Teaching radio telemetry using microcontrollers with low power radio devices

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Abstract

Radio telemetry is used in many remote monitoring and remote control applications, such as in environmental monitoring, pollution monitoring, weather forecasting, and other applications. In typical applications sensors are used to collect data and this data is then transmitted to a remote receiving station where it is analysed. This paper outlines the basic principles of the radio telemetry systems and gives an example to show how such a system can be designed and used in teaching the principles of radio telemetry. The designed system is based on a popular microcontroller.

Keywords: Low power radio; short range device; radio telemetry; teaching radio telemetry

1. Introduction

Short Range Device (SRD), also known as Low Power Radio\textsuperscript{1} (LPR) are small limited power transmitting and receiving devices operated without the need for an end-user license. LPR is used in many remote control and remote monitoring based applications where it may be required to send data from one place to another one wirelessly. One can see LPR used in many embedded remote control and monitoring applications such as:

\footnotesize *

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In this paper we shall be looking at the low power radio communication systems briefly and then give an example system to show how such a system can be used in teaching the basic principles of radio telemetry.

2. Low Power Radio Communication Systems

The designer of a radio telemetry system has several options when it is required to design a system to collect data remotely. Basically, the designer can choose between a number of different devices such as: Bluetooth (Huang, 2007), Wi-Fi (Orhtman, 2003), ZigBee (Gislason, 2008), and Basic Radio Frequency (RF) (Cakir, & Karahoca, 2014; Yun, Kang, & Know, 2014; Yusof, & Sulaiman, 2013). Here, the first three are based on well-known and established protocols, employing high levels of encryption algorithms (Staretu, 2014). Basic RF devices are the main topic of this paper and this is based on communication using the well-known RF communication techniques without employing any of the complex protocols. Brief specifications of LPR communication methods are summarized in Table 1.

<table>
<thead>
<tr>
<th>Method</th>
<th>Bluetooth</th>
<th>Wi-Fi</th>
<th>ZigBee</th>
<th>UHF</th>
<th>VHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>50-100m</td>
<td>100m</td>
<td>75m</td>
<td>500m</td>
<td>5-10km</td>
</tr>
<tr>
<td>Data Rate</td>
<td>24Mbps</td>
<td>54Mbps</td>
<td>250kbps</td>
<td>various</td>
<td>Various</td>
</tr>
<tr>
<td>Security</td>
<td>128-bit encryption</td>
<td>Various</td>
<td>128-bit encryption</td>
<td>various</td>
<td>Various</td>
</tr>
<tr>
<td>Band</td>
<td>2.4GHz</td>
<td>2.4GHz</td>
<td>2.4GHz</td>
<td>433, 866, 915MHz and others</td>
<td>150, 169, 173MHz and others</td>
</tr>
<tr>
<td>Power</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low - medium</td>
<td>Low-medium</td>
</tr>
</tbody>
</table>

2.1 The LPR Frequency Spectrum

The LPR devices are designed to operate within the license-free frequency bands where the devices can be used to transmit data freely without the need of a license. The Industrial, Scientific and Medical (ISM) band is the commonly chosen band for most sensor based industrial, scientific and medical wireless applications. Table 2 gives a list of the frequencies covered by the ISM band. Currently, the heaviest used ISM band is the 2.4GHz band. The most common users of this band at home are the home microwave ovens operating at 2.45GHz. In offices Wi-Fi equipment are the most common users of the ISM band.

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>Bandwidth</th>
<th>Center frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.400 – 2.500GHz</td>
<td>100MHz</td>
<td>2.450GHz10</td>
</tr>
<tr>
<td>902.000 – 928.000MHz</td>
<td>26MHz</td>
<td>915.000MHz</td>
</tr>
<tr>
<td>863.000 – 870.000</td>
<td>7MHz</td>
<td>866.500</td>
</tr>
<tr>
<td>433.050 – 434.790MHz</td>
<td>1.74MHz</td>
<td>433.920MHz</td>
</tr>
<tr>
<td>40.660 – 40.700MHz</td>
<td>40kHz</td>
<td>40.680MHz</td>
</tr>
<tr>
<td>26.957 – 27.283MHz</td>
<td>326kHz</td>
<td>27.120MHz</td>
</tr>
<tr>
<td>13.553 – 13.567MHz</td>
<td>14kHz</td>
<td>13.560MHz</td>
</tr>
</tbody>
</table>
3. Teaching Radio Telemetry With A Project

In this section the design of a simple radio telemetry project is described with the aim of teaching the basic principles of radio telemetry. In this example, the atmospheric pressure is read every second using an analog barometric pressure sensor chip (MPX4115) in a microcontroller based system. This data is then transmitted using an LPR transmitter device to a remote station where it is received using an LPR receiver module and is then displayed on an LCD, again using a microcontroller based system. Fig 1 shows the block diagram of the designed radio telemetry system. The system is in two parts: the transmitter station, and the receiver station. The transmitter station consists of the pressure sensor, a microcontroller, and an LPR transmitter device. The output of the pressure sensor is connected to one of the ADC channels of a PIC microcontroller. The microcontroller receives the pressure data, converts it to mbars, and then drives an LPR transmitter module to transmit the data to the remote receiver station. The received pressure data is displayed on an LCD at the receiving station.

![Fig 1 Block diagram of the example radio telemetry system](image)

3.1 The Transmitter Station

Fig 2 shows the circuit diagram of the transmitter and receiver stations. Ambient pressure is measured using a MPX41115 type barometric pressure chip. In this project the TXL2 type transmitter module is used, which is connected to the microcontroller UART output pin. TXL2 has a matching receiver module called the RXL2. Both modules are developed and manufactured by Radiometrix UK. The company manufactures a wide range of UHF and VHF radio telemetry devices for us in short to long distance LPR applications. Both the TXL2 and RXL2 modules (see Fig 3) are simplex devices that operate in the 433 UHF ISM band at 9600 Baud and they are housed in a SIL package as shown in Fig 3. The output pin of TXL2 is inverted and can be connected directly to a microcontroller UART output. The UART output (TXD) of the microcontroller is connected to pin 7 (TXD) of the TXL2 and serial data sent out from the microcontroller is transmitted by the TXL2.

3.2 The Receiver Station

As shown in Fig 2, the receiver section consists of: the RXL2 receiver module, PIC16F877 microcontroller, and an LCD. Pin 7 of the module is connected to hardware UART input (RXD) of the microcontroller. PORTB of the microcontroller is connected to a standard 16x2 character text based LCD to display the received pressure data.

3.3 The Software

The software used in this example is the popular mikroC Pro for PIC, developed by mikroElektronika. This is a C programming language developed for the PIC series of microcontrollers. Fig 4 shows the transmitter station software listing. At the beginning of the program the ADC and the UART are initialized. The program then enters an endless loop where the pressure data is read from the sensor through the analog channel 0 of the microcontroller, and is then converted into mbars. After converting this value to a string it is sent to the receiving station using the TXL2 transmitter device. The above program loop is repeated after one second delay.
unsigned char Pressure[12], *res;
unsigned long Vin, Pint;
float mV, V, Pmb;
void Read_Pressure()
{
    Vin = ADC_Read(0); // Read from channel 0
    mV = (Vin*5000.0) / 1024.0; // In mV
    V = mV / 1000.0; // In V
    Pmb = (2.0*V + 0.95) / 0.009; // Pressure in mb
    Pint = (int)Pmb; // Pressure in integer
    LongToStr(Pint, Pressure); // Convert to string
    Ltrim(Pressure); // Remove leading spaces
    res = strcat(Pressure, "X"); // Add terminator character
}
```c
void main()
{
    TRISA = 1;                      // AN0 is input
    ADC_init();     // Initialize ADC
    UART1_Init(9600);    // Initialise UART

    while(1)      // Do forever
    {
        Read_Pressure();    // Read pressure
        UART1_Write(res);   // Send to UART
        Delay_Ms(1000);    // Wait for 1 second
    }
}
```

The receiver station program is shown in Fig 5. The program then initializes the LCD and the UART as in the transmitter station. The remainder of the program is executed in an endless loop where the pressure data is received from the RXL2 receiver device through the UART of the microcontroller and is then displayed on the LCD.

```c
sbit LCD_RS at RB4_bit;     // LCD connections
sbit LCD_EN at RB5_bit;
    sbit LCD_D7 at RB3_bit;
    sbit LCD_D6 at RB2_bit;
    sbit LCD_D5 at RB1_bit;
    sbit LCD_D4 at RB0_bit;
    sbit LCD_RS_Direction at TRISB4_bit;
    sbit LCD_EN_Direction at TRISB5_bit;
    sbit LCD_D7_Direction at TRISB3_bit;
    sbit LCD_D6_Direction at TRISB2_bit;
    sbit LCD_D5_Direction at TRISB1_bit;
    sbit LCD_D4_Direction at TRISB0_bit;

void main()
{
    unsigned char rec, k = 0;
    unsigned char rec_buffer[15]; // Initialize LCD
    Lcd_Init();     // Initialize UART
    UART1_Init(9600);

    while(1)      // Do forever
    {
        while(UART1_Data_Ready() == 1) // If data available
        {
            rec = UART1_Read(); // Read a character
            if(rec != 'X') // Is it terminator ?
            {
                rec_buffer[k] = rec; // Save data
                k++; // Increment pointer
            }
        }
    }
```

Fig 4 Transmitter station program
} else {
    rec_buffer[k] = 0x0; // Add NULL chr
    k = 0;
    Lcd_Cmd(_LCD_CLEAR); // Clear LCD
    Lcd_Out(1, 1, rec_buffer); // Display pressure
}

Fig 5 Receiver station program

4. Conclusions

Radio telemetry systems are used in many environmental monitoring and control applications. This paper showed how the principles of radio telemetry can be taught using LPR devices and a microcontroller based system. The system described in this paper is used at the undergraduate laboratories of the Near East University, where the students are asked to construct the radio telemetry system described in this paper. They are then asked to develop the programs given in Fig 4 and Fig 5 so that they can experiment and learn the operation of the radio telemetry system.

References


