CHAPTER III

DESIGN

3.1 Mechanical Concept

There are many locomotion types for mobile robot to maneuver over the rugged terrain including leg, wheel, tread.

3.1.1 Six- wheel Robots

Six-wheel robots offer a good compromise between weight/energy and mobility. This configuration has better obstacle clearing capabilities than four wheels and increased robustness to motor breakdown. Eight-wheel robots offer better in mobility but becomes costly in weight and energy consumption. Six-wheel design also widely distributes the robot's weight, helping avoid sinking on soft terrain, increases payload and towing ability.

3.1.2 Rocker-Bogie Suspension

Rocker-Bogie Suspension is a passive suspension that works well at low-velocity [10]. All six wheels are actuated independently and attached with articulate frame. This frame consists of two rocker arms connected to the sides of the robot body. At one end of each rocker is connected to pivot of the smaller rocker, the bogie, and the other end has a steerable wheel attached. Two wheels are attached to the end of these bogies. The rockers connected to the body via a differential joint. This configuration maintains the pitch of the body equal to the average angle between the two rockers [7]. This mechanism also provides an important mobility characteristic of the robot: one wheel can be lifted vertically while other wheels remain in contact with the ground [11].

In order to climb over an obstacle, the front wheels are forced against the obstacle by the middle and rear wheels. Then the rotations of the front wheels lift the front of the robot up and climb over the obstacle. The middle wheels are pressed against the obstacle by the rear wheels and pulled by the fronts. Finally, the rear wheels are pulled by the front and middle wheels [12].

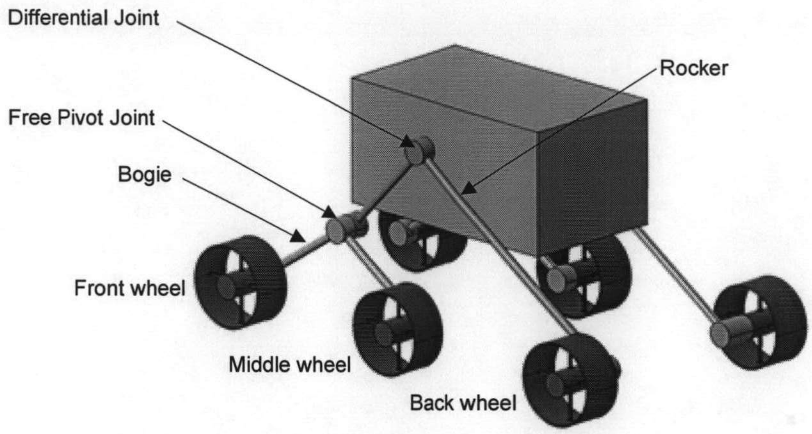

Figure 3.1: Rocker-Bogie Suspension

3.1.3 Drive Scheme

The six-wheel robot can either be driven be centralized actuators or each wheel can be driven individually. The comparisons between these two schemes are shown in table 3.1.

Table 3.1: Comparison of the drive schemes

	Centralize drive	**Individual drive**
Protection	+ Simpler (actuator is in the body)	- Hard (actuators are inside the wheels)
Effect of single transmission failure	- Critical	+ Tolerant
Electrical cabling	+ Cable routing inside the body	- Cable routing from body to wheels
Drive train	- Complex	+ Simple
Power	- Low efficiency due to complex drive train	+ Simple mechanical enables high efficiency
Torque distribution	Differential + viscous coupling	Slip or torque control

The individual drive as known as "In-wheel propulsion" was chosen due to simplicity, efficiency and robustness against single point failure [13]. The in-wheel propulsion unit is independent, no geometric or operation interference with the steering and suspension systems and also has more advantages such as: individual traction control, greater control flexibility and sealed drive units.

3.1.4 Turning by wheel steering

By steering the wheels in such a way that the axes of all wheels meet at the instantaneous center of rotation. The wheel speeds also have to be adjusted according to the distance from the center.

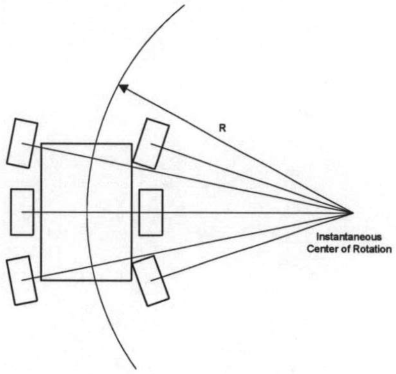

Figure 3.2: Turning around a point

3.1.5 Rotation in place

This is a special case of turning, where the center of rotation located at the center of the robot. By steering front and back wheels into the configuration, that all of the wheels axes meet at the center. The left and right wheels are rolling in opposite direction. The wheel speed also have to be adjusted according to the distance as same as turning.

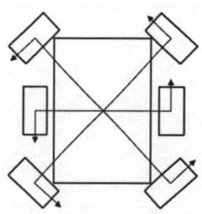

Figure 3.3: Rotation in place

3.2 Robot Models

3.2.1 Lonotech 8

Lonotech 8 has been built in the year 2000 to test the rocker-bogie suspension system [14]. This model is 31 x 35 x 28.5 cm^3, 7.5 kg weight. The wheels are 8 cm. in diameter and 8 cm. width. Each wheel equipped with synchro-drive steering mechanism. Steering angles of all six wheels are controllable to improve the ability of traveling in all directions, especially in the lateral direction (crabbing maneuver).

Lonotech 8 can cross over 50.8 mm vertical wall and can climb the slope up to 20 degree before the front wheel lift off the ground.

Figure 3.4: Lonotech 8

3.2.2 Model for the new robot

After testing with Lonotech 8, the new model is designed by SolidEdge® and simulates with Visual Nastran 4D® for maximum climbing capability.

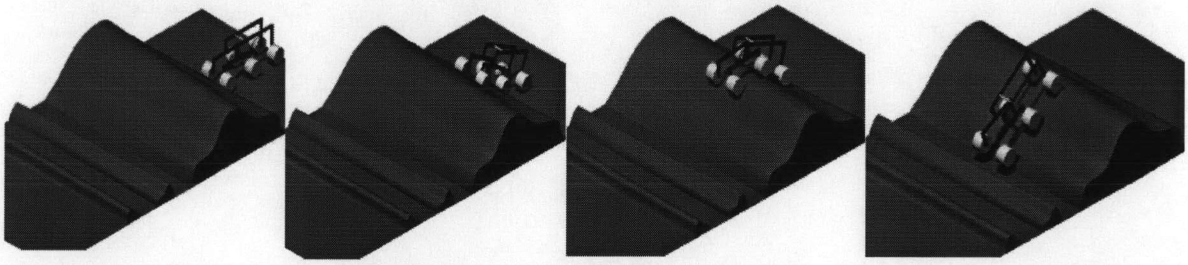

Figure 3.5: Robot Simulation

There are many modifications in the geometry of the rocker and bogie linkages. Then a simple model is built up and test with this new geometry.

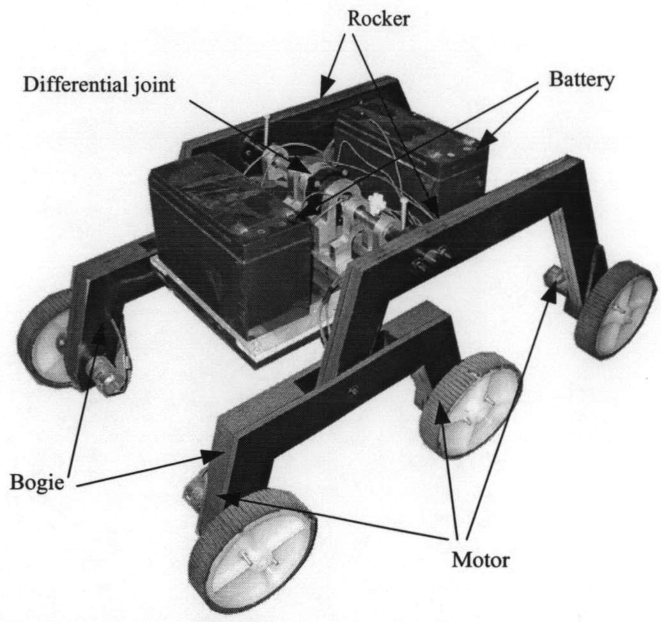

Figure 3.6: A model with geometry modifications

Since this model is made from light weight material with minimum equipments onboard, so the power-to-weight ratio is very high. It can overcome the obstacle, which is double size of its own wheels.

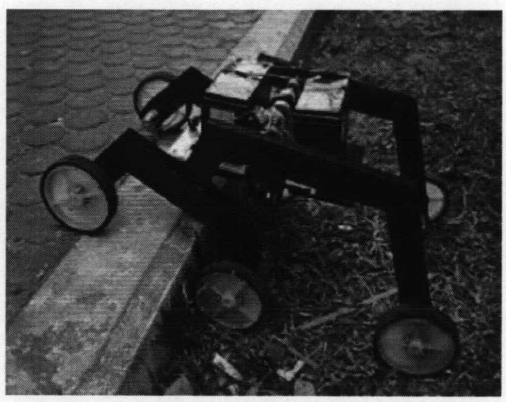

Figure 3.7: Robot model climbed over the obstacle

3.3 A robot test bed "Lonotech 10"

3.3.1 Mechanical

Base on its predecessors, Lonotech 10 has been designed in CATIA®, equipped with more equipment such as CCD camera with pan-tilt mechanism, IR ranger, wireless communication and etc.

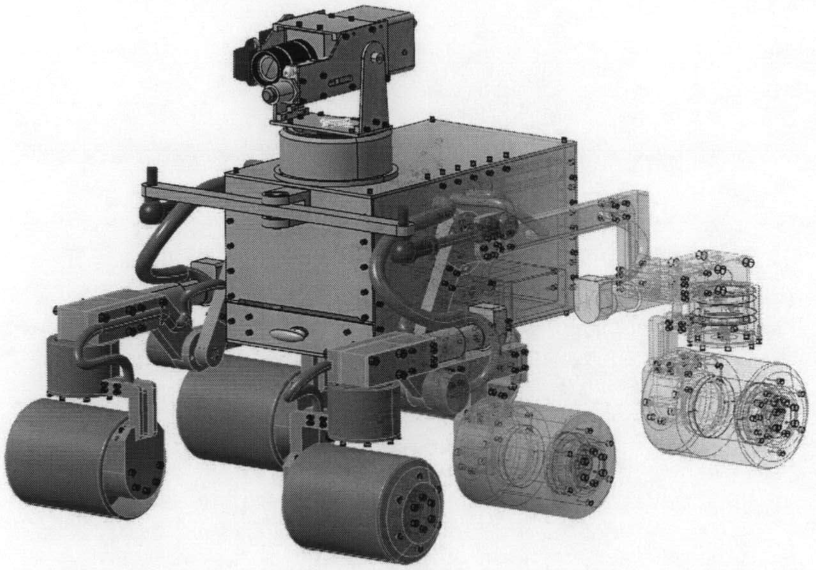

Figure 3.8: Lonotech 10 designed in CATIA®

3.3.2 Electrical

3.3.2.1 Main controller

MSC-51 family microcontroller has been chosen as a main controller. We use Dallas DS89C420, high speed microcontroller, run at 33 MHz. There are several peripherals connected with this processor, such as ADC to convert analog sensor signal to digital, 8255 programmable interface chip to expand I/O, quadrature counter to read encoders attached to rocker and bogie joints, LM629 motion controller to perform low-level control of all wheels and steering, and etc.

3.3.2.2 Motion Controller

LM629 is a microcontroller peripheral that incorporates in one device all the functions of a sample-data motion control system controller [15]. Trajectory profile generation, on-the-fly update of loop compensation and trajectory and status reporting are included in this controller. Both position and velocity motion control systems can be implemented with LM629.

3.3.2.3 Motor Driver

L298 is a high voltage, high current full-bridge driver designed to drive inductive loads such as DC motors. Total number of L298 in the robot is 10, driving six wheels and four steering.

3.3.2.4 Wireless Communication

There are 3 wireless modules in the system, consisted of video and audio sender, robot control module and camera control module. Video and audio signals are transmit back to base station by Video sender at 2.4 GHz. The robot received control signal and send data back thru Radio Packet Controller at 433 MHz. The last module controls pan-tilt of the main camera at 40 MHz.

To increase the operation range, we have built a dipole antenna with balance impedance, equipped with reflector to compress the signal to the desired direction. In the experiment, this antenna can transmit signal through the wall with maximum range about 200 meters in open area.

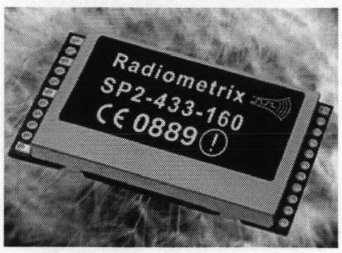

Figure 3.9: Radio Packet Controller

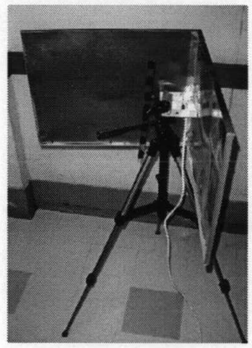

Figure 3.10: Dipole Antenna

3.3.2.5 Sensors

The robot equipped with various sensors for navigation. Most of the sensors are mounted on the pan-tilt mechanism, including CCD Camera, laser pointer, distance measuring sensor and thermal sensors.

Figure 3.11: CCD Camera

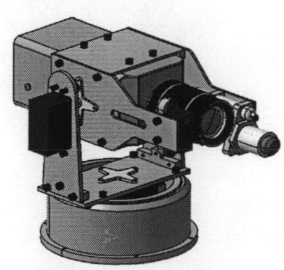

Figure 3.12: Sensor head

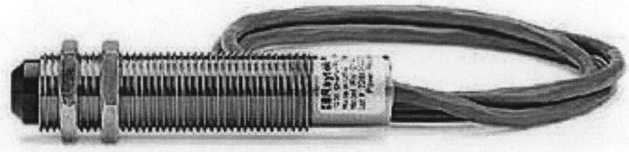

Figure 3.13: Thermal sensor

Three encoders with 2500 PPR resolution are attached to the suspension to sense rocker and bogie angles. Inclinometers, accelerometer and rate gyroscope are installed in the body. The accelerometer used in the robot can sensed up to ± 2g in X and Y direction [16]. Rate gyroscope range is 0 to ± 100 deg/sec [17].

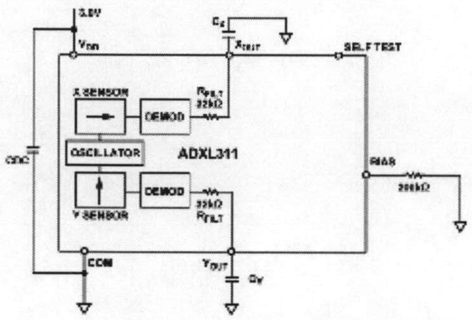

Figure 3.14: Accelerometer

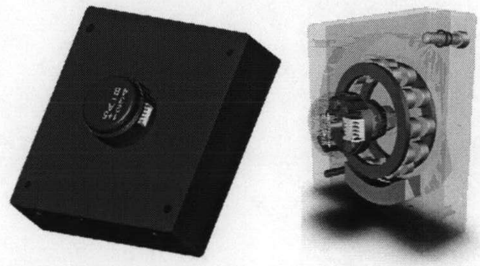

Figure 3.15: Inclinometer [18]

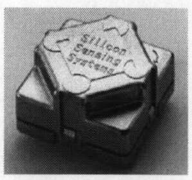

Figure 3.16: Rate Gyroscope

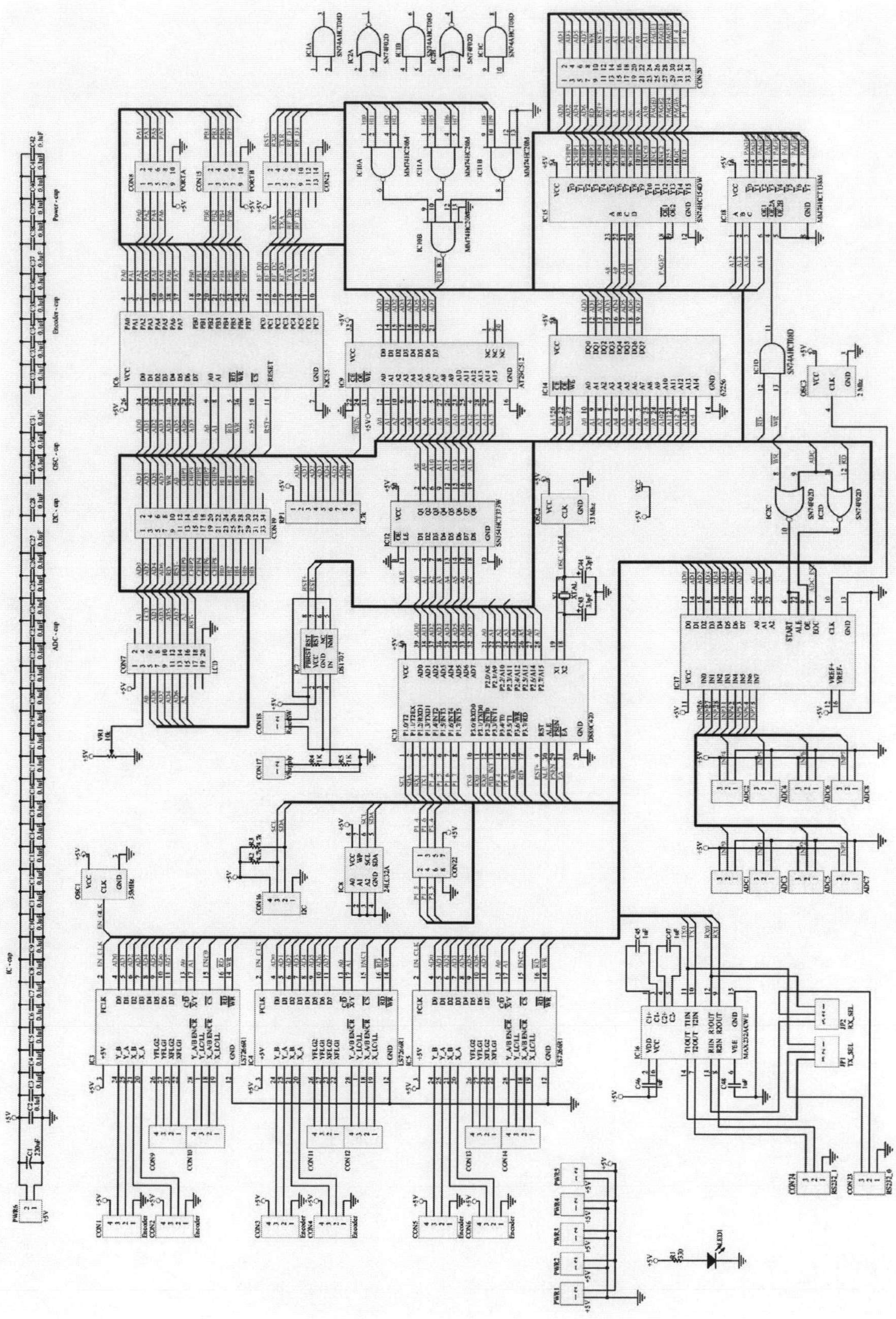

Figure 3.17: Main Controller Schematic

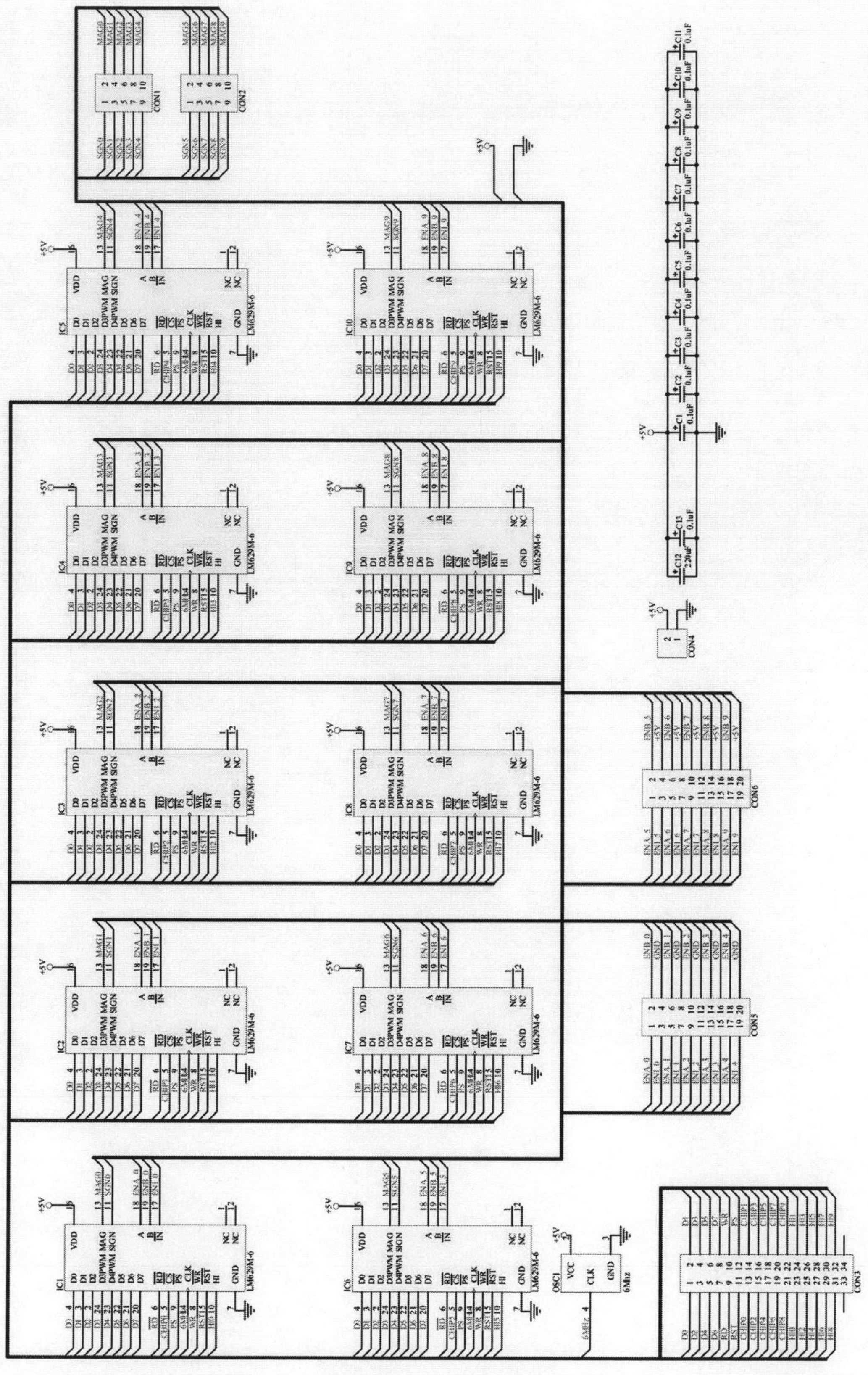

Figure 3.18: Motion Controller Schematic

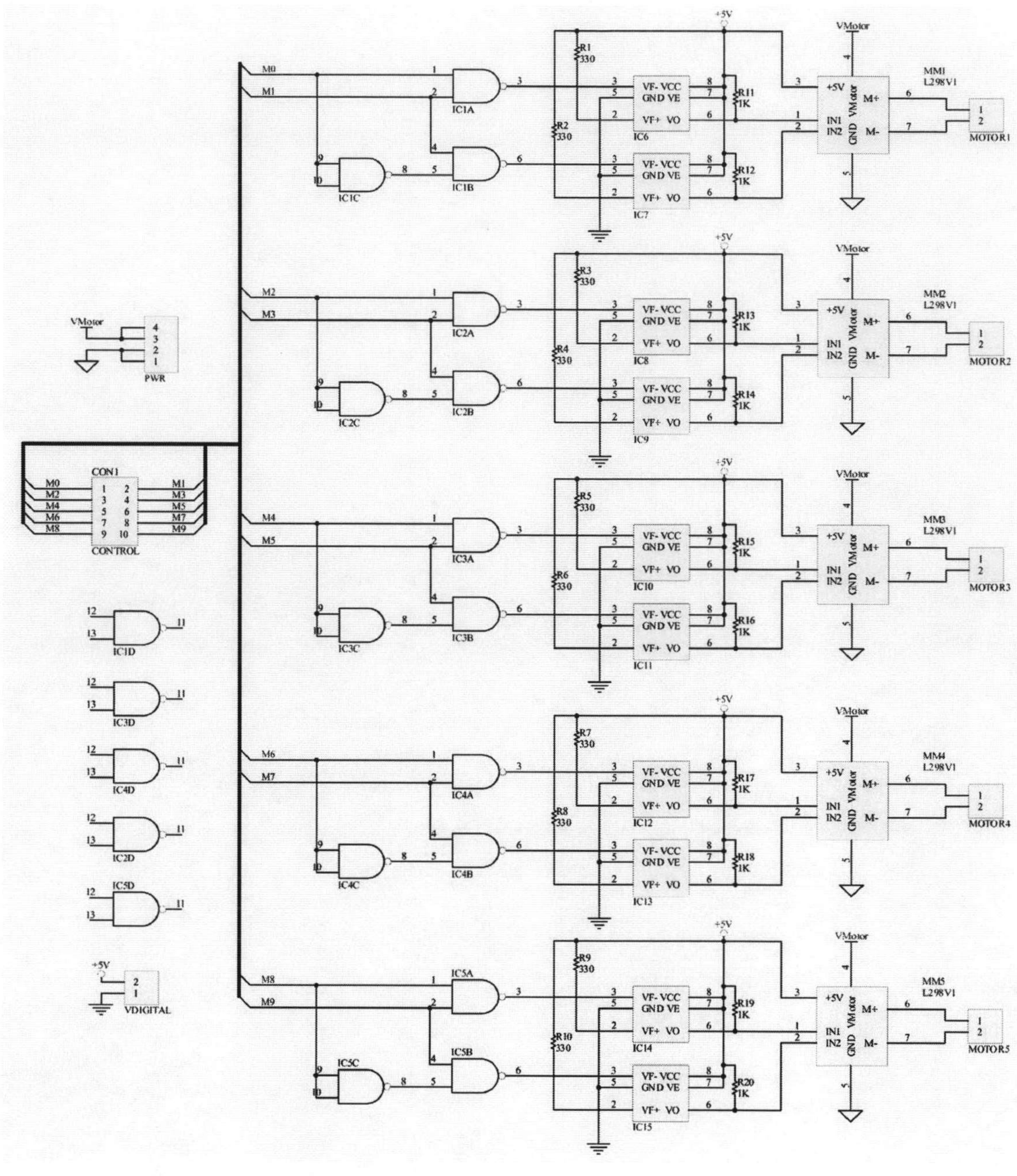

Figure 3.19: Motor Driver Schematic

3.3.3 Programming

Programs for Lonotech 10 are divided into 2 parts. Low-level program is installed onboard and Human interface is installed on base station. During operation, operator can control the robot via wireless communication. Program on base station can received input from dialog box or joystick for easier control.

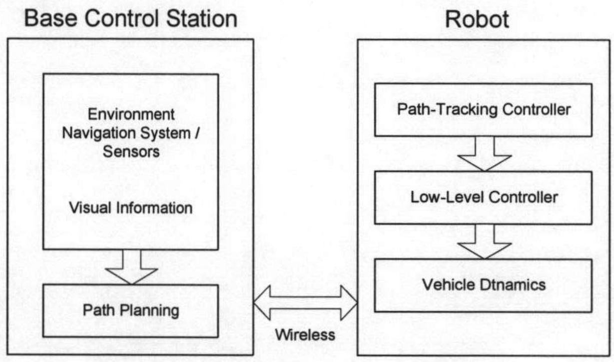

Figure 3.20: Control Schematic

3.3.3.1 Low-level Program

Low-level program controls all equipments installed on the robot, such as PID Controller for all six wheels and 4 steering, ADC Converter for sensor reading, and encoder pulse counter for rocker and bogie joint angles.

Low-level program is developed in C Language, divided into 3 parts as follow:

1) Wireless Communication, run in interrupt mode.
2) Motion Control; send command to PID Controller via memory-mapped I/O.
3) Sensor reading.

3.3.3.2 Base Station Program

Base station program is developed by in C++ as a dialog base style. Run in Microsoft Windows. It received joystick data via Direct input system of DirectX API, then translate and combine with data which input by dialog, sending command to

RF module thru Parallel port. There is 1 command byte, 58 byte arguments and 1 byte checksum combined into a packet and sending to the robot. The robot sends the data back to the station using the same method.

During operation, the operator can mark start and stop position to compute distance and coordinate relative to the starting point.

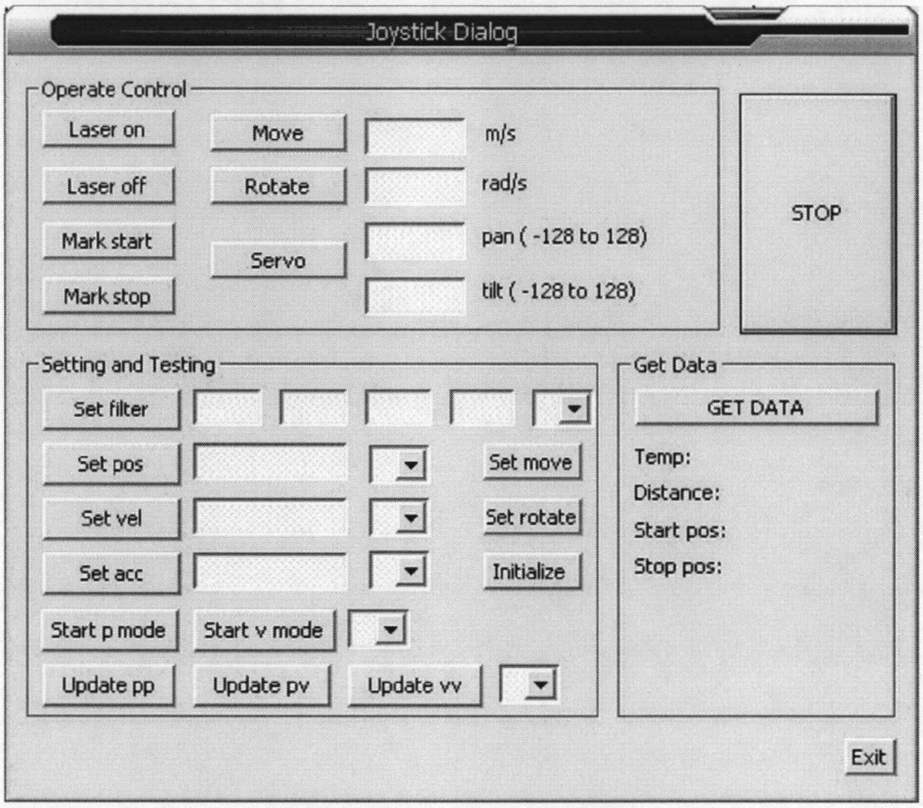

Figure 3.21: Control Dialog

Video signal from a video sender will be captured into computer using video capture card.

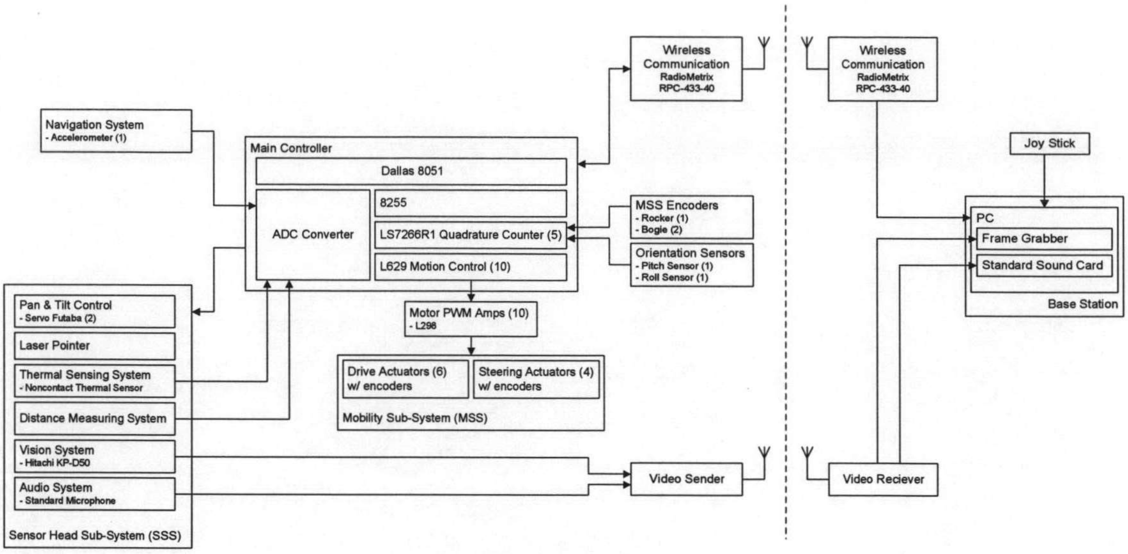

Figure 3.22: Robot System Block Diagram

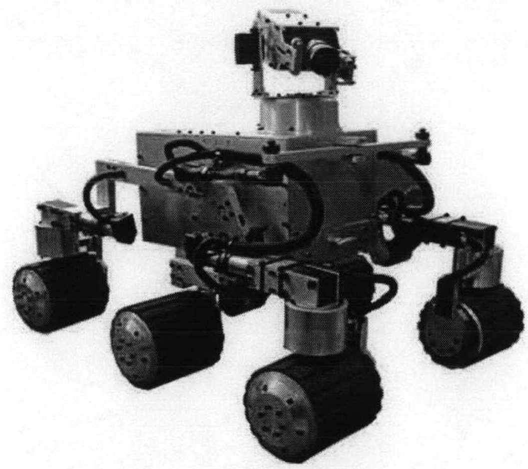

Figure 3.23: Lonotech 10

3.3.4 Specifications

Physical:

Dimensions (W x L x H)	:	480 x 640 x 480 mm^3
Weight	:	30 kg.
Maximum Speed	:	0.2 m/s

Equipments:

CCD Camera	:	Hitachi KP-D50
Thermal Sensor	:	Noncontact Thermal Sensor Raytek CI
Distance Measuring Sensor	:	Sharp GP2D12
Laser pointer		

Wireless Communication:

Robot command	:	Radiometrix RPC, SP2-433-160
		Frequency 433 MHz, 160 kbps
Video feedback	:	Videosender, UFOCOM 2.4 GHz

Controller:

Main Controller	:	Dallas DS89C420 @ 33MHz
Wheel Motion Control	:	National LM629

Power Supply:

Lead-Acid Sealed Battery	:	2.2 Ah x 2