



Remote Controlled Amphibious Robot (R-CAR)

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ABSTRACT

Nowadays it is of major importance to monitor and collect information about the environment and there are several instances wherein the environs are not conducive to human presence. For underwater pipeline monitoring, detection of enemy submarines, exploration of marine life, search and rescue operations, and surveillance in hazardous environments, it is necessary to develop an unmanned remote controlled vehicle which can do all the required functions. Considering terrains under water and on land, an amphibious robot is best suited for these kinds of activities. The amphibious robot (R-CAR) designed is capable of moving on land as well as on water. It swims with the help of its flaps, rather than using conventional thrusters and control surfaces for propulsion. Through an appropriate set of gaits, this robot is capable of translatory and rotatory motion in the open water. Wheels are attached for movement on land. This robot is controlled by Dual Tone Multi Frequency (DTMF) tones produced by a mobile phone which acts as a remote. These tones are then transmitted by a transmitter-encoder module. The receiver-decoder pair placed inside the robot receives and decodes the signal to detect what key the user has pressed. This signal is then received by an on-board microcontroller which is programmed to drive the powerful servo motors by pulse width modulation. The hydro dynamically designed flaps are fastened to the servo motors which provide movement to this robot. All the electronic circuitry is enclosed in streamlined water sealed enclosure. For movement on land, wheels are driven by the DC motors which are programmed by the microcontroller. The robot was found to move satisfactorily on land as well as in water as per the design.

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Introduction

A robot is a mechanical or a virtual intelligent agent that can perform tasks autonomously or with an external control. Robots can be autonomous, semi-autonomous or remotely controlled. Today, robotics is a rapidly growing field, as we continue to research, design, and build new robots that serve various practical purposes, whether domestically, commercially or militarily. Some robots are specifically designed to perform several hazardous jobs such as defusing bombs, exploring shipwrecks, and mines. Achieving reliable communication is an important open area of research in robotics as well as in several other domains. As interest in robotics continues to grow, robots are increasingly being primary mode for communication in robotics. Radio Frequency is an obvious choice for communication since it allows more information to be transferred at a smaller distance. Although appearance and capabilities of robot vary vastly, all robots share the feature of a mechanical, movable structure under some form of control. The control of robot involves three distinct phases: perception, processing and action. Generally, the perception is performed by sensors mounted on the robot, processing is done by the on-board microcontroller or processor, and the mechanical action is performed using motors or other actuators. R-CAR is a specially designed robot for both under water and on land operation. Its main aim is to manoeuvre efficiently underwater, so the whole electronic circuitry is sealed completely inside a water tight box and is provided with sufficient driving power that it can move underwater. The driving power is achieved by using four servo motors to which the flaps are attached. Movement on land is

provided by wheels which are attached to the DC motors. Wireless control of the robot is achieved using Dual Tone Multi Frequency (DTMF) signals generated by a mobile phone. Microcontroller ATmega32 is used to control the direction of robot using Pulse Width Modulation (PWM) technique. The robot is equipped with four servo motors and two DC motors which gesticulate the robot in different directions. Control signals are provided to robot through wireless remote implemented using RF transmission.

METHODOLOGY

DTMF Generation

There are two connections coming out of the phone used to generate the DTMF tones, these are namely the tip and the ring as shown in Fig 1. The 3.5mm TRS (Tip, Ring, Sleeve) connector (commonly known as headphone jack) used here is the one similar to that used for iPods and other hands free headsets. The tip of the connector which transmits the information is called the "tip" and the rest after a black strip is called the "ring" and is connected to the ground.



Fig. 1 3.5mm TRS Connector

DTMF Decoder

The HT9170B DTMF decoder outputs a Binary Coded Decimal (BCD) equivalent of the key pressed on the DTMF keypad. The DTMF decoder consists of three band pass filters and two digital decode circuits to convert a DTMF signal into digital code output. An operational amplifier is built-in to adjust the input signal. The pre-filter is a band rejection filter which reduces the dialling tone from 350Hz to 400Hz. The low group filter filters low group frequency signal output whereas the high group filter filters high group frequency signal output. Each filter output is followed by a zero-crossing detector with hysteresis. When each signal amplitude at the output exceeds the specified level, it is transferred to full swing logic signal. It is a DTMF receiver integrated with digital decoder and a band split filter. Such devices use digital counting techniques to detect and decode all the 16 DTMF tone pairs into a 4-bit code output. Highly accurate switched capacitor filters are employed to divide DTMF tone signals into low and high group signals. A built-in dial tone rejection circuit is provided to eliminate the need for pre-filtering. This DTMF receiver minimizes external component count by providing an on-chip differential input amplifier, clock generator, and a latched three-state interface bus. The on-chip clock generator requires only a low cost TV crystal or ceramic resonator as an external component. Its architecture consists of a band split filter section, which separates the high and low group tones, followed by a digital counting section which verifies the frequency and duration of the received tones before passing the corresponding code to the output bus.

Encoder – Transmitter Pair

A Dual Tone Multi Frequency (DTMF) tone is generated by the keypad when a number is pressed. A mobile phone is used to generate DTMF tones & IC HT9170B decodes it provides the binary equivalent of the key pressed. IC HT12E encodes the 4 bit binary data and transmits it using the TXC1 transmitter module. An antenna of length depends on the frequency used for communication. Here, an antenna of 10 to 15 cm is incorporated to provide a good range. The antenna is necessary to increase the operating range of R-CAR. The block diagram of the encoder-transmitter pair is illustrated in Fig. 2

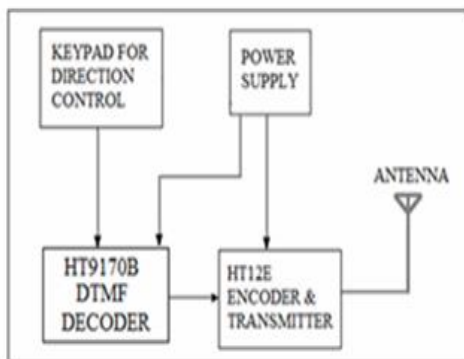


Fig. 2 Block diagram of the transmitter module

The 2^{12} encoders (IC HT12E) are a series of CMOS LSIs for remote control system applications. They are capable of encoding information which consists of N address bits.

Each address/ data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF or an infrared transmission medium upon receipt of a trigger signal.

The 4 bits received from the HT9170B DTMF Decoder (D0-D3) is encoded, and the DOUT of the HT12E encoder gives the encoder data serial transmission output i.e., the 4 parallel bits are converted to a serial output which can be transmitted from the transmitter module TX-C1. The TX-C1 is an amplitude shift keying transmitter module designed specifically for remote control applications operating at 315/433.92 MHz.

Receiver – Decoder Pair

Encoded signal is received by RXD1 Receiver module placed on the R-CAR. IC HT12D decodes and obtains the original 4 bit binary data. The transmitter-receiver operating frequency is 433MHz & operating range is 100 m. RX-D1 is a miniature receiver module that receives on-off keyed modulation signal and demodulated to digital signal for the next decoder stage.

Local Oscillator is made of LC structure. The result is excellent performance in a simple-to-use, with a low external component count. The RXD1 is designed specifically for remote-control and wireless security receiver operating at 315/434 MHz.

The 2^{12} decoders (IC HT12D) are a series of CMOS LSIs for remote control system applications. They are paired with Holtek's 2^{12} series of encoders. For proper operation, a pair of encoder/decoder with the same number of addresses and data format should be chosen. The decoders receive serial addresses and data from a programmed 2^{12} series of encoders that are transmitted by a carrier using an RF or an IR transmission medium. They compare the serial input data three times continuously with their local addresses. If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. Valid transmission is indicated by a corresponding signal on the VT pin.

The data from the receiver module is sent to input of the HT12D decoder. The 4 bit decoded data which consists of the binary equivalent of the key pressed from the DTMF decoder is then obtained from the HT12D decoder. This is sent to the microcontroller which in turn provides control signals to gesticulate the R-CAR.

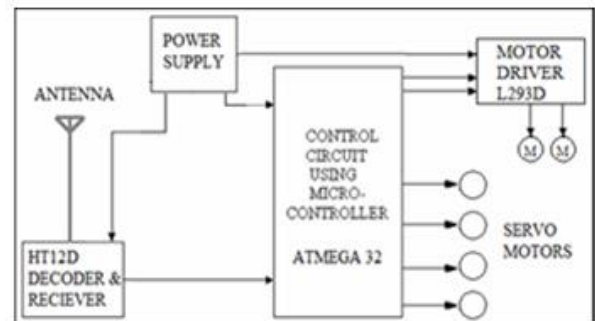


Fig. 3 Block diagram of the receiver module
Microcontroller Atmega32

Binary Coded Decimal (BCD) output of HT12D decoder is obtained by the ATmega32 Microcontroller. Depending on the BCD code, the microcontroller controls the direction and selection of the motors on the main body.

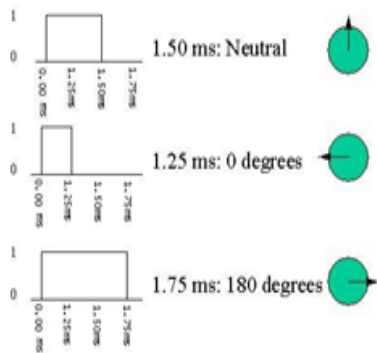
The Atmel AVR ATmega32 is a low power CMOS 8-bit microcontroller based on the RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. Atmega32 has 32 kB of In-System Programmable Flash Program memory with Read-While-Write

capabilities, 1024 Bytes EEPROM, 2Kb SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundary-scan, On-Chip Debugging support and programming, three flexible Timer/Counters with compare modes, Internal and External interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8 channel, 10 bit ADC with optional differential input stage with programmable gain, a programmable WDT with Internal Oscillator, an SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next External interrupt or Hardware reset. In the power save mode, the Asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping.

The device is manufactured using Atmel's high density non-volatile memory technology. The On chip ISP Flash allows the memory to be reprogrammed in-system through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip Boot program running on the AVR core. The boot program can use any interface to download the application. By combining an 8-bit RISC CPU with In-system self-programmable flash on a monolithic chip, the Atmel ATmega32 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications.

F. Servo Motors

The servo motor has 3 pins – Power supply, Ground & the control wire. The angle of rotation of the servo is determined by the duration of a pulse that is applied to the control wire of the servo motor. The servo expects to see a pulse every 20 milliseconds. The length of the pulse will determine how far the motor turns. A 1.5 millisecond pulse, for example, will make the motor turn to the 90 degree position (often called the neutral position). If the pulse is shorter than 1.5 ms, then the motor will turn the shaft to closer to 0 degrees as shown in Fig. 4.



If the pulse is longer than 1.5ms, the shaft turns closer to 180 degrees. The specification of servo motor is shown in Table 1.

Motor driver

The L293D motor driver is used to drive the R-CAR on land. It is a quadruple high-current half-H driver. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5V to 36 V. The device is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications. All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. The L293D is characterized for operation from 0°C to 70°C. When an enable input is high, the associated drivers are enabled and their outputs are active and in phase with their inputs. When the

enable input is low, those drivers are disabled and their outputs are off and in the high-impedance state.

Table 1 Servo motor specification

Control System:	Pulse width control, 1500µs neutral	
Operating Voltage:	4.8V~6.0V (DC)	
Test Voltage:	@4.8V	@6.0V
Stall Torque:	≥3.2kgf.cm	≥3.5kgf.cm
Operating Speed:	0.20sec/60 ⁰	0.17sec/60 ⁰
Running Current:	~0.2A	~0.25A
Stall Current:	~0.8A	~1.0A
Output Angle:	≥170 ⁰	

ALGORITHM

A DTMF tone is generated when a key is pressed on the mobile phone. IC HT9170B decodes the signal and provides the binary equivalent of the key pressed. IC HT12E encodes the 4 bit binary data and transmits it using the TXC1 transmitter module. Encoded signal is received by the RXD1 Receiver module placed in the R-CAR. IC HT12D decodes and obtains the original 4 bit binary data. This 4 bit data is then sent to the microcontroller on board the robot. The microcontroller then sends the corresponding signal to the motor driver or the servo motor depending on the key pressed.

- 2 is pressed, all the servo motors are activated and the robot moves front by flapping.
- 4 is pressed, only the 2 servo motors on the left are activated and the 2 servo motors on the right are deactivated, so the robot moves to its left.
- 6 is pressed, only the 2 servo motors on the right are activated and the 2 servo motors on the left are deactivated, so the robot moves to its right.
- 7 is pressed, only the 2 servo motors on the front are activated and the 2 servo motors on the back are deactivated, so the robot tilts at the back.
- 9 is pressed, only the 2 servo motors on the back are activated and the 2 servo motors on the front are deactivated, so the robot tilts at the front.
- 5 is pressed, all the motors are deactivated, so the robot stops.
- 1 is pressed, both the DC motors are activated in clockwise direction, so the robot moves forward on land.
- 3 is pressed, both the DC motors are activated in anticlockwise direction, so the robot moves forward on land.
- 8 is pressed, only the left DC motor is activated, so the robot moves to the left.
- 0 is pressed, only the right DC motor is activated, so the robot moves to the right.

RESULT

For the robot to move forward on water, all the servo motors are actuated & the flaps fixed to the servo motor using the connector provide thrust to the robot to move forward. The flaps are designed in such a way that it goes down pushing enough water to provide thrust but when the flap comes back to its original position, it faces minimal resistance from the water. The movement on land is provided by the two DC motors. When the robot is on land, the servo motors are turned off. The wheels at the side along with castor wheels attached at the front

and rear end at the bottom of the chassis provide free movement to the robot. Table 2 shows the movement of the robot for the key pressed. Figure 5 shows the outline of the robot with the numbers indicating the position of the motors.

Table 2 Table of results

Key pressed	Output of DTMF Decoder	Output from microcontroller	Motor (M) Status (Ref. Fig.5)	Movement/Output of the robot
ON WATER: 4 Servo motors are activated, 2 DC motors are deactivated				
2	0x02 - 0010	1111	All ON	Forward
4	0x04 - 0100	1010	1,3 ON	Leftward
6	0x06 - 0110	0101	2,4 ON	Rightward
5	0x05 - 1000	0000	All OFF	Stop
7	0x07 - 0111	0011	3,4 ON	Front Tilt
9	0x09 - 1001	1100	1,2 ON	Rear Tilt
ON LAND: 2 DC motors are activated, 4 Servo motors are deactivated				
1	0x01 - 0001	1010	M1, M2 ON (Clockwise)	Forward
3	0x03 - 0011	1001	M1 ON	Leftward
8	0x08 - 1000	0110	M2 ON	Rightward
0	0x0A - 1010	0101	M1, M2 ON (Anti clockwise)	Reverse

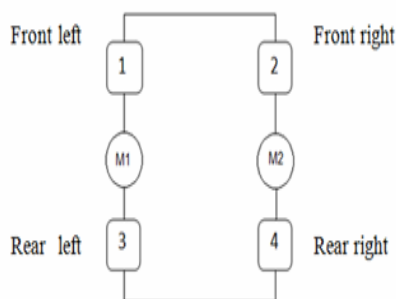


Fig. 5 Outline of the robot with numbers indicating the position of the motors

V. Conclusion

The R-CAR was able to move efficiently on land as well as in water. The operating range on land was found to be 100 m and it was tested in a tank 5m deep and was found to be working satisfactorily. The microcontroller was programmed to control the actuation of the motors. AVR Studio software was used to write and compile the program and AVR Dude software was used to burn the hex file onto the microcontroller.

Future Scope

- Cameras can be fitted to each side to obtain a 360° panoramic view.
- A total of six servos can be attached to the robot hence providing better maneuverability.
- The R-CAR can be modified to have six degrees of freedom; hence possessing better steering capabilities.
- A sensor network can be developed with one robot acting as the main controller and several other robots connected to the master robot.
- It can be designed to function as a pick and place robot.

Limitations

- The range of the transmitter-receiver is limited to 100 metres on land.
- The speed obtained by using the 3.2-3.5 kg.f.cm servo motors is very less.
- Servo motors used in R-CAR consume 1A each, hence a supply which provides high ampere rating is required which can be provided only by a tethered supply or a heavy battery.
- DC Motors were not used to drive the robot underwater as it had very low rpm and torque rating.

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