CASUALLY LOADED®

BIPOLAR STEPPER-MOTOR DRIVER KIT. DATASHEET, ASSEMBLY INSTRUCTIONS, CIRCUIT EXPLANATION & CODE.

Overview: This kit builds an 80mm by 60mm circuit board, able to achieve half and full step accurate, dual directional control of Bipolar Stepper-Motors. These motors are designed to achieve high speeds, accuracy and torque meaning they are found across the board in many automation and robotics applications, most commonly in 3D printers, CNC machines and laser cutters. Everything needed to start working with this type of motor is provided by the kit, making it ideal for those looking to learn about and then build a customisable motor driver that can be easily integrated into their own projects.

General Power Ratings & Usage:

PARAMETER	MIN	MAX	UNITS
Operating voltage	5	18	**V**
Continuous Current	-	20	**A**
Operating Temperature	-10	100	**°C**
Output BEC voltage	4.8	5.1	**V**
Output BEC current	-	200	**mA**

- For motors that require more than 4A of current to run, the exposed power traces on the underside of the board should be heavily tinned, with the motor connected directly to the breakout points.
- **Do not touch board during operation, especially the power stage.**
- A high pulse (5V) on the step input pin will cause the driver to take 1 step. Pulling the pins labelled rev & half logical high (5V) will trigger the reverse and/or half step drive modes.
- The BEC (battery eliminator circuit) also supplies 5V power to the board meaning excess current draw will impact the driver's performance

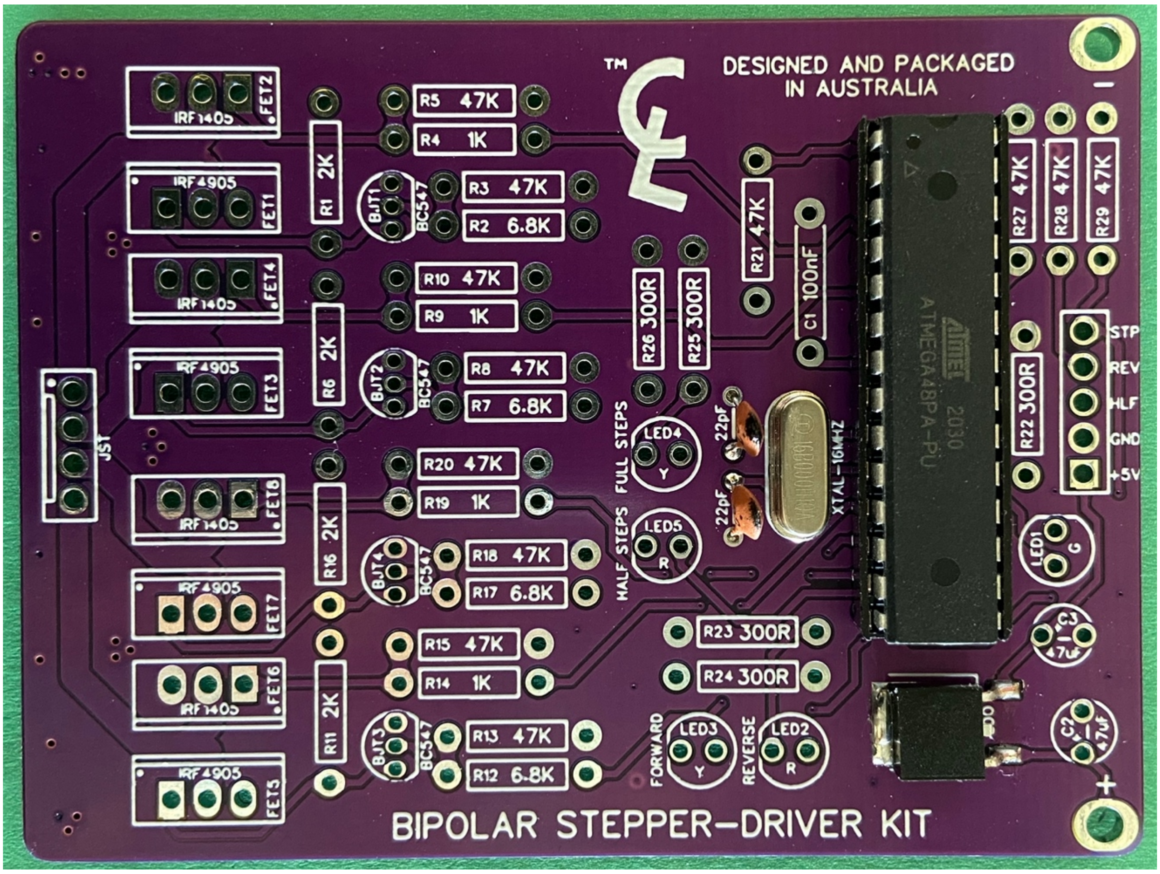
Component List/BOM:

QUANTITY	NAME	TYPE	PCB DESIGNATION
4x	IRF1405	N-Channel MOSFET	FET2, FET4, FET6, FET8
4x	IRF4905	P-Channel MOSFET	FET1, FET3, FET5, FET7
4x	BC547	NPN BJT	BJT1 - 4
1x	L78M05	5V Linear Regulator	LDO
1x	Atmega48P	Microcontroller	MCU
1x	XTAL	16Mhz crystal oscillator	XTAL-16MHZ
5x	R, Y, G	LED	LED1 – 5
1x	Header Pins	Row of 5 Header Pins	STEP REV HALF GND 5V
1x	JST connector	4 Pin	JST
5x	300R (Ohm)	0.25W 1% metal film resistor	R22, R23, R24, R25, R26

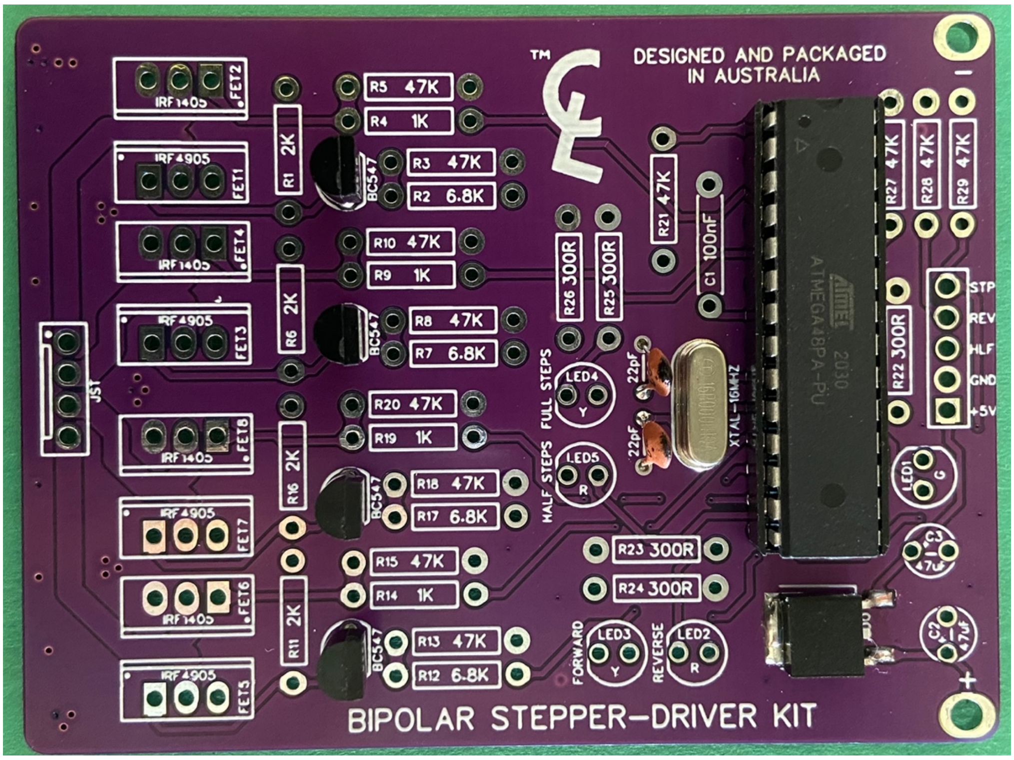
4x	1K	0.25W 1% metal film resistor	R4, R9, R14, R19
4x	2k	0.25W 1% metal film resistor	R1, R6, R16, R11
4x	6.8K	0.25W 1% metal film resistor	R2, R7, R12, R17
12x	47K	0.25W 1% metal film resistor	R3, R5, R8, R10, R13, R15, R18, R20, R21, R27, R28, R29
2x	22pF	Ceramic capacitor	C4, C5
1x	100nF	Film Capacitor	C1
2x	47uF	Electrolytic capacitor	C2, C3

Assembly Instructions

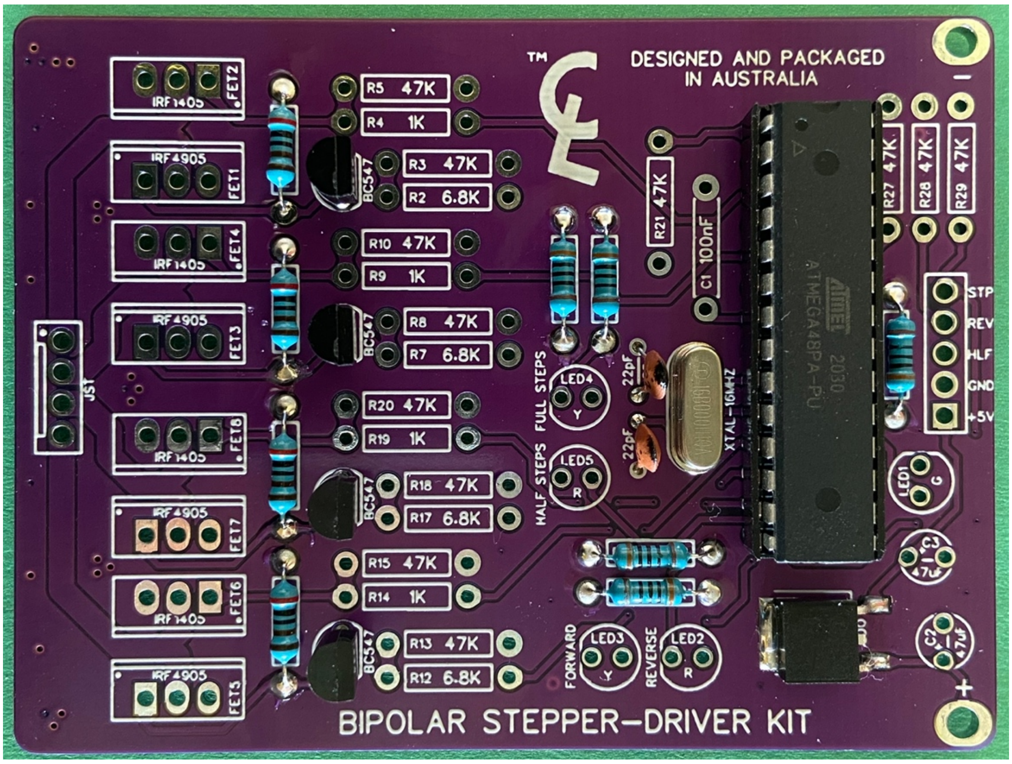
Step-1/Image-1: Solder the L78M05 linear voltage regulator to the space labelled LDO. Lightly tin the large square pad before placing the component, once it's in the correct position use a flat head screwdriver or a thin piece of tape to hold it in place and solder down the legs and ground tab. Then solder the Atmega48P *or a dip28 socket* to the space labelled MCU, followed by the 16Mhz oscillator to label XTAL-16MHZ and the 22pF capacitors to spaces C4 and C5. These connections must be made on the underside of the board so hold the components in place with tape while soldering.



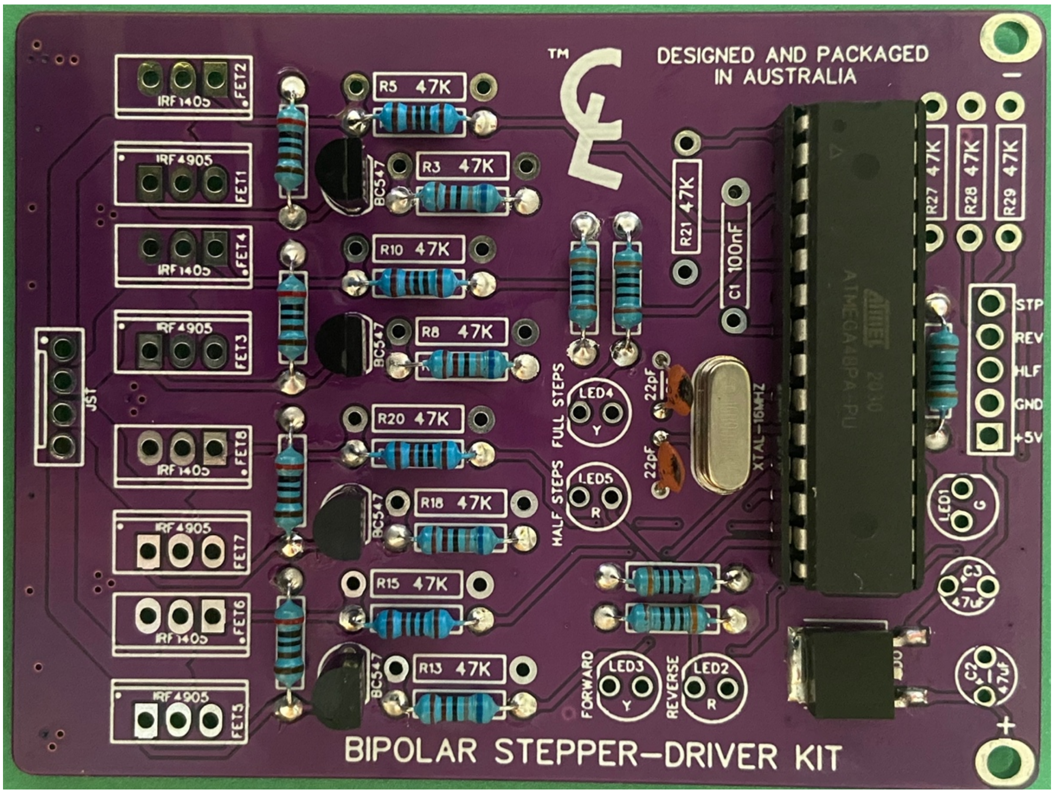
Step-2/Image-2: Solder the BC547 NPN, Bipolar Junction Transistors to the board at spaces BJT1 – 4. Spread the legs out slightly and place the components into each space with roughly a 3mm gap between them and the boards surface. *Make sure the BJTs flat edge aligns with the flat edge on the board's silkscreen as these devices must not be placed backward.* As the solder connections will be made on the board's underside, bend the legs to stop the BJTs from falling out when the board is flipped over and trim the excess once the soldering is finished.



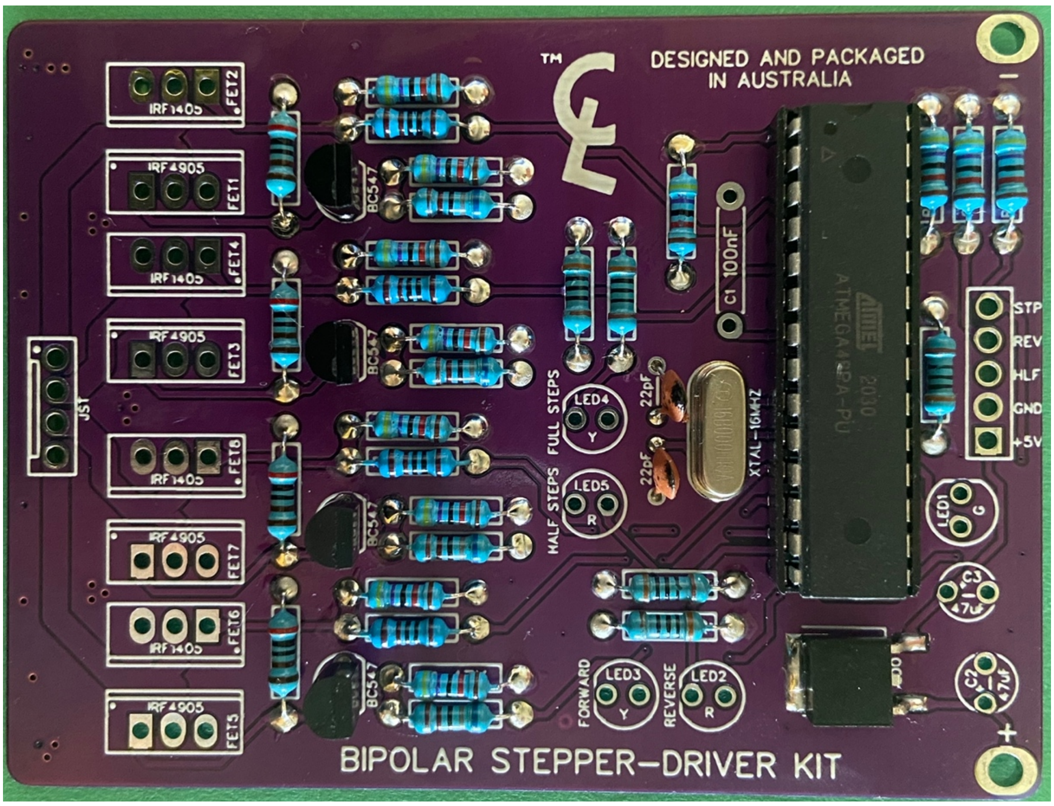
Step-3/Image-3: Solder the 300R (R = Ohm) resistors to the board at labels R22, R23, R24, R25 and R26. Then solder the 2K Ohm resistors to the board at labels R1, R6, R16 and R11. Place the resistors as shown below, solder one end and then check that the resistor is still well positioned, if it is, solder the other end and then repeat. After all the solder connections are made, carefully cut off the extra resistor legs from the board's underside.



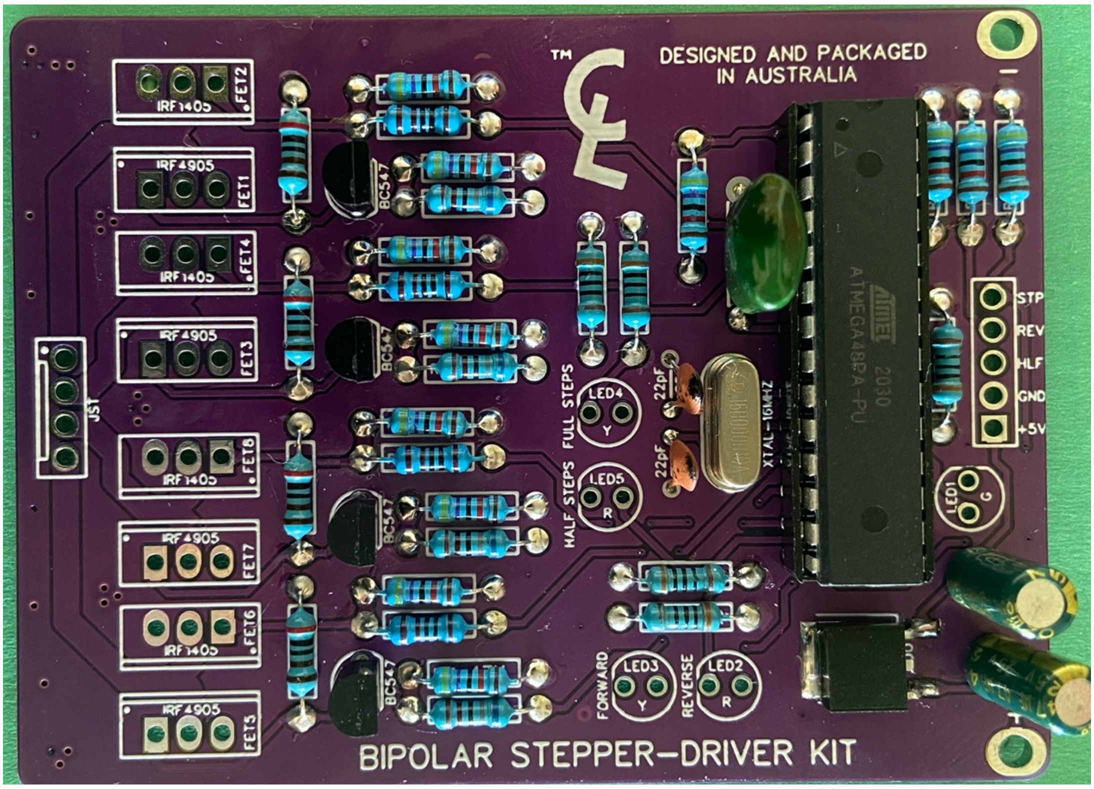
Step-4/Image-4: Solder the 1K Ohm resistors to the board at labels R4, R9, R14 and R19. Following this, solder the 6.8K Ohm resistors the board at labels R2, R7, R12 and R17. Place the resistors as shown below, solder one end and then check that the resistor is still well positioned, if it is, solder the other end and then repeat. After all the solder connections are made, carefully cut off the extra resistor legs from the board's underside.



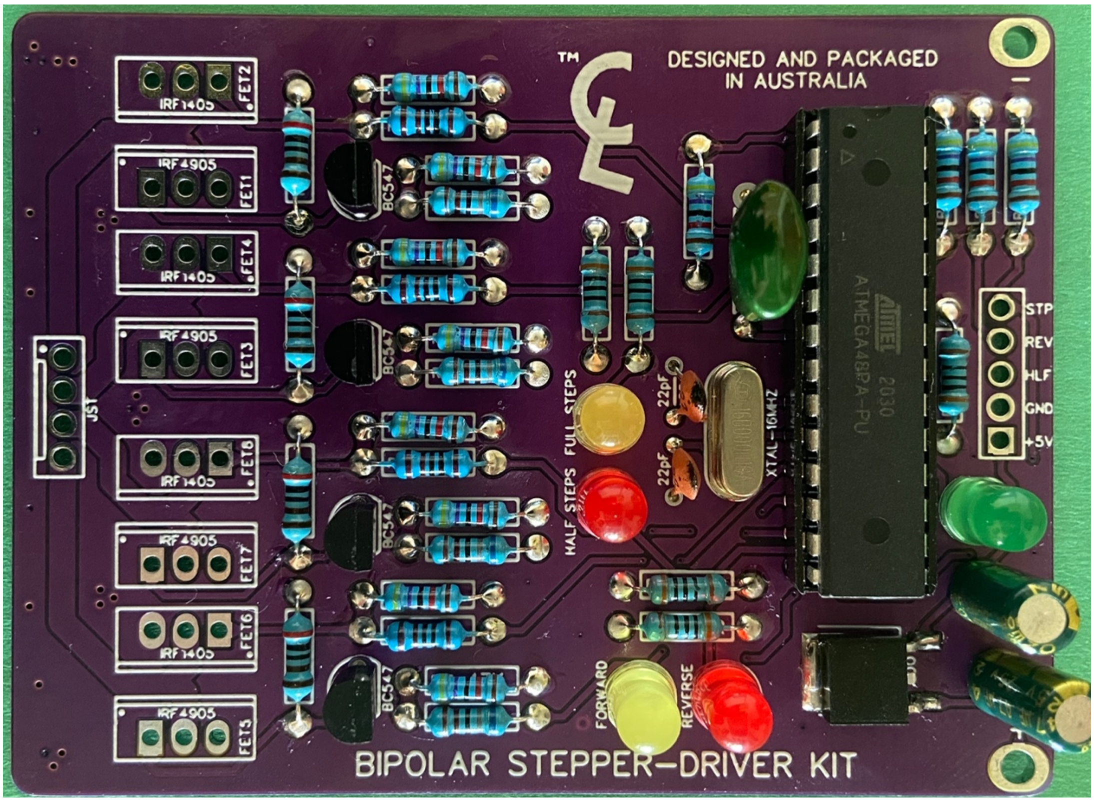
Step-5/Image-5: Solder the 47K Ohm resistors to the board at labels R3, R5, R8, R10, R13, R15, R18, R20, R21, R27, R28 and R29. Place the resistors as shown below, solder one end and then check that the resistor is still well positioned, if it is, solder the other end and then repeat. After all the solder connections are made, carefully cut off the extra resistor legs from the board's underside.



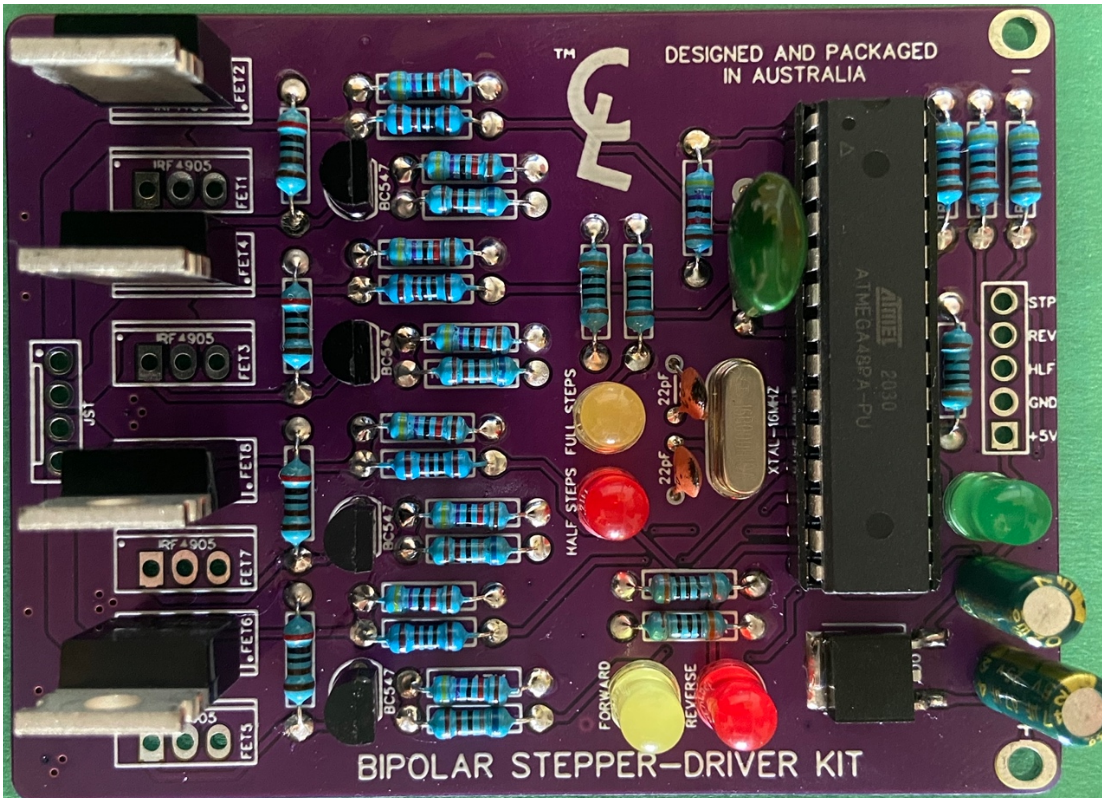
Step-6/Image-6: Solder the power supply and decoupling capacitors to the board. First place the large green 100nF film capacitor into the spot labelled C1. Then place the two 47uF electrolytic capacitors into C2 and C3, ensuring the longer lead goes through the hole marked with a + as electrolytic capacitors are polarised. Again, make all solder connections on the PCBs underside utilising tape.



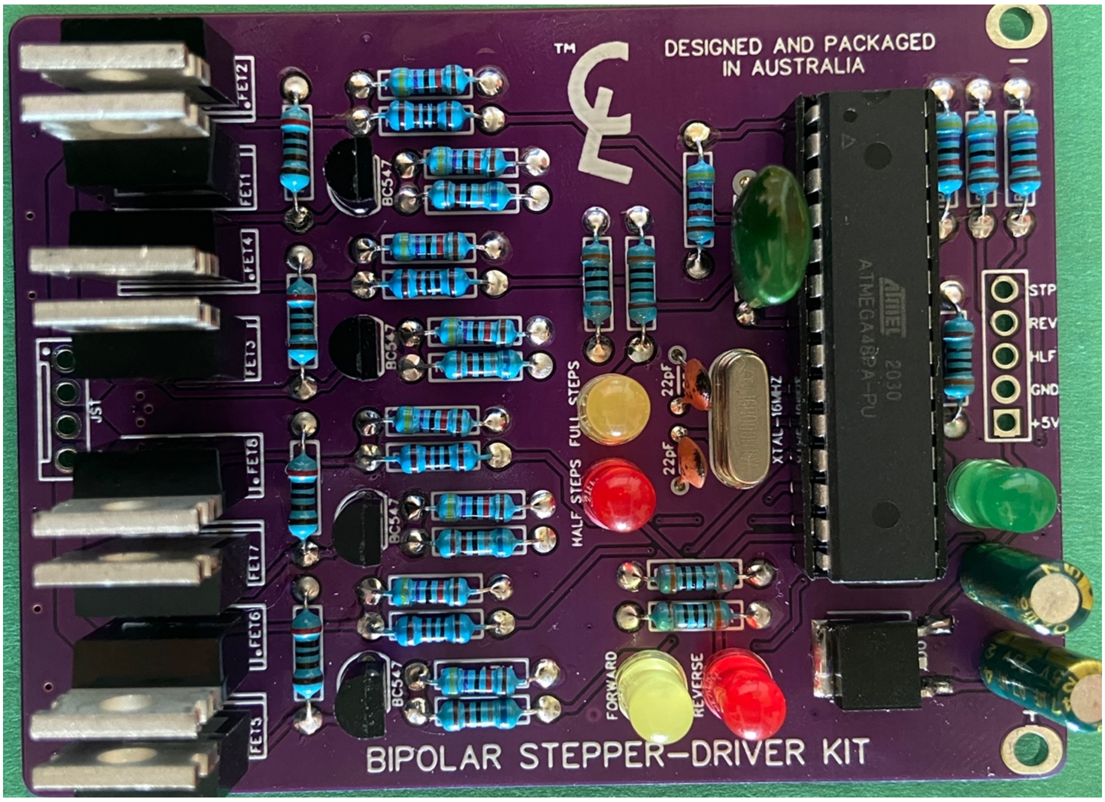
Step-7/Image-7: Connect the indicator LEDs to the board at the spaces labelled LED1, LED2, LED3, LED4 and LED5, each space is also marked with a letter to show the correct colour. *Ensure the flat edge of each LED is aligned with the flat edge on the boards silkscreen as LEDs are polarised and will not work backwards*. The solder connections must be made on the underside of the board, so secure the LEDs with tape, when done trim the excess legs.



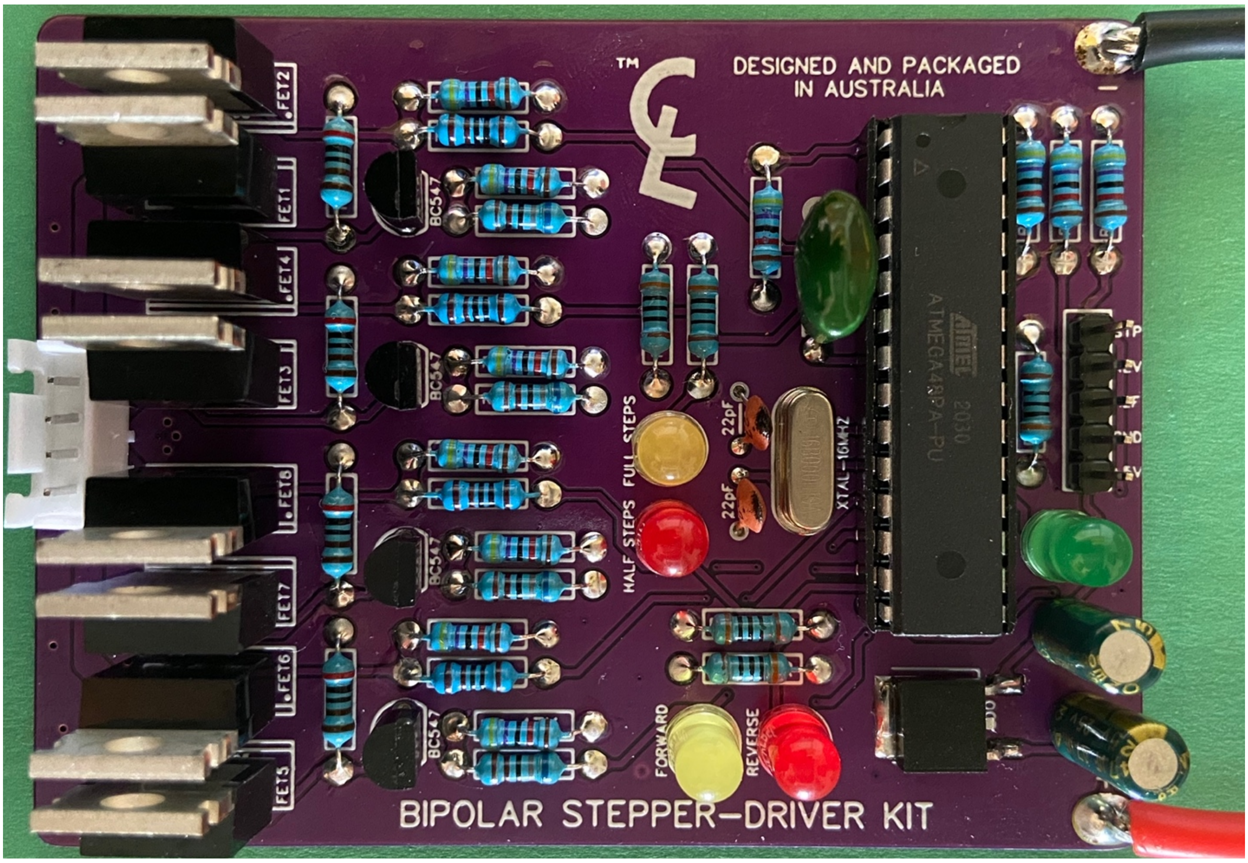
Step-8/Image-8: Place the IRF1405 N-Channel MOSFETs into the spaces labelled FET2, FET4, FET6 and FET8. *Ensure the drain tab of each MOSFET is correctly aligned with the back two lines on the component's silkscreen, placing the device with the gate pin going through the* *<u>square hole</u>*. As the solder connections must be made on the underside of the board tape should be used to hold each component in place, trimming all excess legs when done.



Step-9/Image-9: Place the IRF4905 P-Channel MOSFETs into the spaces labelled FET1, FET3, FET5 and FET7. *Ensure the drain tab of each MOSFET is correctly aligned with the back two lines on the component's silkscreen, placing the device with the gate pin going through the* *<u>square hole</u>*. As the solder connections must be made on the underside of the board tape should be used to hold each component in place, trimming all excess legs when done.



Step-10/Image-10: Place the five-pin header row and four pin JST connector into their corresponding spaces. *Make sure the slots in the JST connector align with the markings on the silkscreen, as it will not function correctly if soldered backwards.* Secure both components with tape and make the solder connections on the underside of the board. Finally solder the power wires to the + and - pads on the board, with between 8 and 18 AWG wire being recommended. *The exposed traces on the underside of the board must also be tinned for high current capability*.



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 Bipolar Stepper-Motor Driver, congratulations!

Driving Bipolar Stepper-Motors

Summary: To run a bipolar stepper-motor the direction of current flow through both coils, *also referred to as phases 1A, 1B, 2A and 2B* must be switched between the supply voltage and ground, allowing both phases which are just electromagnets to be polarised in each possible direction, hence the name bipolar. To achieve the necessary control of current flow two full-bridges are used, they are run by an AVR microcontroller and utilise both N and P channel MOSFETs alongside NPN transistors and some resistors to create four half-bridges. These can then be turned into the two full-bridges necessary for controlling the motor. Although they require more components to run, have a more complex circuit and are more power hungry than their unipolar counterparts, their use of the whole of each coil makes bipolar stepper-motors typically output more torque, achieve higher speeds and in some cases better accuracy, making them ideal for more demanding and advanced robotics projects.

Drive sequence: The following tables show the full and half step drive sequences used in this kits source code. *1 means the MOSFET/phase half bridge side (this can be either LS for the low-side or HS for high-side) should be in an on state (Closed/conducting current) and a 0 means it should be in an off state (Open/not conducting current).*

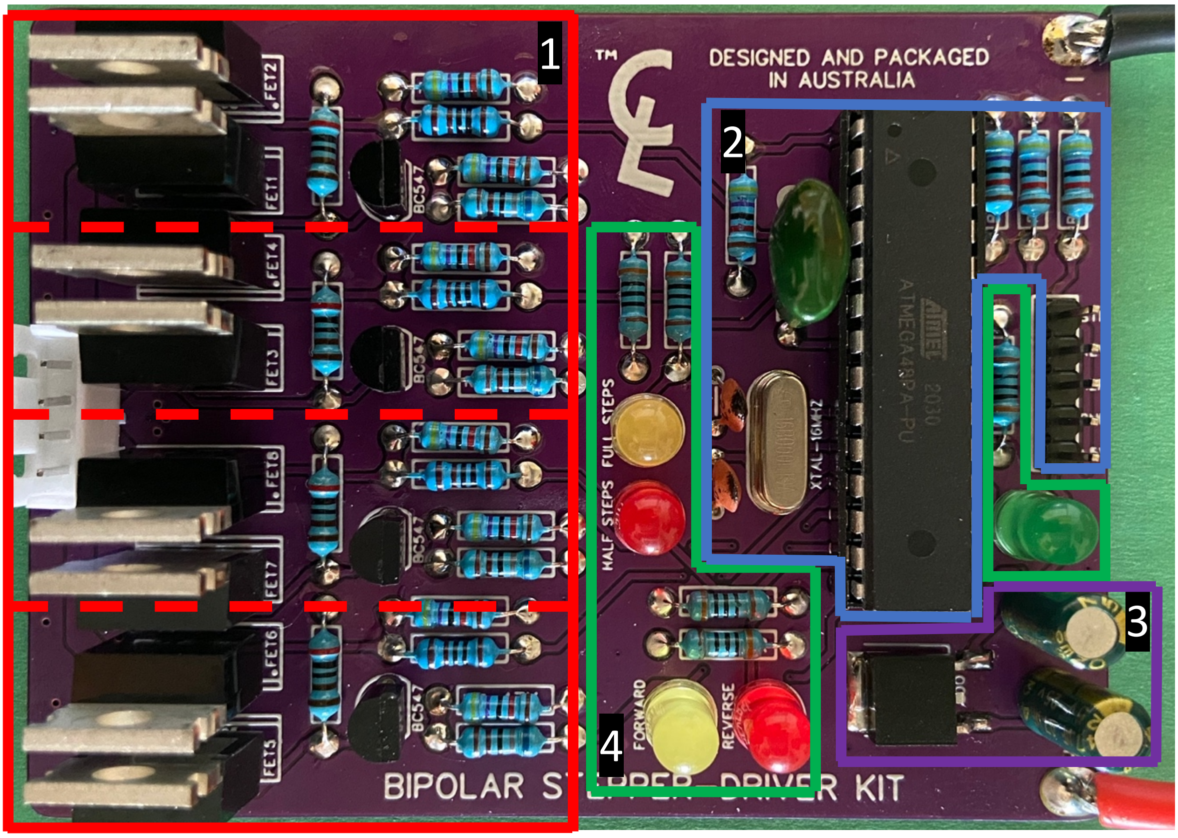
Bipolar Half-Step:

STEP #	PHASE1A-HS / FET1	PHASE1A-LS / FET2	PHASE1B-HS / FET3	PHASE1B-LS / FET4	PHASE2A-HS / FET5	PHASE2A-LS / FET6	PHASE2B-HS / FET7	PHASE2B-LS / FET8
1	1	0	0	1	0	0	0	0
2	1	0	0	1	1	0	0	1
3	0	0	0	0	1	0	0	1
4	0	1	1	0	1	0	0	1
5	0	1	1	0	0	0	0	0
6	0	1	1	0	0	1	1	0
7	0	0	0	0	0	1	1	0
8	1	0	0	1	0	1	1	0

Bipolar Full-Step:

STEP #	PHASE1A-HS / FET1	PHASE1A-LS / FET2	PHASE1B-HS / FET3	PHASE1B-LS / FET4	PHASE2A-HS / FET5	PHASE2A-LS / FET6	PHASE2B-HS / FET7	PHASE2B-LS / FET8
1	1	0	0	1	1	0	0	1
2	0	1	1	0	1	0	0	1
3	0	1	1	0	0	1	1	0
4	1	0	0	1	0	1	1	0

Circuit Board Breakdown:



Circuit Explanation.

1) RED: Power Stage. The IRF1405 N-channel and IRF4905 P-channel MOSFETs alongside some resistors and BC547 NPN transistors create four H-bridges. These can connect each of their outputs, *which is the combined drains of both MOSFETs*, to either ground when the N-channel is on or the supply voltage when the P-channel is on.

The N-channel MOSFET in this configuration can be referred to as the low-side of the H-bridge. The 1K gate drive resistor must be low enough as to not impact upon the switching time but also high enough to stop the gate from drawing a large in-rush current when charged, then it can safely be connected to the microcontrollers IO. The 47K pull-down is used to is help discharge the gate as the IO goes low and isn't as critical, requiring a high value resistor typically between 10 and 100K.

The P-channel MOSFET in this configuration can be referred to as the high-side of the H-bridge. Controlling it is more complex and is done through an NPN Transistor as unlike their N-channel counterparts P-channel MOSFET gates must be connected to ground to turn on and the supply voltage to turn off. Since the microcontroller cannot do this above 5 volts a transistor is used. Its collector is connected to the MOSFETs gate which is being pulled up to the supply voltage via a 2K resistor, the emitter is connected to ground and the base connects to the microcontroller via a 6.8K drive and 47K pull-down resistor. The former allowing the transistor enough current to be fully saturated or on, whilst limiting the current draw on the IO. The transistors state, which can now be safely controlled by the microcontroller will reflect the state of the H-Bridges high-side output.

2) BLUE: Microcontroller & Signal inputs. This is the brain of the driver, its an Atmel Atmega48P microcontroller or MCU for short, its configured to run on an external clock consisting of a 16Mhz crystal oscillator and two 22pF load capacitors. It also uses a 47K pull a up resistor holding the reset/brown out detect port on the MCU at 5V and a 100nF decoupling capacitor to protect the MCU against any noise on the power lines. This gives the MCU everything it requires to function correctly.

The row of five header pins allows external inputs to be connected, giving users control of the motor's steps, spin direction and the step size. Three of the pins connect to input IO ports on the MCU with the other two at ground and +5V. Each input also has a 47K pull down resistor connected across it to ensure the signal ports are never left in a floating state.

3) PURPLE: 5V Power Supply. The L78M05 regulator and two 47uF noise reduction capacitors create a stable 5 Volt power supply. This supply powers the microcontroller and the +5V header pin, it is a very simple supply although being a linear regulator, its inefficient. Higher supply voltages into the regulator, or higher current draw on the 5V output, will cause the L78M05 to dissipate heat. This is not a problem when powering the MCU as it draws a low amount of current but be careful connecting more power-hungry devices to the +5V pin.

4) GREEN: Indicator LEDs. This visual representation of the drive options set, as well as a motion indicator, is not necessary to achieve motor drive but has been included for user friendliness. It consists of one green, two red and two yellow LEDs connected to the MCU and grounding via 300R current limiting resistors. The two sets of red and yellow LEDs are set to be on or off, this depends on if half-steps or full-steps are set and if the motor is spinning forward or in reverse. The green indicator LED will blink at 100 millisecond intervals to show that the motor is in motion turning off when it's not. *Forward, full stepping is set as default.*

Source Code: The drivers source code has been preprogramed into the Atmega48P microcontroller. But for those who are looking to customise this driver for their own application the annotated and Arduino IDE friendly program is made available via the product page at www.casuallyloaded.com as a .ino file. The code does assume the user has a basic understanding of C++, bitwise operators, interrupt vectors, direct AVR port manipulation and Arduino variables namely the millis() function.