SEINÄJOEN AMMATTIKORKEAKOULU
SEINÄJOKI UNIVERSITY OF APPLIED SCIENCES

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1 Theory

1.1 Presentation of work

In this presentation, we will discuss the project of DC motor control with a transistor and Arduino. DC motors are commonly used in various applications like robotics, electric vehicles, automation, and many others. The project aims to control the speed and direction of a DC motor using a transistor and Arduino.

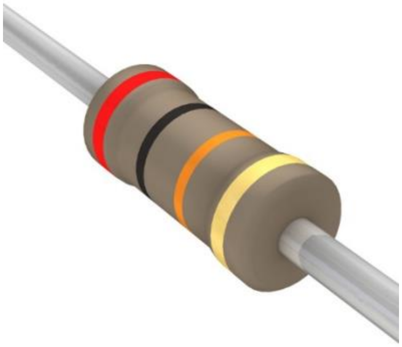
1.2 Components

1.2.1 Motor

A **DC motor** is any of a class of rotary electrical motors that converts direct current (DC) electrical energy into mechanical energy. The most common types rely on the forces produced by induced magnetic fields due to flowing current in the coil. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.

DC motors were the first form of motors widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor, a lightweight brushed motor used for portable power tools and appliances can operate on direct current and alternating current. Larger DC motors are currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.

1.2.2 Resistor



20 kilo Ohm

Resistors are devices used in circuits to limit current flow or to set voltage levels within circuits. R is the resistance or the resistor expressed in ohms (Ω), P is the power loss in watts (W), V or U is the voltage in volts (V), and I is the current in amperes (A).

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various com-pounds and forms. Resistors are also implemented within integrated circuits.

The electrical function of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. The nominal value of the resistance falls within the manufacturing tolerance, indicated on the component.

1.2.3 Transistor

A transistor is a semiconductor device used to amplify or switch electrical signals and power. It is one of the basic building blocks of modern electronics. It is composed of semiconductor material, usually with at least three terminals for connection to an electronic circuit. A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals. Because the con-trolled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. Some transistors are packaged individually, but many more in miniature form are found embedded in integrated circuits.

Most transistors are made from very pure silicon, and some from germanium, but certain other semi-conductor materials are sometimes used. A transistor may have only one kind of charge carrier, in a field-effect transistor, or may have two kinds of charge carriers in bipolar junction transistor devices.

Transistors revolutionized the field of electronics and paved the way for smaller and cheaper radios, calculators, computers, and other electronic devices.

- **NPN transistors TIP 122**

TIP122	TIP122	TO-220 3L (Single Gauge)	Bulk
TIP122TU	TIP122	TO-220 3L (Single Gauge)	Rail

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at TC = 25°C unless otherwise noted.

Symbol	Parameter	Value	Unit	
VCBO	Collector-Base Voltage	TIP122	100	V
VCEO	Collector-Emitter Voltage	TIP122	100	V
VEBO	Emitter-Base Voltage	5	V	
IC	Collector Current (DC)	5	A	
ICP	Collector Current (Pulse)	8	A	
IB	Base Current (DC)	120	mA	
TJ	Junction Temperature	150	°C	
TSTG	Storage Temperature Range	-65 to 150	°C	

Thermal Characteristics

Values are at TC = 25°C unless otherwise noted.

Symbol	Parameter	Value	Unit
PC	Collector Dissipation (TA = 25°C)	2	W
Collector Dissipation (TC = 25°C)	65		

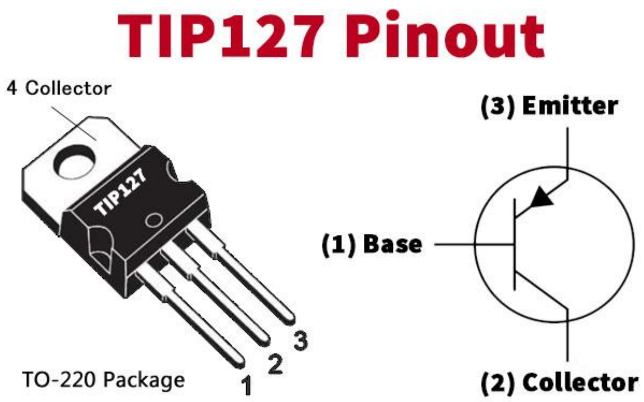
Electrical Characteristics
Values are at TC = 25°C unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Max.	Unit
VCEO(sus)	Collector-Emitter Sustaining Voltage	TIP120	IC = 100 mA, IB = 0	60	V
TIP121	80				
TIP122	100				
ICEO	Collector Cut-Off Current	TIP120	VCE = 30 V, IB = 0	0.5	mA
TIP121	VCE = 40 V, IB = 0	0.5			
TIP122	VCE = 50 V, IB = 0	0.5			
ICBO	Collector Cut-Off Current	TIP120	VCB = 60 V, IE = 0	0.2	mA
TIP121	VCB = 80 V, IE = 0	0.2			
TIP122	VCB = 100 V, IE = 0	0.2			
IEBO	Emitter Cut-Off Current	VEB = 5 V, IC = 0	2	mA	
hFE	DC Current Gain(1)	VCE = 3 V, IC = 0.5 A	1000		
VCE = 3 V, IC = 3 A	1000				
VCE(sat)	Collector-Emitter Saturation Voltage(1)	IC = 3 A, IB = 12 mA	2.0	V	
IC = 5 A, IB = 20 mA	4.0				
VBE(on)	Base-Emitter On Voltage(1)	VCE = 3 V, IC = 3 A	2.5	V	
Cob	Output Capacitance	VCB = 10 V, IE = 0, f = 0.1 MHz	200	pF	

Note:

1. Pulse test: pw δ 300 ⌠s, duty cycle δ 2%.

- **PNP transistors TIP 127**



TIP127 Key Features

High DC Current Gain —
hFE = 2500 (Typ) @ IC = 4.0 Adc
Collector–Emitter Sustaining Voltage — @ 100 mAdc
VCEO(sus) = 100 Vdc (Min) — TIP127
Low Collector–Emitter Saturation Voltage —
VCE(sat) = 2.0 Vdc (Max) @ IC = 3.0 Adc
VCE(sat) = 4.0 Vdc (Max) @ IC = 5.0
Type Designator: TIP127
Material of Transistor: Si
Polarity: PNP

Ic (mA)	**Pd (mW)**	**Vce (max)**	**Vcb**	**hfe**	**@Ic**
5	65	100	100	1000	500

1.2.4 Diode

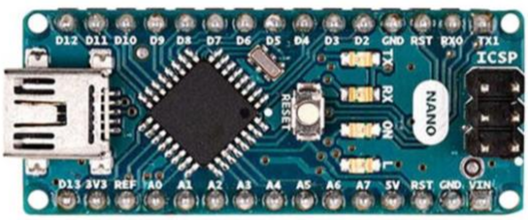
A diode is a two-terminal electronic component that conducts current primarily in one direction (asymmetric conductance); it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other.

A semiconductor diode, the most commonly used type today, is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals. It has an exponential current–voltage characteristic. Semiconductor diodes were the first semiconductor elec-tronic devices. Today, most diodes are made of silicon, but other semiconducting materials such as gallium arsenide and germanium are also used.

The obsolete thermionic diode is a vacuum tube with two electrodes, a heated cathode and a plate, in which electrons can flow in only one direction, from cathode to plate.

Among many uses, diodes are found in rectifiers to convert AC power to DC, demodulation in radio re-ceivers, and can even be used for logic or as temperature sensors. A common variant of a diode is a light emitting diode, which is used as electric lighting and status indicators on electronic devices.

1.2.5 Arduino



Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ('shields') or breadboards (for prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs. The microcontrollers can be programmed using the C and C++ programming languages, using a standard API which is also known as the Arduino Programming Language, inspired by the Processing language and used with a modified version of the Processing IDE. In addition to using traditional compiler toolchains, the Arduino project pro-vides an integrated development environment (IDE) and a command line tool developed in Go.

1.3 Connection theory

The DC motor is connected to the collector of the transistor and the emitter is connected to ground. The base of the transistor is connected to the Arduino output pin through a 20kilo ohm resistor.

The diode is connected across the motor terminals to protect the transistor from the back EMF generated by the motor.

The Arduino code is uploaded to the board that generates the PWM signal to control the motor's speed and direction. The PWM signal is sent to the base of the transistor, which acts as a switch and controls the motor's operation.

By varying the duty cycle of the PWM signal, the speed of the motor can be controlled. By changing the polarity of the PWM signal, the direction of the motor can be reversed.

Codes that needed for running arduino

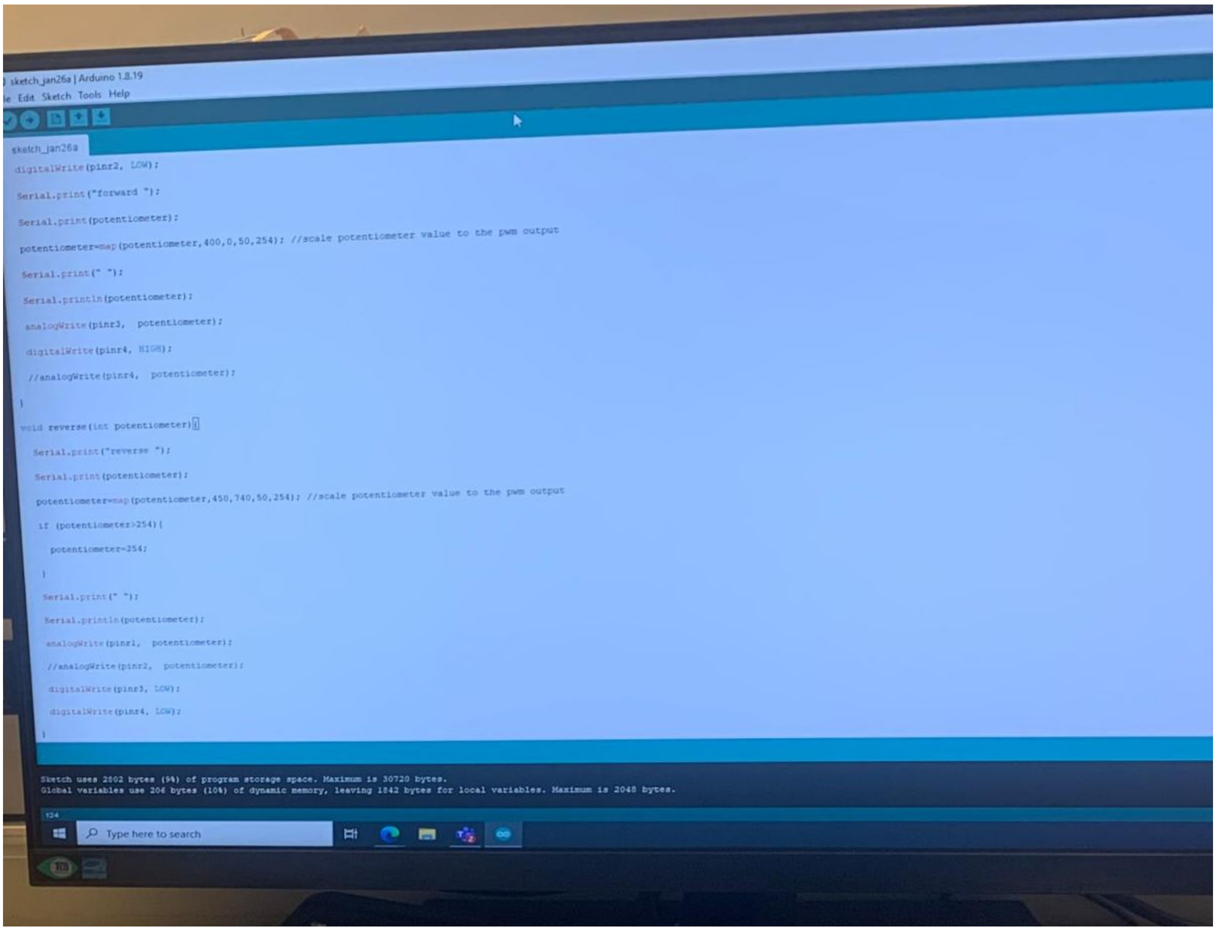


Figure 1Code that needed for runing Arduino

Conclusion:

DC motor control with a transistor and Arduino is an easy and cost-effective way to control the speed and direction of DC motors. This project is useful for various applications that require motor control. With further modifications, this project can be expanded to control multiple motors and even control them wirelessly.

Diagram of the circuit.

This circuit is called an H-bridge, which is a type of electronic circuit used to control the direction and speed of a DC motor. Q1 and Q3 are NPN transistors that are used to connect the motor to ground, while Q2 and Q4 are PNP transistors that are used to connect the motor to the positive terminal of the battery. The value of resistors R1-R4 is 1 kilohm, which is chosen to provide enough current to fully turn on the transistors. The diodes D1-D4 provide a safe path for the motor energy to be dispersed or returned to the battery when the motor is commanded to coast or stop, preventing voltage spikes that could damage or destroy the transistors.

The motor used in this circuit is a DC motor, which is very common and can be found in surplus stores online or in salvaged toys. It should have only two wires, and the resistance of the two wires should be measured using a multimeter. If the motor resistance is less than 5 ohms, then the transistor parts listed in this article are too weak to power the motor effectively. It is important to choose a battery with enough capacity to power your motor and transistors for the desired amount of time.

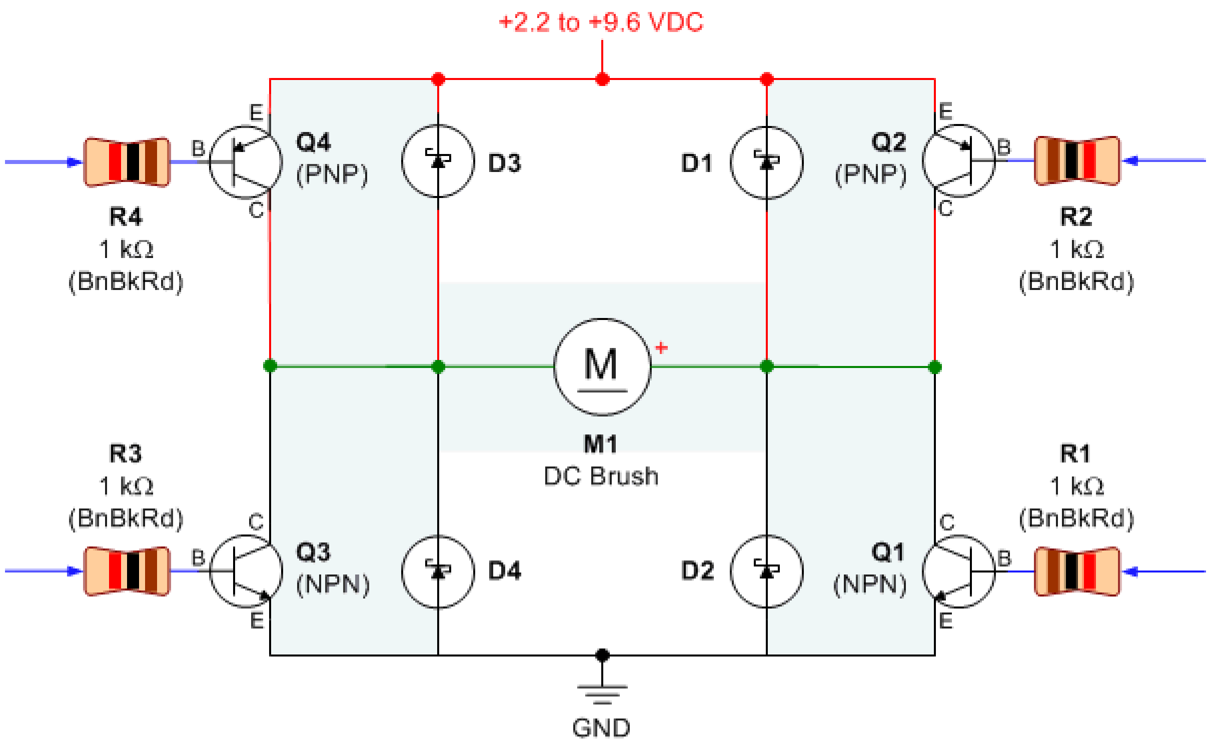


Figure 2 Circuit Diagram

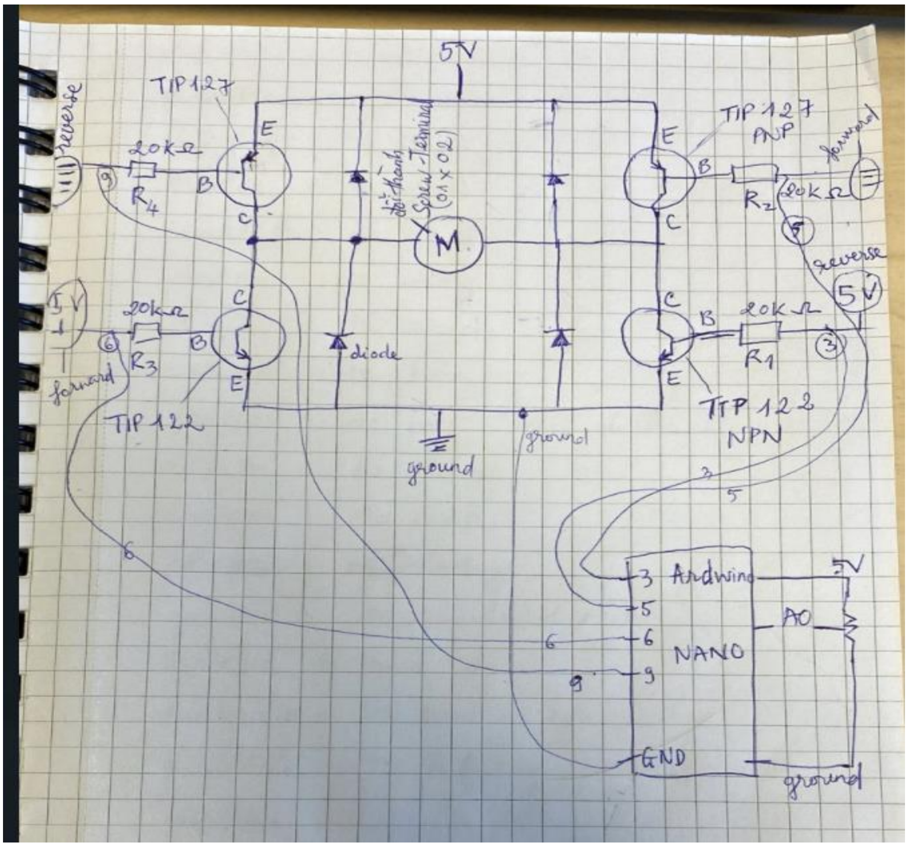
We create a single circuit called an H-Bridge to allow bi-directional control of a DC motor. The circuit is made with 4 NPN transistors (I used 2N4401) and 4 220 Ohm resistors. By writing a digital high to the left pair, and a digital low to the other the motor spins in one direction. By reversing the high and low signals we can reverse the direction of rotation, and speed can be controlled by PWM. This is the first step in a multipart robot build.

Controlling the H-Bridge Motor Driver

Command	R1	R2	R3	R4
Coast/Roll/Off:	GND or disconnected	+VDC or disconnected	GND or disconnected	+VDC or disconnected
Forward:	GND or disconnected	GND	+VDC	+VDC or disconnected
Reverse:	+VDC	+VDC or disconnected	GND or disconnected	GND
Brake/Slow Down:	+VDC	+VDC or disconnected	+VDC	+VDC or disconnected

2 Practical

2.1 Test circuit

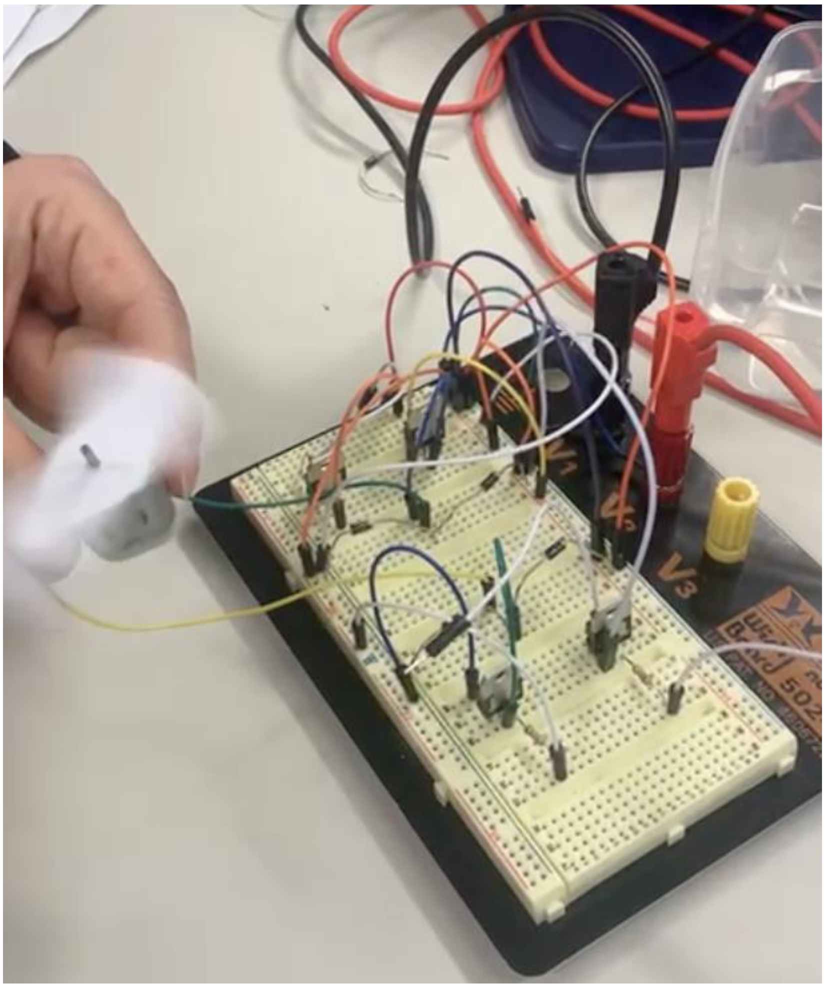


First of all, we planned to have a draw to summarise what we will build. We can see in the picture that DC motor control uses transistors, and Arduino involves using an Arduino microcontroller to send signals to a transistor which, in turn, controls the voltage applied to the DC motor. A test circuit for DC motor control with transistor and Arduino is a simple circuit that allows you to experiment with controlling the speed and direction of a DC motor using an Arduino microcontroller and a transistor.

A detailed explanation of the procedure is provided below:

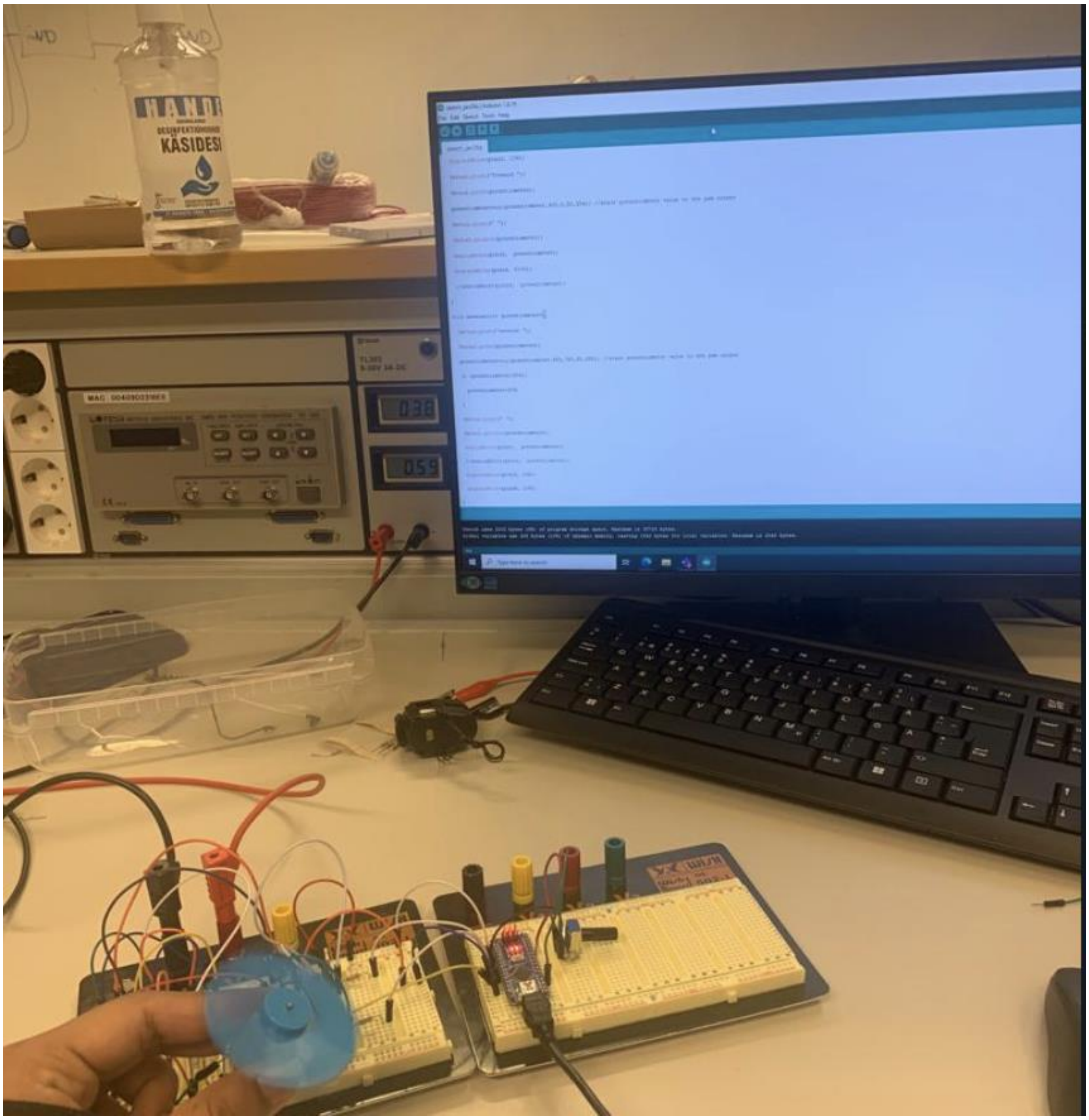
1. Connect the DC motor to the transistor. The transistor acts as a switch, allowing current to flow through the motor when the transistor is activated by the Arduino.

2. Attach one of the Arduino's digital output pins to the transistor's base. The transistor will receive a signal from this pin to turn on or off.

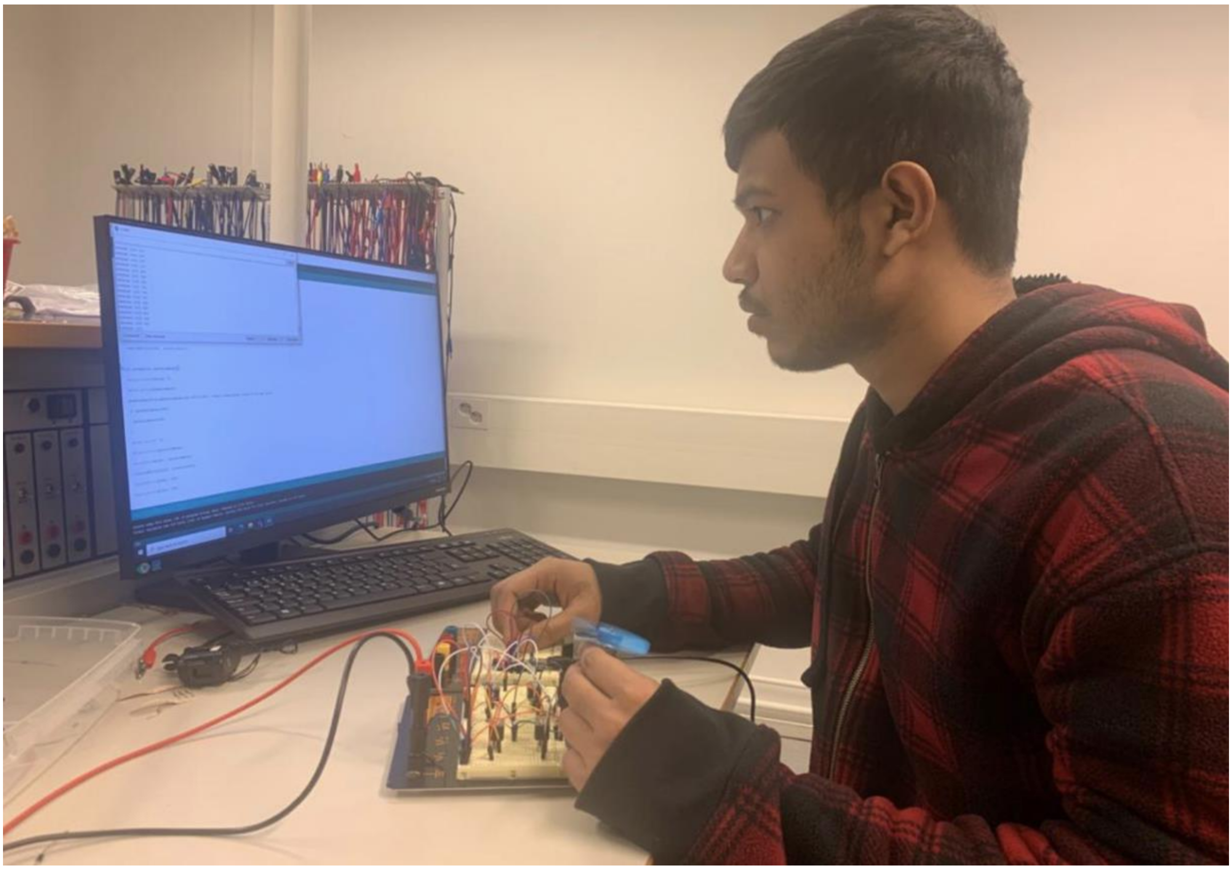


3. To set the output pin to high or low, create a program in the Arduino IDE. The transistor will turn on when the output pin is set to high, which will also turn on the DC motor. The transistor will shut off and the DC motor will halt when the output pin is set to low.

4. Connect the Arduino to a power source. You can use a USB cable to connect the Arduino to your computer, or you can use a separate power supply.

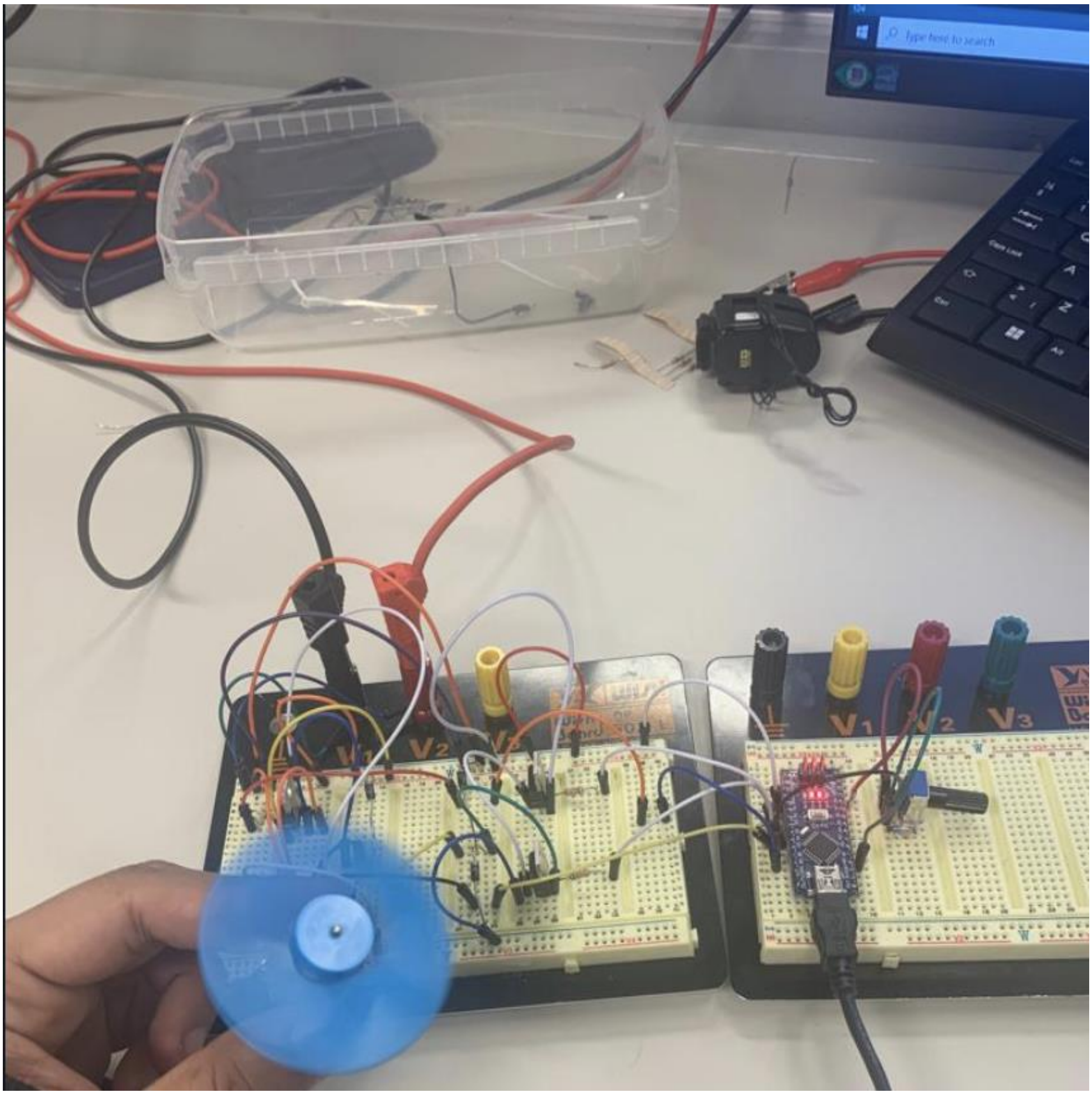


5. PWM (pulse-width modulation) can be used to change the motor's speed. PWM is a method that rapidly alternates between turning on and off the output pin, with the ratio of on to off time dictating the average voltage provided to the motor. The duty cycle of the PWM signal, which controls the motor's speed, can be changed.



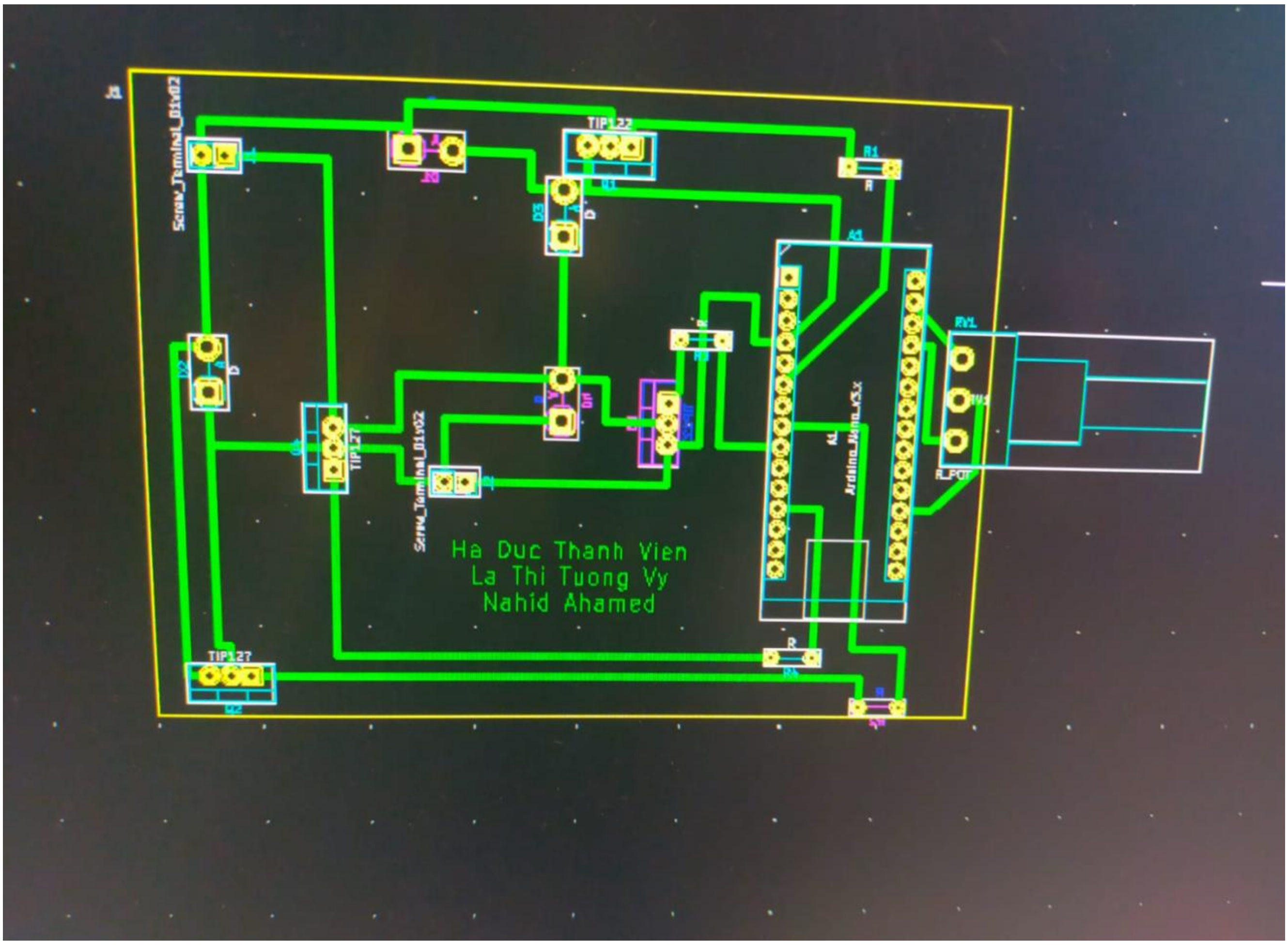
6. Test the circuit. Upload your program to the Arduino, and connect the motor to a power source. Verify that the motor turns on and off when you set the output pins to high or low, and that the motor speed changes when you adjust the duty cycle of the PWM signal. Also verify that the motor changes direction when you change the output pin values.

Overall, controlling a DC motor with transistors and an Arduino board is a fairly straightforward operation that can be completed with simple electronic components and programming know-how. A variety of motor control applications, from simple robotics projects to complex industrial automation systems, can be made with a little experimenting.



2.2 Schematic

The process of creating a graphic representation of an electronic circuit is called circuit diagram design. A circuit diagram uses standardized symbols to represent the elements of the circuit and the connections that connect them.



A circuit diagram is primarily used to explain and visualize how a circuit operates. It enables you to comprehend the circuit's current flow and the connections between various components. You can troubleshoot issues and modify the circuit with the aid of a well-designed circuit diagram.

A circuit diagram must contain a number of essential components, including:

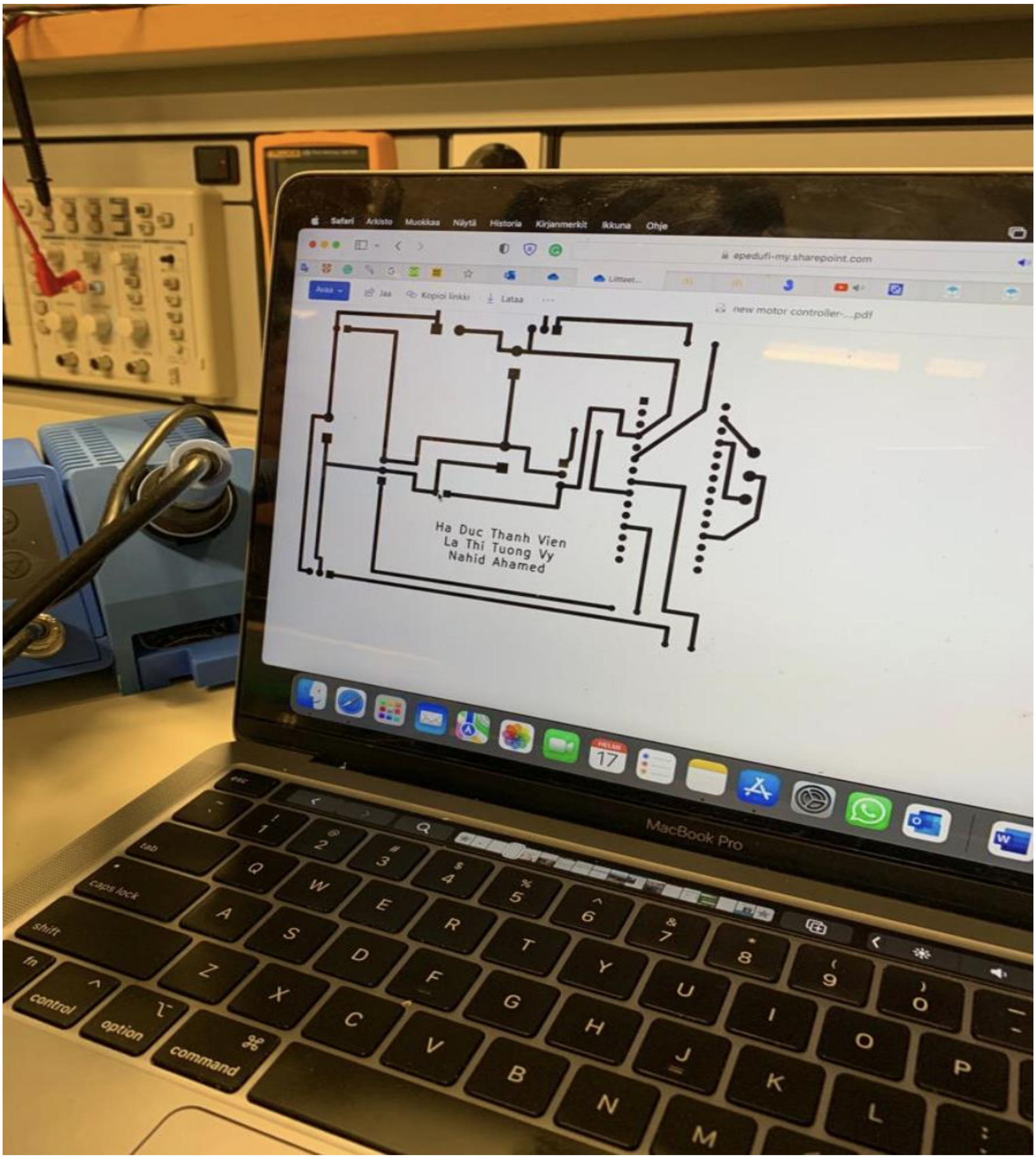
1. Symbols: Different circuit components, such as transistors, resistors, and capacitors, are represented by standardized symbols.

2. Connections: Lines are used to depict the connections between the components. The lines may be straight or curved, and they may also include symbols to represent the direction of current flow, such as arrows or dots.

3. Labels: Labels are used to identify each component in a circuit and can also include extra details like part numbers or component values.

4. Power sources: The circuit diagram also includes power sources to show how the circuit is powered, such as batteries or AC adapters.

5. Ground symbols: Ground symbols are used to indicate the point in the circuit that is used as the reference point for measuring voltage.



1. Draw your circuit schematic pcb board. Once the schematic and layout are drawn, it is time to print the layout onto a transparency.You choose PDF and Cu and then save it to print a circuit schematic or diagram

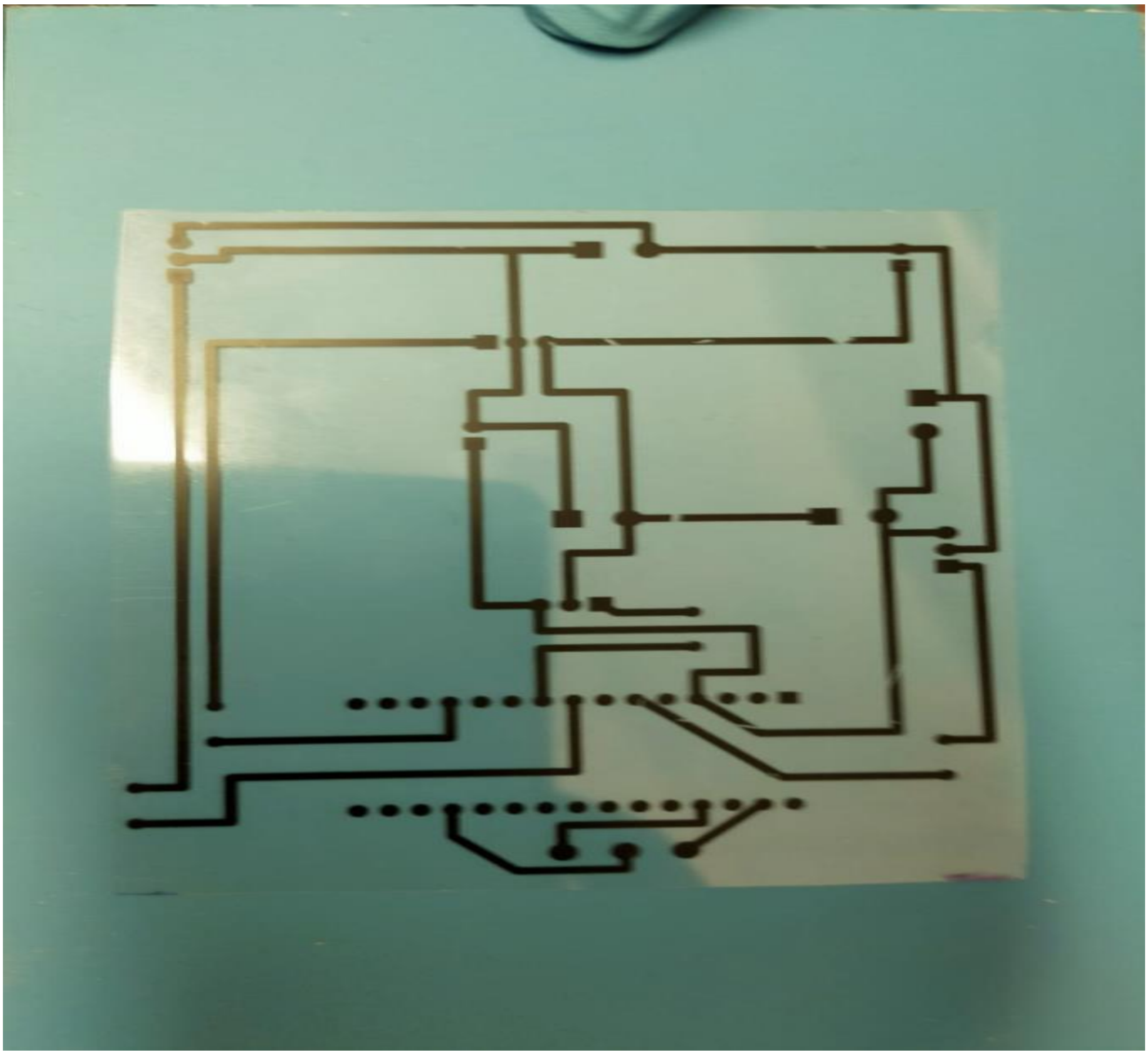
2. Draw your circuit schematic pcb board. Once the schematic and layout are drawn, it is time to print the layout onto a transparency.

3. To print only the desired circuit, turn on only the Top Layer, Pads, Vias, and Dimension. This is done by selecting View -> pcb board Display/Hide Layers in the Layout editor and selecting the correct settings.

4. The Layout is now ready to be printed, make sure that the image is mirrored so that text shows up correctly after being transferred onto the PCB. We printed the circuit with our Brother HL-2070N (on highest quality) laser printer and MG Chemicals transparencies pcb board.

2.3 PCB

PCB (Printed Circuit Board) design is the process of creating a layout or pattern for the physical board that will hold the electronic components and connections for a circuit. In the case of a DC motor control circuit with a transistor and an Arduino, the PCB design will include the layout of the components, their connections, and the traces or conductive pathways that will connect them on the PCB.



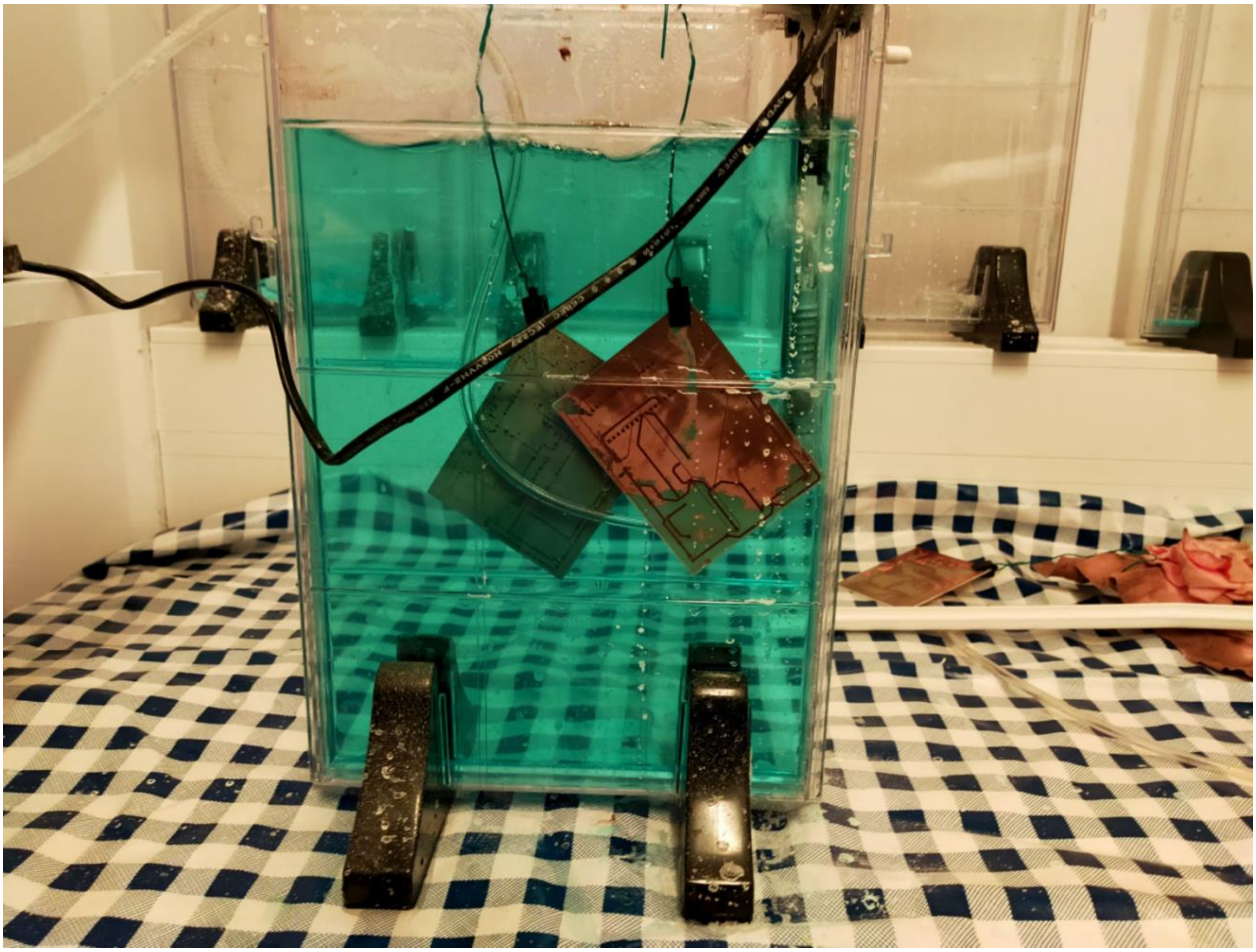
2.4 PCB manufacturing

Expose the presensitized circuit board to UV light. Place the printed transparency on the elevated plastic about 10 inches above the LED. The ink should be facing up towards the sky. While the room is somewhat dark, peel the white film off the presensitized circuit board to expose the photoresist. Place the PCB on top of the transparency, photoresist facing pcb board down towards the LED. Stack about 8-10 textbooks on top of the PCB to make sure the photoresist is tightly pressed against the ink of the transparency. No scotch tape is necessary to hold the PCB down to the transparency. Turn the UV light box on. Exactly 1.5 minute exposure time worked well. You may have to experiment with different times depending on the height above the LED. Turn off after 1.5 minute.

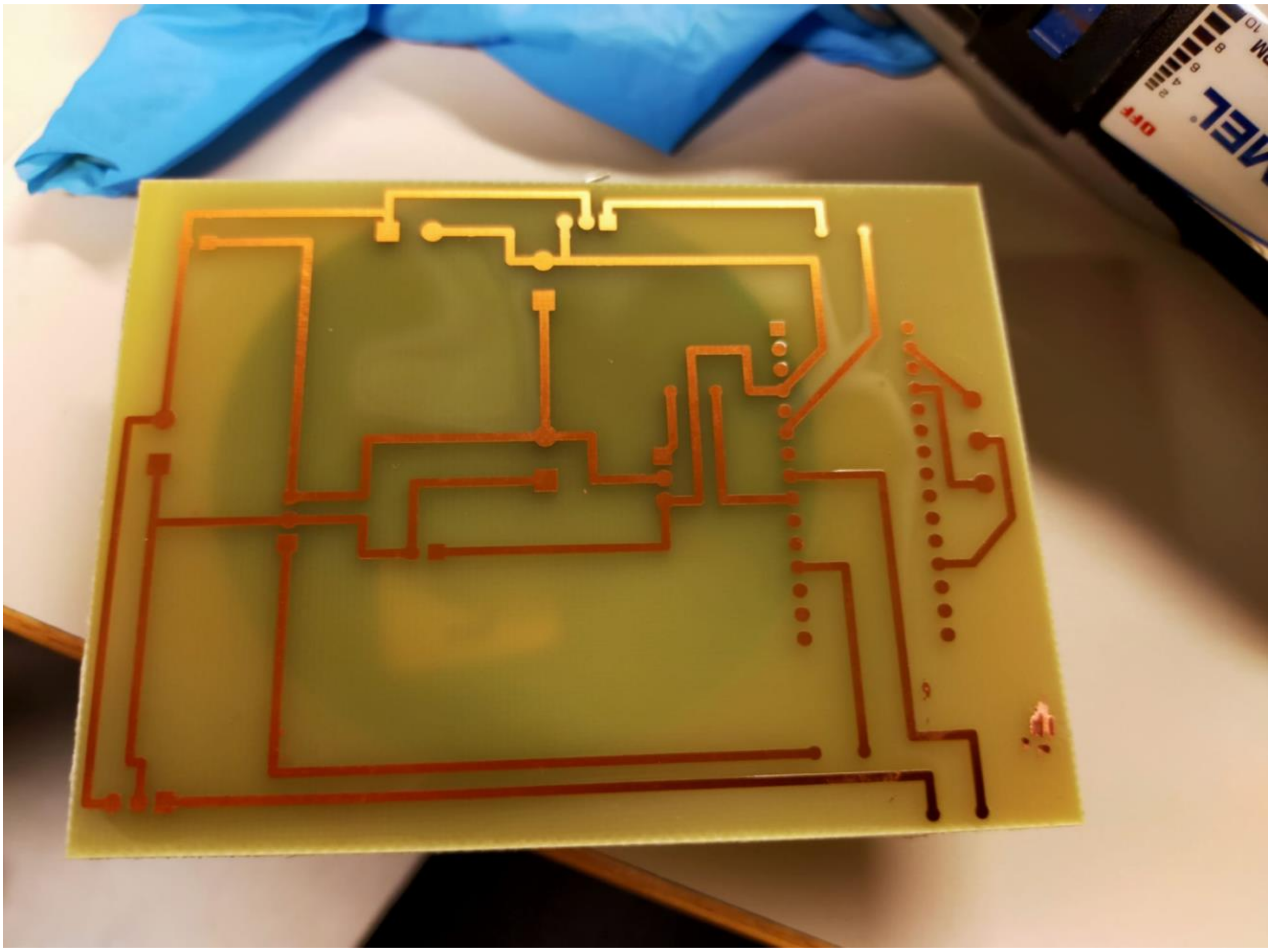
Prepare the developer solution. Prepare the MG Chemical developer solution with 1 part developer, 10 parts tap water. I used 1/4 cup developer, pcb board 2 1/2 cups of tap water. Be sure to mix the solution with tap water thoroughly before placing the PCB in the solution, otherwise the photoresist will be eaten away in undesired spots. Place the PCB in the mixed solution and shake it around face up pcb board. The parts where the photoresist was exposed to UV light will be washed away in about 5-10 seconds. Do not leave the board in the developer solution for too long, otherwise all the photoresist will be washed away. Place the PCB in cold water immediately to stop the reaction once the board is finished. The developer solution can be re-used for multiple PCB. You could try using Sodium Hydroxide (Lye from Ace Hardware) but you will have to experiment with what % to put in tap water. pcb board The percentage of Sodium Hydroxide to tap water is important because too strong of a solution will wash away your non-exposed UV photoresist pcb board.


Pirkka putkenavaaja/
propplösare för avloppet
1 L
Sisältää/Innehåller:
natriumhydroksidi/
natriumhydroxid
pH 12,5
VAARA/FARA
Natriumhydroxid NaOH
Ätzend
Voimakkaasti syövyttävää
Säilytettävä lukitussa tilassa ja lasten ulottumattomissa. Roiskeet silmistä huuhdeltava välittömästi runsaalla vedellä (15 min ajan) ja mentävä lääkäriin. Käytettävä sopivia suojakäsineitä ja silmien- tai kasvonsuojainta. Onnettomuuden sattuessa tai tunnettaessa pahoinvointia hakeuduttava heti lääkärin hoitoon (näytettävä tätä etikettiä, mikäli mahdollista).

Copper can be removed by etching. board of pcb Make a mixture of 1 part circuit board with muriatic acid and 2 parts hydrogen peroxide. I used 16 oz. of hydrogen peroxide and 8 oz. of muriatic acid. Because this acid is much stronger than the photoresist developer, use caution when working with it. To avoid inhaling any of the fumes, I advise using a fan over the bucket. Wear pcb board gloves and goggles. Carefully shake the bucket after adding the PCB to the solution. As the copper is removed from the circuit board by being etched, the solution will begin to turn green. When all of the copper has been removed by the etching, take it out of the bucket. It will take approximately 2 minutes to completely etch the copper from the PCB board. Cleanse the PCB.



Populate your PCB with parts At this point, you have a PCB to populate with integrated circuits and parts. Enjoy your PCB and let me know if you have any questions.



2.5 Soldering components to the PCB

Drilling a printed circuit board (PCB) is an important step in the PCB fabrication process, as it allows you to create holes for mounting components and connecting traces on different layers. Here are the general steps for drilling a PCB:

1. First, you will need a drill bit that is appropriate for the size of the holes you need to make. PCB drill bits are typically very small, and they come in various sizes ranging from 0.2mm to 3.0mm.

2. Next, secure the PCB in a drill press or a vise. Make sure the PCB is stable and won't move around while you are drilling.

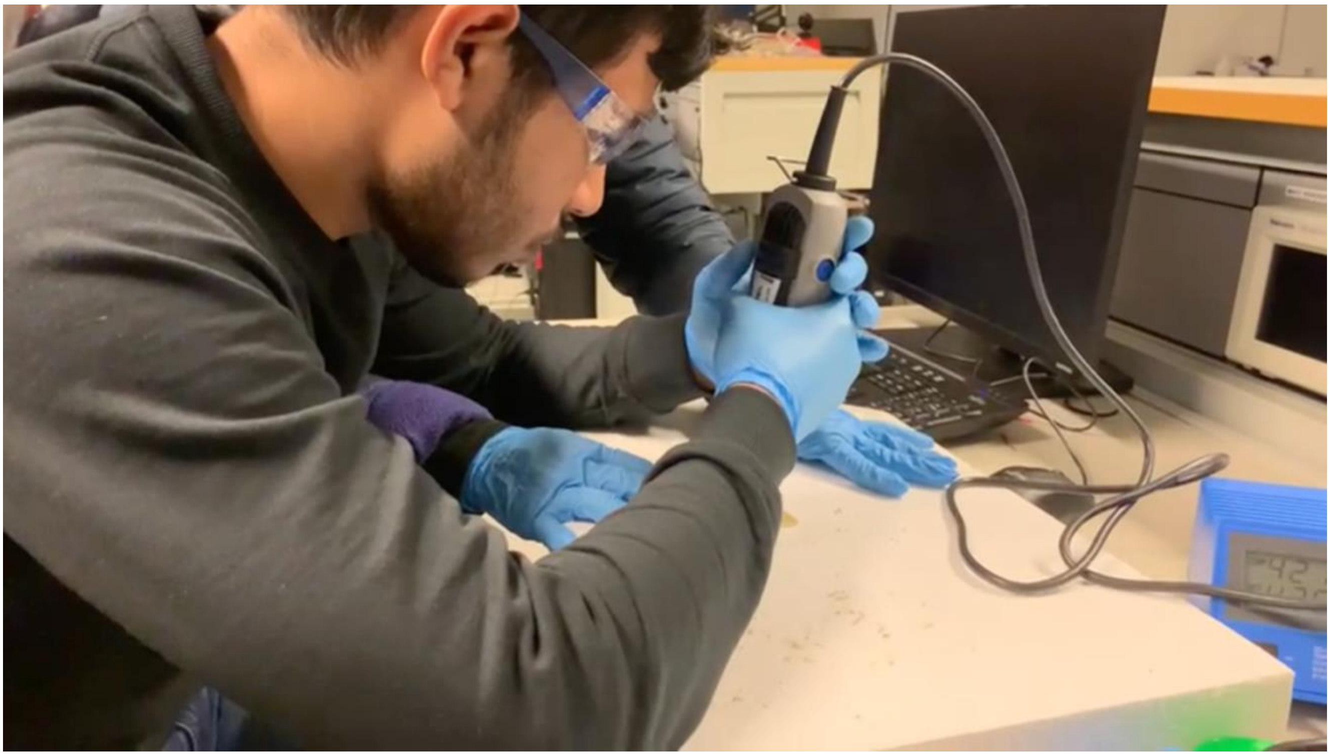
3. Set the drill press to the appropriate speed for the size of the drill bit and the material of the PCB. For most PCBs, a speed of around 10,000 RPM is sufficient.

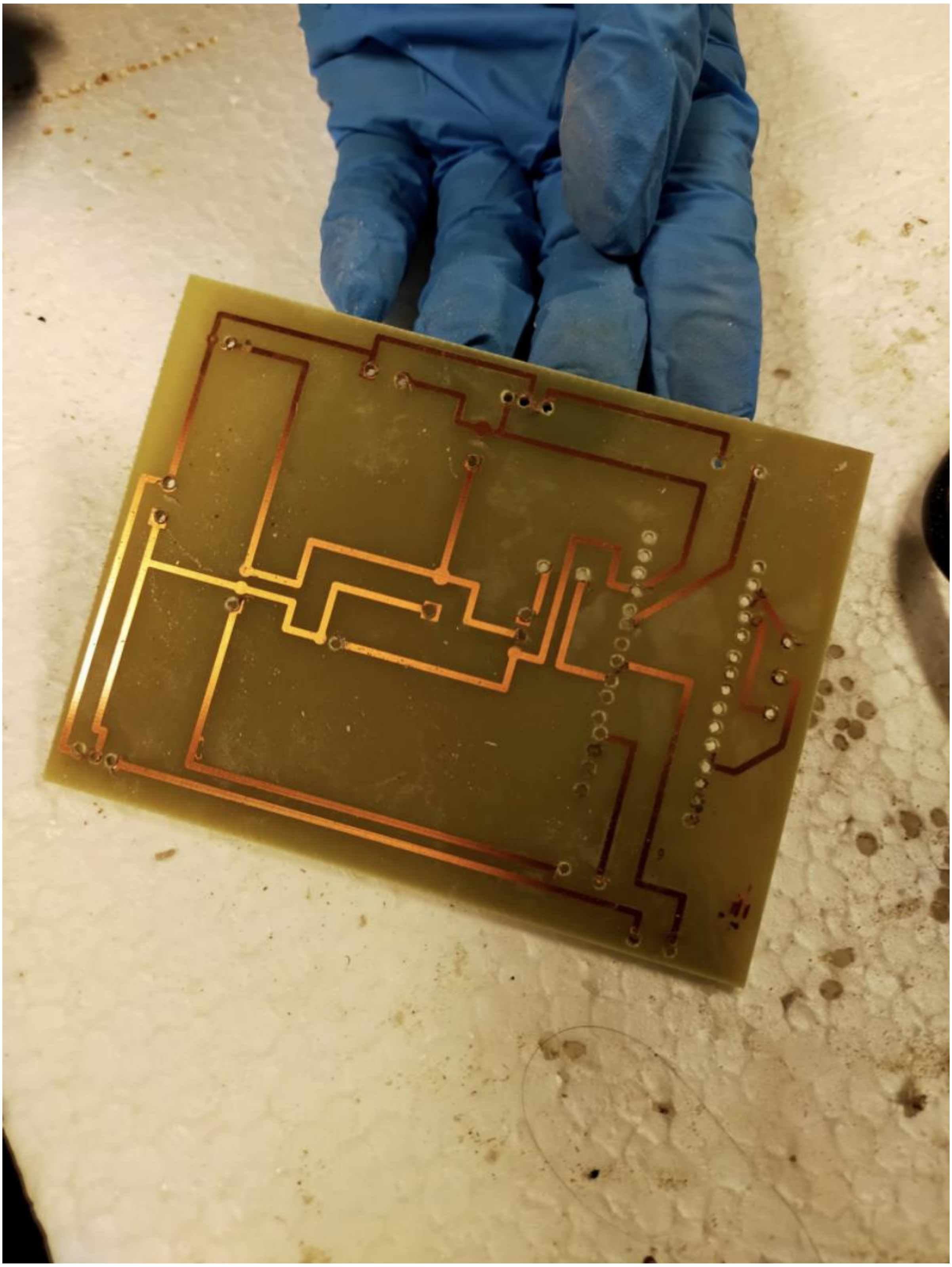
4. Begin drilling the holes in the PCB. Use a light touch and make sure to keep the drill bit perpendicular to the PCB to avoid breaking the bit or damaging the PCB.

5. After you have drilled all of the holes, use a vacuum or compressed air to remove any debris or dust from the PCB.

6. Finally, inspect the PCB to make sure all of the holes are clean and clear of debris. You can use a magnifying glass or microscope to get a better view of the holes and make any necessary adjustments.

Once you have drilled the PCB, you can begin the soldering process by inserting the appropriate components into the holes and soldering them to the traces on the PCB.





Soldering components to a printed circuit board (PCB) involves heating the solder and applying it to the component leads and the PCB pads to create a strong electrical connection.

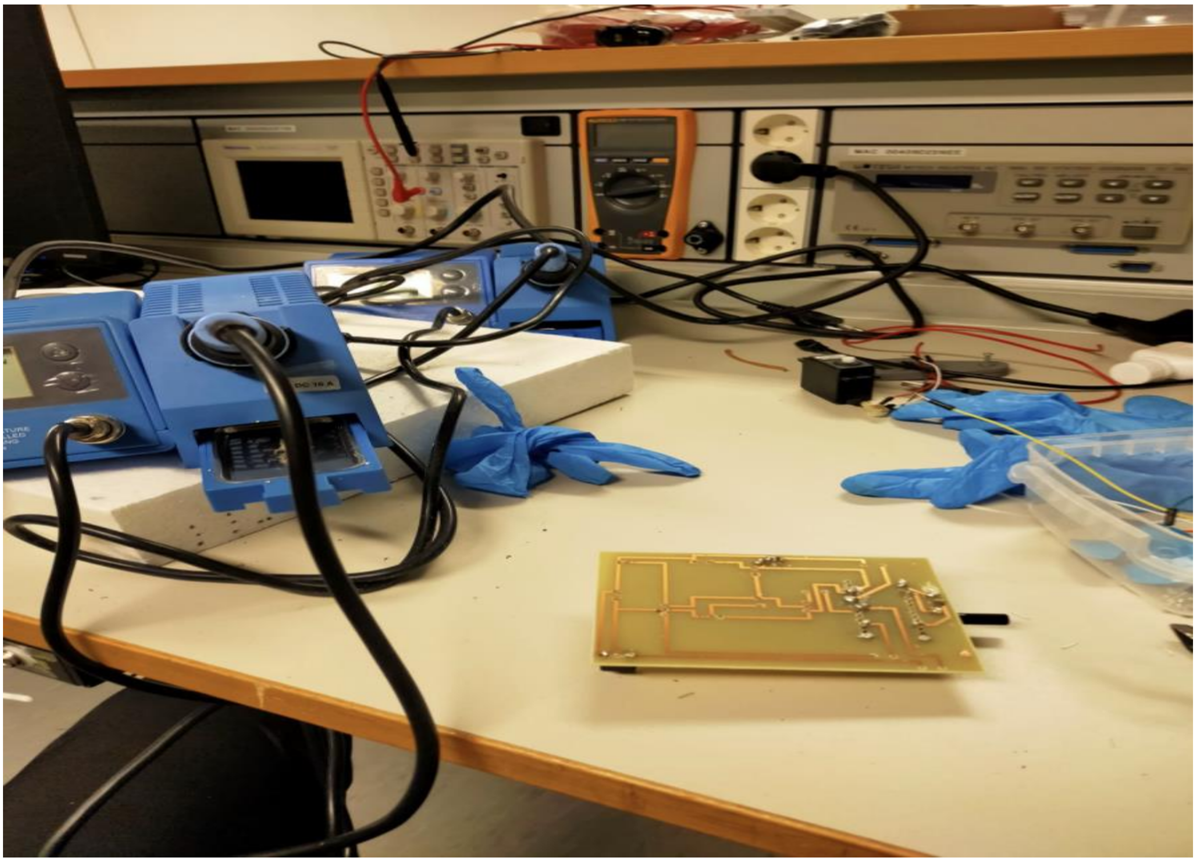
1. Heat up your iron (315-370 degrees C)

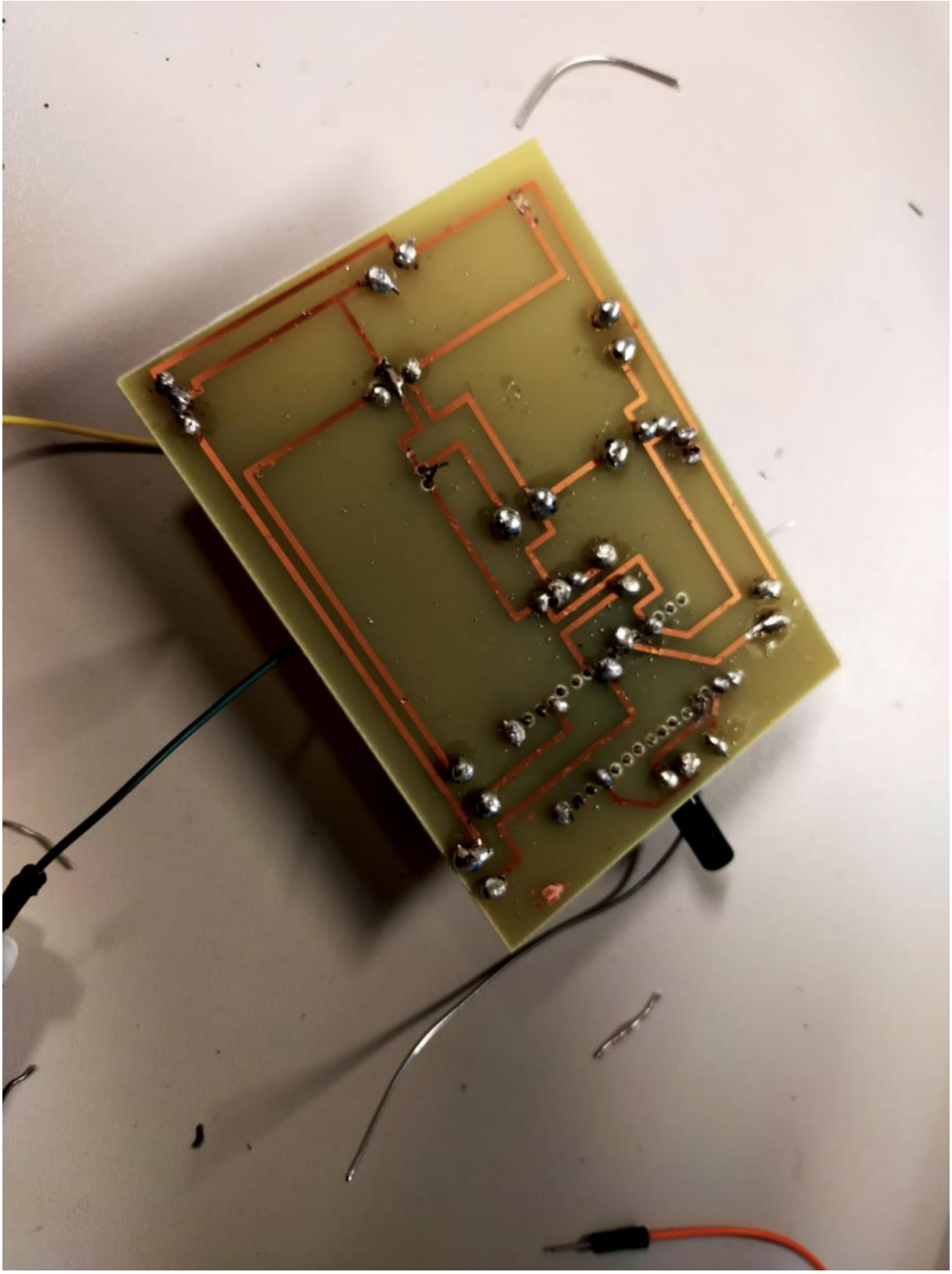
2. Make your connection mechanically stable. Use helping hands to keep your parts steady. Slightly bend leads of through-hole components. Get creative with sticky tape

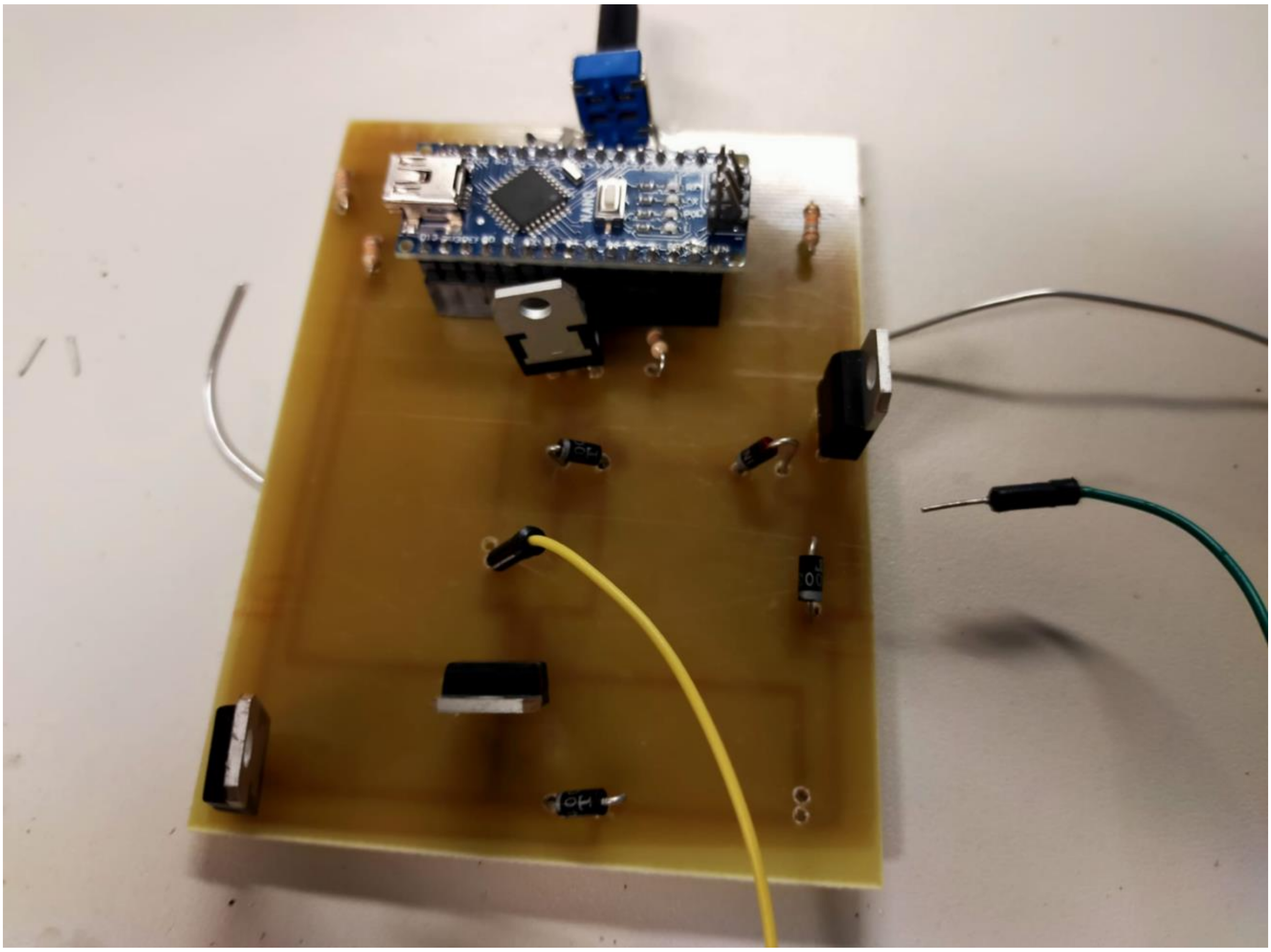
3. Clean your iron. The surfaces of hot metals quickly build up and oxide layer, which inhibits heat transfer and solder adhesion.

4. Apply heat and solder. The amount of time it takes for the joint to heat to the appropriate temperature varies. Tinning the iron can help with heat transfer. Ensure good contact between the iron and the joint. The joint needs some time to cool.

5. Inspect the joint







2.6 Testing

To test a PCB for DC motor control with transistor and Arduino

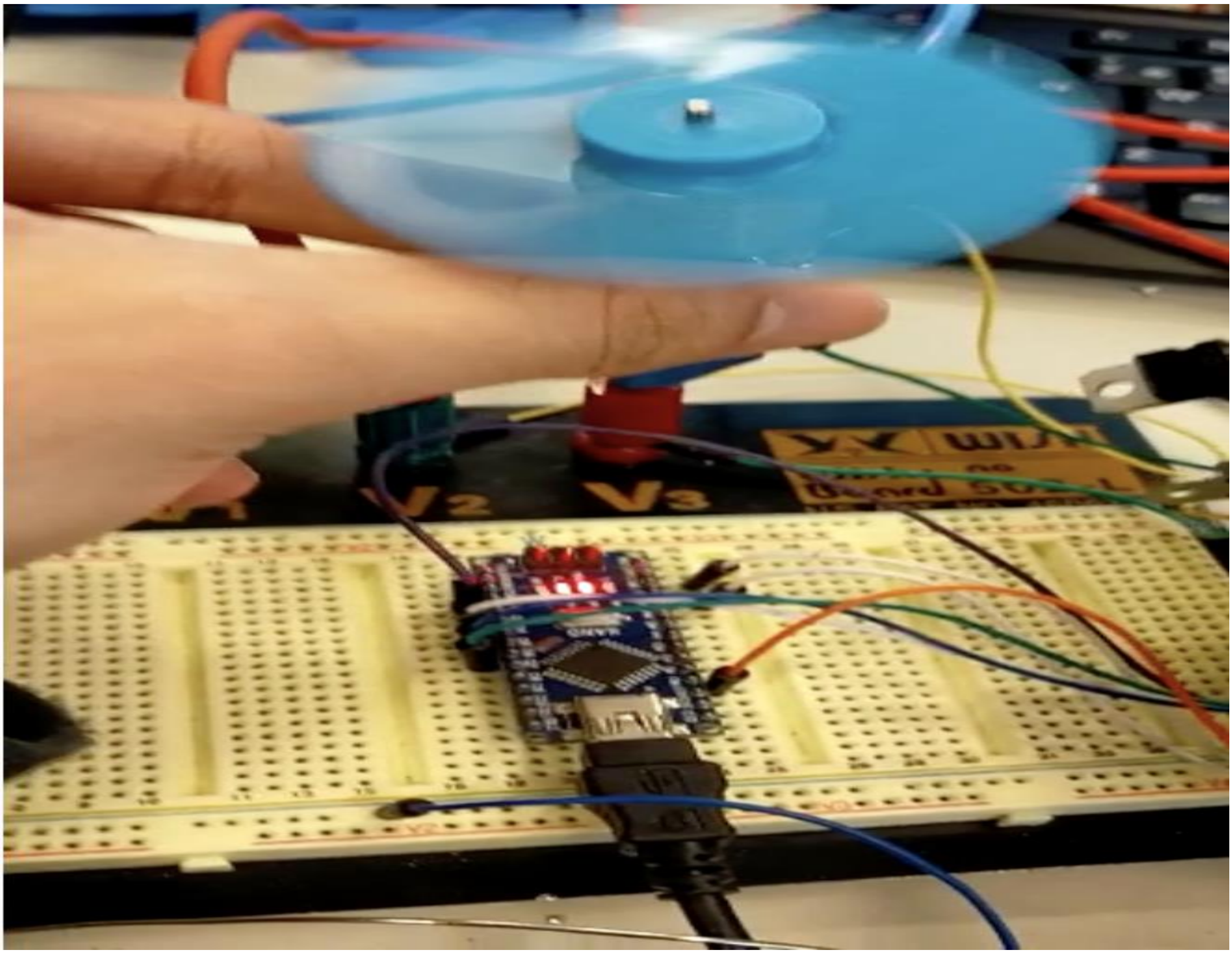
1. Connect the DC motor to the transistor circuit on the PCB, making sure to connect the correct leads to the motor and transistor.

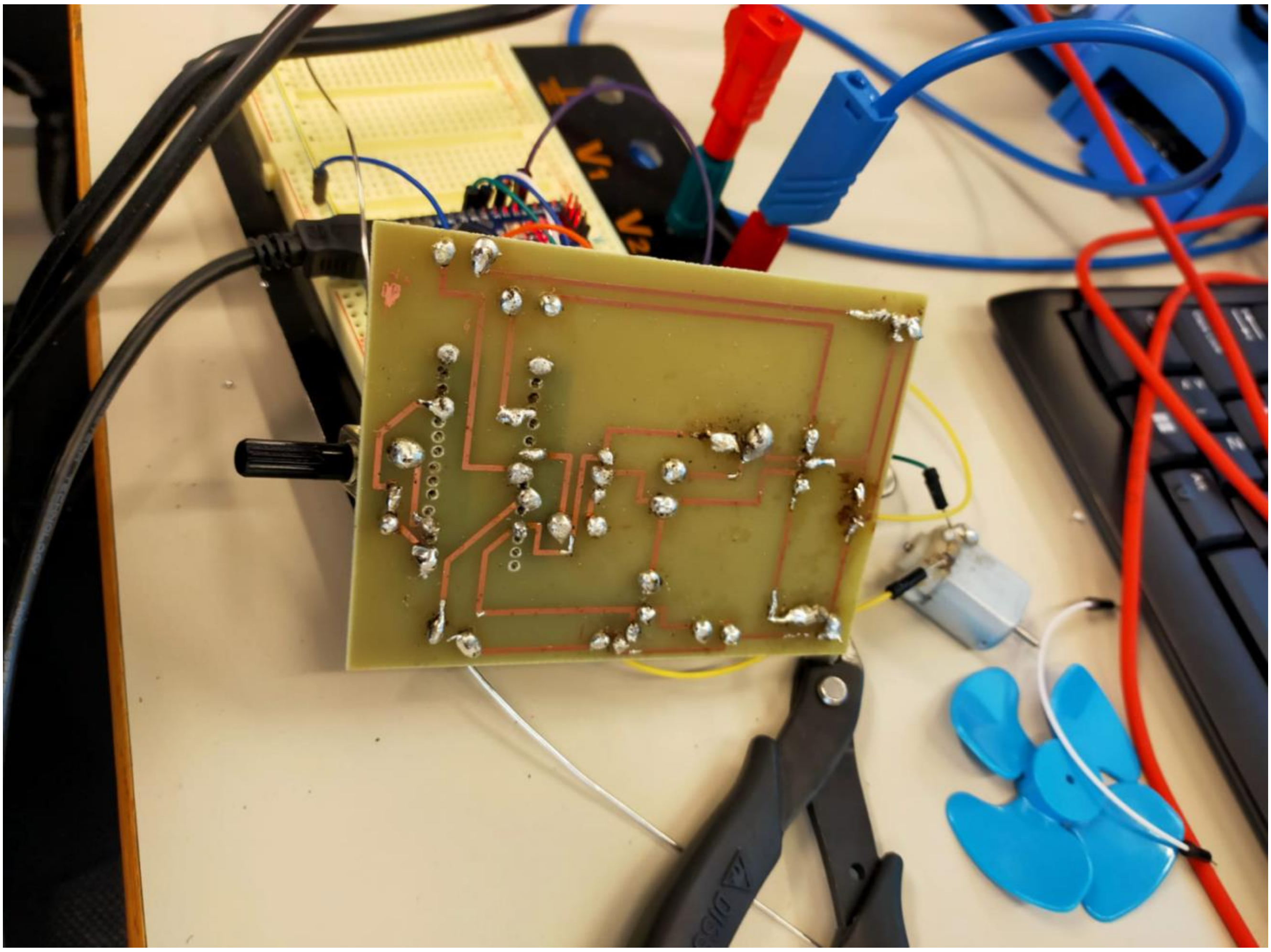
2. Power on the circuit using a suitable power supply, ensuring that the voltage and current rating are correct for the components.

3. Test the motor control by running the sample code and verifying that the motor turns on and off correctly.

4. Monitor the voltage and current levels using a multimeter or other measurement device to ensure that they are within the safe operating range of the components.

5. Inspect the PCB and components for any signs of damage or overheating, such as discoloration or burnt components. If everything is functioning correctly, you can move on to more advanced motor control code and testing to ensure that the circuit is reliable and robust.





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https://www.youtube.com/watch?v=Qps9woUGkvI