BRUSHLESS DC MOTOR DRIVER KIT. DATASHEET, ASSEMBLY INSTRUCTIONS, CIRCUIT BREAKDOWN & CODE.

Overview: This kit builds a Brushless DC-Motor driver commonly referred to as an electronic speed controller or ESC. The circuit board itself is 95 by 55mm in size, with a height of 20mm once assembled. It can handle up to 30A of continuous current at 18 volts and is compatible with most BLDC motors. Brushless motors are typically considered the most complex form of DC motor as they have three phases and require a specialised drive circuit to run smoothly. That said, the benefits of brushless motors over their simpler brushed counterparts are numerous, they have no mechanical parts and will last for decades, are very power efficient, can achieve extremely high speeds and provide huge amounts of torque relative to their size. Overall, their excellent efficiency and power to weight ratio make BLDC motors ideal for use within high stress, demanding robotics applications such as drones, e-scooters and e-bikes, irrigation systems, cooling fan systems and nearly all hobby vehicles such as cars, planes and submarines. This kit provides an easy to assemble and modify driver ideal for advanced users looking to incorporate brushless DC-Motors into their own applications.

General Power Ratings & Usage:

PARAMETER	MIN	MAX	UNITS
Operating voltage	10	18	**V**
Continuous current	-	30	**A**
Operating Temperature	-10	80	**°C**
Output BEC voltage	4.8	5.1	**V**
Output BEC voltage	-	200	**mA**
Suggested Motor KV	100	2500	**KV (RPM Per Volt Applied)**

- For motors that require more than **2A** of current to run, the exposed power traces should be heavily tinned, with the motor connecting to the PHASEA, PHASEB and PHASEC breakout points on the board's underside.
- The BEC (battery eliminator circuit) also supplies 5V power to the board and is not recommend for use as a main project power supply, as sometimes seen in other ESC designs.
- Starting into 100% power it is not recommended, instead on start-up bring the motor to roughly 30% power for 3 seconds this ensures a smooth start.
- The speed input signal is the same as any other standard ESC or Servo. A 5V, 50Hz square wave with a duty cycle between 1000 microseconds for off and 2000 microseconds for full power.
- The reverse input is digital, requiring a high 5V signal to trigger and a low 0.3-0V signal to disengage. The reverse will also only engage once the motor has come to a full stop.
- **DO NOT TOUCH THE CIRCUIT BOARD DURING OPERATION, ESPECIALLY THE POWER STAGE.**

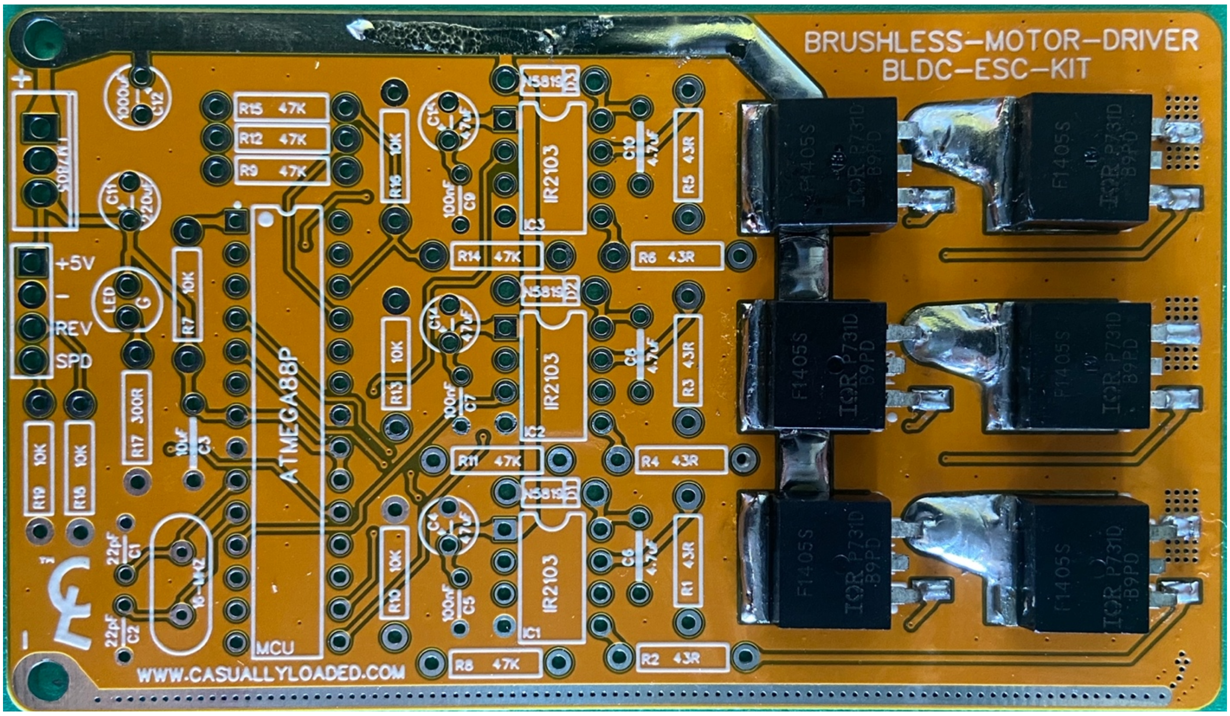
Component list/BOM:

QUANTITY	NAME	TYPE	PCB DESIGNATION
1x	Atmega88P	Microcontroller	MCU

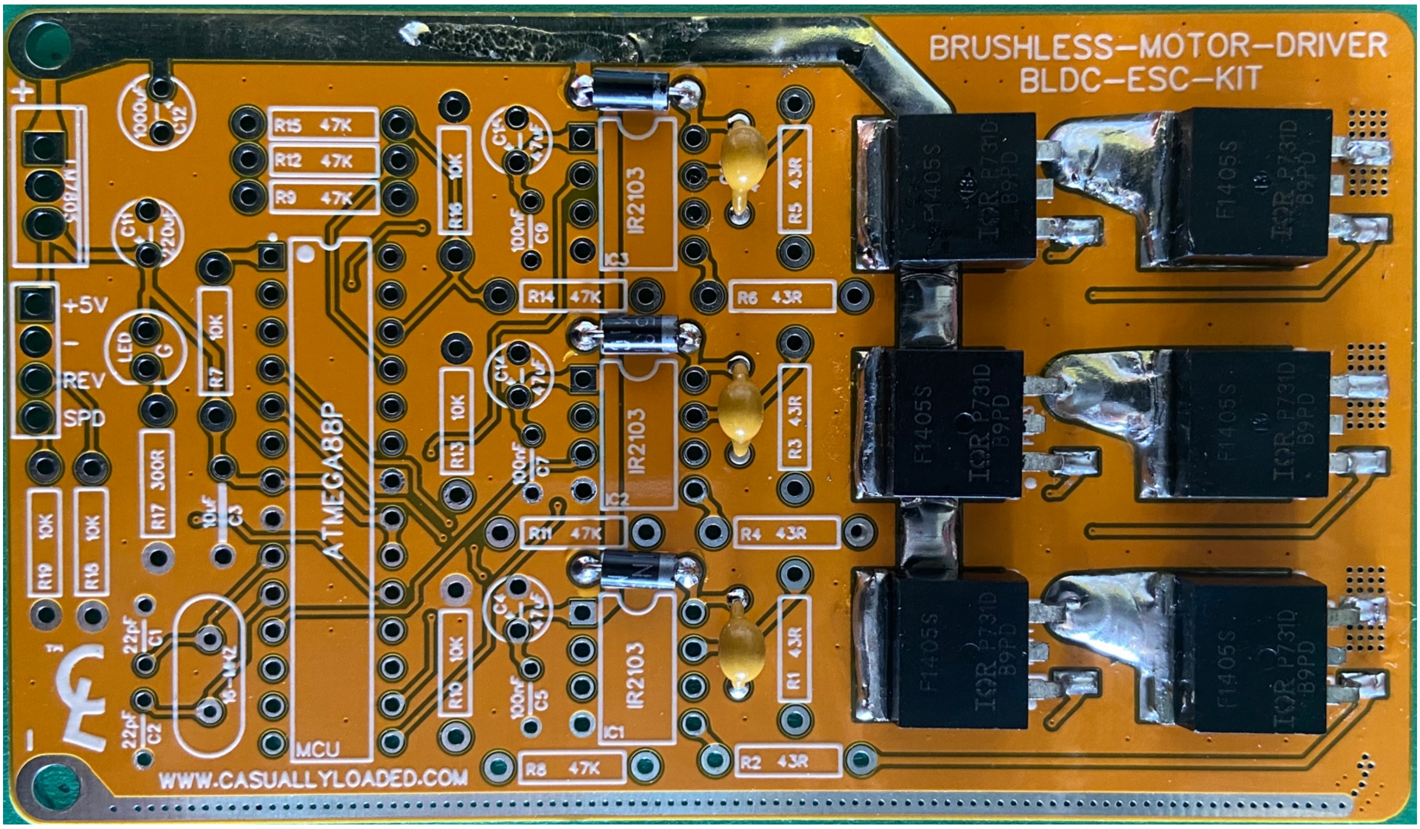
3x	IR2103	H-Bridge Bootstrap Driver IC	IC1, IC2, IC3
6x	IRF1405	N-Channel MOSFET	FET1, FET2, FET3, FET4, FET5, FET6
3x	1N5819	Schottky Diode	D1, D2 D3
1x	LED	Green LED	LED
1x	LM7805	5V linear voltage regulator	LDO
1x	Header pins	Row of 4 header pins	+5V, -, REV, SPD
1x	XTAL	16Mhz crystal oscillator	16-MHZ
3x	4.7uF	Monolithic capacitor	C6, C8, C10
1x	10uF	Monolithic capacitor	C3
2x	22pF	Ceramic capacitor	C1, C2
1x	100nF	Ceramic capacitor	C5, C7, C9
1x	1000uF	Electrolytic capacitor	C12
1x	220uF	Electrolytic capacitor	C11
3x	47uF	Electrolytic capacitor	C4, C14, C15
6x	10K	0.25W 1% metal film resistor	R7, R10, R13, R16, R18, R19
6x	47K	0.25W 1% metal film resistor	R8, R9, R11, R12, R14, R15
6x	43R	0.25W 1% metal film resistor	R1, R2, R3, R4, R5, R6
1x	300R	0.25W 1% metal film resistor	R17

Assembly Instructions

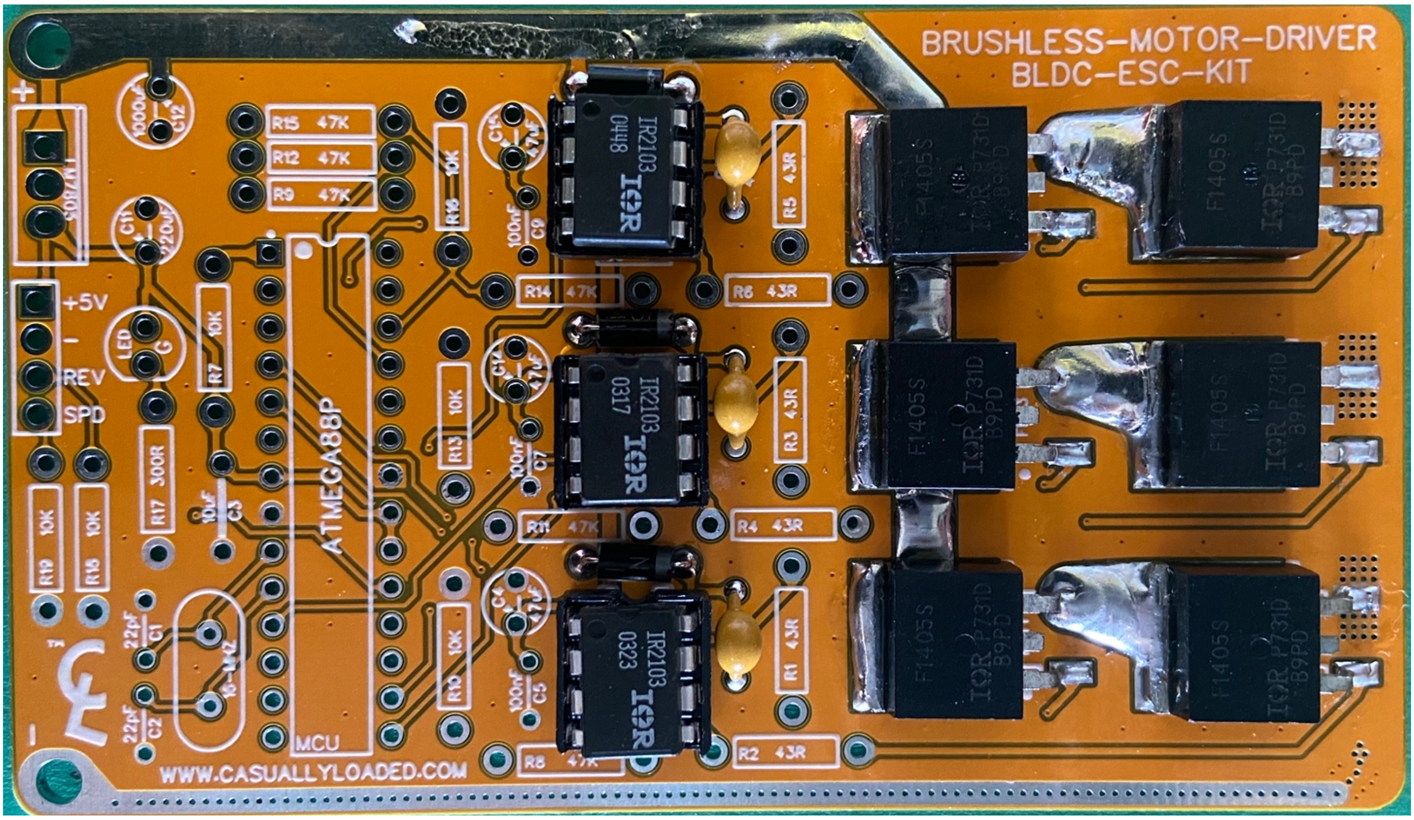
Step-1/Image-1: Solder the IRF1405 N-channel MOSFETs to the board at the spaces labelled FET1 – 6. When soldering lightly tin the large square pad before placing each component, once the MOSFET is positioned correctly use a flat head screwdriver or a thin piece of tape to hold it in place while the two small legs and the top tab are soldered down.



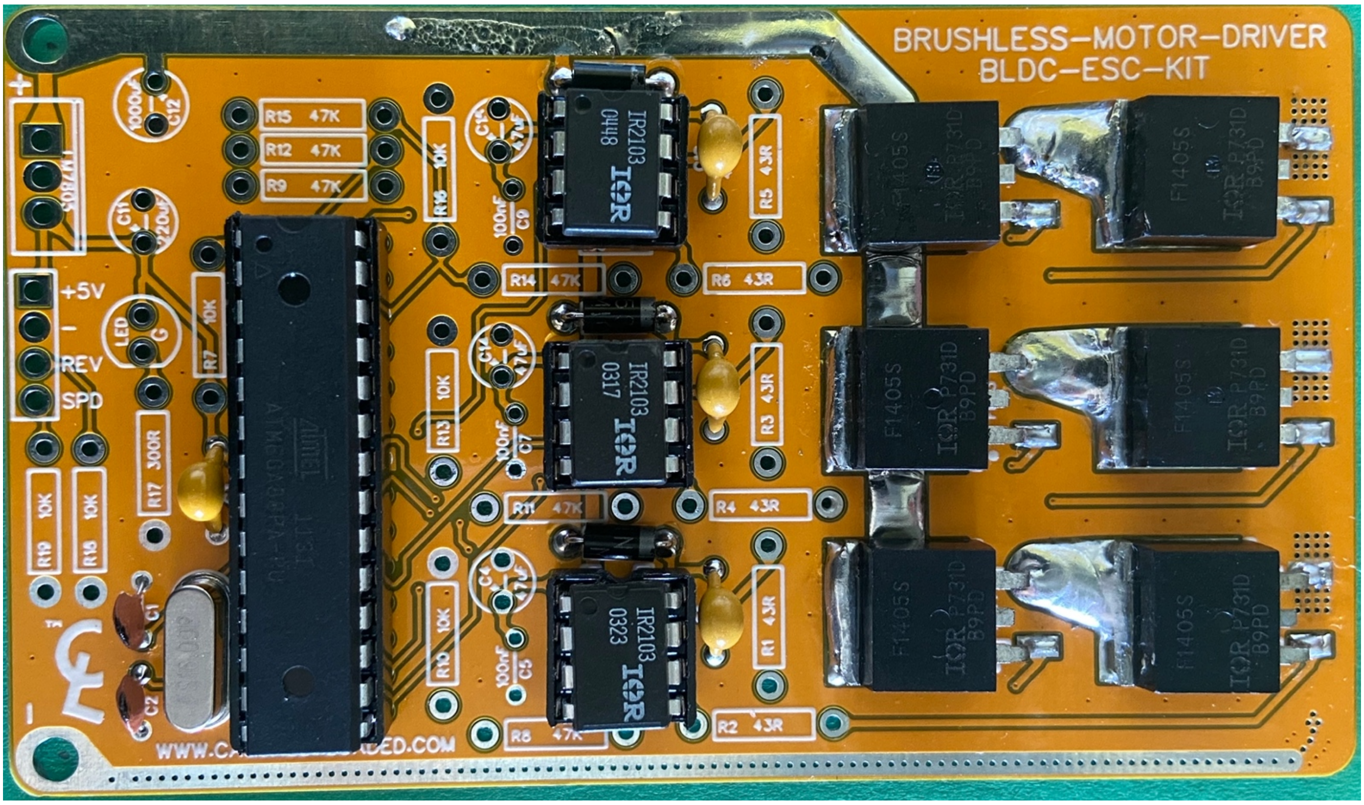
Step-2/Image-2: Solder the 1N5819 Schottky bootstrap diodes to the board at labels D1, D2 and D3, *lining up the grey stripe with the silkscreens outline as diodes are polarised*. Then solder the 4.7uF monolithic ceramic bootstrap capacitors to the board at labels C6, C8 and C10. These connections can be made on either side of the board, but the underside is recommended, *trim the excess legs when done*.



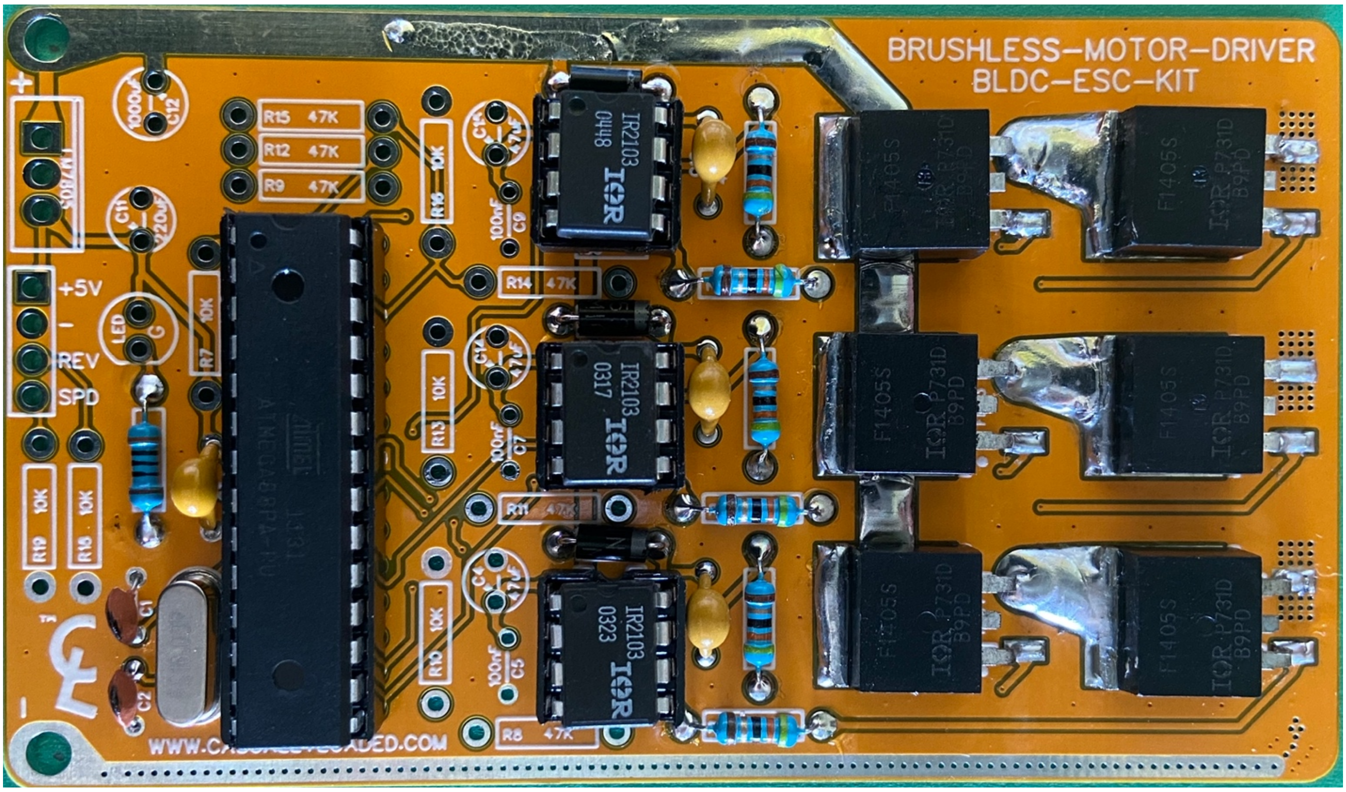
Step-3/Image-3: Solder the IR2103 H-Bridge driver ICs *or a DIP8 socket* to the board at the spaces labelled IC1, IC2 and IC3. These components will need to be soldered on the underside of the board so use tape to hold them in place while soldering.



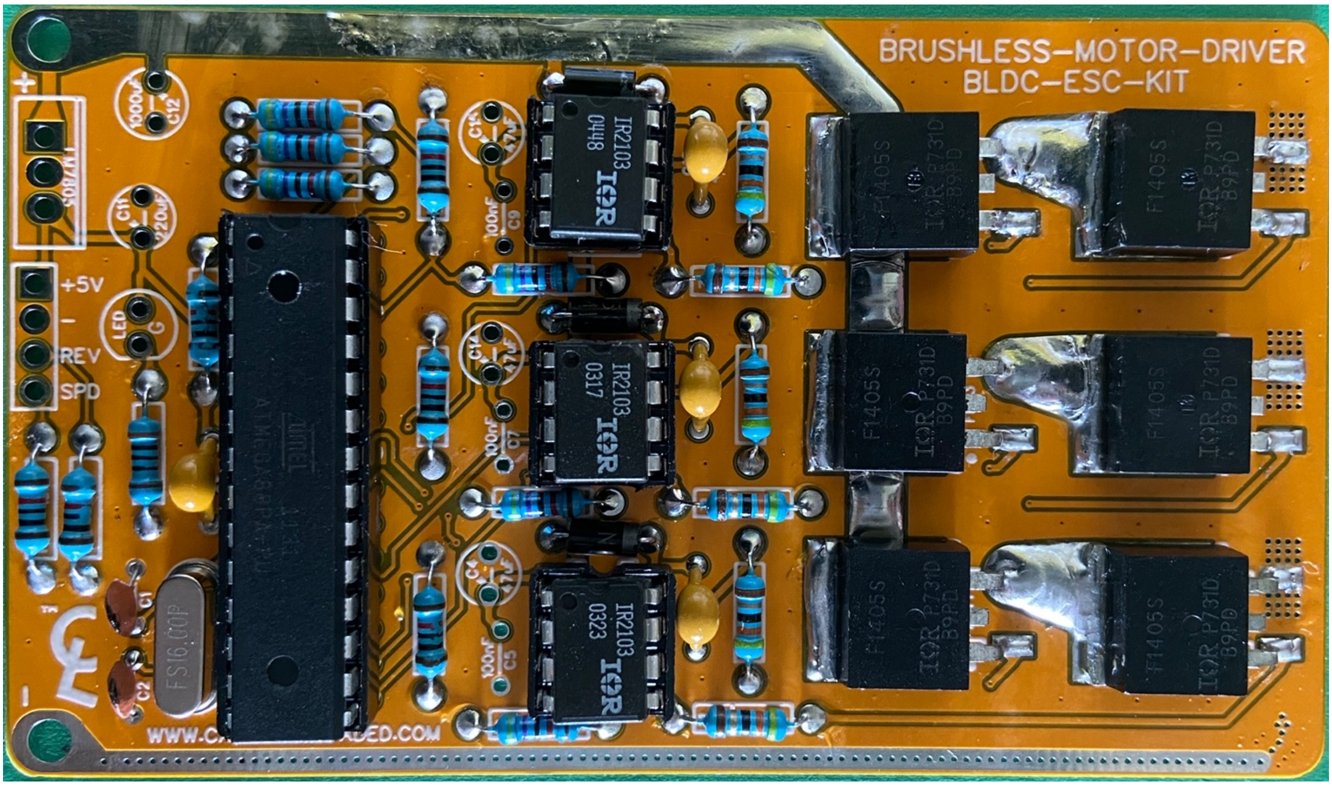
Step-4/Image-4: Solder the Atmega88P *or a DIP28 socket* to the space labelled MCU, followed by the 16Mhz oscillator to label 16-MHZ, the 22pF capacitors to C1 and C2 and the 10uF decoupling capacitor to C3. These connections must all be made on the underside of the board so hold the components in place with tape while soldering.



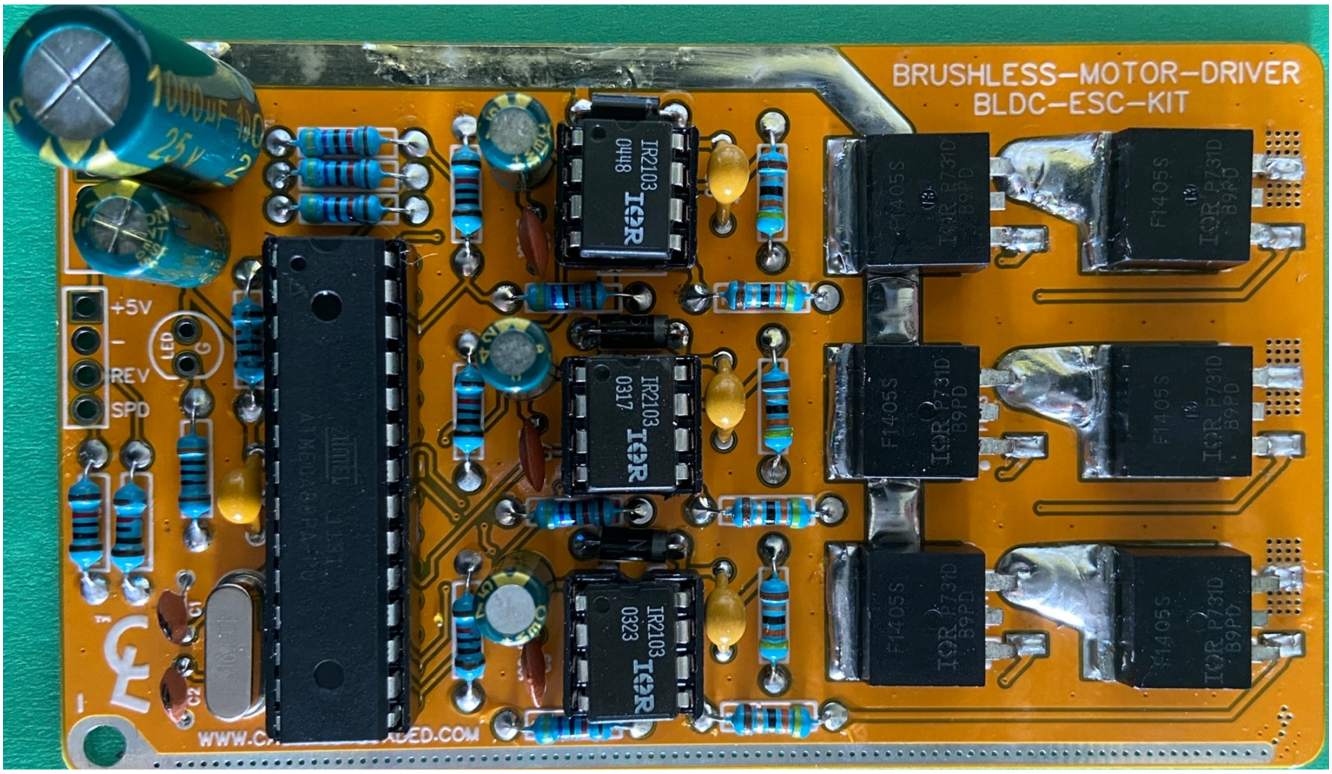
Step-5/Image-5: Solder the 300R (R = Ohm) resistor to the board at the label R17. Then solder the 43R resistors to the board at labels R1, R2, R3, R4, R5 and R6. Place the resistors as shown below, solder one end and then check that the resistor is still well positioned, if it is, solder the other end and then repeat. When all the solder connections are made, carefully cut off the extra resistor legs from the board's underside.



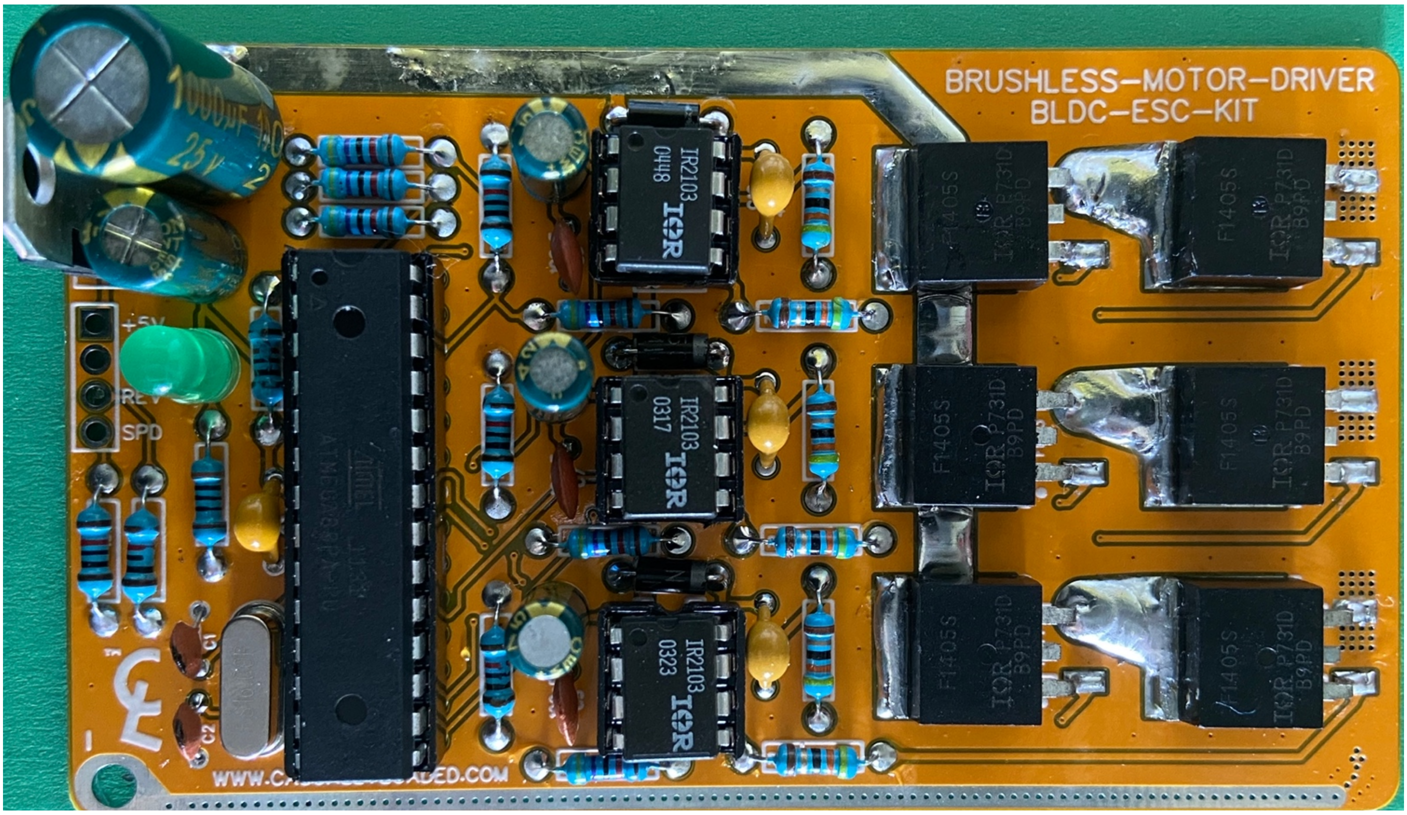
Step-6/Image-6: Solder the 10K Ohm resistors to the board at the labels R7, R10, R13, R16, R18 and R19. Then solder the 47K Ohm resistors to the board at labels R8, R9, R11, R12, R14 and R15. Place the resistors as shown below, solder one end and then check that the resistor is still well positioned, if it is, solder the other end and then repeat. Once the soldering is done, carefully cut off the extra resistor legs from the board's underside.



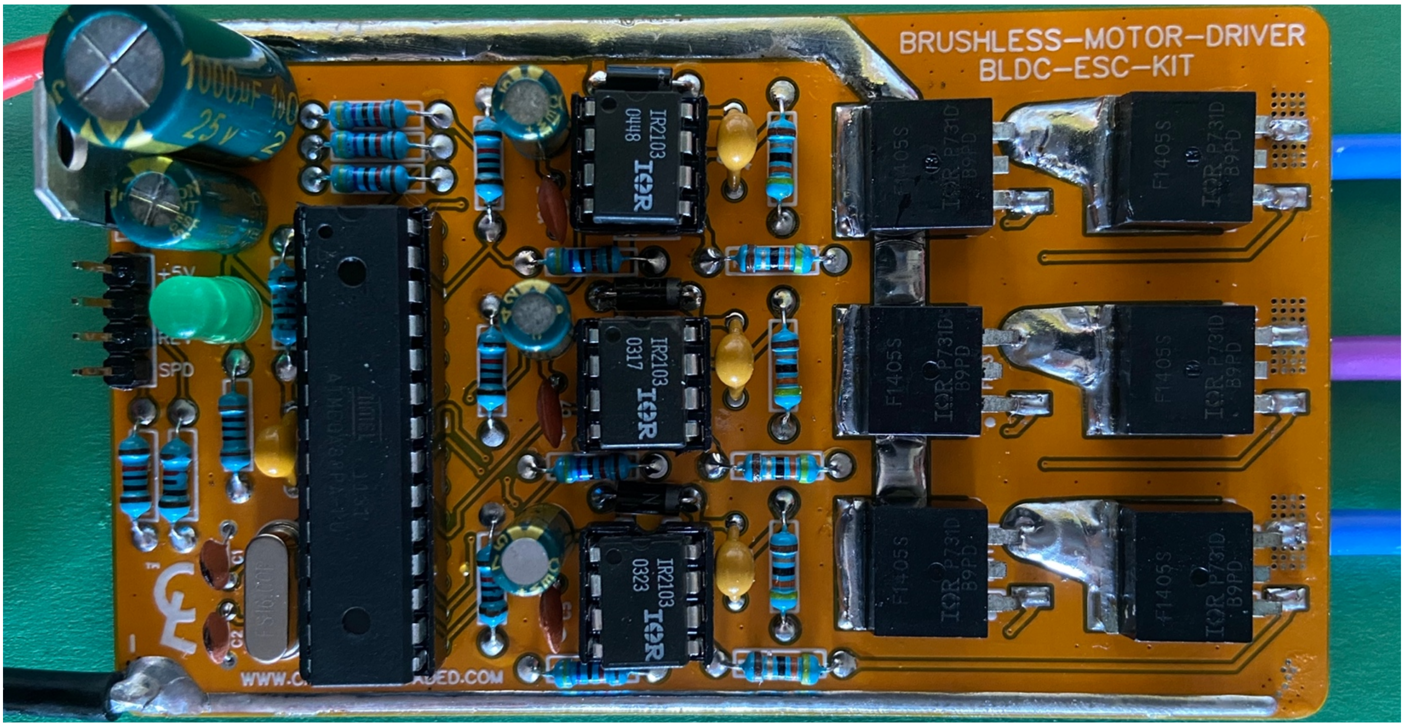
Step-7/Image-7: Solder the three 47uF electrolytic decoupling capacitors to the spaces labelled C4, C14 and C15 then place the three 100nF ceramic decoupling capacitors into the spaces C5, C7 and C9. Finally place the 1000uF electrolytic capacitor into C12 and the 220uF electrolytic capacitor into C11. *Make sure the longer lead goes through the hole marked with a + as electrolytic capacitors are polarised and then solder on the board's underside*.



Step-8/Image-8: Connect the indicator LED to the board at the space labelled LED, ensure the flat edge aligns with the flat edge on the boards silkscreen as LEDs are polarised and will not work backwards. Then solder the LM7805 linear voltage regulator to the space labelled LDO, *make sure the back (ground) tab aligns with the double line on the component's silkscreen*. These solder connections must be made on the underside of the board, so secure the LED and LDO with tape, trimming excess legs when done.



Step-9/Image-9: Solder the row of four header pins to the spaces labelled +5V – REV and SPD, these pins will need to be soldered to the board's underside, so use tape to hold them in place. Then solder power wires to the +VCC, -GND, PHASEA, PHASEB and PHASEC pads with between 8 and 18 AWG wire being recommended.



Final Step: Clean any excess flux and any other grime that may have been left behind during the soldering process from the board, using a cotton swab or a cloth dipped in isopropyl alcohol is recommended. Ensure all solder connections look good via visual inspection, using a powerful torch helps noticeably with this and then that's it, you have just built your own Brushless DC-Motor Driver or ESC, congratulations!

Driving Brushless DC-Motors

Summary: Driving a sensor-less three phase Brushless DC-Motor is a complex task that requires its own specialised circuit typically called an ESC. At its core the circuit is responsible for two things, energising the coils or phases in the correct pattern and sensing the back electromotive force or BEMF being generated by the motor as it spins. This achieves precise and efficient motor control by monitoring the BEMF with the microcontroller's internal comparator. This will show the optimal time for the program to switch the three half bridges to reflect the next step in the motors drive sequence, allowing the motor to run in what's known as a "closed loop" configuration. Meaning it will spin with the highest possible torque, speed and efficiency as the motor's rotation and the resulting BEMF it generates dictates the timing of the step changes, *although due to the nature of how the motor generates this BEMF its use is only viable at high speeds*.

BLDC drive sequence represented as phase states:

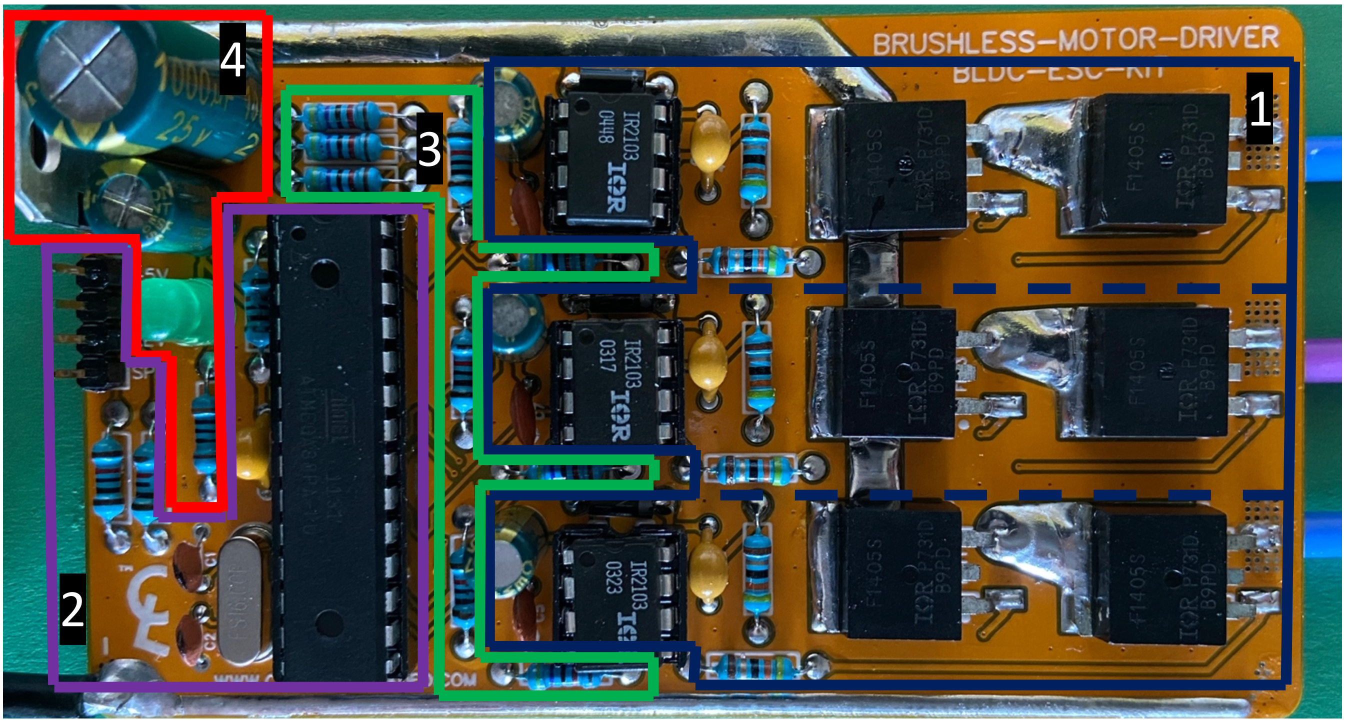
STEP	PHASE A	PHASE B	PHASE C
1	1 (PWM)	0	BEMF SENSE
2	1 (PWM)	BEMF SENSE	0
3	BEMF SENSE	1 (PWM)	0
4	0	1 (PWM)	BEMF SENSE
5	0	BEMF SENSE	1 (PWM)
6	BEMF SENSE	0	1(PWM)

BLDC drive sequence represented as half-bridge MOSFET states:

STEP	PHASE A		PHASE B		PHASE C	
	HIGH-SIDE	LOW-SIDE	HIGH-SIDE	LOW-SIDE	HIGH-SIDE	LOW-SIDE
1	1 (PWM)	0	0	1	0	0
3	1 (PWM)	0	0	0	0	1
3	0	0	1 (PWM)	0	0	1
4	0	1	1 (PWM)	0	0	0
5	0	1	0	0	1 (PWM)	0
6	0	0	0	1	1 (PWM)	0

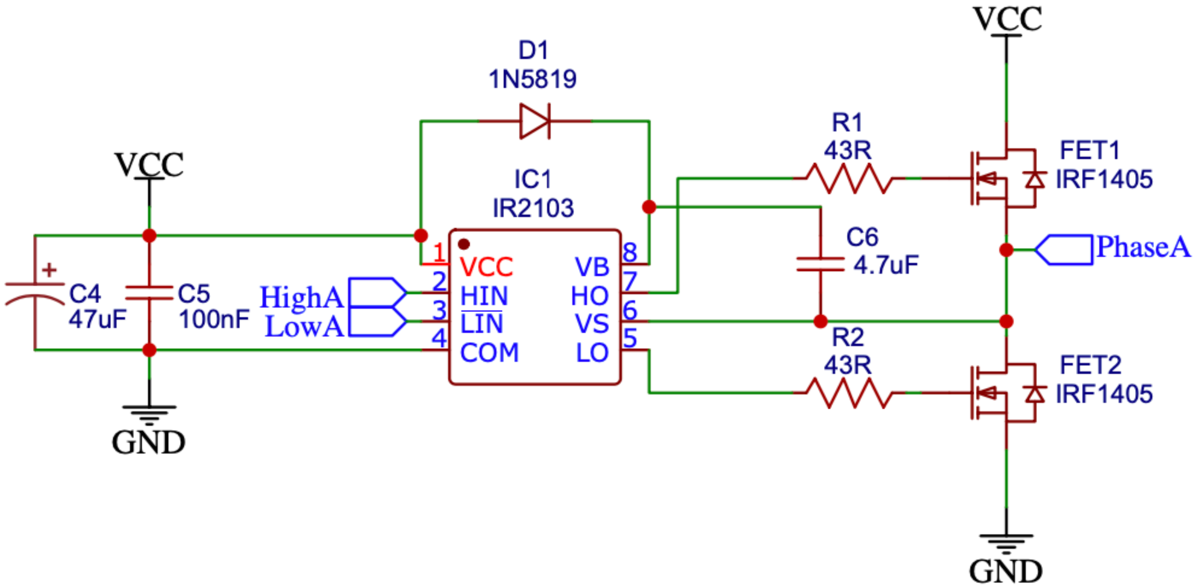
Note: for reverse motor rotation set the step order backwards (6->1)

Circuit Board Breakdown:

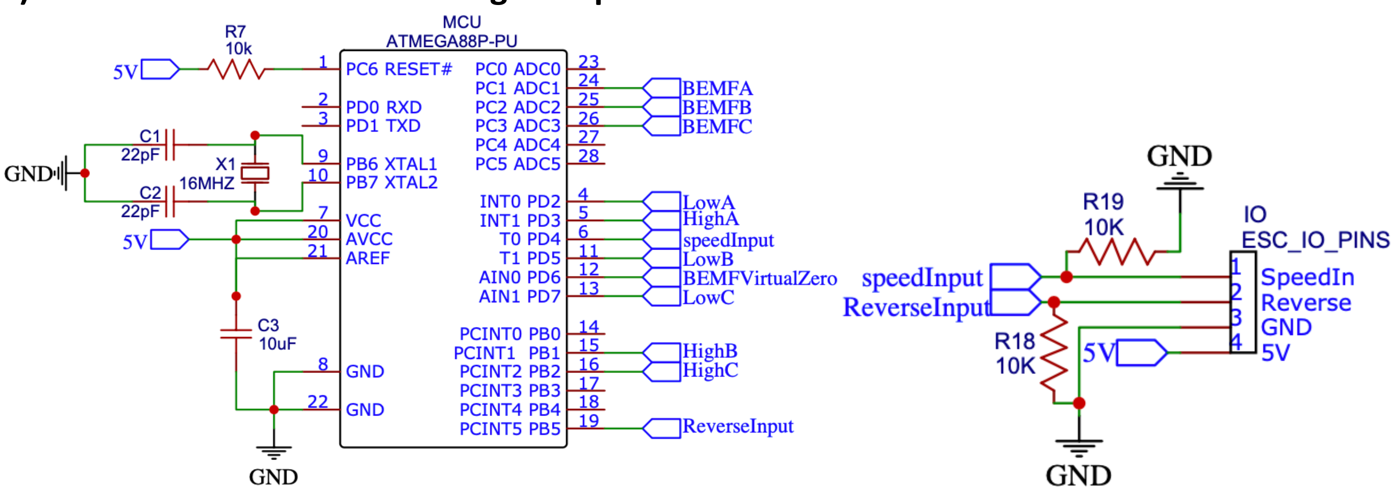


Circuit Schematics:

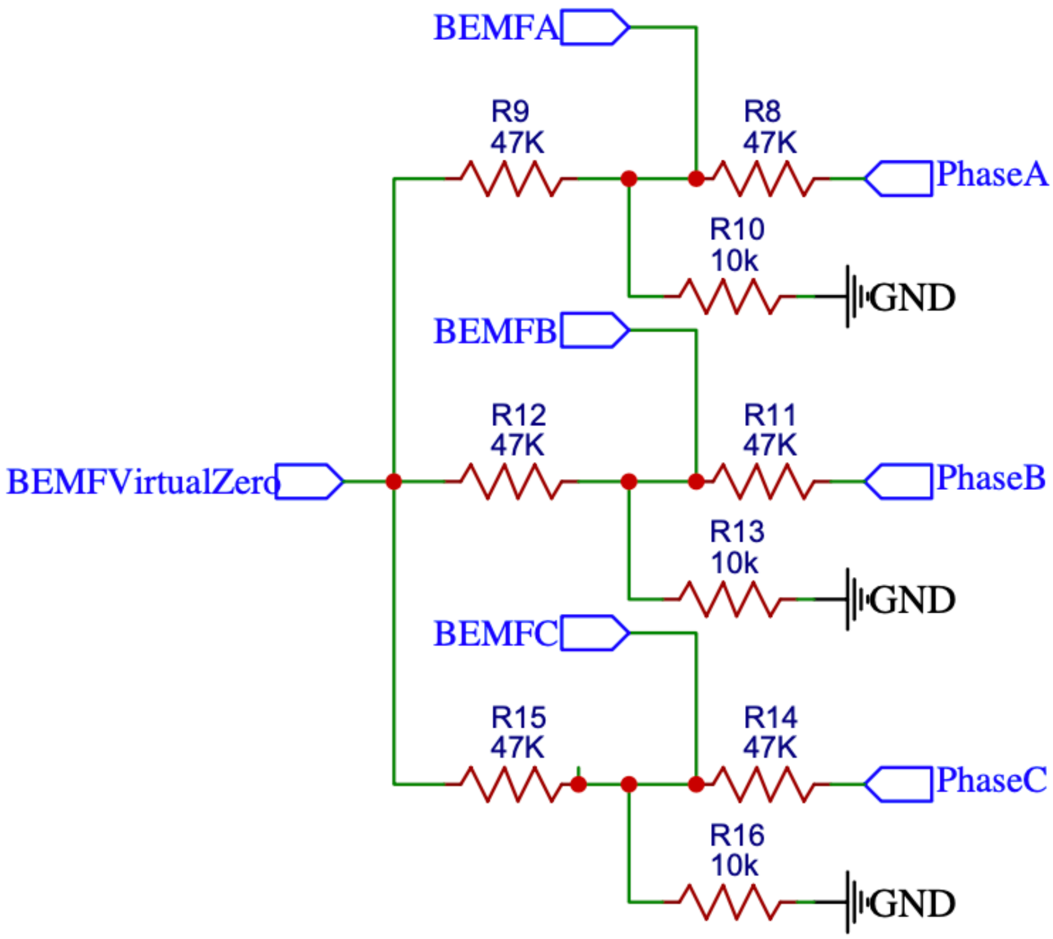
1) BLUE: Power Stage.



2) PURPLE: Microcontroller & Signal Inputs.



3) GREEN: BEMF Sense Resistor Block.



4) RED: 5V Power Supply.