line IRTXD of a controller for both IrDA and RC, the IrDA TXD port should be a multifunction port, which supports also GPIO (General Purpose Output) and UART (asynchronous serial data Transmit, in case using its Baud Rate Generator), and its functions can be alternated by software. To use the same input line IRRXD of a controller for both IrDA and RC "Teaching/Learning" function, the IrDA RXD port should be a multifunction port, which supports also GPIO (General Purpose Input), and its functions can be alternated by software.

If the IrDA port does not support UART or GPIO one has to find another port and an extra multiplexer to do the RC.

The circuit diagram in figure 2 shows additionally to the connections for the logic the little external circuit to be added for filtering the supply voltage (low-pass R1, C) and a resistor R2 for limiting the LED drive current. The resistor R2 is only necessary when the transceiver has no internal current control or the current should be reduced to a level lower than the internally controlled current.

Also when operated with a supply voltage Vcc > 4 V the resistor R2 may be necessary when the application is operated close to the maximum temperature limits. "Transceiver" stands here for e.g. TFDU4300 (SIR, 115.2 kbit/s) or TFBS6614 (FIR, 4 Mbit/s). For these the pin numbers are valid.

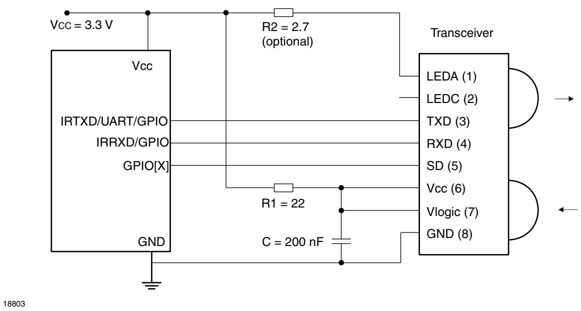


Figure 2. General Interfacing Block Diagram for IrDA and RC
Pin Function Description:
IRRXD/GPIO: IrDA and RC data input
RTXD2/UART/GPIO: IrDA and RC data output
GPIO[x]: the available General Purpose pin, used for SD and Bandwidth Select

In case when only an external RC port is available that can be used to independently switch the LED (or more precise IRED as indicated).

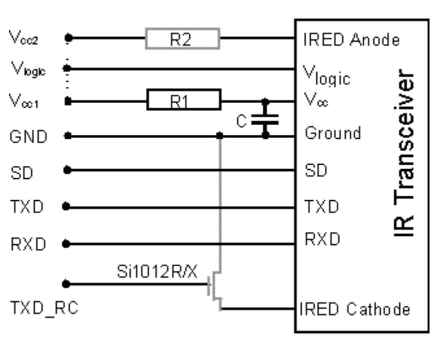


Figure 3. General Interfacing Block Diagram for IrDA® and RC using an n-channel FET when only a separate RC port is available.

In the chapter "Application Examples" samples with the interfacing circuit diagrams of the three most common used microcontrollers are shown, which have the IrDA port built-in and the port supports both UART and GPIO.

Transmit Distance

Factors Influencing Transmit Distance

This section provides a detailed description of factors influencing transmit distance:

- Wavelength of emitter and detector
- Optical intensity of the emitter
- Receiver Sensitivity
- Frequency of the emitter and detector.

Operating Range

The primary factors in the theoretical distance calculation are radiant intensity of the emitter (I_e in mW/sr) and sensitivity of the receiver (given as minimum or threshold irradiance E_{emin} in mW/m²). Calculating transmission distance in the simplest case assumes a square-law relationship between distance d and irradiance Eemin on the receiver. Shown below is the calculation using a receiver sensitivity of E_{emin} = 0.4 m W/m^2 and an intensity of I_e = 40 mW/sr. The distance d is resulting as

$$d = \sqrt{\frac{\text{Intensity}}{\text{Sensitivity}}} = \sqrt{\frac{I_e}{E_{emin}}} = \sqrt{\frac{40}{0.4}} = 10 \text{ m}$$

Transmission distance increases as the intensity increases and as the receiver becomes more sensitive.

Wavelength

Standard infrared remote control uses a wavelength of 900 nm to 950 nm and a subcarrier frequency of 33 kHz to 40 kHz (IEC61603-1). Some manufacturers use a subcarrier frequency range from 30 kHz to 56 kHz. After the use of these wavelengths became standard, the still more efficient and much faster 850 nm to 900 nm emitters became available. These emitters are used in IrDA applications. Vishay further limits the peak wavelength used in its IrDA transceivers to 880 nm to 900 nm with a typical value of 886 nm.

The main difference between an LED used exclusively for remote control and an IrDA LED is the emitted wavelength. The wavelength of Vishay's IrDA LED is ≥ 880 nm while the wavelength of a typical remote control LED is 940 nm.

For longer transmit distances, the spectral distribution of an emitting LED should match the remote control receiver spectral sensitivity. Vishay's IrDA transceivers are effective for remote control because the remote control receiver is sensitive to the wavelength emitted by the transceiver. Figure 4 shows that Vishay's IrDA (886 nm) LED emits a wavelength long enough to be received by the remote control receivers. Though the peak wavelength of the emitter and receiver are not matched, enough radiation is received to function well. Figure 5 shows spectral sensitivity curve of the leading remote control receivers.

Because the peak wavelengths of the IrDA emitter and receiver are not matched, transmit distance is a function of a reduction factor, R_f, derived from the relative responsivity of the receiver $R_f = E_{emin}/E_e$ (with E_{emin} = threshold irradiance at the maximum at 950 nm and E_e = threshold irradiance at the given wavelength). This reduction factor, R_f, is obtained from the curves by reading the normalized sensitivity value (Y-axis) where the receiver sensitivity curve intersects the IrDA emitter's peak wavelength of 886 nm.The wavelength of 886 nm is the specified typical peak wavelength of Vishay's IrDA-transceivers. In the following equations the parameter IrDA represents the wavelength range from 880 nm to 900 nm, CIR refers to the consumer IR wavelength of 930 nm to 950 nm.

$$E_{emin} = \frac{I_e}{d^2}$$

$$d = \sqrt{\frac{I_e}{E_{emin}}}$$

$$E_{emin}(\mathrm{IrDA}) = E_{emin}(\mathrm{CIR}) \times \frac{1}{R_f}$$

$$E_{emin}(\mathrm{CIR}) = \frac{I_e}{d(\mathrm{CIR})^2}$$

$$E_{emin}(\mathrm{IrDA}) = E_{emin}(\mathrm{CIR}) \times \frac{1}{R_f} = \frac{I_e}{d(\mathrm{IrDA})^2}$$

$$d(\mathrm{IrDA}) = \sqrt{R_f} \times \sqrt{\frac{I_e}{E_{emin}(\mathrm{CIR})}} = \sqrt{R_f} \times d(\mathrm{CIR})$$

$$d(\mathrm{IrDA}) = \sqrt{R_f} \times d(\mathrm{CIR})$$

E.g. in Figure 6,

$$R_f = 0.79\ ,\quad \sqrt{R_f} = \sqrt{0.79} = 0.89$$

meaning there is an 11 % range loss when using an 886-nm emitter instead of a 950-nm emitter.

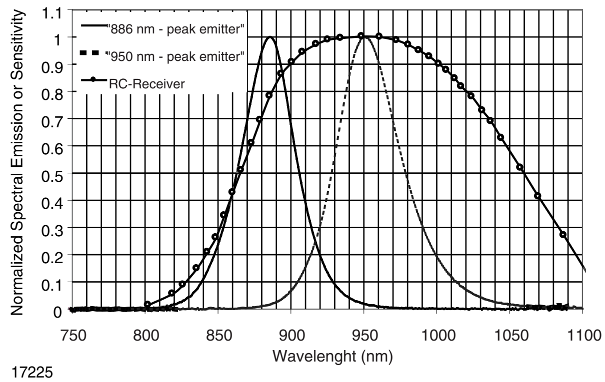
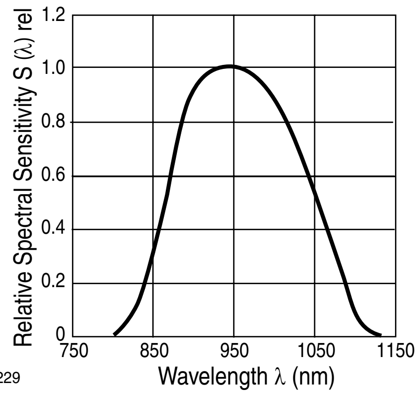
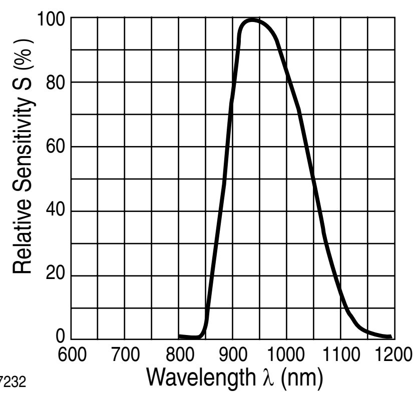


Figure 4. Spectral sensitivity and emitter „Overlap“





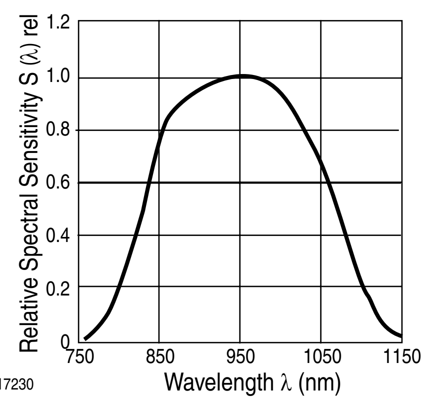


Figure 5. Collection of different spectral sensitivity curves of different types from different manufacturers

Optical Intensity

As already described, remote control transmit distance is a function of emitter intensity. Transmit distance increases as the intensity of the emitter diode increases. Vishay lab results indicate that to transmit over a distance of 10 meters, the minimum intensity of the 880-nm emitter should be 70 mW/sr. Most low-power IrDA transceivers have a LED intensity of less than 9 mW/sr, woefully inadequate to be used for remote control function.

The intensity of the emitter depends on its peak current and efficiency. The peak current can be controlled by using a serial, current-limiting resistor. By reducing the value of the resistor, the LED peak current will increase which increases the intensity. Each IrDA transceiver, however, has a limit or maximum intensity. For example, the TFDU6102, the world's leading FIR transceiver, has a peak current of typically 550 mA and typical intensity of 170 mW/sr (max. 350 mW/sr). Similarly, the TFDU4300 peak current and resulting intensity are typically 300 mA and 65 mW/sr.

While the TFDU6102 does not require a current limiting resistor, figure 6 shows the dependence of intensity on the value of the serial resistor for randomly selected transceivers. The serial resistor may be used to reduce the internal power dissipation or to reduce the current consumption with resulting lower intensity. Note that these curves are for a few transceivers only. Single devices may deviate from average or normal behavior due to device parameter tolerances.

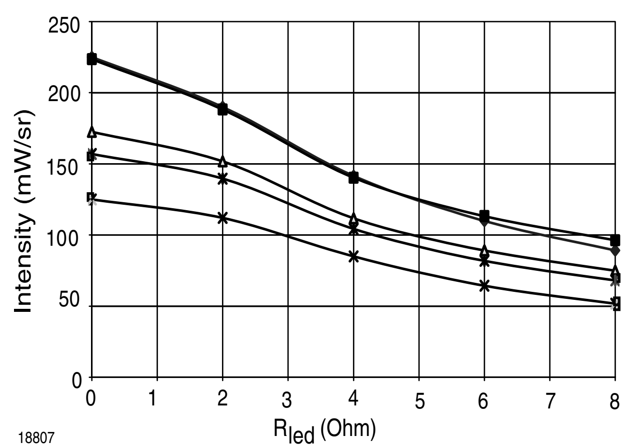


Figure 6. Current-limiting resistor vs. on-axis intensitity for TFDU6102 (five randomly selected transceivers). Applied operating voltage V2 = 3.3 V

Carrier Frequency

The sensitivity of an infrared remote control receiver is dependent on the carrier frequency as shown in Figure 7. The 3-dB bandwidth f is about 1/10 of its central frequency f_0.

A carrier based modulation scheme is used for remote control to efficiently filter the signal from disturbed ambient. Therefore remote control receivers can be much more sensitive (x 100 to x 200) than baseband transmission systems as e.g. IrDA equivalent receivers.

The carrier frequency of the handheld device's controller should be the same as the central frequency of the target device. A difference will result in a loss in sensitivity and subsequent transmit distance. For example, the transmit distance of a system which uses a 36-kHz controller with a Vishay TSOP1238 receiver (center frequency of 38 kHz) will be reduced by approximately 10 %. The selectivity is not that high to allow multi-channel operation. With strong signals as e.g. in a distance of 1 m a TSOP1238 will receive also 30 kHz and 56 kHz carriers.

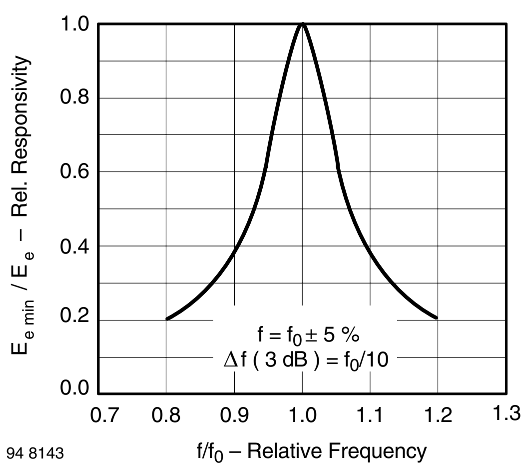


Figure 7. Frequency dependence of responsivity

Battery Charge

A weakly charged battery causes a drop in the strength of the emitted signal, particularly the beginning of the signal. In the following two diagrams (see figure 8 and 9) the effect of charging state of the battery is shown. This drop at the beginning of the signal may reduce the efficiency of the gain control of the receiver, requiring longer response times or repeating of the signal. Note that this is not RC-5 code. This code provides a long header to allow the receiver to adjust gain but with a weak battery the header is dropped.

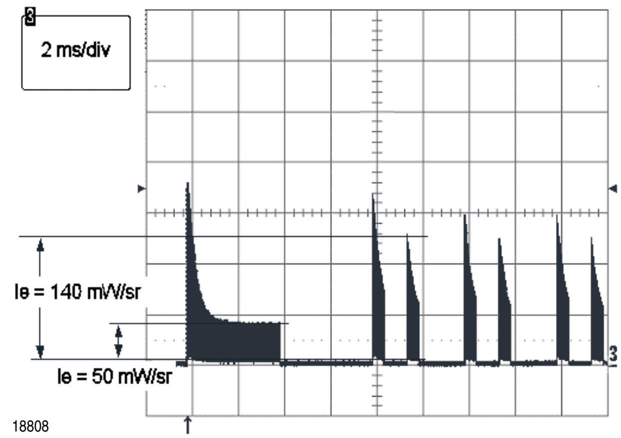


Figure 8. Signal from the IR transmitter with empty batteries. The measured intensity is decreasing during the burst.

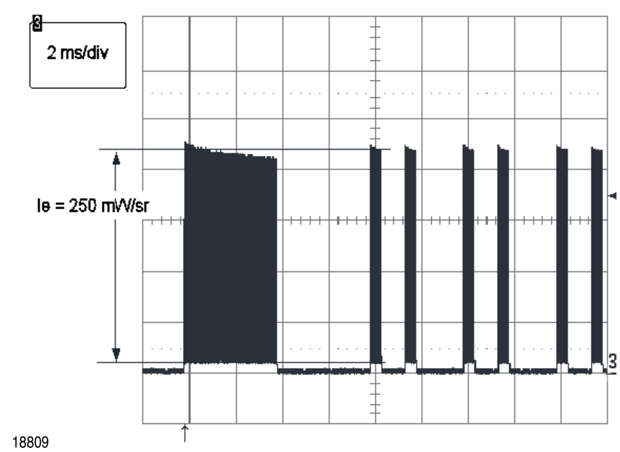


Figure 9. Signal from the IR transmitter with new Alkaline batteries. The measured intensity is constant.

Test Results

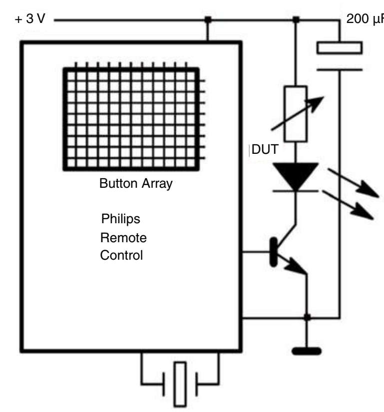
Tests have verified that Vishay's IrDA transceivers can easily and effectively be used as remote control emitters. These tests were performed using Vishay's standard remote control test procedures and equipment. Vishay, the leading supplier of remote control receivers, as well other leading supplier's receivers were tested. The measurements are performed on a long corridor, where reflections from walls, floor and ceiling improve the transmit distance. Therefore the range data does not follow the square law rule for free air transmission mentioned above. The measured ranges are not resulting from a statistical relevant number of devices. When comparing with table 2, remember that the test conditions may be different.

Test Results	Remote Control	IrDA Transceivers			
	Emitter	SIR		MIR	FIR
	Vishay	Vishay	Vishay	Vishay	Vishay
Part Number	TSAL6400	TFDU4100	TFDU4300	TFDU5307	TFDU6614
IRED Peak Current (mA)	100	100	300	420	550
Intensity (mW/sr)	41	48	145	235	110
Peak Wavelength (nm)	940	886	886	886	886
RC Receivers	Transmit Distance (m)				
Vishay TSOP1238	19	11	20	25	17
Panasonic PNA4612	11	8	13	17	11
Vishay TSOP4838	25	22	39	> 42	34

The signal was generated using a Philips remote control transmitter, Figure 10 and Figure 11 and Philips RC5® code with a modified carrier frequency of 38 kHz with a pulse width of 9 µs.

17226

Figure 10. Philips remote control used in test

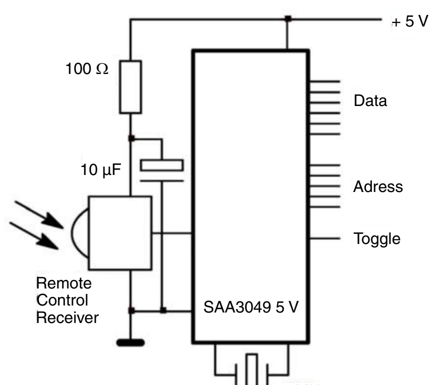


17227

Figure 11. Circuit diagram for driver the DUT

Since carrier frequency has no influence on the optical matching of transmitter to receiver, the collected data can be transferred to any other carrier frequency system. This remote control transmitter generated a digital signal. The signal is fed to an IRED driver transistor. When testing IrDA transceivers with internal current controllers, the signal from the remote control was directly fed to the TXD input of the transceiver. For transceivers without internal current controllers, a serial resistor was used to generate constant current signal during the pulse. The transmitter supply voltage was set to 3 V.

With the different receivers listed in the tables a Philips decoder SAA3049 was used, see the circuit diagram in Figure 12.



17228

Figure 12. Receive circuit diagram

Expected Performance

Remote Control and IrDA® applications are both using Infrared as transmission medium. The remote control applications are using historically the wavelength band from 930 nm to 960 nm while IrDA covers the band from 850 nm to 900 nm. In the early days the 950-nm band was also under consideration for the IrDA organization. However, expecting future higher speed, IrDA decided to go with the shorter wavelength range. Standard IrDA receivers are able to receive RC signals, while RC receivers may not necessarily be able to receive IrDA signals. The typical RC receivers have cut-off filters which are in the center of the IrDA band. In general one can state, that the sensitivity of remote control receivers is questionable in the lower part of the IrDA band while above 880 nm the sensitivity of remote control receivers is quite good and can be used. This opens up the option to use IrDA transmitters also with remote control without spending an additional long wavelength chip.

The experience confirms, that for the wavelength range from 880 nm to 900 nm for the majority of state-of-the-art remote control receivers a sensitivity threshold of 0.7 mW/m^2 can be assumed.

In the following table 1 the range is listed which can be expected under IrDA intensity conditions with the boundary condition that the wavelength is above 880 nm.

In table 2 the expected range with some VISHAY transceivers is listed.

Table 1: Expected Minimum RC Range under Standardized IrDA Conditions (Wavelength > 880 nm)

Wavelength > 880 nm	**Min Intensity**		
Sensitivity = 0.7 mW/m^2 (VISHAY TSOP1238 receiver)	Ie	RC Range	
IrDA	[mW/sr]	[m]	
VFIR/FIR/MIR Standard	100	12.0	at IrDA nominal conditions
VFIR/FIR/MIR extended LowPower 70 cm	50	8.5	> SIR 70 cm IrDA range with standard
VFIR/FIR/MIR extended LowPower 50 cm	25	6.0	> SIR 50 cm IrDA range with standard
VFIR/FIR/MIR LowPower	9	3.6	at IrDA nominal conditions
SIR Standard	40	7.6	at IrDA nominal conditions
SIR extended LowPower 70 cm	20	5.3	SIR 70 cm IrDA range with standard
SIR extended LowPower 50 cm	10	3.8	SIR 50 cm IrDA range with standard
SIR LowPower	3.6	2.3	at IrDA nominal conditions
Bold: IrDA Physical Layer IrPHY 1.4			

Table 2: Expected RC Range with Selected VISHAY IrDA Transceivers

Transceiver	RC Range [m]	Remark
TFDU4100	14.1	at 5.0 V, Rs = 14 Ohm, about 210 mA
TFDU6102	20.0	at 550 mA
TFDU8108	20.0	at 550 mA
TFBS4710	12.5	at 300 mA internally controlled
TFBS6614	18.2	at 3.3 V, R = 0 Ohm
TFDU5307	18.1	at 3.3 V, internally controlled
TFDU4300	10.5	at 300 mA internally controlled
TFBS4711	9.3	at 300 mA internally controlled
TFBS6711	12.8	at 440 mA internally controlled
TFBS5700	9.3	at 3.3 V, R = 4.7 Ohm, about 300 mA
TFBS4650/4652	9.3	at 300 mA internally controlled, device specified operation
TFBS4650/4652	3.8	at 50 mA externally limited, LowPower operation
TFDU4202	14.6	at 320 mA resistor limited
TFDU4203	14.6	at 320 mA resistor limited

Receiver: VISHAY TSOP1238, Sensitivity = 0.7 mW/m^2 at 885 nm

Document Number 82606
Rev. 1.6, 20-Sep-06

Remote Control Data Formats

There are many different coding systems used for remote control. The most common codes are the RC5® and RC6® codes from Philips and the NEC code. For more information see the application note Data Formats for IR Remote Control. Figure 13 is an example of a remote control signal using the Philips RC5 code when channel "3" is pressed. It was recorded using an oscilloscope connected to IR PIN detector.

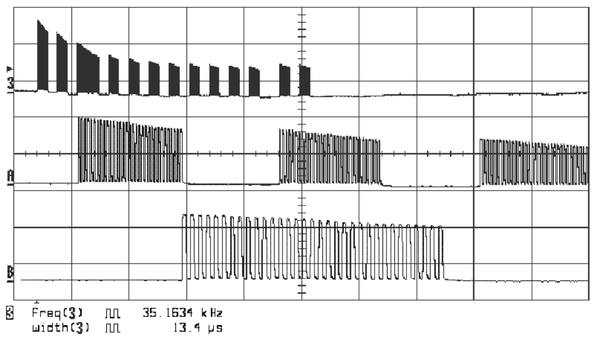


Figure 13. RC5 optical signals of Key '3'
Channel 3: The RC5 code of key '3' (RC5 0 3)
Channel A: Zoom-in of the start bits (11) and toggle bit.
Channel B: Zoom-in of the start bit.

Figure 14 shows the data format of the RC5 code.

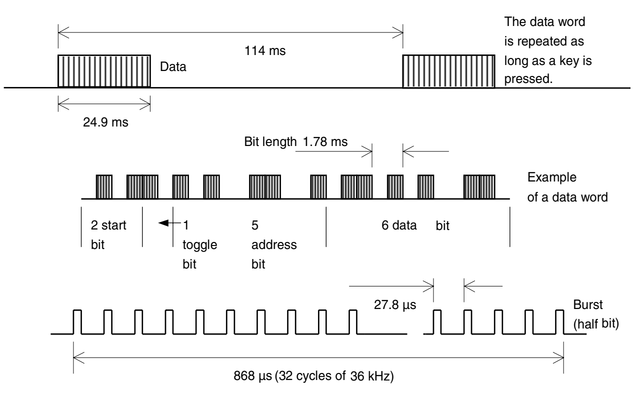


Figure 14. Philips RC5 IR remote control protocol

The RC5 - code has an instruction set of 2048 different instructions and is divided into 32 addresses (5 bits) of each 64 instructions or commands (6 bits). Each remote controlled device has its own address, making it possible to change the volume of the TV without changing the volume of the CD player. The transmitted code is a data word that consists of 14 bits and is defined as:

- 2 start bits (ss) for the automatic gain control in the infrared receiver.
  - ss = 10 (Add 64 to command)[1)]
  - ss = 11 (Use command as it is)
- 1 toggle bit (change every time when a new button is pressed on the IR transmitter)
- 5 address bits for the system address
- 6 instruction bits for the command or key pressed

The RC5 code uses the Bi-Phase modulation technique, meaning that a single bit is split up into two half bits:

0 -> 10
1 -> 01

The duration time of each bit is equal to 1.778 ms containing 32 pulses with a repetition rate of 36 kHz, the carrier frequency of this code. The total time of a full RC5 code is 24.889 ms. The space between two transmitted codes is 50 bit times or 88.889 ms. The carrier frequency is used to enable a narrow band reception to improve the noise rejection. The carrier frequency of the RC5 code is 36 kHz. The complete signal is repeated every 114 ms as long as the command button is still pressed. The toggle bit is changing its polarity each time the button is pressed.

For example, pressing and holding the volume key will hold the toggle bit constant and the volume will continuously increase bar by bar, the signal will not change but will be repeated. By discretely pressing the volume button, the toggle bit will change its value each time. The final result is the same. In this case, the toggle bit has no influence. However, when selecting channel "1" and pressing and holding the "1"- key, the receiver will detect the unchanged toggle bit and will recognize only the "1" ignoring identical signals regardless of how long the button is pressed. Even if the transmission path is interrupted, it will not detect "11" or "111". To change to channel "11", the number "1" must be pressed twice. With each press, the polarity of the toggle bit changes and the receiver recognizes the command.

Additional Components Required for Remote Control

No additional components are required when using Vishay transceivers. Vishay's transceivers have an emitter driver built-in and use the same digital input pin, TXD, for IrDA and RC. No MOSFET is required.

[1)]The command set can be increased by 64 commands by using a modified start bit "10" instead of "11" using the second start bit as a 7th command bit.

Application Examples

Motorola MC68SZ328 Processor (DragonBall)

The Motorola MC68SZ328 Processor (DragonBall) is a high-performance low-power 32-bit microcontroller with an integrated IrDA block for direct support of the IrDA physical layer protocol (SIR, 9.6 kbit/s to 115.2 kbit/s).

The application circuit is shown in figure 15.

This processor uses the pin TXD / PE5 for IrDA or RC data output and RXD / PE4 as IrDA or RC data input. The pin RTS* / PE6 serves originally as RTS or GPIO. Here this pin is used as a general-purpose output. It is connected to SD for controlling the transceiver operating mode by asserting this pin low or high to enable or shutdown it. It is controlled by RTS bit of UMISC register.

TXD/PE5, RXD/PE4 and RTS/PE6 pins are dedicated to the UART/Infrared Communication Port. For RC data output or recording, set the SEL4-6 of the PESEL register to 1. Control of these pins is given to the Port E for use as general-purpose input/output pins.

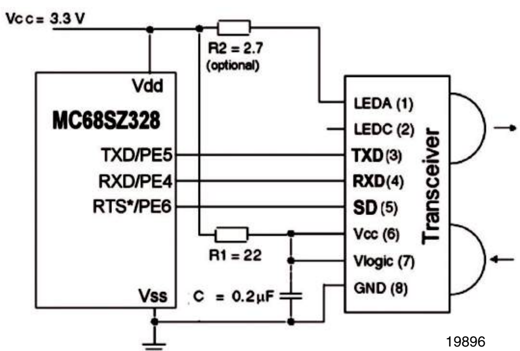


Figure 15. Motorola MC68SZ328 Processor, DragonBall, interfaced for IrDA/RC applications

The pin numbers are related to the VISHAY transceiver TFDU4300. Depending on the demand also TFBS4650, TFBS4652, or other SIR transceivers can be used, the pin numbering may be different in that case.

Intel SA-1110 Processor, StrongArm

The Intel SA-1110 Processor or StrongArm is a high performance, low-power microcontroller with an IrDA interface which supports SIR (9.6 kbit/s to 115.2 kbit/s) and FIR (4 Mbit/s). It does not support MIR (1 Mbit/s). The Vishay low profile (2.7 mm) transceiver TFBS6614 is an option to operate with this processor in the FIR range while the low profile (2.5 mm) transceiver TFDU4300 supports SIR in this application. Both can be used for IrDA and remote control operations.

Other transceivers depending on the demand of the application (device profile, and range) may be applicable, too. The pin numbering of the transceiver may be different from that shown in figure 15.

The SA1110 pin functions (see figure 16) are RXD2 as IrDA data input, and TXD2 as IrDA data output. GPx is an available general-purpose pin used for SD and Bandwidth selection. TXD2 and RXD2 pins are dedicated to the infrared communication port.

If serial transmission is not required and this port is disabled, control of these pins is given to the peripheral pin control (PPC) unit for use as general-purpose input/output pins, uninterruptible. Refer to section 11.13 entitled "Peripheral Pin Controller" on page 11-167 of the Intel StrongArm SA-1110 Microprocessor Developers Manual. To use these pins for remote control, the user must also program the PPC pin direction register. The direction of TXD2 should be output and RXD2 should be input.

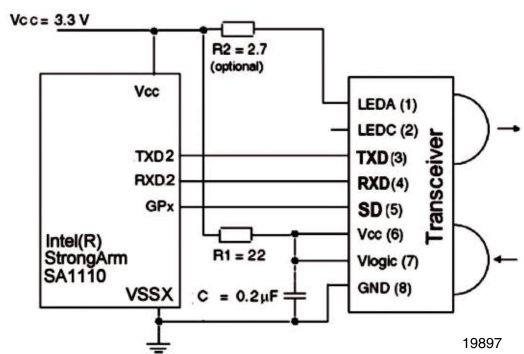


Figure 16. Intel SA-1110 Processor, StrongArm, in IrDA/RC applications

Intel PXA255 Processor or XScale

The Intel PXA255 Processor or XScale is a high-performance low-power microcontroller and has an IrDA interface which supports both SIR (9.6 kbit/s to 115.2 kbit/s) and FIR (4 Mbit/s), see figure 17.

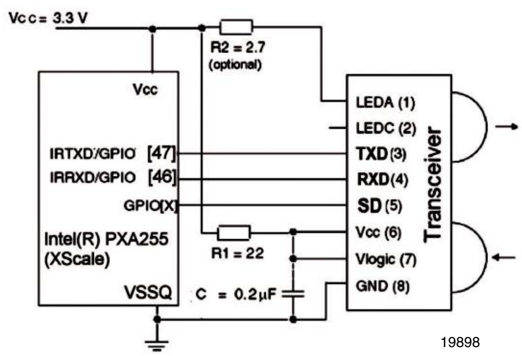


Figure 17. Intel PXA255 Processor, Xscale, in IrDA/RC applications

The Vishay low profile (2.7 mm) transceiver TFBS6614 is an option to operate with this processor in the FIR range while the low profile transceiver (2.5 mm) TFDU4300 supports SIR in this application. Both can be used for IrDA and remote control operations. The circuit diagram is shown in figure 17.

The transmitter input TXD (pin-3) of the transceiver is connected to the processor's pin IRTXD/GPIO[47], the receiver output RXD (pin-4) is connected to IRRXD/GPIO[46] and the shutdown SD (pin-5) to one of any available GPIO pins.

The I/Os IRRXD/GPIO[47] and IRTXD2/GPIO[46] are multifunctional pins. To change their function between IrDA and RC the bit-pair AF47 and AF46 of the GPIO Alternate Function Select Registers (GAFR1) is to be programmed. For example, setting the bit-pair of GAFR1_L AF47 alters its function between SIR, FIR, STD_UART and GPIO for remote control as shown in the following table.

bits <31,30>	Name	Description
00	GP47	General Purpose IO port (for CIR)
01	TXD	STD_UART transmit data
10	ICP_TXD	FIR transmit data

Programming Example for RC operation (direct access the GPIO ports):

Refer to section 4.1.3 GPIO Register Definitions, on page 4-6 of "Intel® PXA255 Processor Developer's Manual", March 2003

1. Set the direction of port GPIO[47] to Output, by setting 1 to bit-15 (PD47) of register GPDR1 (GPIO Pin Direction). Set the direction of port GPIO[46] to input, by setting 0 to bit-14 (PD46) of register GPDR1 (GPIO Pin Direction).
2. Set the IRTXD/GPIO[47] port to GPIO, by writing 00 to bit-pair <31,30> (AF47) of register GAFR1_L. Set the IRRXD/GPIO[46] port to GPIO, by writing 00 to bit-pair <29,28> (AF46) of register GAFR1_L.
3. Send the same signals through the output port, by writing one to either bit-15 (PS47) of register GPSR1 (to set) or bit-15 (PC47) of GPCR1 (to clear).
4. Read and record the inputs from port IRRXD/GPIO[46] for RC simulation. The pin state can be read by reading the bit-14 (pl46) of register GPLR1.