Miniature PCM Remote Control (2)

part 2: the software protocol

In this second and final part of the remote control design we put it all together and take a closer look at the workings of the transmitter and receiver software.

As with any communication system it is necessary to decide on a suitable message format to convey the information. This system does not need to comply with any existing communication standard so we are free to design our own. The main objectives are to enable a high data rate together with good reliability and error detection. The specification of the transmitters and receivers must also be considered to ensure, for example, we do not exceed the maximum clock rate or channel bandwidth. With these constraints in mind a message protocol is used (**Figure 1**) that is suitable for transmission using either IR or RF.

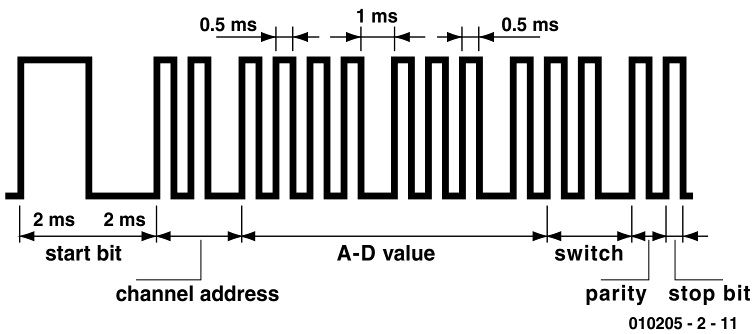


Figure 1. Message protocol.

Start bit

The start bit allows the receiver software to synchronise on a new message. The length of the high and low phase of the start bit ensures that it cannot be confused with any part of the rest of the message.

Channel address (2 bits)

The channel address is used to indicate which channel the A/D value is intended for so that moving a joystick on the transmitter will cause the correct servo to move at the receiver. Two address bits allow four channels to be encoded.
For example:
Left joystick up/down value: Address 00
Left joystick left/right value: Address 01

A/D value (8 bits)

The angular positions of the joysticks are read from the potentiometer values mounted in the joystick. These values are converted into 8 bit digital values in the A/D converter and transmitted in the message. The corresponding channel number is also sent in front of each value.

Switch bits

The status of the two momentary action pushbuttons at the transmitter is sent using these two bits. A toggle action is implemented in software so that each time the switch is pressed the status of the corre-

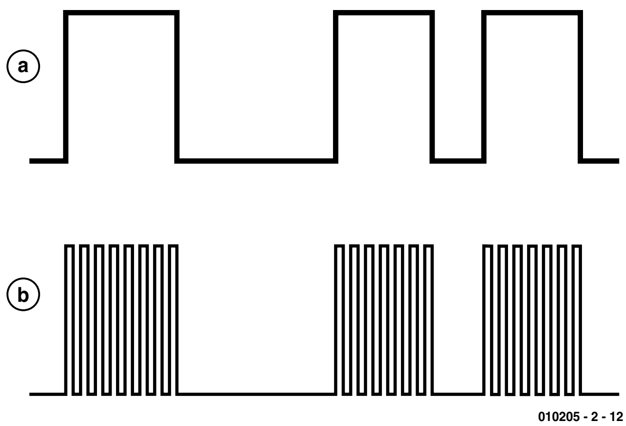


Figure 2.Control of the RF module (a) and the IR LED (b).

Operating Range

RF Module
Radiometrix quote the free-field range of the modules used here as 300 m. This should be more than adequate for a radio-controlled car.

Infrared
The range of the infrared version is somewhat less than the RF variant. The IR link needs a line-of-sight path from the IR transmitter diode to the receiver either directly or indirectly by bouncing off a reflective surface. The IR receiving diode should therefore be mounted on the roof of the model or somewhere where it will be more likely to see the IR signal from any direction.

The transmitting IR LED beam propagation pattern is cone shaped with an angle of ±15°. If the receiver is not subject to direct sunlight then you can expect a range in the order of 5 m.

sponding bit will change state and stay at this level until it is pressed again.

Parity bit
The parity bit allows the receiver to detect single bit errors in the transmitted message. The transmitter software counts all the '1's in the transmitted message and if the count is odd then the parity bit will be set (1). If the count is even the parity bit is reset (0). The receiver simply counts all the '1's in the received message (including the parity bit) if the result is odd it knows that the message was corrupted:
Message = 0010101100, Parity = 0
Message = 0011101100, Parity = 1

Stop bit
The stop bit marks the end of the message. It conveys no other information.

A complete message is not sent every cycle. To achieve smooth, high speed servo positioning and reduce transmitter power consumption, information is only transmitted if there is a change in the position of the joysticks or if a switch is pressed. The transmitter software reads in the joystick and switch values, compares them to their previous values and prioritises any changes before a message is sent. If you tried sending all the data in every message with the data rate that is available in this system, the servos would have a very jerky response. The software also averages out the joystick position. It reads an A/D converter output four times, adds the values together and then divides the result by four. This process smoothes out changes and helps to reduce supply current. If you have an oscilloscope handy you will be able to see that the transmitter sends hardly anything when the transmitter controls are left untouched and its only when a switch is pressed or a joystick moved that a message is sent. This feature prolongs battery life, especially when the IR transmitter option is used. The receiver always stores and uses the last value sent until it is overwritten by a new value. The digital message stream is connected to the RF modules modulation input pin where it frequency modulates the 433 MHz carrier. If the IR option is selected the data must be modulated at 36 kHz (**Figure 2**).

The Transmitter and receiver programs

The program flow for both the transmitter and receiver software is very simple and can be represented as a list of tasks:

Transmitter
1. Initialisation of ports and internal controller hardware.
2. Watchdog reset.
3. Check the battery voltage level and control the LED correspondingly.
4. Input values from the four joysticks.
5. Check for pushbutton presses.
6. If any changes then send a message:
   For infrared:
   Modulate with a 36 kHz carrier.
   For RF: Modulate the transmitter frequency with the message bit pattern.
7. If in infrared mode then wait 10 ms.
8. Return to 2.

Receiver
1. Initialisation of ports and internal controller hardware.
2. Watchdog reset.
3. Check the battery voltage level.
4. Sample the receiver module output and check the signal tolerances.
5. Check the message parity.
6. Service the switch output signals, the soft-start switch and the speed regulator.
7. Calculate the servo pulse width from the 8-bit value.
8. Load the timer with the servo pulse width value.
9. Return to 2.

A time of 200 µs is used to check the pulse length tolerance.

The software for this project is available on floppy disk only. Due to contractual agreements with the author, the programs are not available as free downloads from the Publishers' website.

Construction

Your chances of success in building a fully functioning control system are greatly

Transmitter to receiver control action.

Transmitter	Receiver output
Left joystick up/down	Servo at Pin P1.7
	Speed controller at Pin P0.1 (jumper coding!)
Left joystick left/right	Servo at Pin P0.4
Right joystick up/down	Servo at Pin P1.6
Right joystick left/right	Servo at Pin P1.4 Switch 1 on
Left joystick (Pin P1.1)	Switch output on Pin P1.0 Switch 2 on
Right joystick (Pin P1.0)	Switch output on Pin P1.1
	Soft start on Pin P0.1 (coding!)

increased if you use the professionally made PCBs available from *Elektor Electronics*.

Transmitter

The transmitter component placement is shown in **Figure 3.** The A/D converters need a stable supply voltage so the extensive earth plane helps to isolate the A/D converters from the large current pulses drawn by the IR LED. Fitting the components to the PCB begins by first soldering the five wire links in position. The microcontroller should be mounted on an IC socket. Ensure that the trim pots P1 to P4 will fit the unit.

To achieve maximum range from the RF transmitter module it should be sited as far away as possible from any metal so when mounting it on the PCB try not to shorten the modules' connection leads. A 1 cm length of PCB track forms part of the aerial so that 14.5 cm length of insulated wire connected to pin A1 should be sufficient to act as the transmitter aerial. The infrared LED is mounted and bent at 90° so that the IR light is beamed out of the front of the unit.

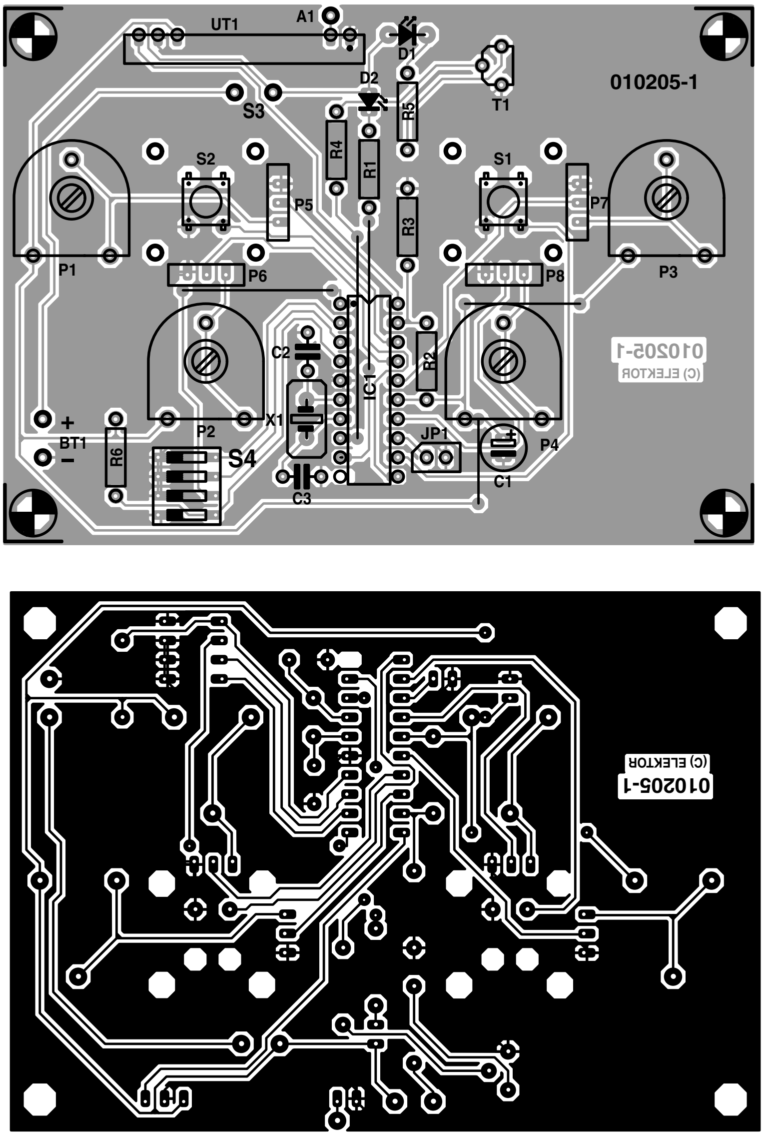
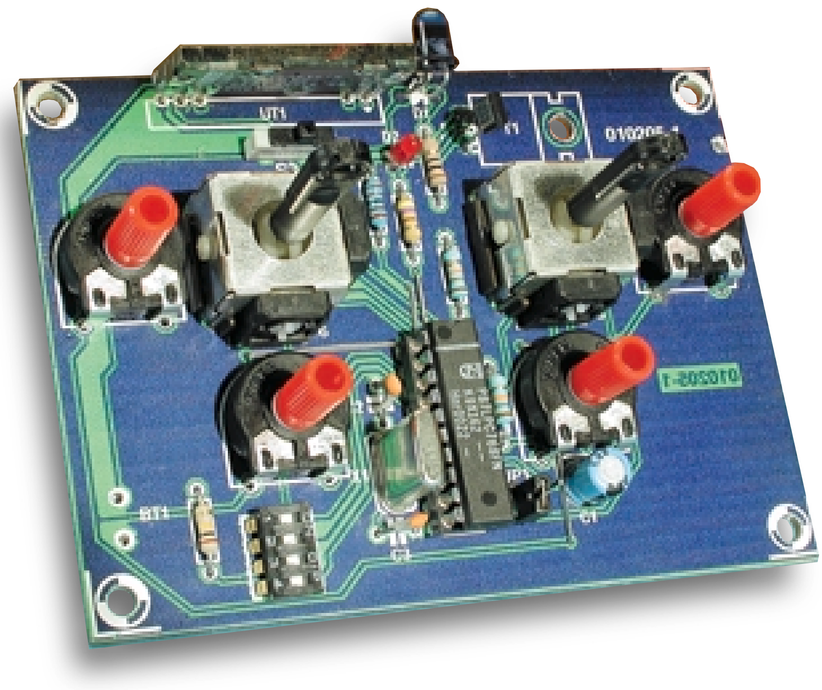


Figure 3. Layout and component placement of the transmitter PCB.



COMPONENTS LIST

Transmitter

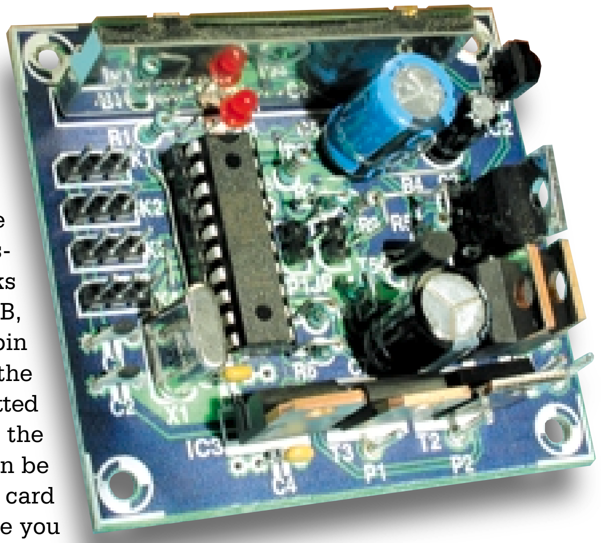
Resistors:
R1 = 470Ω
R2,R3 = 18kΩ
R3 = 10kΩ
R4 = 1kΩ
R5 = 10Ω
R6 = 100kΩ
P1-P4 = potentiometer, 20kΩ, linear
P5-P8 = joystick (CTS # 252A104A60TB with internal switch)

Capacitors:
C1 = 220µF 16V
C2,C3 = 15pF

Semiconductors:
D1 = TSUS5201 or LD271
D2 = LED, red, 3mm
T1 = ZTX603 (Zetex) or TIP110
IC1 = 87LPC768FN, programmed, order code **010205-41**

Miscellaneous:
X1 = 6MHz quartz crystal
S3 = on/off switch, 1 make contact
S4 = 4-way DIP switch
JP1 = 2-way pinheader with jumper
UT1 = 433MHz transmitter module type TX2 from Radiometrix (Farnell)
Battery holder for 3 AA cells
PCB, order code **010205-1**

Receiver



The receiver PCB layout is shown in **Figure 4.** To keep the receiver as compact as possible, all the components are mounted a little more snugly than in the transmitter. The six wire links are first fitted to the PCB, followed by the 20-pin socket for IC1. Once all the components have been fitted (except for IC1, IC2 and the radio module), power can be applied to the receiver card and with a DVM or scope you can check the voltages around the PCB. If everything is in order then the rest of the components can be fitted. Make sure that the metal screen on the RF module does not cause a short circuit with components on the board. Finally, a 15.5 cm length of insulated wire is soldered to point A1 on the PCB to act as an aerial. To make the unit a little more robust, this connection and the RF module should be secured to the PCB with the aid of a little hot glue or silicon adhesive. The current consumption of the receiver unit alone is approximately 40 mA.

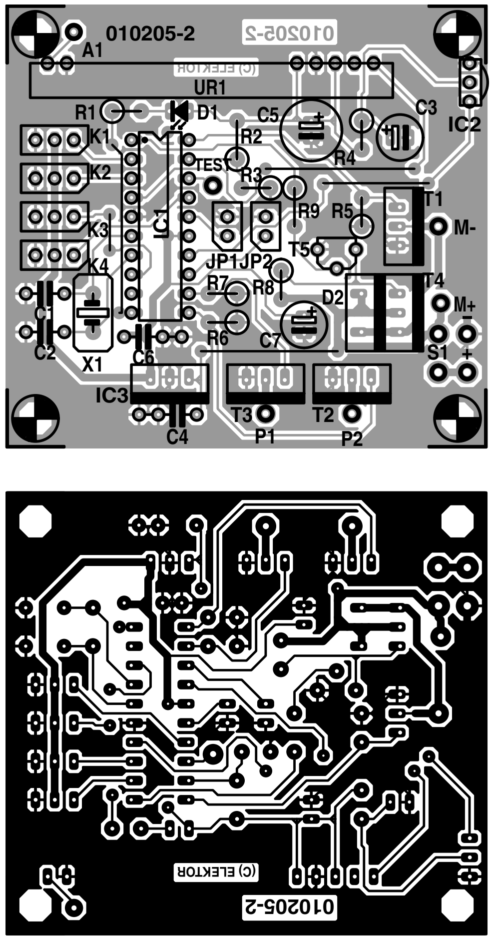


Figure 4. Layout and component placement of the receiver PCB.

Diagnostics

For debugging purposes a diagnostic output is available from pin P0.3 on the receiver controller. This test point can be fitted with a solder or test pin. The receiver controller uses this pin to output a signal every time it detects an error anywhere in the received message. It checks the received message values after the start bit and flags an error when they are not within tolerance. Using this signal it is possible to optimise the receiver siting away from sources of interference. Comparing this signal with the received telegram on a scope will indicate which part of the telegram has been corrupted.

(010205-2)

COMPONENTS LIST
Receiver

Resistors:
R1 = 470Ω
R2,R9 = 27kΩ
R3,R8 = 10kΩ
R4 = 100Ω
R5,R6,R7 = 100kΩ

Capacitors:
C1,C2 = 15pF
C3 = 10µF 16V
C4,C6 = 100nF
C5 = 470µF 16V
C7 = 220µF 16V

Semiconductors:
D1 = LED, red, 3mm
D2 = MBR745
T1 = SUP75N03, IRL2203
T2,T3 = BUZ11
T4 = IRF4905L (International Rectifier)
T5 = BC547
IC1 = 87LPC762BN, programmed, order code **010205-42**
IC2 = SFH5110-36 (Siemens)
IC3 = LM2940

Miscellaneous:
X1 = 6MHz quartz crystal
S1 = on/off switch, 1 make contact
JP1,JP2 = 2-way pinheader with jumper
4 servo connector plugs, 3-way
UR1 = 433MHz RX2 receiver module from Radiometrix (Farnell)
PCB, order code **010205-2**
Disk, project software, order code **010205-11**

Addresses

The European branch of
CTS Corporation is at
High Blantyre
Glasgow G72 0XA
Tel. 01698 824 331
www.ctscorp.com

CTS resistive products are also supplied by
Quiller Electronics Ltd.
Bournemouth BH6 5EU
Tel. 01202 417744

Joystick: www.ur-home.com
Microcontroller: www.semiconductors.com/mcu/
LM2940: www.national.com/pf/LM/LM2940.html
MBR745: www.fairchildsemi.com/pf/MB/MBR745.html
SUP75N03: www.vishay.com
RF Module: www.radiometrix.com