T.E. Project Report

On

Design and Fabrication of a Multi-robot System as a Simulation of Swarm Robotics

Submitted by,

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TE Div: II

Year: 2017-2018

Maharashtra Institute of Technology, Pune – 38.

CERTIFICATE

MAEER's

MAHARASHTRA INSTITUTE OF TECHNOLOGY, PUNE.

This is to certify that the project entitled

Design and Fabrication of a Multi-robot System as a Simulation of Swarm Robotics

has been carried out successfully by

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during the Academic Year **2017-2018** in partial fulfillment of their course of study for the third year in ***Electronics and Telecommunication*** as per the syllabus prescribed by the **Savitribai Phule Pune University.**

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Internal Guide

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Abstract

While we study the relatively new branch of a multi-robot system called swarm robotics, we are able to understand how to coordinate a group of relatively simple robots through the use of local rules. Our project focuses on designing a simple robot and then replicating this design in a group of robots to understand their group dynamic and controlling behavior. Since its introduction in 2000, several successful swarm projects such as Jasmine bots, Calois, Zooids, Mona, etc. have been realized. These projects have been the base of our research and design procedure. This report seeks to demonstrate our process, the outcomes of the project and the various problems we faced, and the solutions we applied to solve them.

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INTRODUCTION

In a nutshell, swarm robotics (SR) is basically a large number of robots mimicking insects or animals that gather and act together as a collective such as ants or bees. All robots in swarm robotics are identical and preferably small. This is the homogeneous model.

The original intent of introducing swarm robotics as separate research is meant to address the need for large numbers of very small, cheap robots moving and working together as a swarm. This includes the ability to perform physical formation like the weave ants. Robots are expected to be simple because it is cheaper and can be mass-produced so that it acts like nodes on the internet - the destruction of a single point/section will not annihilate the swarm.

SR is and is not Multi-Agent System (MAS). MAS was the predecessor of the swarm, in a way Distributed AI (DAI) is the predecessor of MAS. MAS is mainly about how to have multiple robots working together. It created the foundation for communication, coordination, task planning, and distributed agent frameworks. SR needs to scale to potentially thousands of robots. Many old MAS algorithms could not support such large numbers and did not address robot physical formation.

Within this project, we have attempted to design one such simple robot and replicate it in a smaller number to understand how robots perform within the swarm and most importantly how the field of swarm robotics is different from a Multi-Agent System.

SCOPE

Robot swarms might one day tunnel through the rubble to find survivors, monitor the environment and remove contaminants, assist dwindling bee populations in pollinating crops, and self-assemble to form support structures in collapsed buildings. Swarms of robots acting together to carry out jobs could provide new opportunities for humans to harness the power of machines. They could play a part in military, or search and rescue operations, acting together in areas where it would be too dangerous or impractical for humans to go. In industry too, robot swarms could be put to use, improving manufacturing processes and workplace safety. Researchers are developing Artificial Intelligence to control robots in a variety of ways. The key is to work out what is the minimum amount of information needed by the robot to accomplish its task. That's important because it means the robot may not need any memory, and possibly not even a processing unit, so this technology could work for nanoscale robots, for example in medical applications.

REVIEW OF LITERATURE

MONA

Mona is an open-hardware/open-source robotic platform that has been developed to be used in swarm robotic scenarios especially to study Perpetual Robotic Swarms. Mona-E is a version of the robot developed for educational purposes and it is currently used for lab demonstration for the Mobile Robots and Autonomous Systems course at the University of Manchester.
Mona was designed and developed (in 2016) at UoM Robotic Lab.

JASMINE

The JASMINE project is devoted to the development of the open-source hardware and software micro-robotic platform in the size of less-then-3cm-cube. The main goal of this project is to develop a cheap, reliable, and swarm-capable micro-robot that can be easily reproduced even at home. This robot allows the building of a large-scale swarm system (100 and more robots) to investigate artificial self-organization, emergent phenomena, control in large robotic groups, and so on. This research is important to understand the underlying principle of information and knowledge processing, adaptation, and learning for the design and development of very limited autonomous systems.

COLAIS

Colias is a low-cost, open-platform, autonomous micro-robot that has been developed for swarm robotic applications. Colias employs a circular platform with a diameter of 4 cm.
It has a maximum speed of 35 cm/s which gives it the ability to be used in swarm scenarios very quickly in large arenas. Long-range infrared modules with adjustable output power
allow the robot to communicate with its direct neighbors from a range of 0.5 cm to 3 m.

PRESENT SCENARIO

These days swarm robotics has been successfully adapted and designed to solve numerous problems posed to humans. From military applications to medical applications, from research to construction work, today swarm robotics has made its presence known.

As an example, the MARCbot IV developed by the US military has been deployed into war zones to detect IEDs before the army moves in. this is a very important application that ends up saving countless lives.

The Kilobot is designed to make tests of collective algorithms on hundreds or thousands of robots accessible to robotics researchers. Despite being low-cost, the Kilobot maintains abilities similar to other collective robots. These abilities include differential drive locomotion, onboard computation power, neighbor-to-neighbor communication, neighbor-to-neighbor distance sensing, and ambient light sensing. Additionally, they are designed to operate such that no robot requires any individual attention from a human operator.

From the medical point of view, the Department of Aerospace Engineering, School of Engineering, University of Glasgow, UK is working on a unique concept called Artificial Immune System of Swarm Robotics, an algorithm through which we will be able to simulate the immune system of a human body within a swarm of robots.

The TERMES project being developed at Harvard School of Engineering plans on bringing automation into the construction industry with help from swarm robotic systems.

SYSTEM SPECIFICATIONS

ATMEGA328PPU:

8-bit AVR Microcontroller with 32kBytes FLASH Program Memory

- 28-pin AVR Microcontroller.
- Flash Program Memory: 32 kbytes.
- EEPROM Data Memory: 1 kbytes.
- SRAM Data Memory: 2 kbytes.
- I/O Pins: 23.
- Timers: Two 8-bit / One 16-bit.
- A/D Converter: 10-bit Six Channel.
- PWM: Six Channels.

L293D:

- Supply Voltage Range 4.5V to 36V.
- 600-mA Output current capability per driver.
- Separate Input-logic supply.
- It can drive small DC-geared motors and bipolar stepper motors.
- Pulsed Current 1.2-A Per Driver.
- Thermal Shutdown.
- Internal ESD Protection.
- High-Noise-Immunity Inputs.

HC05:

- Bluetooth protocol: Bluetooth Specification v2.0+EDR.
- Frequency: 2.4GHz ISM band.
- Modulation: GFSK(Gaussian Frequency Shift Keying)
- Emission power: ≤4dBm, Class 2.
- Sensitivity: ≤-84dBm at 0.1% BER.
- Speed: Asynchronous: 2.1Mbps(Max) / 160 kbps, Synchronous: 1Mbps/1Mbps.

ESP 32 DEV-KIT C:

Processors:

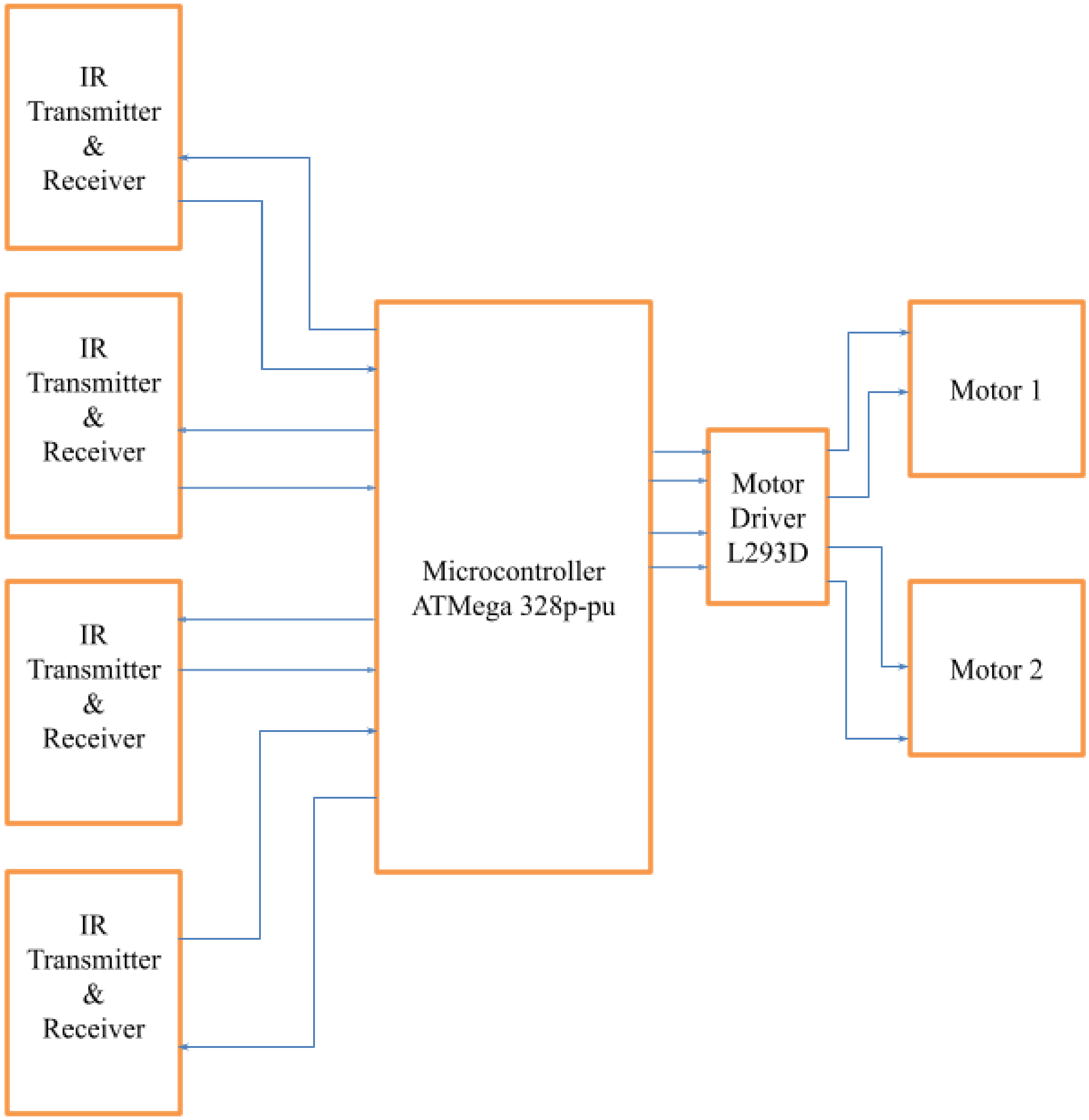
- CPU: Xtensa dual-core (or single-core) 32-bit LX6 microprocessor, operating at 160 or 240 MHz and performing at up to 600 DMIPS
- Ultra low power (ULP) co-processor
- Memory: 520 KiB SRAM
- Wireless connectivity:

- Wi-Fi: 802.11 b/g/n
- Bluetooth: v4.2 BR/EDR and BLE
- Peripheral interfaces:
- 12-bit SAR ADC up to 18 channels
- 2 × 8-bit DACs
- 10 × touch sensors (capacitive sensing GPIOs)
- Temperature sensor
- 4 × SPI
- 2 × I^2S interfaces
- 2 × I^2C interfaces
- 3 × UART
- SD/SDIO/CE-ATA/MMC/eMMC host controller
- SDIO/SPI slave controller
- Ethernet MAC interface with dedicated DMA and IEEE 1588 Precision Time Protocol support
- CAN bus 2.0
- Infrared remote controller (TX/RX, up to 8 channels)
- Motor PWM
- LED PWM (up to 16 channels)
- Hall effect sensor
- Ultra low power analog pre-amplifier
- Security:
- IEEE 802.11 standard security features all supported, including WFA, WPA/WPA2 and WAPI
- Secure boot
- Flash encryption
- 1024-bit OTP, up to 768-bit for customers
- Cryptographic hardware acceleration: AES, SHA-2, RSA, elliptic curve cryptography (ECC), random number generator (RNG)
- Power management:
- Internal low-dropout regulator
- Individual power domain for RTC
- 5uA deep sleep current
- Wake up from GPIO interrupt, timer, ADC measurements, capacitive touch sensor interrupt.

GP2Y0A21YK:

- Distance measuring sensor is united with PSD, infrared LED, and signal processing circuit
- Short measuring cycle (16.5ms)
- Distance measuring range : 4 to 30 cm
- Package size (29.5 × 13.0 × 13.5mm)
- Analog output type

BLOCK DIAGRAM



COMPLEXITIES INVOLVED

One of the major complexities involved with implementing swarm robotics is being able to provide reliable bot-to-bot communication. For this, we have used IR transmitter-receiver pairs on every bot, and the master control is given through the Bluetooth module attached to one of the bots. The reception of a signal transmitted by another bot was not being received by the other bots, this posed a huge problem since the robots must be able to communicate with each other for the swarm to function effectively.

Another major complexity is making an efficient but accommodating design, since the robot must be relatively simple in design as well as be able to hold all the necessary components to be able to function properly.

Providing a continuous power supply to all the components without making the bot bulky is a major challenge as well.

MODULAR DESIGN

Esp32 Dev kit-c

Created by Espressif Systems, ESP32 is a low-cost, low-power system on a chip (SoC) series with Wi-Fi & dual-mode Bluetooth capabilities! It's the successor to the highly hyped esp8266. The board was selected as its caters to the most important need of any swarm system, i.e. communication. The communication is done through Wi-Fi, which comes built-in with the esp32 chip. Although it also has BLE, we use Wi-FI specifically to interface the data with MATLAB & Thingspeak. This specific module was selected due to its powerful functionality combined with the added factor of a compact package and numerous programming options, e.g.; Arduino, Micropython, Lua, AT, etc. A swarm robot is supposed to have maximum functionality with a minimum size factor. This module has both.

Sharp GP2Y0A21YK0F Analog Distance Sensor

This sensor module caters to the other important purpose of a swarm system - sensing of the environment. Sharp distance sensors are a popular choice for many projects that require accurate distance measurements. This IR sensor is more economical than sonar rangefinders, yet it provides much better performance than other IR alternatives. Interfacing with most microcontrollers is straightforward: the single analog output can be connected to an analog-to-digital converter for taking distance measurements, or the output can be connected to a comparator for threshold detection. The detection range of this version is approximately 10 cm to 80 cm (4″ to 32″).

ATmega328p-pu

Created by ATMEL, ATmega328p-pu is a low-cost, low-power IC. The IC has dual in-line packaging and 23 GPIO pins. The microcontroller was selected as the IC is easy to program as well as debug. With 32kB flash memory, the controller provides sufficient memory for the program to be loaded and executed.

HC-05 Bluetooth Module

Bluetooth communication in this project is used for communication between the master bot and the user. The user sends commands to the master bot using an application on his/her phone, and the master executes this command with the help of the slave bots.
HC-05 is used on this project as it is low-powered and highly reliable. HC-05 is the most widely used Bluetooth module. The module has 6 pins out of which we use 4 pins for this project.
HC-05 transmits the data serially to the microcontroller.

L293D Motor Driver

The L293D motor driver is a low-cost IC. The L293D motor driver IC has a very simple structure. The motor driver IC provides no speed control on the motors which is also not required for this project. The packaging is 16-pin dual in line. The IC gives out binary output as per the input.

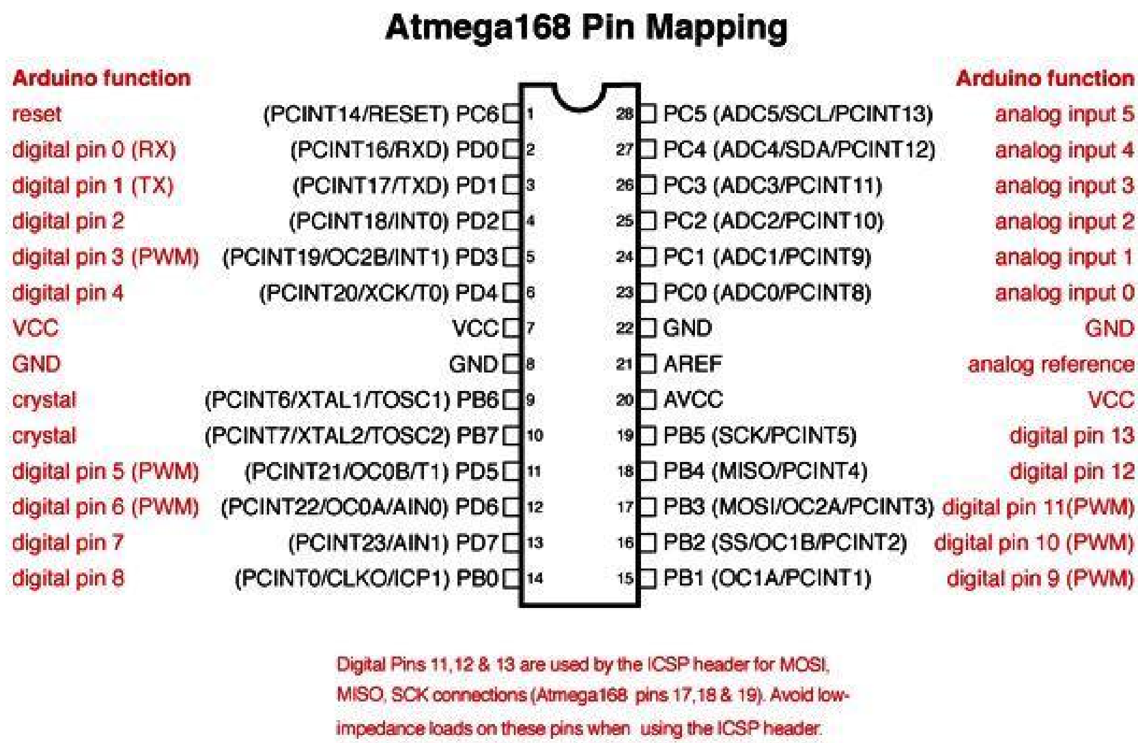
BILL OF MATERIALS

SR. NO.	NAME OF COMPONENT	DESCRIPTION	PRICE (Rs.)
1.	IR TIL78	IR RECEIVER	40.0
2.	IR TIL32	IR TRANSMITTER	40.0
3.	CRYSTAL	16 MHz CRYSTAL	6.0
4.	L293D WITH MODULE	MOTOR DRIVER IC	240.0
5.	ATMEGA328PPU	MAIN CONTROLLER IC	220.0
6.	BO MOTOR	DC MOTOR	400.0
7.	BALANCING WHEEL	WHEEL	120.0
8.	PROTOTYPE BOARDS	10X10 ZERO PCB	70.0
9.	IC BRACKET	28 PIN IC BRACKET	6.0
10.	RESISTANCES	220, 330, AND 1K	6.0
11.	HEAT SLEEVE	-	10.0
12.	CAPACITOR	22 pF	3.0
13.	BATTERY	9V	30.0
14.	MALE CONNECTORS	-	30.0
15.	HC05	BLUETOOTH MODULE	200.0
16.	ESP32 DEV-KIT C	MICROCONTROLLER	3600.0
17.	GP2Y0A21YK	SHARP IR SENSORS	3600.0
		TOTAL AMOUNT	8,621.0

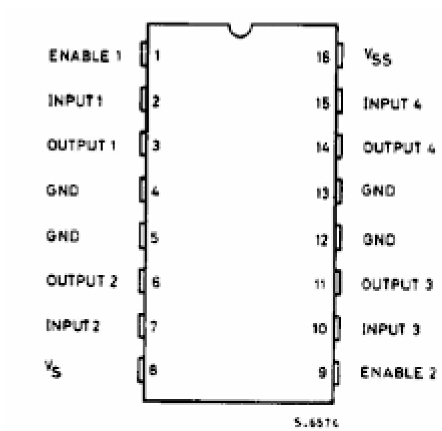
APPENDIX

APPENDIX A:

ATMEGA328P-PU PINOUT DIAGRAM:

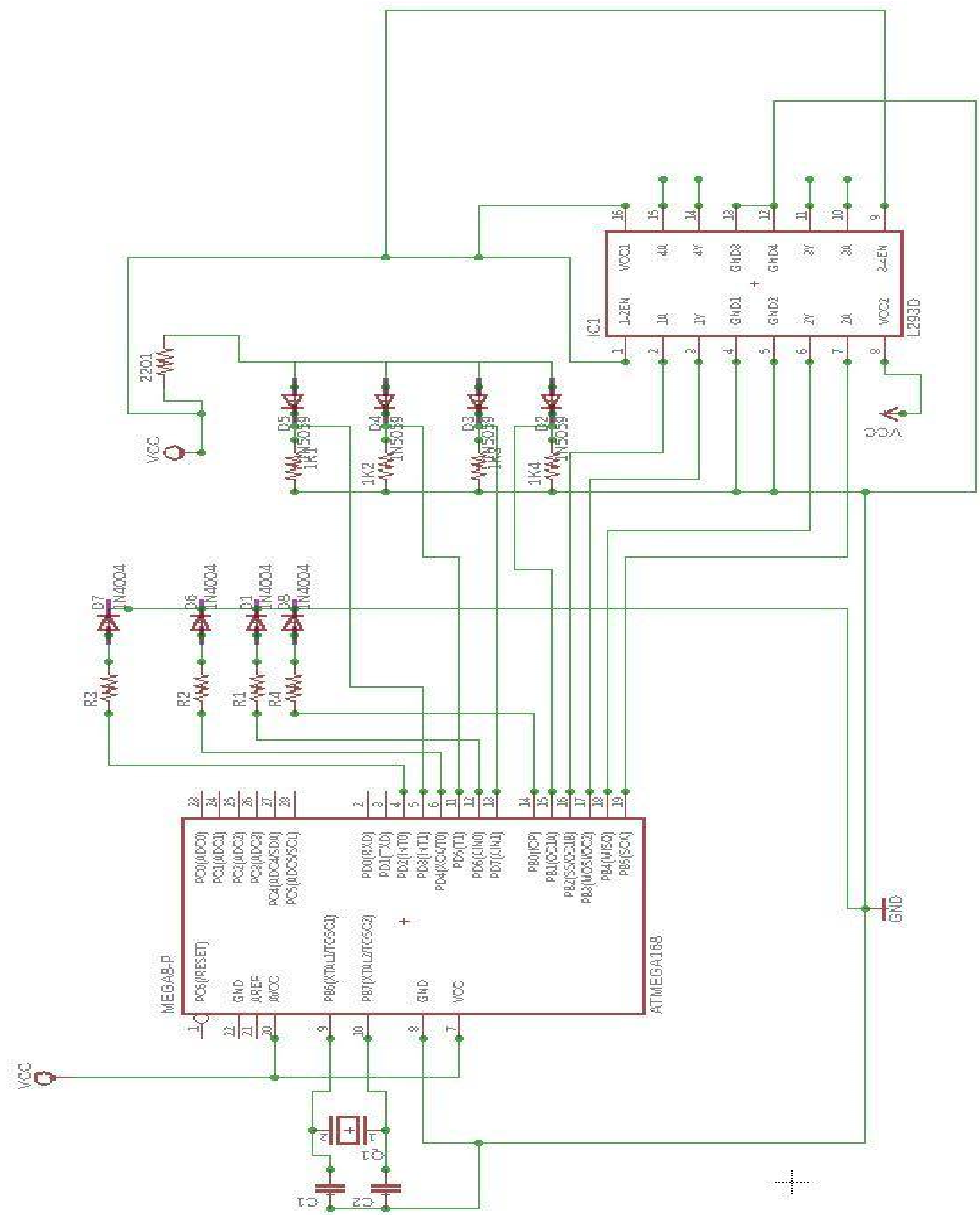


L293D PINOUT DIAGRAM:



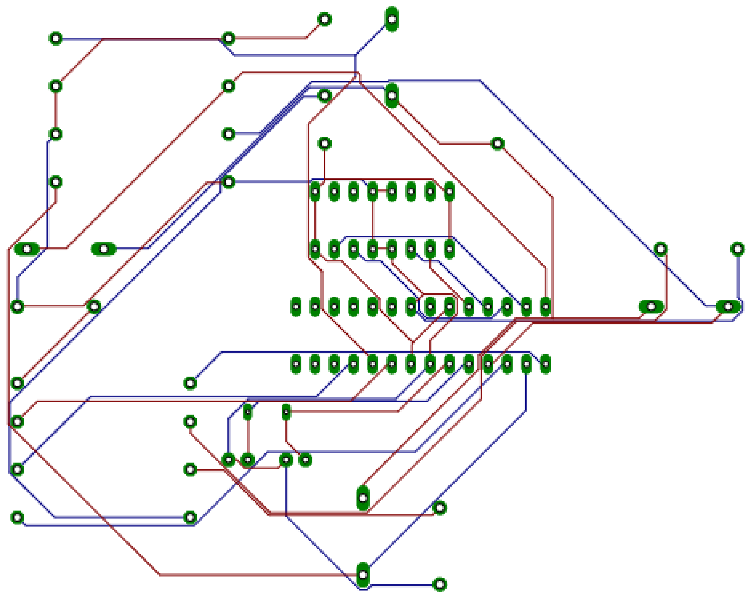
APPENDIX B:

CIRCUIT DIAGRAM:



APPENDIX C:

PCB LAYOUT:



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