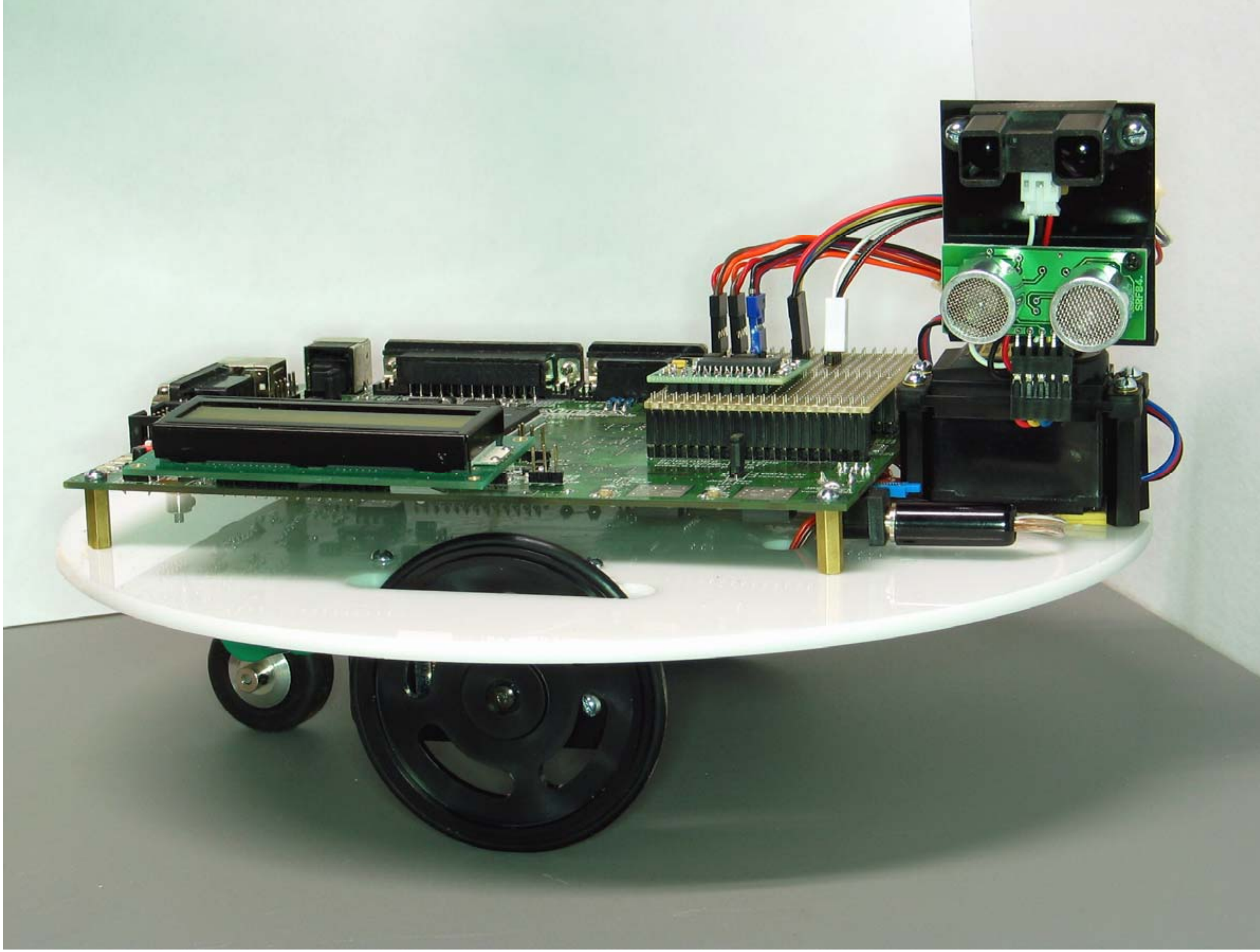


Figure 13.1 The UP3-bot uses an R/C car battery and R/C servos for drive motors.

Figure 13.2 Left: Radio Control Servo Motor and Right: Servo with Case and Gears Removed.

```
LIBRARY IEEE;
USE  IEEE.STD_LOGIC_1164.ALL;
USE  IEEE.STD_LOGIC_ARITH.ALL;
USE  IEEE.STD_LOGIC_UNSIGNED.ALL;
ENTITY motor_control IS
        PORT      (clock_1kHz                              : IN           STD_LOGIC;
                  lmotor_dir, rmotor_dir                   : IN STD_LOGIC;
                  lmotor_speed, rmotor_speed     : IN STD_LOGIC;
                  lmotor, rmotor                 : OUT           STD_LOGIC);
END motor_control;
ARCHITECTURE a OF motor_control IS
        SIGNAL count_motor: STD_LOGIC_VECTOR( 4 DOWNTO 0 );
BEGIN
        PROCESS
            BEGIN
                                        -- Count_motor is a 20ms  timer
                  WAIT UNTIL clock_1kHz'EVENT AND clock_1kHz = '1';
                             IF count_motor /=19 THEN
                                  count_motor <= count_motor + 1;
                             ELSE
                                  count_motor <= "00000";
                             END IF;
                             IF count_motor >= 17 AND count_motor < 18 THEN
                                        -- Don't generate any pulse for speed = 0
                                        IF lmotor_speed = '0' THEN
                                             lmotor <= '0';
                                        ELSE
                                             lmotor <= '1';
                                        END IF;
                                        IF rmotor_speed = '0' THEN
                                             rmotor <= '0';
                                        ELSE
                                             rmotor <= '1';
                                        END IF;
```

```
                -- Generate a 1 or 2ms pulse for each motor
                -- depending on direction
                -- reverse directions between the two motors because
                -- of servo mounting on the UP3-bot base
            ELSIF count_motor >=18 AND count_motor <19 THEN
                IF lmotor_speed /= '0' THEN
                    CASE lmotor_dir IS
                        -- FORWARD
                        WHEN '0' =>
                                lmotor <= '1';
                        -- REVERSE
                        WHEN '1' =>
                                lmotor <= '0';
                        WHEN OTHERS => NULL;
                        END CASE;
                ELSE
                        lmotor <= '0';
                END IF;
                IF rmotor_speed /= '0' THEN
                    CASE rmotor_dir IS
                        -- FORWARD
                        WHEN '1' =>
                                rmotor <= '1';
                        -- REVERSE
                        WHEN '0' =>
                                rmotor <= '0';
                        WHEN OTHERS => NULL;
                        END CASE;
                ELSE
                        rmotor <= '0';
                END IF;
            ELSE
                lmotor <= '0';
                rmotor <= '0';
            END IF;
    END PROCESS;
END a;
```

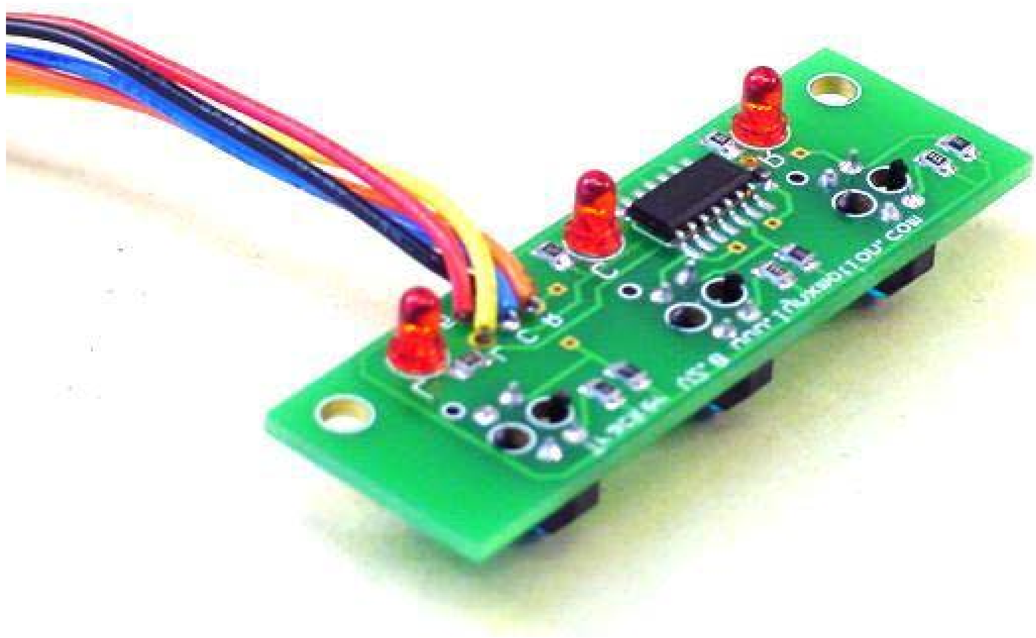


Figure 13.3 – Three LEDs and phototransistors are mounted on bottom of the Line Tracker board.

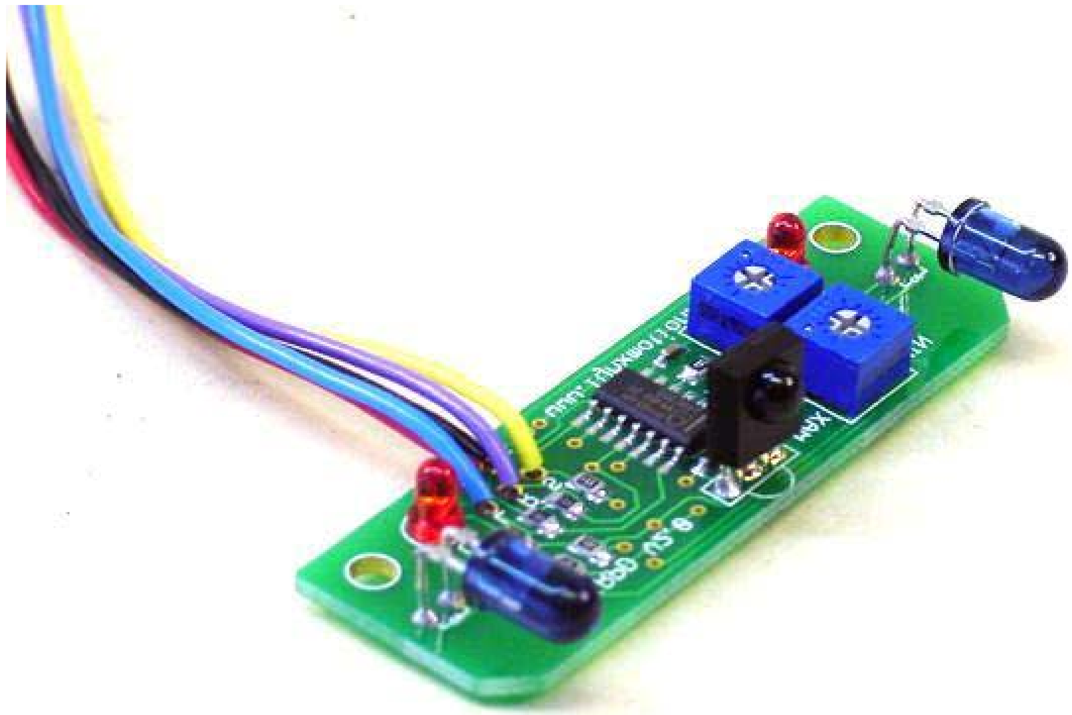


Figure 13.4 IR Proximity Sensor Module – Two IR LEDs on sides and one IR sensor in middle.

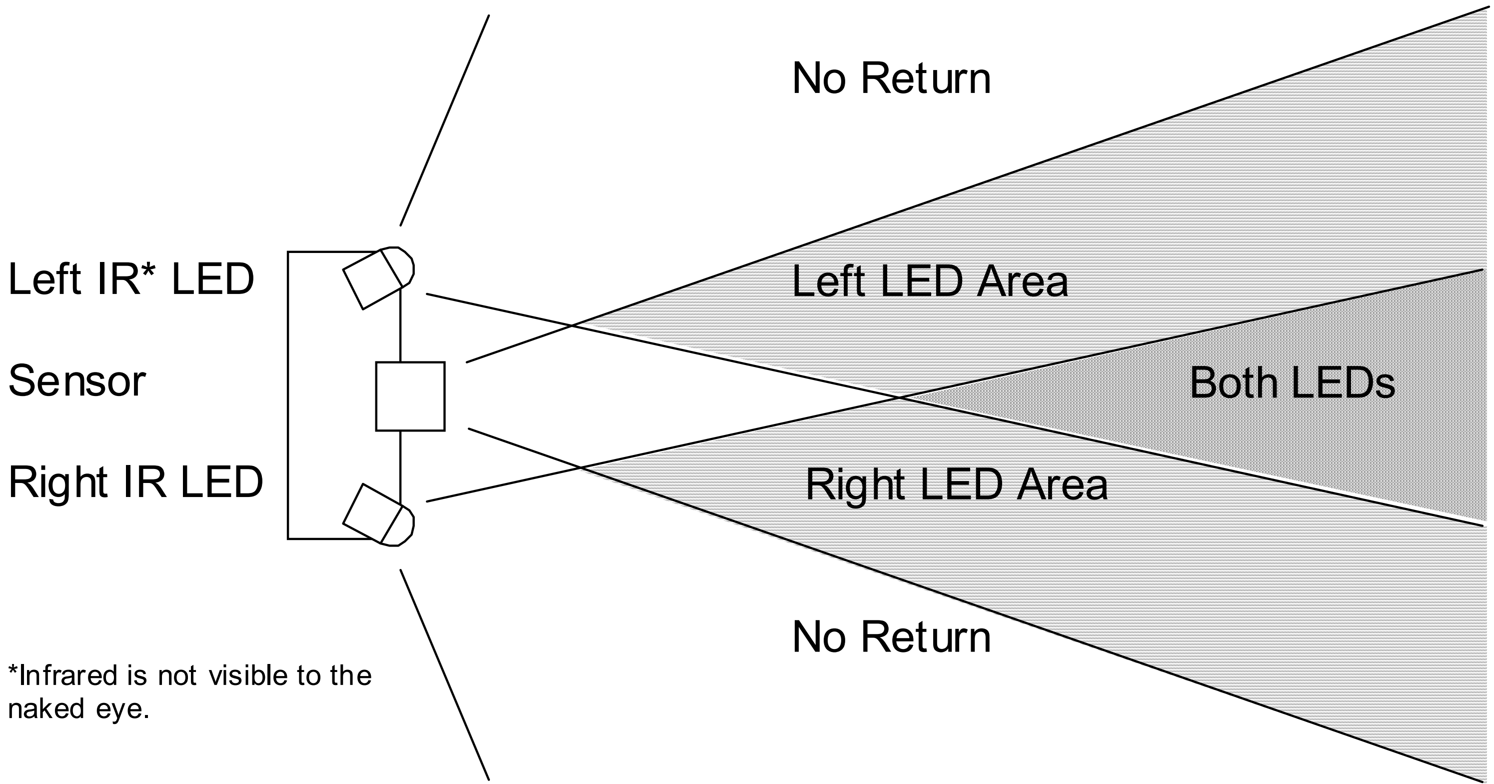


Figure 13.5 Proximity detector active sensor area.

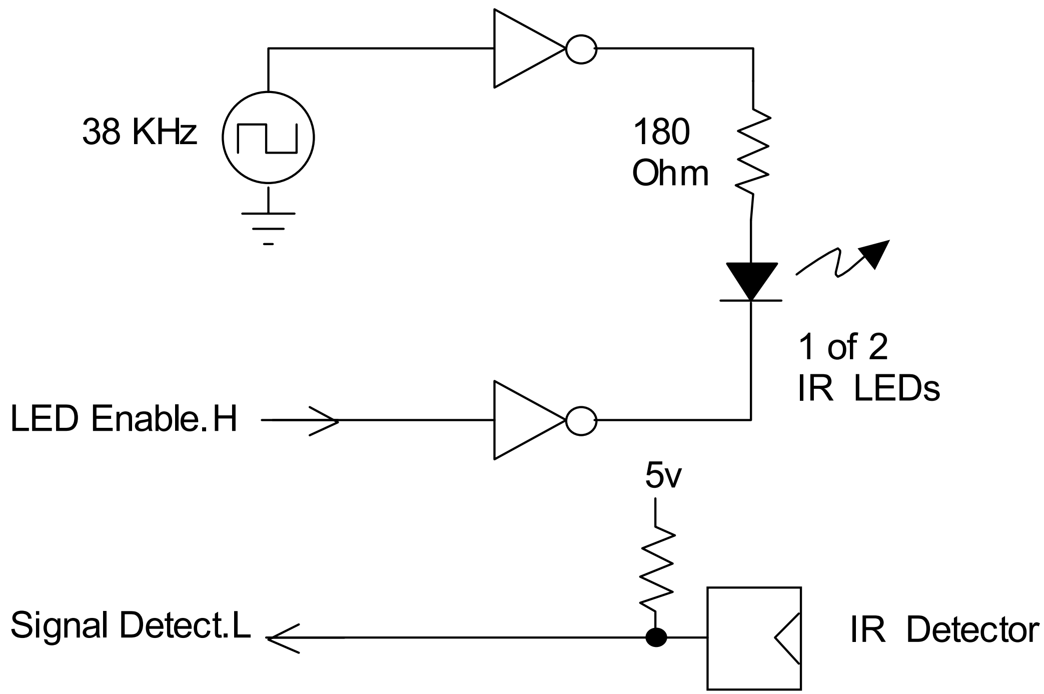


Figure 13.6 Circuit layout of one LED and the receiver module on the infrared detector.

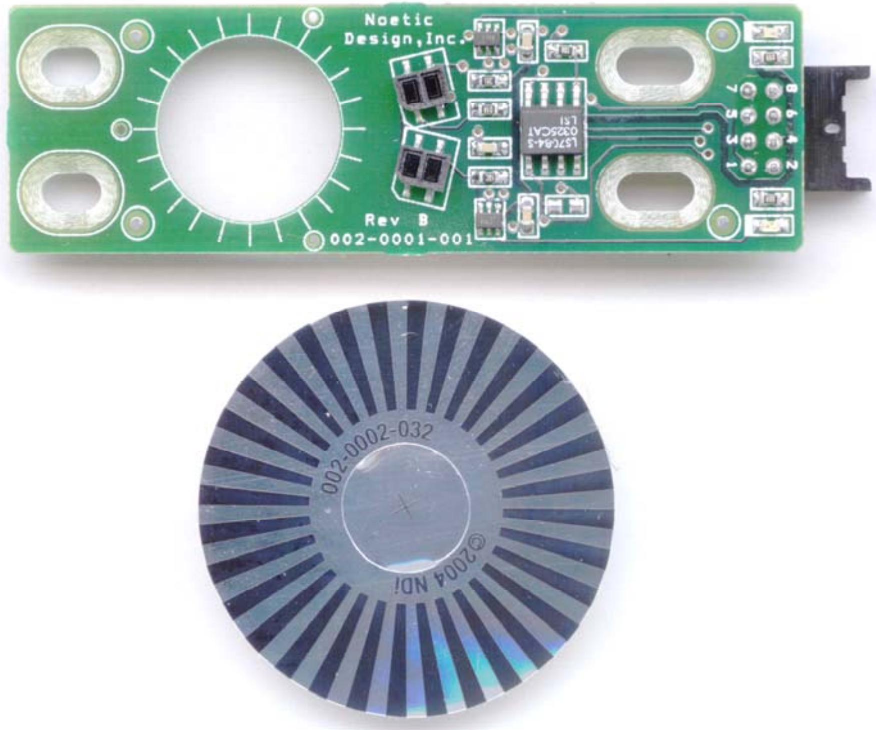


Figure 13.7 Nubotics WW-01 Wheel Watcher Incremental Encoder System.

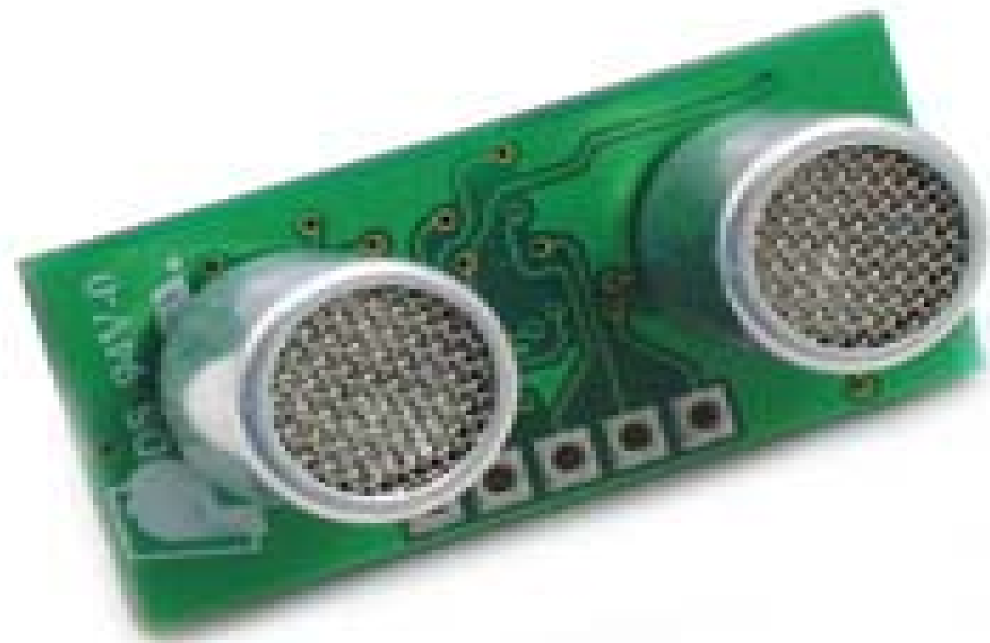


Figure 13.8 Devantech SRF10 Ultrasonic Range Finder.

Figure 13.9 Sharp IR Ranging Module.

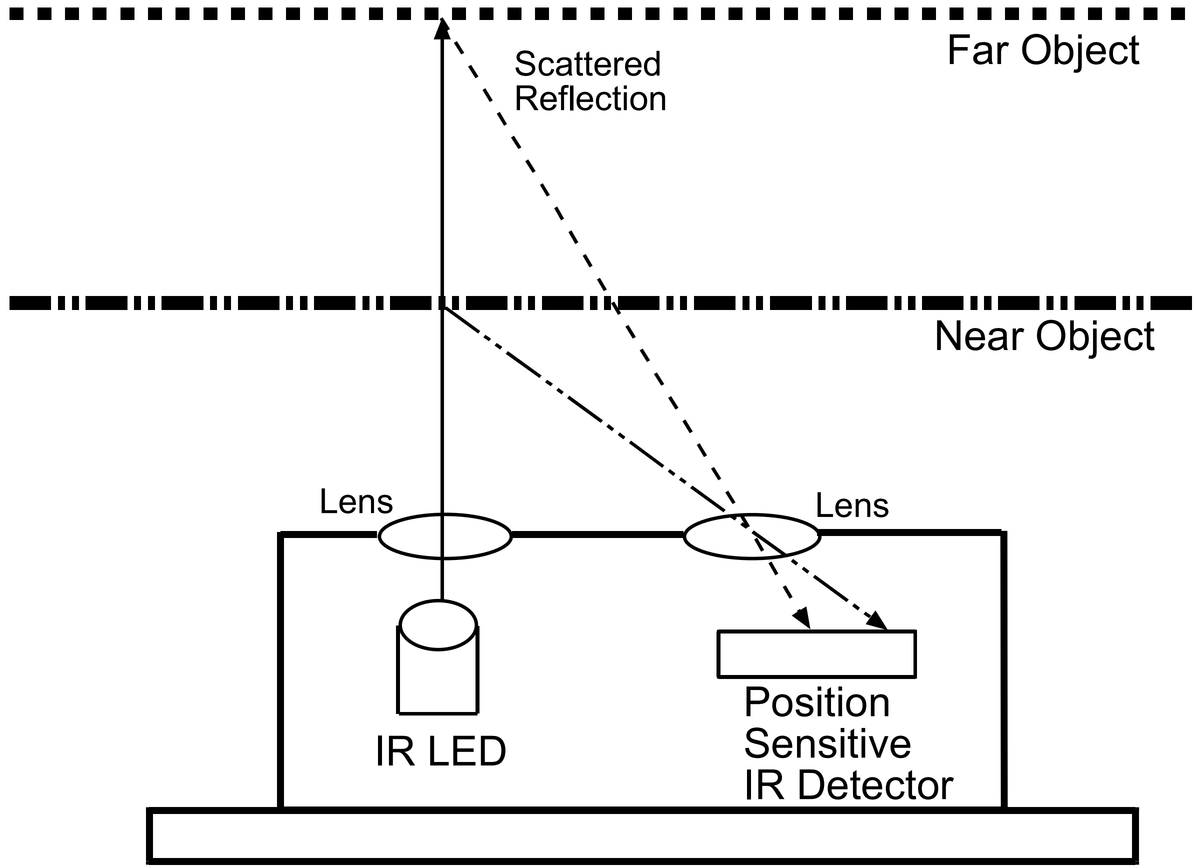


Figure 13.10 Operation of Sharp IR Ranging Module.

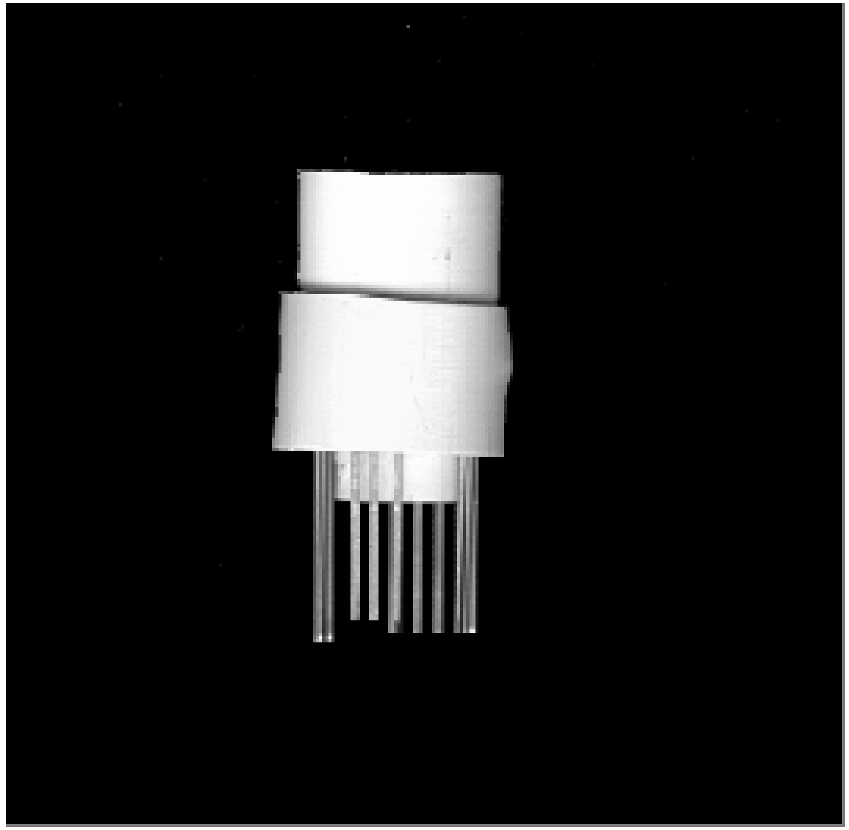


Figure 13.10 Dinsmore 1490 Digital Compass Sensor

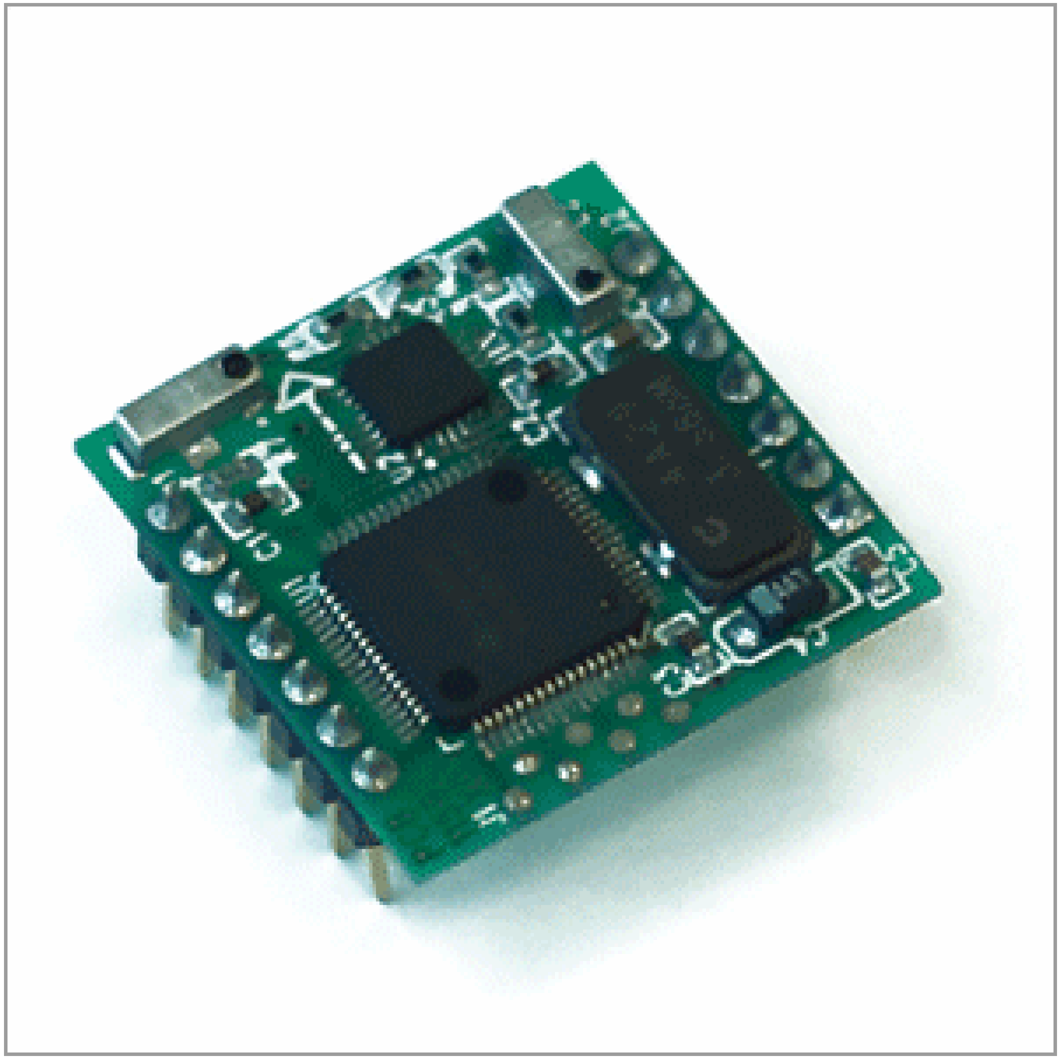


Figure 13.11 PNI Electronic Compass Module.

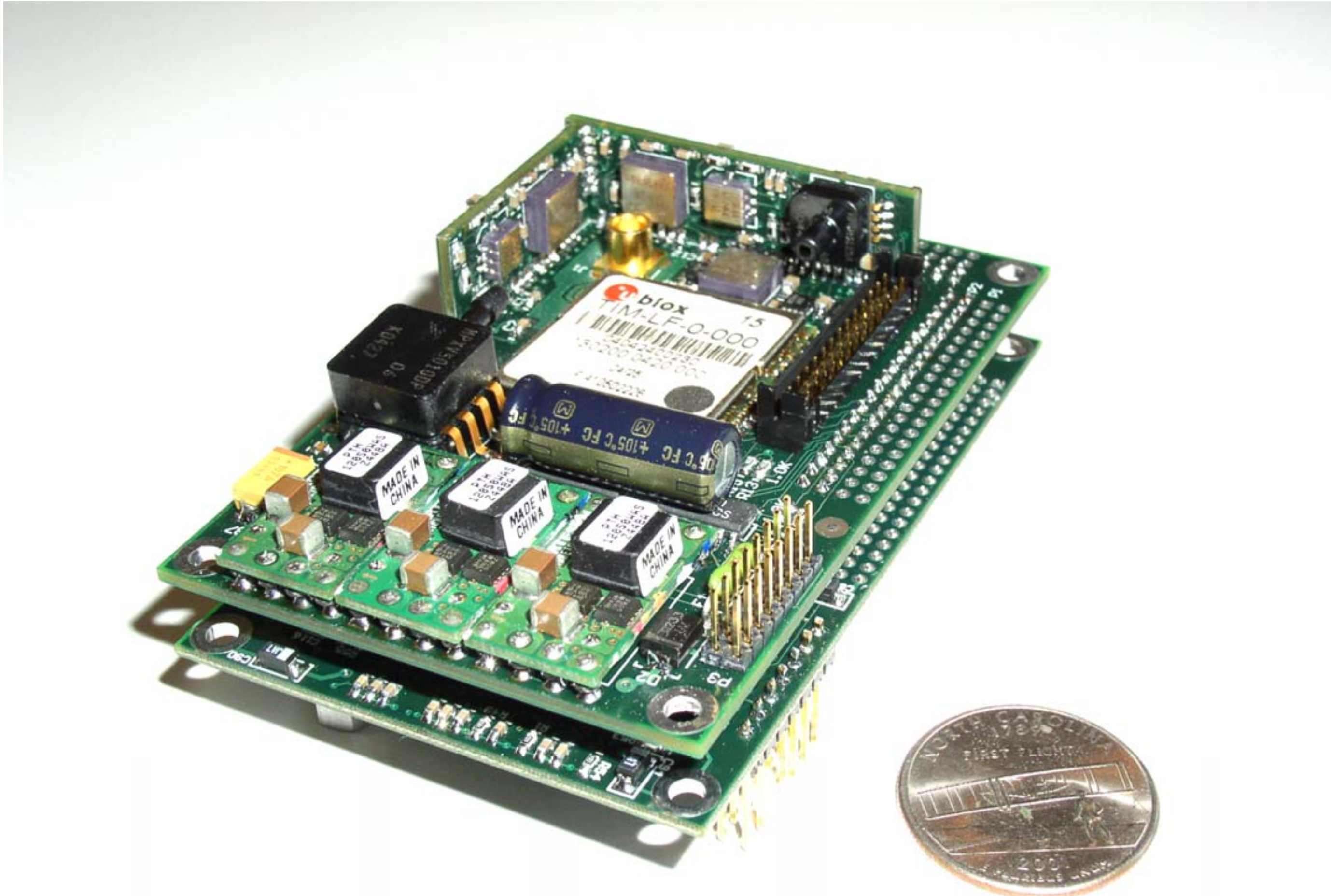


Figure 13.12 Small sensor board for an aircraft autopilot system. Photograph ©2004 courtesy of Henrik Christophersen , Georgia Institute of Technology Unmanned Aerial Research Facility.

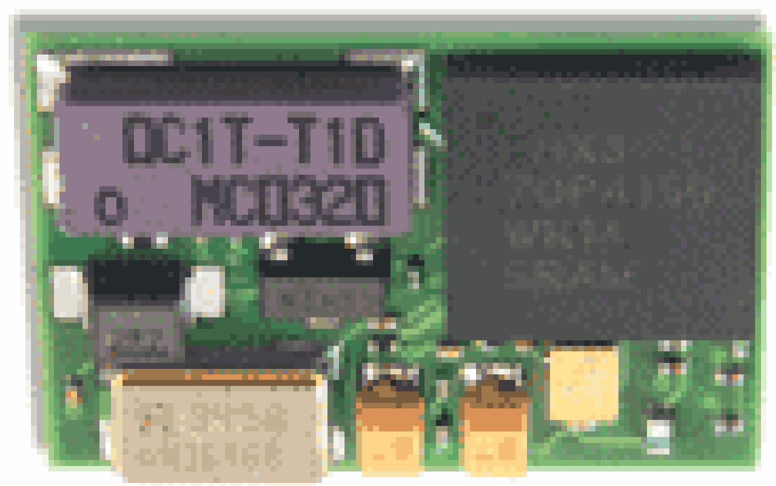


Figure 13.13 Motorola Single Chip GPS module.

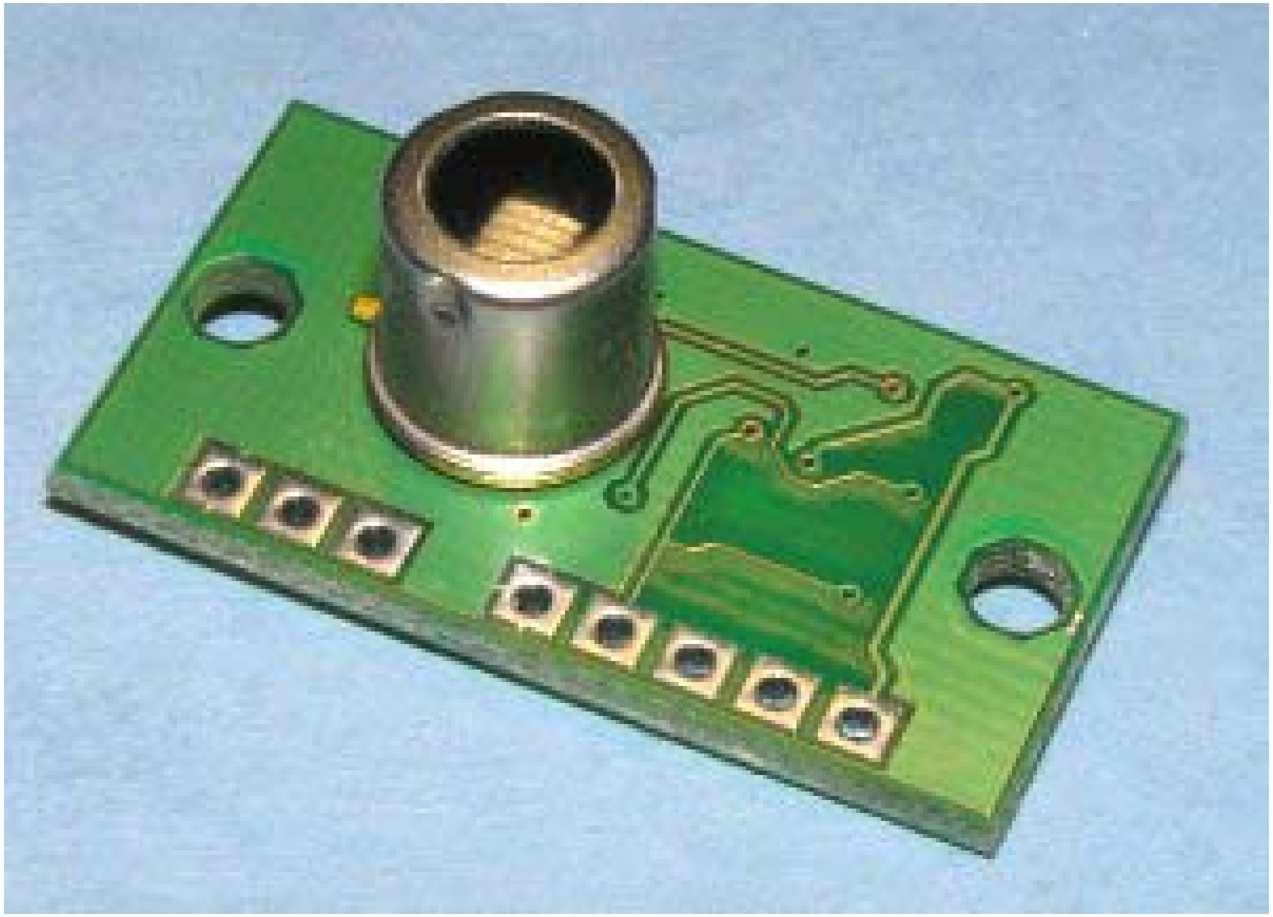


Figure 13.14 Devantech TPA81 Eight Pixel Thermal Array Sensor.

Figure 13.15 The CMUCAM2 contains a color video camera on a chip and a PIC microcontroller.

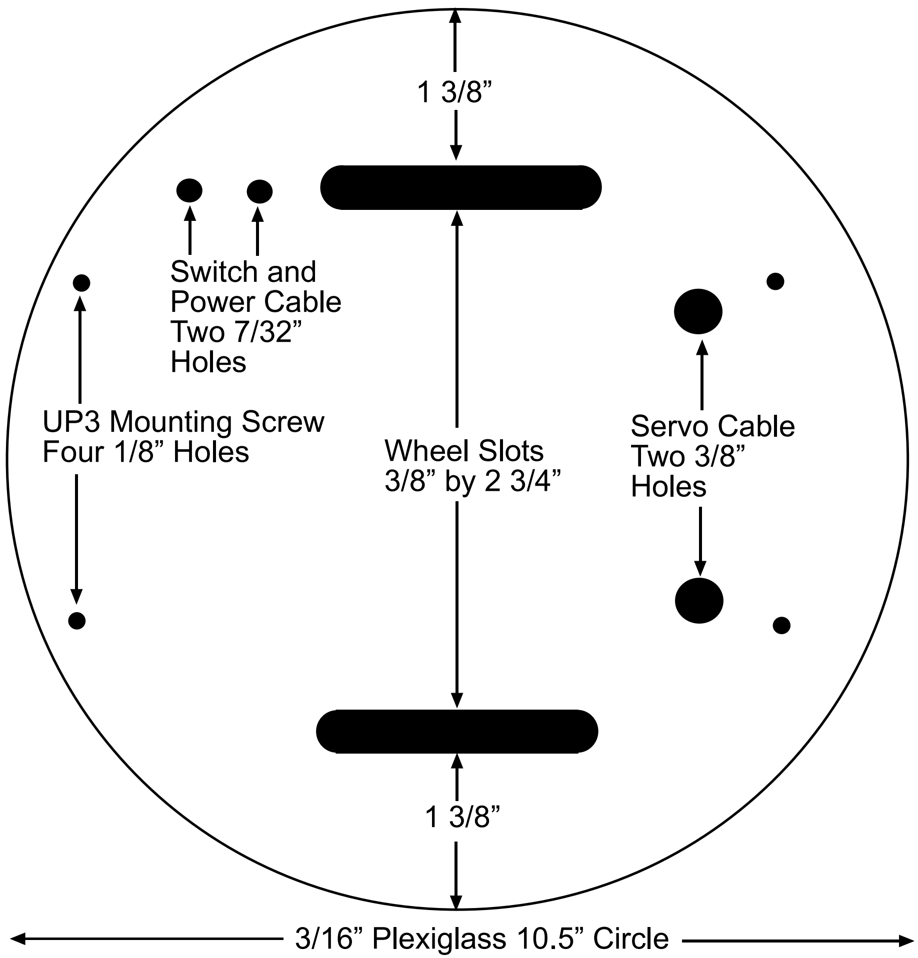


Figure 13.16 UP3-bot Plexiglas Base with wheel slots and drill hole locations.

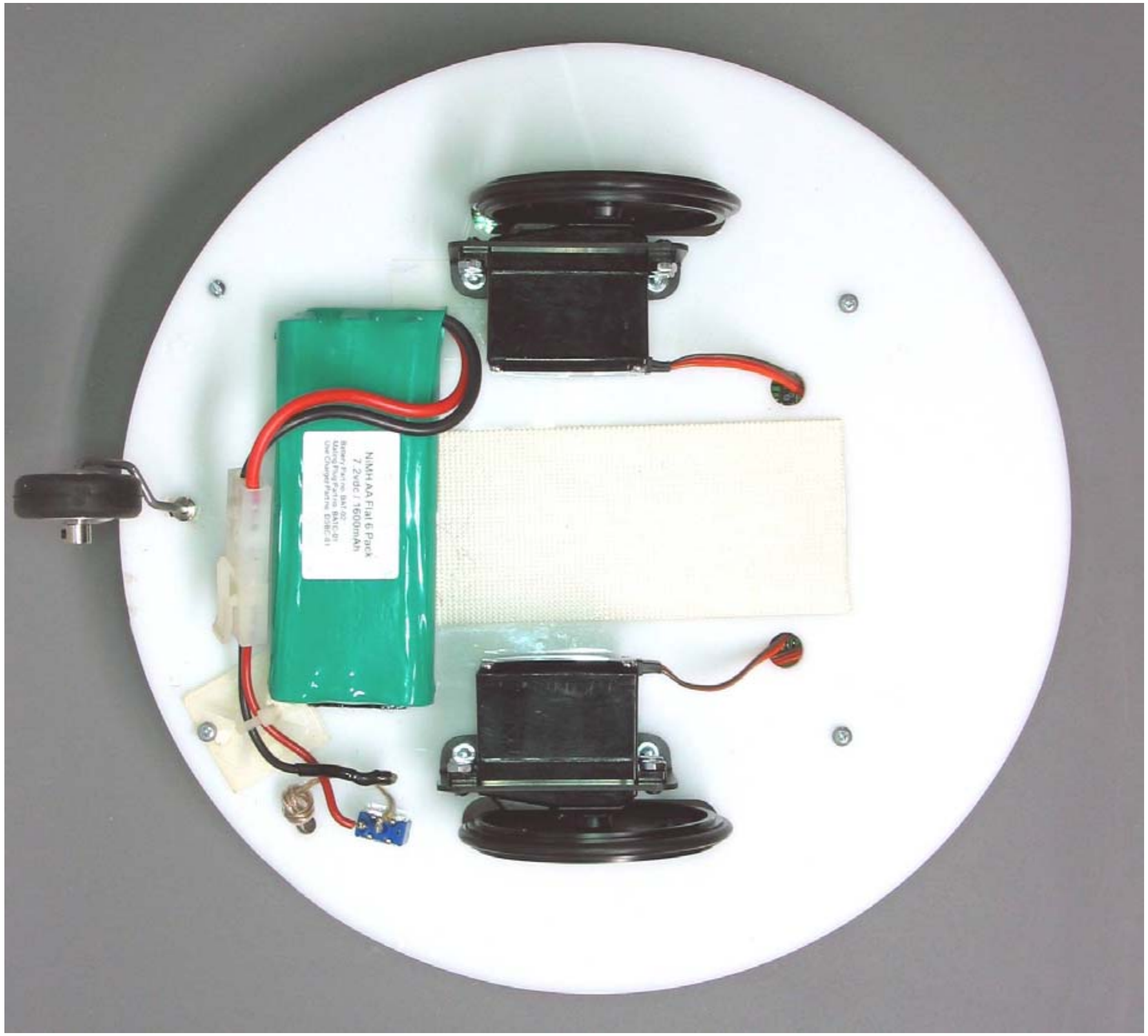


Figure 13.17 Bottom view of UP3-bot base showing battery, servos, wheels, and cabling.

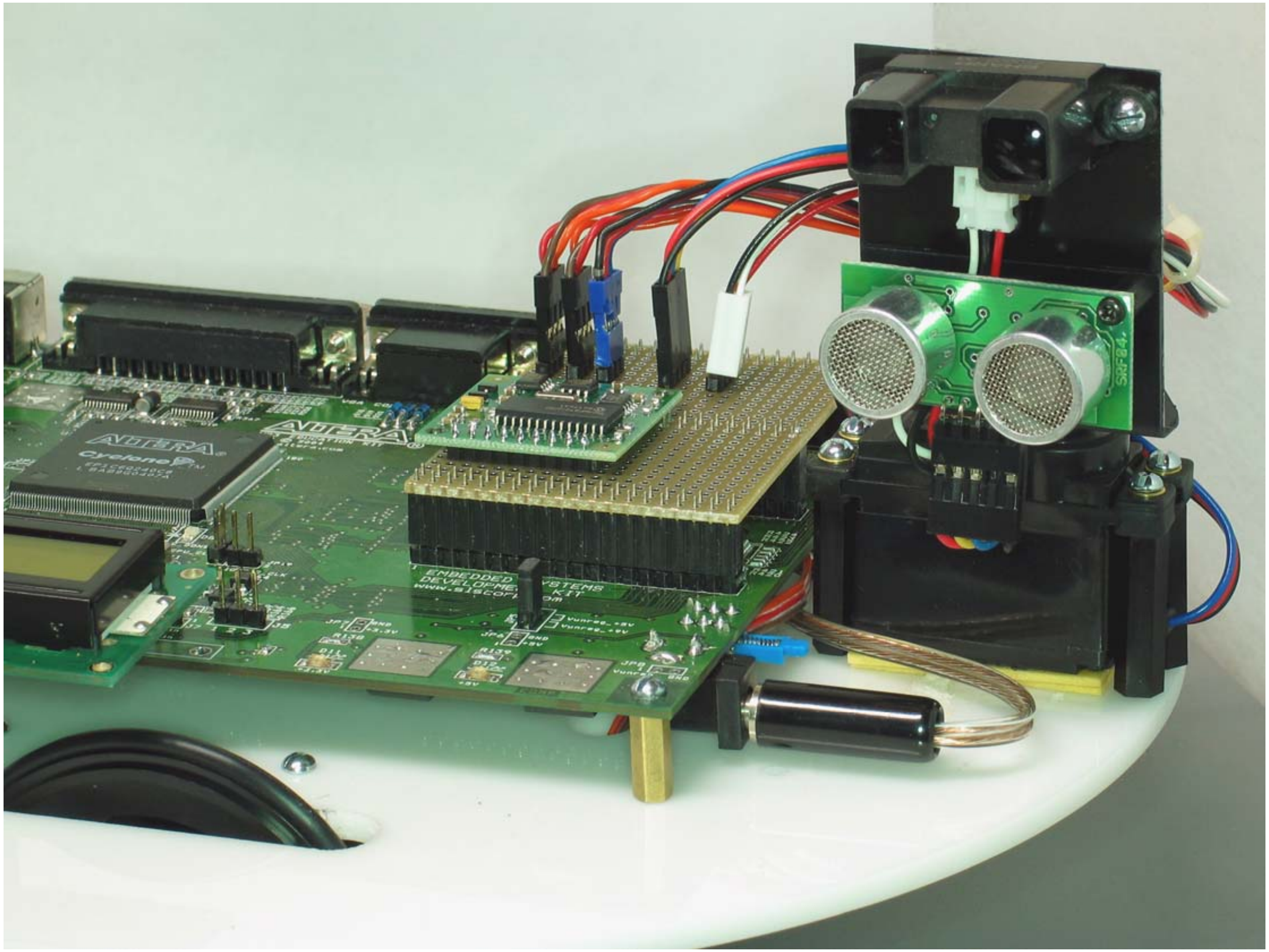


Figure 13.18 Top View of UP3-bot Base with Compass, IR, and Sonar Sensor Modules.

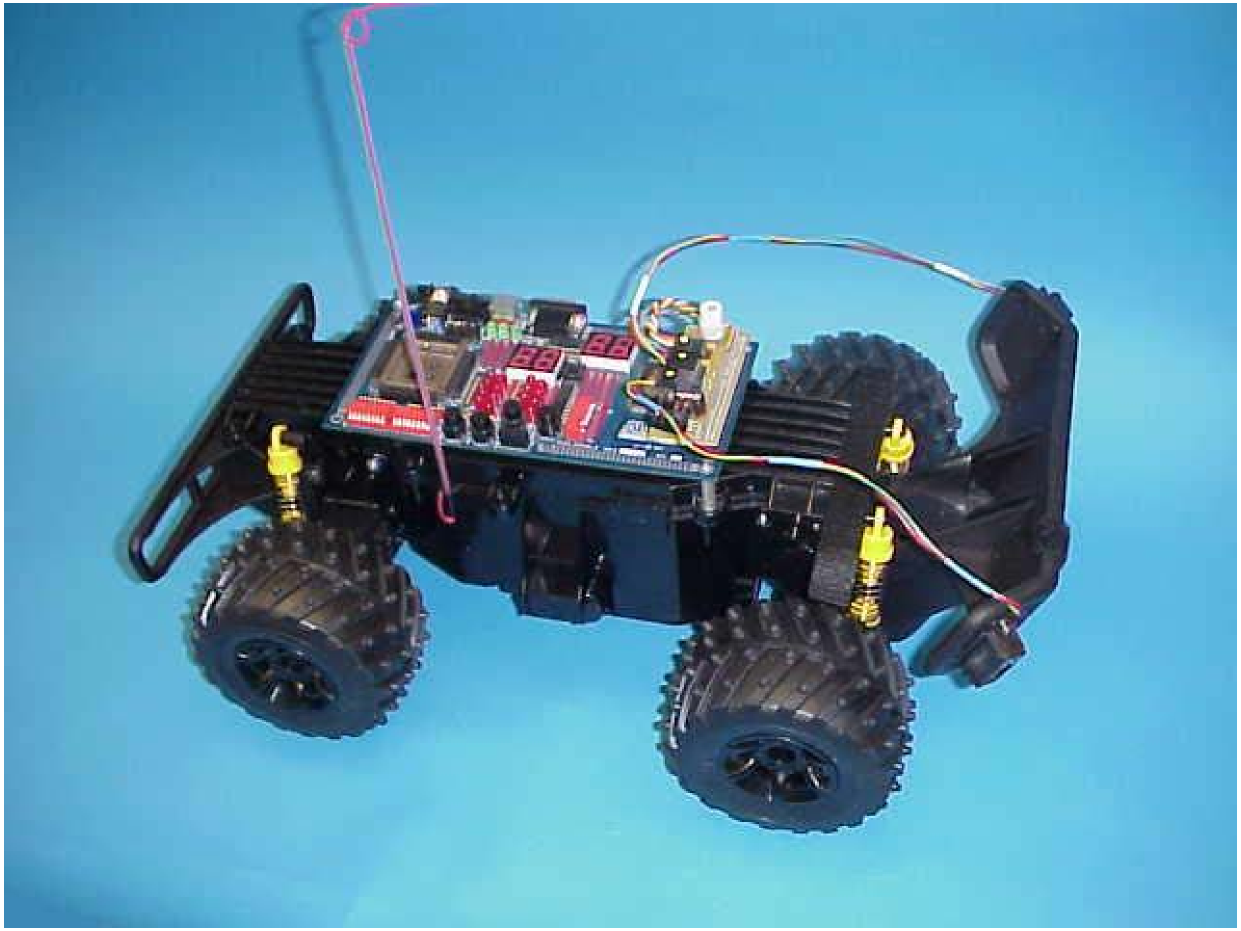
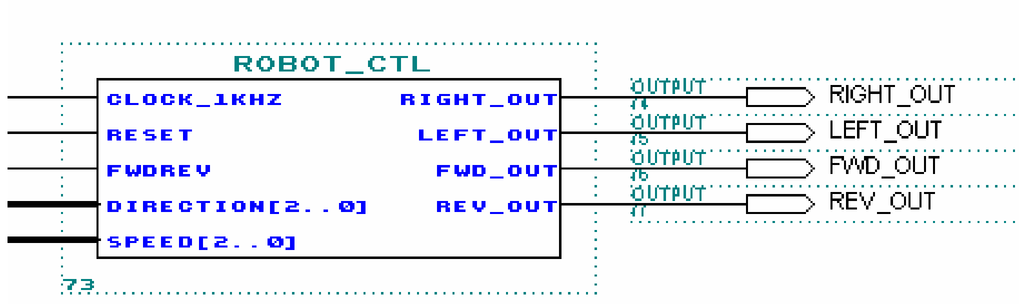


Figure 13.19 FPGA Controlled Toy R/C Truck with IR Distance Sensors.



FwdRev	1 Bit	0 = Forward/1 = Reverse
Direction	3 Bits	First bit Left/Right, 2nd and 3rd bit is angle.
		0-00 = Left – Straight*
		0-01 = Left – Slight Turn
		0-10 = Left – Medium Turn
		0-11 = Left – Full Turn
		1-00 = Right – Straight*
		1-01 = Right – Slight Turn
		1-10 = Right – Medium Turn
		1-11 = Right – Full Turn
		* Note: 000 and 100 are both Straight
Speed	3 Bits	000 = Stop
		001 = Slowest Speed
		: : :
		111 = Fastest Speed

Figure 13.20 Robot Control IP Core with Pulsed Speed & Steering Control.

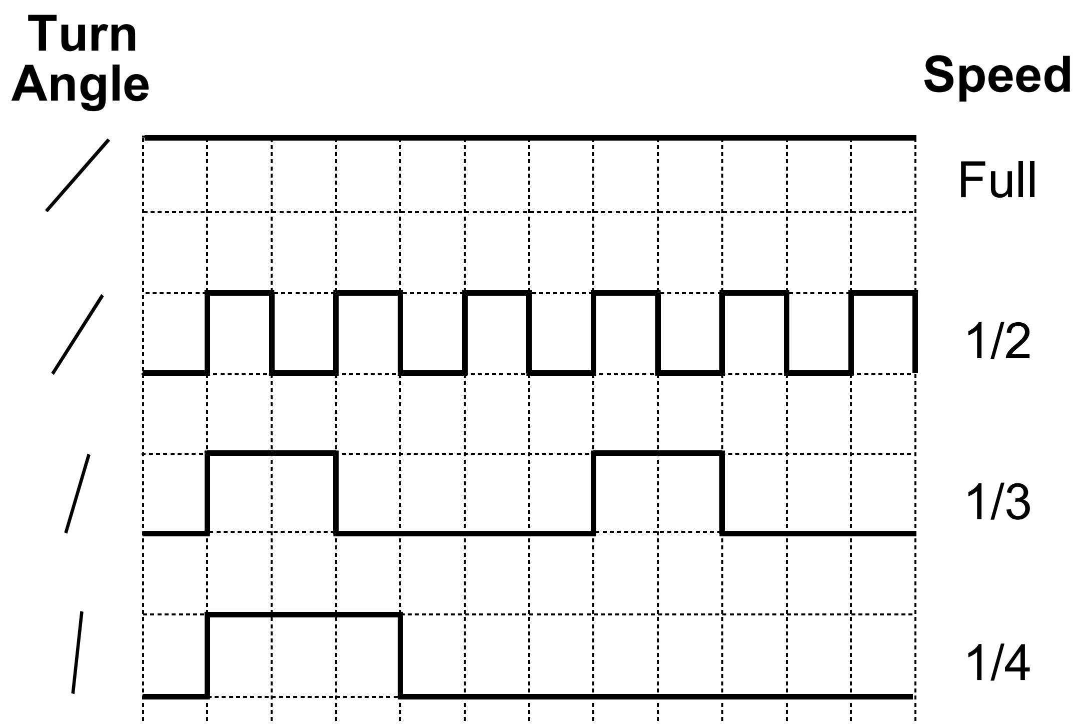


Figure 13.21 Affect of Duty Cycle on Turning Angle and Speed.

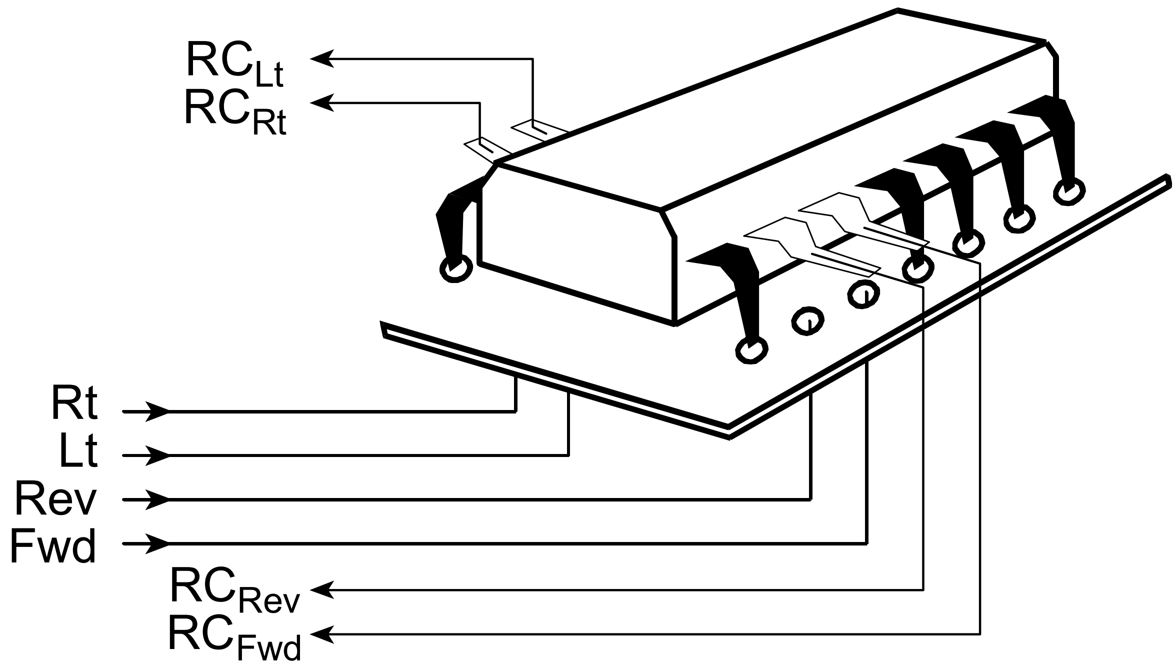


Figure 13.22 Interfacing to the R/C Car's Internal Control Signals at the Demodulator IC.

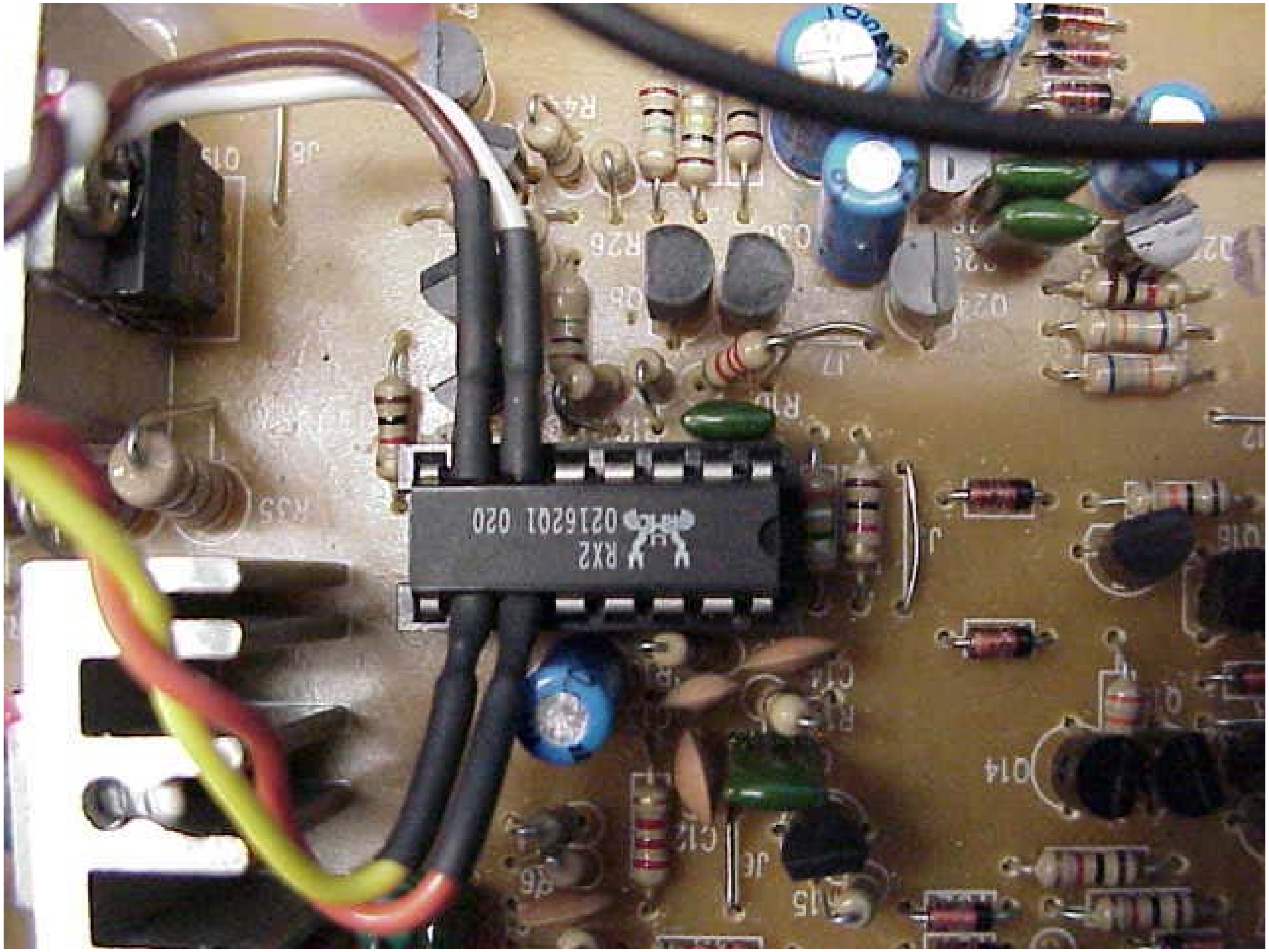


Figure 13.23 Photo Showing Control Modifications to R/C Car Control Board.

Figure 13.24 Hobbyist R/C model with a CMU camera and R/C PWM servos controlled by an FPGA

Figure 13.25 Lynxmotion Hexpod Walking Robot Kit with 12 R/C servos.

Figure 13.26 ActiveMedia's Amigobot robot base controlled by an FPGA with a Nios Processor