TI Designs
3D Printerpack: 40-Pin BoosterPack for 3D Printer Control

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

Design Resources

3D-PRINTERPACK	Product Folder
CSD18534KCS	Product Folder
DRV8825	Product Folder
MSP-EXP430F5529LP	Product Folder
UA78M33	Product Folder

TI E2E™ Community

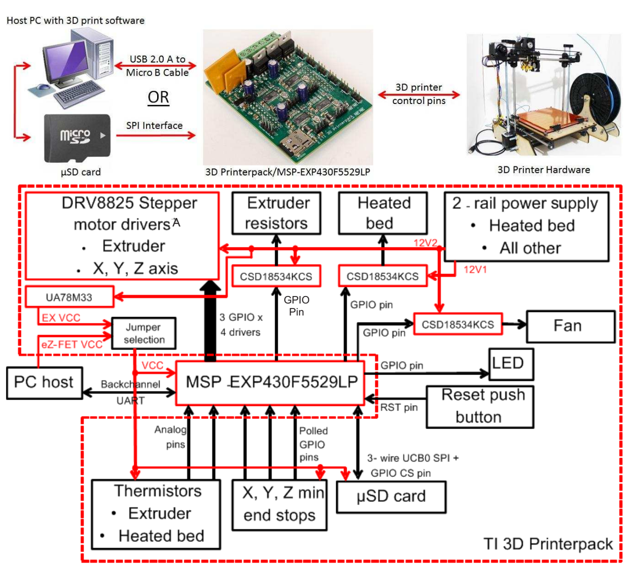
ASK Our E2E Experts
TI LaunchPad

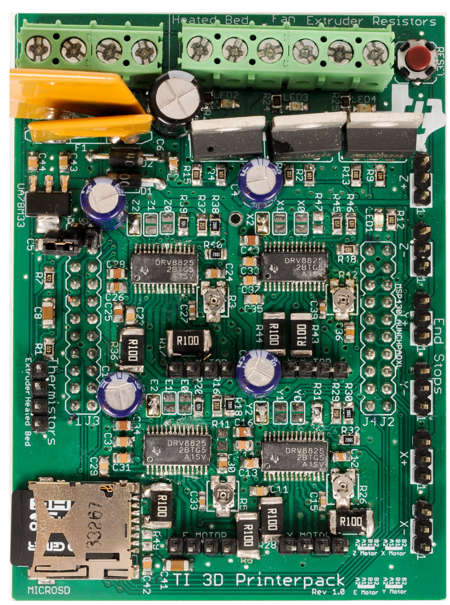
Design Features

- Four On-Board DRV8825 Stepper Motor Drivers for Extruder and X, Y, and Z Motor Control
- Current Limiting Technology Incorporation for Motor Overcurrent Conditions
- Three CSD18534KCS N-Channel MOSFETs for Voltage Boost of Extruder Resistors, Heated Bed, and Fans
- Support Tested With Multiple Software Programs Including Pronterface and Repetier
- uSD Card Slot Included for Printing Without the Need for a Host Computer
- Circuit Design Tested With Firmware and Design Files Included

Featured Applications

- 3D Printing
- Stepper Motor Control





An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 System Description

The 3D Printerpack is a 40-pin BoosterPack™ designed for use with TI's LaunchPad™, specifically the MSP-EXP430F5529LP. It is intended to be used as logic for 3D printers but also serves well for controlling stepper motor drivers in any application. Inspiration of the design, both hardware and software, were sourced from the RepRap open-source projects RAMPS v1.4 board and Tonokip firmware.

This BoosterPack provides everything necessary to control a 3D printer, including: 12 V power supply connections, four DRV8825 stepper motor drivers for the extruder and X, Y, and Z axis motors, four CSD18534KCS N-channel MOSFETs for the extruder resistors, heated bed, and fan control, six end stop switch connections, and thermistor analog inputs for the extruder and heated bed. All printer I/O pins are conveniently located at headers for ease of access. The LaunchPad itself provides the necessary universal asynchronous receiver/transmitter (UART) communication with a host PC to transfer print instructions. The overall system diagram is provided in Figure 1.

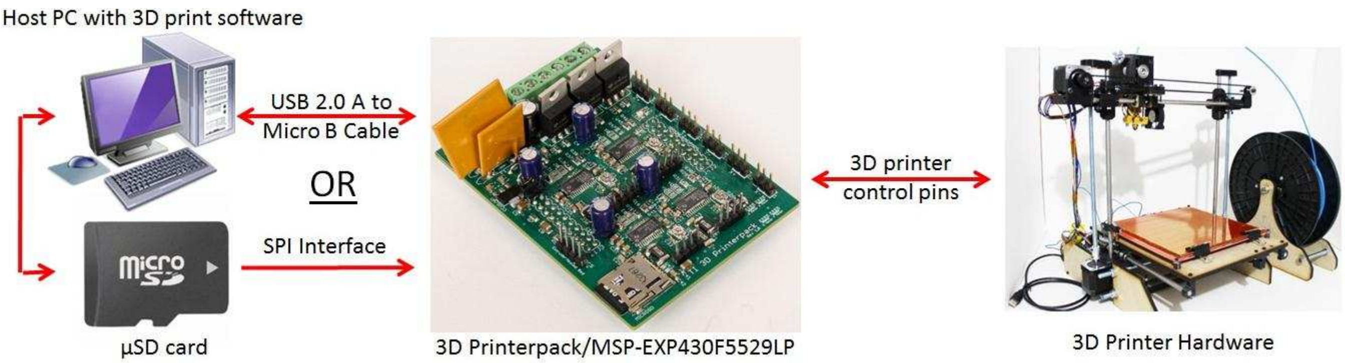


Figure 1. 3D Printer System Diagram

As a word of caution, this document assumes that the reader understands intermediate 3D printer terminology and operation. The area of focus will primarily detail BoosterPack hardware and software without intricately discussing the 3D printer environment itself.

1.1 CSD18534KCS

The CSD18534KCS device is a logic level 7.6 mΩ 60 V TO-220 NexFET™ power MOSFET offering low Q_g, Q_{gd}, and thermal resistance. Their design excels in minimizing losses in power conversion applications. Regarding the Printerpack, three CSD18534KCSs are used as voltage boost converters to supply the extruder resistors, heated bed, and fans with the 12 V power supply using logic from the LaunchPad microcontroller (MCU).

1.2 DRV8825

The DRV8825 provides an integrated motor driver solution with two H-bridge drivers capable of driving a bipolar stepper motor or two DC motors. The output driver block for each consists of N-channel power MOSFETs configured as full H-bridges to drive the motor windings. The DRV8825 can supply up to 2.5 A peak output current and its simple step/direction interface allows easy interfacing to controller circuits. Pins allow for motor configuration from full-step to 1/32-step modes and internal shutdown functions are provided for overcurrent protection, short circuit protection, or undervoltage lockout and overtemperature.

Four DRV8825s are used on the BoosterPack to control all stepper motors required for a 3D printer, including the extruder motor as well as the three axis motors. Each motor driver's enable, direction, and step pins are the only three needed for proper operation using the LaunchPad microcontroller. Step size is manually set through the use of solder jumper bridges, but the recommended step size utilized by the firmware is 1/16 steps. To understand how the stepping format is initialized, see DRV8825 Stepping Format. Each mode pin corresponds to the BoosterPack solder jumper that is labeled with the motor designator followed by the pin number (for example, solder jumper E0 corresponds to the mode 0 pin of the extruder motor, Y1 to the mode 1 pin of the Y-axis motor, and so forth).

DRV8825 Stepping Format

MODE2	MODE1	MODE0	STEP MODE
0	0	0	Ful step (2-phase excitation) with 71% current
0	0	1	1/2 step (1-2 phase excitation)
0	1	0	1/4 step (W1-2 excitation)
0	1	1	8 microsteps/step
1	0	0	16 microsteps/step
1	0	1	32 microsteps/step
1	1	0	32 microsteps/step
1	1	1	32 microsteps/step

1.3 MSP-EXP430F5529LP

The MSP-EXP430F5529LP LaunchPad (F5529 LaunchPad, for short) is an inexpensive, simple evaluation module for the MSP430F5529 USB microcontroller. It is an easy way to start developing on the MSP430™ with on-board emulation for programming and debugging in addition to buttons and LEDs for simple user interface. This LaunchPad includes the MSP430F5529 16-bit MCU with 128 KB Flash, 8 KB RAM, up to 25 MHz CPU speed, integrated USB 2.0 PHY, 12-bit analog-to-digital converter (ADC), timers, and serial communication through UART, inter-integrated circuit (I2C), or serial peripheral interface (SPI). Rapid prototyping is accomplished with the use of 40-pin BoosterPack expansion headers along with a wide range of available BoosterPack plug-in modules, compatibility with smaller 20-pin BoosterPacks included.

This TI design was developed using a MSP-EXP430F5529LP Rev1.5 LaunchPad and Energia version 0101E0012. The F5529 Launchpad available on the eStore might be a different version than the one used to test the Printerpack and there is a slight chance that the minor changes between revisions will affect compatibility. If encountering such issues, see the *MSP-EXP430F5529LP LaunchPad™ Development Kit User's Guide* (SLAU533), which includes a revision history that will aid in understanding the differences in hardware. It should also be noted that Energia's download page includes previously released versions of Energia if encountering compatibility problems involving software.

Although the Printerpack can utilize any 40-pin LaunchPad, the 5529 LaunchPad was chosen for development with the Tonokip firmware. The firmware supports programming from Energia. F5529 features implicated in the firmware includes 22 GPIOs for motor and endstop control as well as two analog-to-digital pins for the extruder and heated bed thermistor. Table 1 explains how each printer utility connects to a MSP430F5529 pin.

Table 1. MSP430F5529 Pin Connections to the 3D Printer Functions

PRINTER FUNCTION	F5529 PIN	PIN FUNCTION	PRINTER FUNCTION	F5529 PIN	PIN FUNCTION
X axis step	2.0	GPIO	Extruder step	6.3	GPIO
X axis direction	2.2	GPIO	Extruder direction	6.4	GPIO
X axis enable	4.3	GPIO	Extruder enable	7.0	GPIO
X minimum endstop	2.3	GPIO			GPIO
X maximum endstop	2.6	GPIO	LED	1.5	GPIO
			Fan	2.4	GPIO
X axis step	4.0	GPIO	Extruder resistors	2.5	GPIO
X axis direction	3.6	GPIO	Heated bed	1.6	GPIO
X axis enable	3.5	GPIO	Extruder thermistor	6.5	A5
X minimum endstop	1.2	GPIO	Heated bed thermistor	6.6	A6
X maximum endstop	1.3	GPIO			
			SCK (1)	3.2	UCB0CLK
Z axis step	6.0	GPIO	MISO (1)	3.1	UCB0SOMI
Z axis direction	6.1	GPIO	MOSI (1)	3.0	UCB0SIMO

(1) µSD card functionality yet to be implemented.

Table 1. MSP430F5529 Pin Connections to the 3D Printer Functions (continued)

PRINTER FUNCTION	F5529 PIN	PIN FUNCTION	PRINTER FUNCTION	F5529 PIN	PIN FUNCTION
Z axis enable	6.2	GPIO	CS [(1)]	8.1	GPIO
Z minimum endstop	1.4	GPIO			
Z maximum endstop	2.7	GPIO			

1.4 UA78M33

The UA78M33 is included in a series of fixed-voltage integrated-circuit voltage regulators designed for a wide range of applications. This regulator can deliver up to 500 mA of output current and utilizes internal current-limiting and thermal-shutdown features to essentially make it immune to overload. Along with use as fixed-voltage regulators, this device can be used with external components to obtain adjustable output voltages and currents and also as the power-pass element in precision regulators.

Concerning the Printerpack, the UA78M33 is an optional element that, if the EX_VCC jumper is connected, will supply the board with a 3.3 V rail used to power the LaunchPad and all stepper motor driver pins that the LaunchPad would have supplied, including the mode, reset, sleep, and fault pins.

2 Block Diagram

2.1 3D Printerpack System Block Diagram

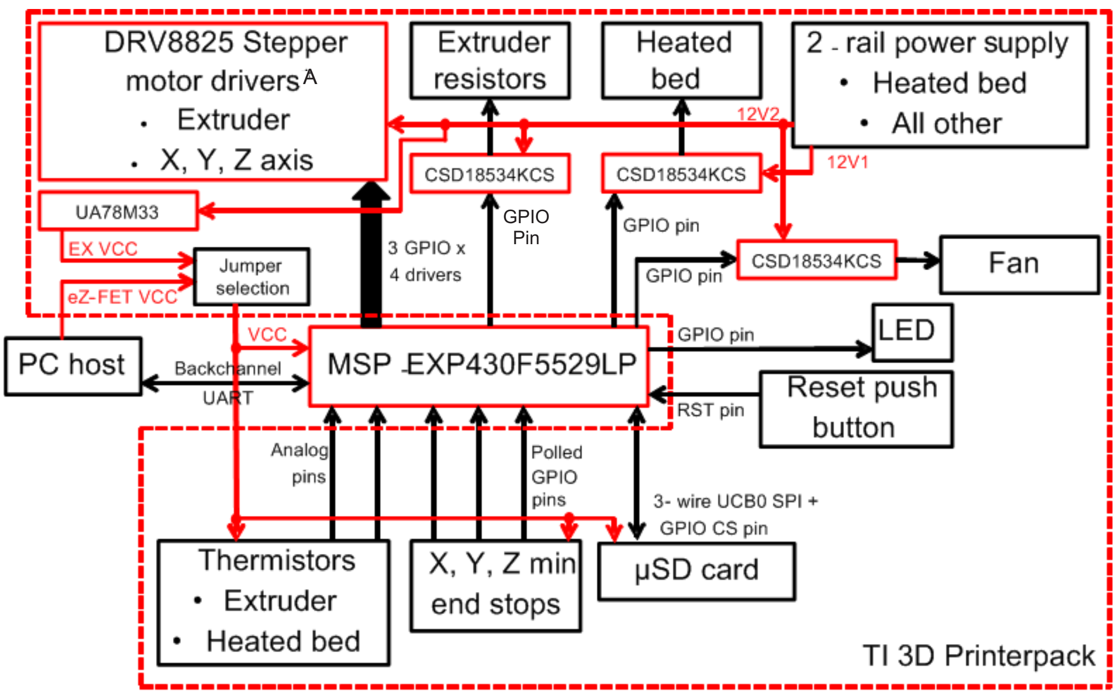


Figure 2. 3D Printerpack Block Diagram

2.1.1 DRV8825 Functional Diagram

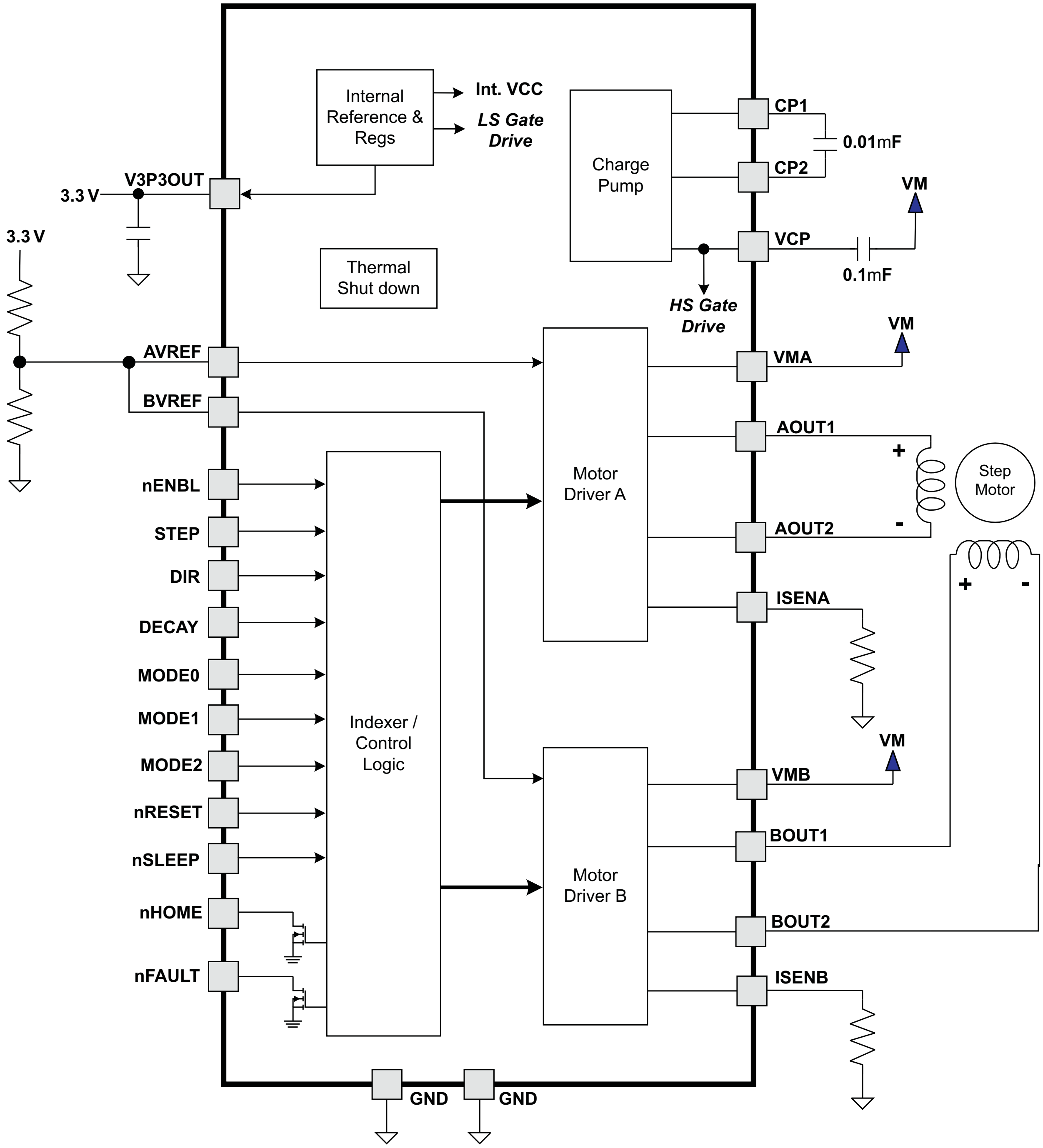


Figure 3. DRV8825 Functional Diagram

2.1.2 MSP-EXP430F5529LP Functional Diagrams

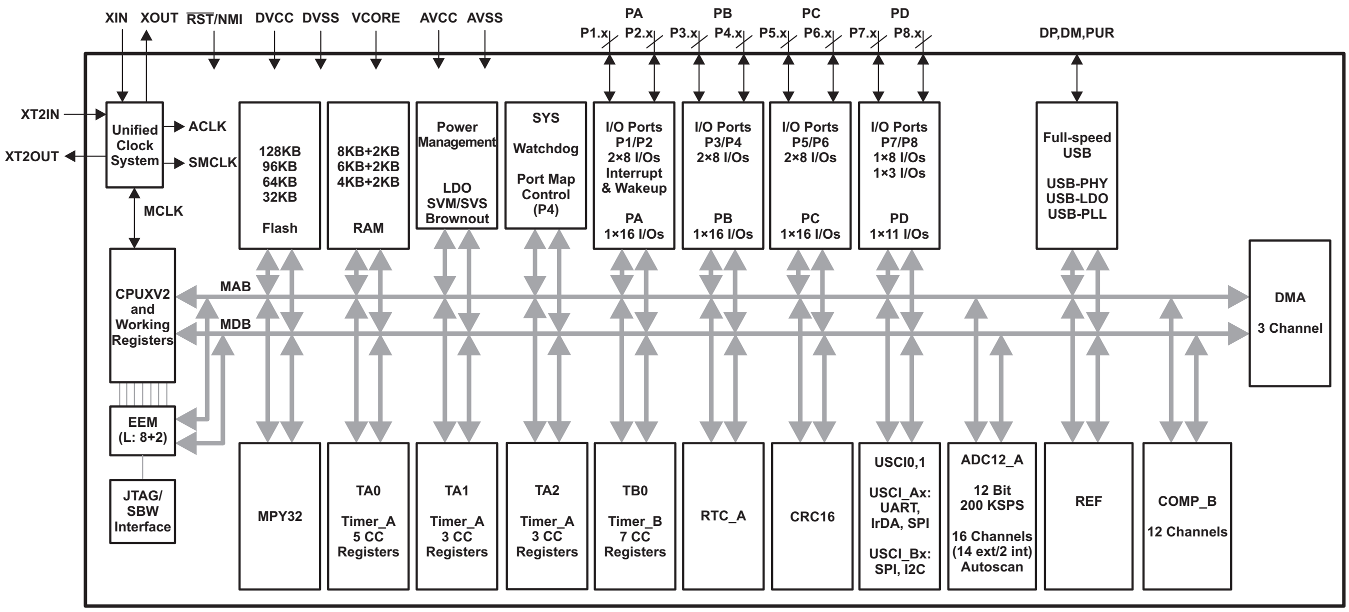


Figure 4. MSP430F5529 Functional Diagram

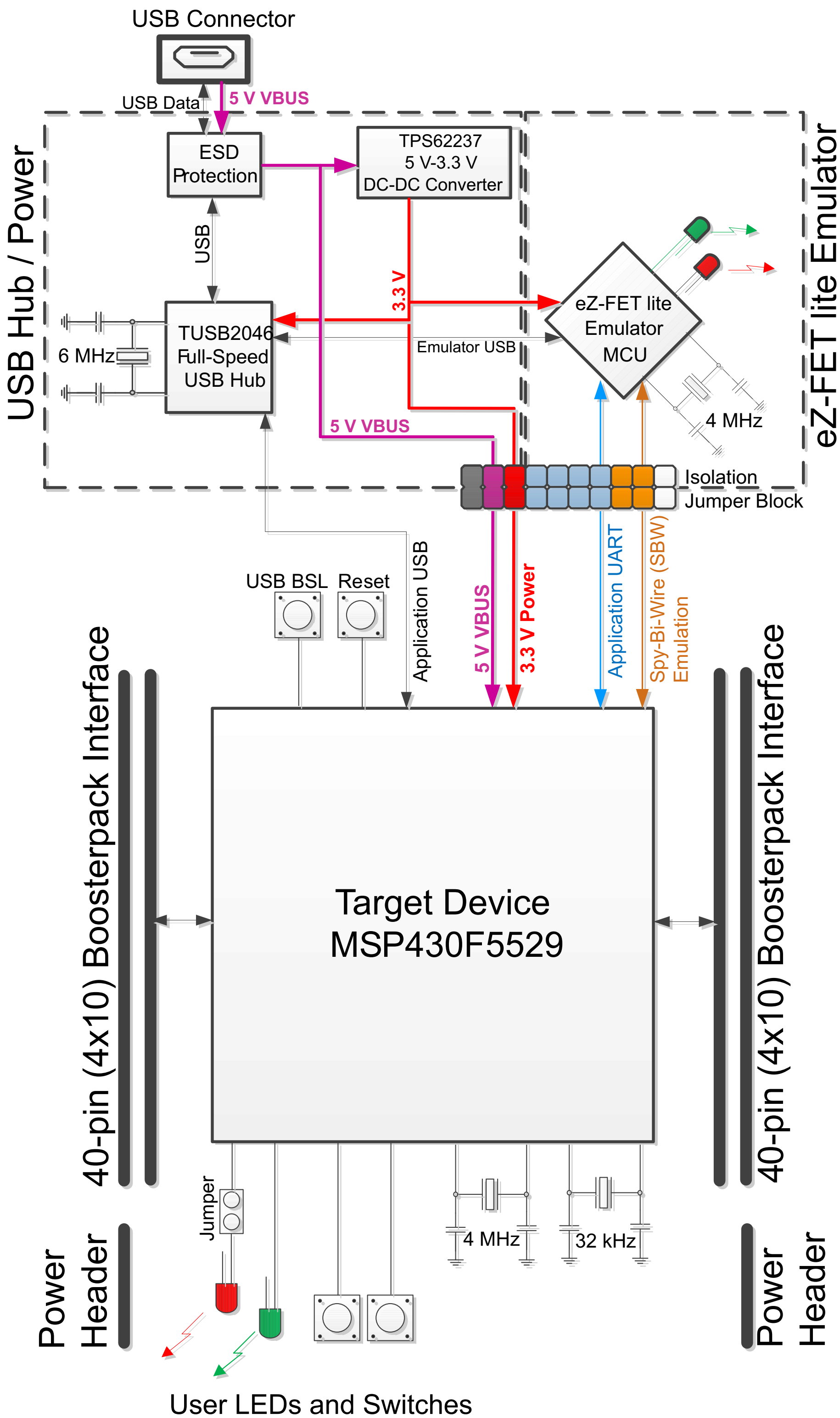
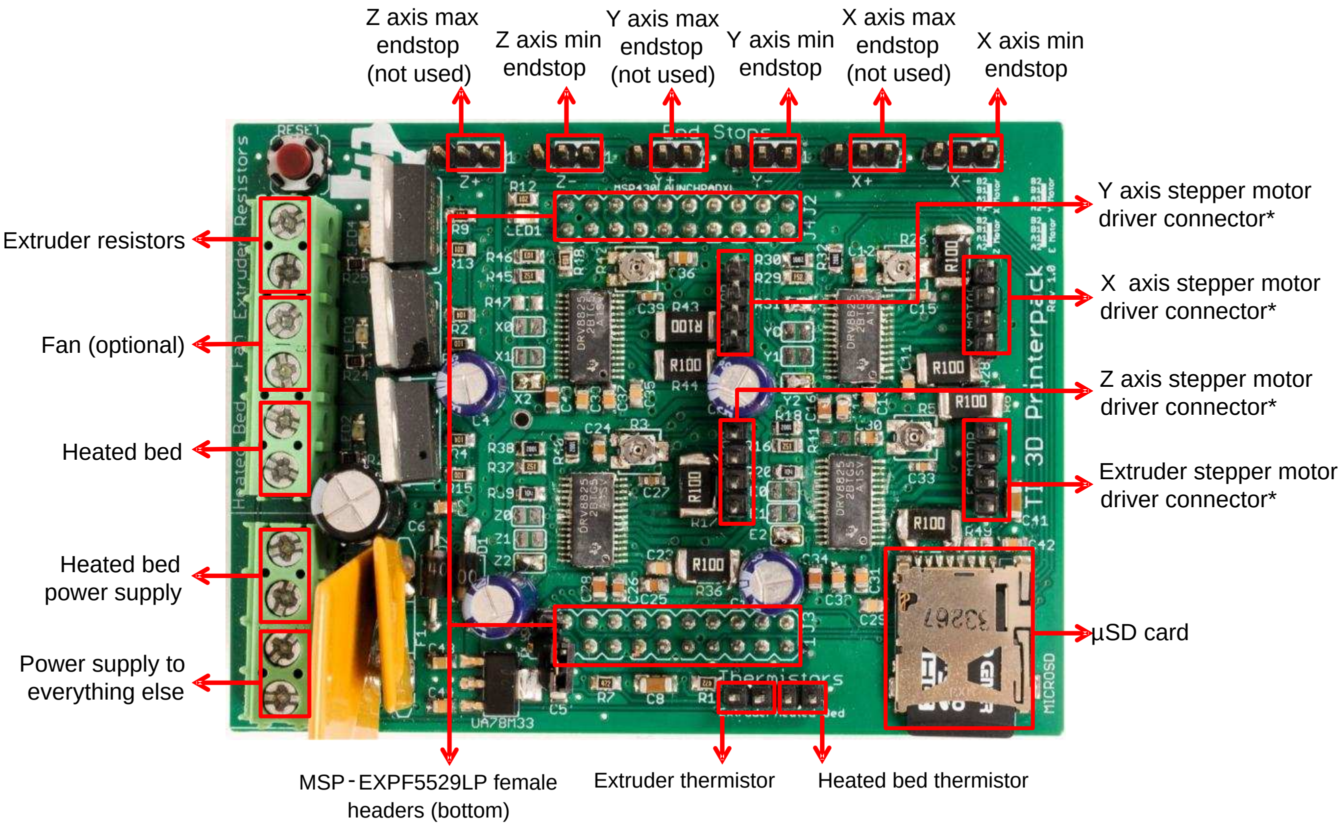


Figure 5. MSP-EXP430F5529LP Functional Diagram

3 Getting Started Hardware

3.1 BoosterPack Connections

To understand where each 3D printer module should be connected to the Printerpack, see Figure 6.



*Stepper motor connectors can be flipped if motion on 3D printer is opposite of that expected

**µSD card functionality has yet to be implemented

Figure 6. 3D Printerpack Connection Map

A few important items to consider when connecting 3D printer components to the Printerpack:

- The female headers on the bottom of the Printerpack should connect to the male headers on top of the LaunchPad such that the TI logo sits above the LaunchPad eZ-FET and, likewise, the text “TI 3D Printerpack” is above the LaunchPad LEDs and push buttons.
- If using a host software program to communicate instructions to the Printerpack, jumper EX VCC should be left unpopulated so that the Launchpad is powered by the eZ-FET 3V3 VCC. The main purpose of the EX VCC is to allow the Printerpack to act independent of a PC by running print commands from a µSD card. Hence only when using a µSD card to print a job without the need for a host computer should this jumper be populated. If the Printerpack is supplying the VCC through EX VCC, jumpers 3V3 and RST on the Launchpad should be removed to avoid a power supply conflict.
- Maximum end stops are not used in the firmware and can be ignored. Although each end stop connection includes three pins, the only two pins used are highlighted through the PCB silkscreen and are also defined as the two rightmost pins as labeled in Figure 6.
- Orientation of thermistors, end stops, and extruder resistors is insignificant. However, it is vital to pay close attention to the coordination of the power supplies as well as the heated bed and stepper motors as incorrect orientation could possibly damage components. The specific alignment of each header position is labeled to avoid confusion.

- To the right of the text “TI 3D Printerpack” is a legend that gives the order of the stepper motor pins, which from top to bottom reads: B2, B1, A1, A2. The user must guarantee that the stepper motor connections attach to the Printerpack as such. Dependent upon orientation of the axis and extruder on the 3D printer, the motors may initially operate in the direction opposite than intended. If this occurs, simply inverse the motor driver connector after ensuring that the 12 V Printerpack power supply is turned off to avoid damage to the motors or drivers.

3.2 Potentiometer Tuning

Each stepper motor driver utilizes a current limiting potentiometer to safeguard the motors from overcurrent conditions. If it is found that the stepper motors are not moving, will cease action after a given amount of time, or possibly start to miss steps, the potentiometers are most likely setting the reference voltage too low and need to be tuned. Current limit is defined by the DRV8825 as reference voltage times two. Therefore, for a stepper motor such as the 3D-printer-favorite Nema 17 with a rated current of 1.7 A/phase (current varies dependent on the specific Nema 17 motor chosen), the potentiometer needs to be tuned such that the reference voltage is near 0.85 V (this may be doubled to 1.7 V for the z-axis if it incorporates two stepper motors). The stepper motor drivers need to be fully powered but do not have to be connected to or operating stepper motors for the potentiometers to be tuned. Setup for tuning the potentiometers on the Printerpack using a multimeter is shown in Figure 7.

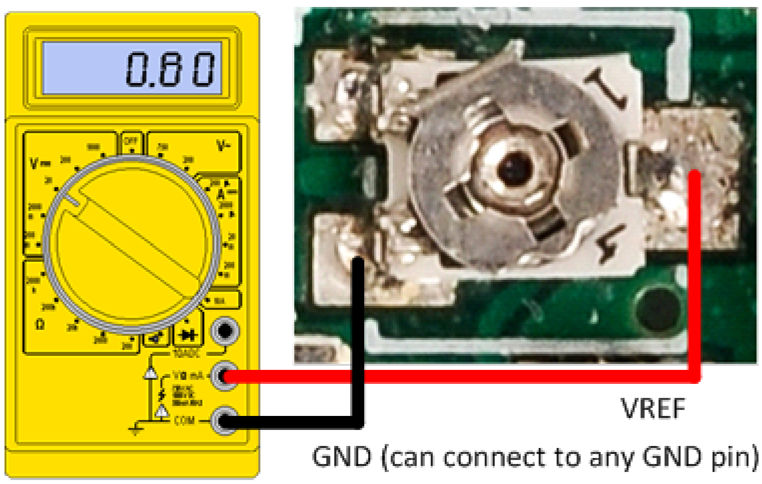


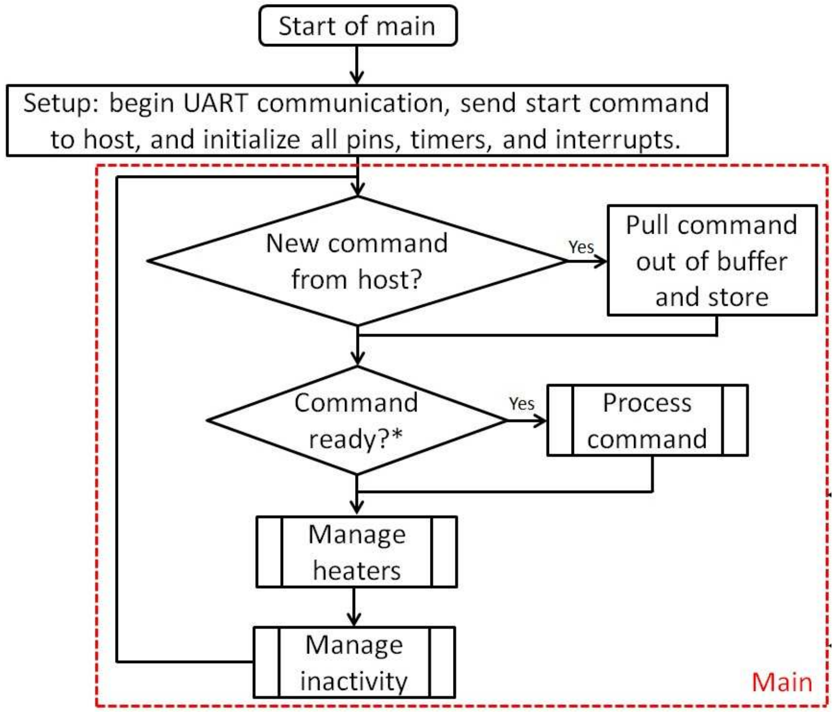
Figure 7. Tuning the VREF Potentiometers

3.3 Thermistor Selection

The firmware only supports the use of 100 KΩ thermistors, which are also pulled up with a 4.7 KΩ resistor on the Printerpack. If a thermistor with a different resistance is used, then the 3D printer will be unable to correctly regulate the temperature of both the extruder and the heated bed, causing improper heating of the filament and possible damage to the printer. Recommended thermistors to use include the B57540G0104F000, the 135-104LAG-J01, or any other thermistor with similar properties.

4 Getting Started Firmware

4.1 Firmware Simple Block Diagram



A Commands can either be coming from the host software or a µSD card.

Figure 8. Firmware Simple Block Diagram

4.2 Altering the Serial Buffer Size

Before uploading the firmware to the F5529 LaunchPad, it is first essential to modify an existing Energia source file. First, locate the Hardware Serial.cpp file (located in the Energia install location under hardware\msp430\cores\msp430). Once opened, locate the constant SERIAL_BUFFER_SIZE and change its value to 128. If the value is already 128, leave it as is. This change is necessary so that the UART communication buffer size is large enough to contain lengthy printer commands.

4.3 Changing Configuration Variables

Included in the Energia project files is a header file named configuration.h. This file includes settings that may need to be changed based on the variant of printer being used, most important of all being the _steps_per_unit variables which define the unit speed of all three axis motor as well as the extruder motor. Several different printer settings are already defined for user convenience, all that is required is correct selection of the settings desired. Even with these pre-defined settings, it is still recommended to test each motor step size with the setup described in Section 5.3.1 as failure to do so may cause incorrect prints. Figure 9 gives an example of what the step unit declaration looks like, specifically initialized for the Mix G1 variant printer. Another constant to recognize in the configuration.h file includes BAUDRATE which should be kept at 9600. If altered, do not forget to change the host software program's expected baud rate as well to avoid communication failure.

Example 1. Unit Step Configuration for Mix G1 3D Printer

```
// Calibration variables
// For Mix G1
float x_steps_per_unit = 80;
float y_steps_per_unit = 80;
float z_steps_per_unit = 2560;
float e_steps_per_unit = 140;
// For Prusa i3
//float x_steps_per_unit = 80;
//float y_steps_per_unit = 80;
//float z_steps_per_unit = 4000;
//float e_steps_per_unit = 841;
```

For setting the calibration variables in accordance with a personalized hardware setup, Equation 1 through Equation 3 can be used:

$$\text{Steps per mm (threaded rod)} = \frac{\text{microstep size} * \text{motor steps per full revolution}}{\text{threaded rod pitch}} \quad (1)$$

$$\text{Steps per mm (belt)} = \frac{\text{microstep size} * \text{motor steps per full revolution}}{\text{belt pitch} * \text{number of gear teeth}} \quad (2)$$

$$\text{Steps per mm (extruder)} = \frac{\text{microstep size} * \text{motor steps per full revolution} * \text{extruder gear ratio}}{\pi * \text{hobbed bolt diameter}} \quad (3)$$

As an example, the above calibration variables for the Mix G1 setup were found using the belt equation for the X and Y axis and threaded rod equation for the Z axis with variables as such: microstep size of 16, 200 motor steps per full revolution (1.8° Nema 17 stepper motors), threaded rod pitch of 1.25 mm, belt pitch of 5 mm, and gears with 8 teeth. The Mix G1 3D printer does not use a gear system for extrusion, so the extruder gear ratio is fixed at one. The extruder equation itself is the hardest to get precise values for since the hobbed bolt diameter varies slightly for each setup. This value will most likely have to be further calibrated after testing on a host PC program. More information on calibrating the extruder can be found by following the links provided in Section 5.4. Also note that taking the reciprocal of the values found with the equations will reveal the minimum obtainable resolution for the corresponding axis. This resolution can be improved by increasing the microstep size on the DRV8825 to 32 or by upgrading the stepper motors to those of a higher step per full revolution value.

4.4 Uploading Firmware in Energia

After installing Energia,

1. Energia must be opened first, then select Open under the File tab.
2. In the directory, navigate to the location of the TIDM_3D_PRINTERPACK.ino file and open it. All of the project files should now be displayed as tabs in the Energia environment.
3. Go to the Tools tab and check that the board selected is the Launchpad with msp430f5529 (16 MHz). Although not required, the Serial Port under the Tools tab can also be selected to align with the Launchpad's application UART (specified in the computer's device manager).
4. After these steps are finished, the firmware can now be uploaded to the Launchpad by clicking on the Upload button. The firmware itself does not actually include support for a µSD although a card slot is included on the Printerpack hardware design. If the SD card functionality is desired, it will have to be developed and added to the firmware package. There is an existent Energia SD card library that can communicate with the MSP-EXP430F5529LP using the UART pins connected to the Printerpack's card slot and could help ramp development time.

5 Test Setup

There are currently two PC software programs, Pronterface and Repetier-Host, that have been confirmed for use in properly sending 3D print commands to the LaunchPad. They also include built-in Slic3r software for easy slicing of stl files into g-code, which can then be sent directly to the printer through UART communication. The setup for each, along with guidelines for testing the individual components and calibrating the 3D printer, are provided in the following sections.

5.1 Connecting in Pronterface

While the GUI is not as polished, Pronterface is forthright and offers straightforward UART connection to the Printerpack. As shown in Figure 9, simply select the COM Port from the drop-down menu that corresponds to the LaunchPad's application UART (which once again can be found in the device manager), set the baud rate to 9600 and click Connect. If done correctly, the instruction window to the right will say "Printer is now online." Assuming that the power supply is connected, all printer mechanisms can now be manually controlled using the buttons on the left.

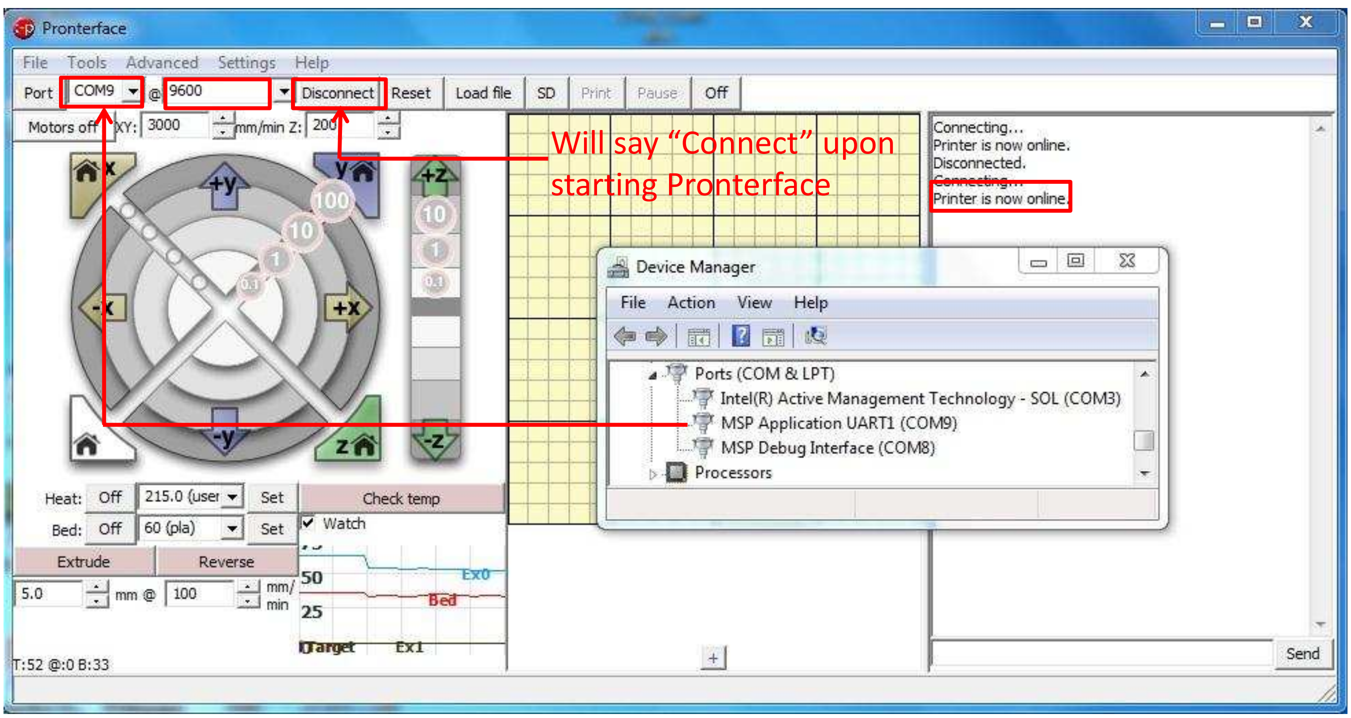


Figure 9. Connecting to Pronterface

5.2 Connecting in Repetier-Host

Although boasting a sophisticated GUI, connecting to the Printerpack in Repetier is more complicated. First, go to the Config tab and select Printer Settings. In the new window, choose the COM Port and baud rate just like instructed in Section 5.1. Additionally, the Receive Cache Size must be set to 63 and the Use Ping-Pong Communication box selected. All correct setting can be seen in Figure 10.

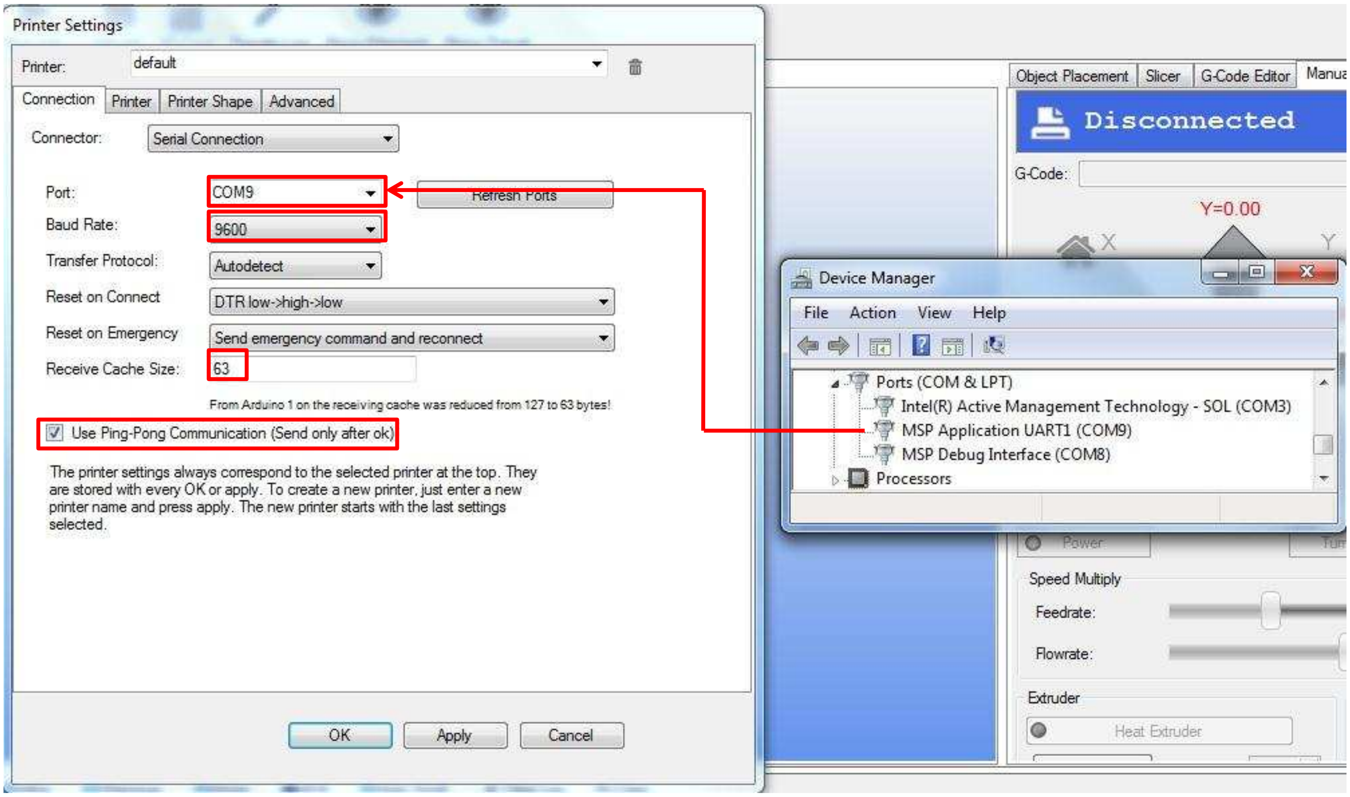


Figure 10. Printer Settings in Repetier

Once all of the printer settings are in order, the red connect button in Repetier can now be pressed. However, the LaunchPad will not be able to communicate with Repetier until a reset has been performed. Under the Manual Control tab on the right of the Repetier interface is a command window that, after connecting, will read “[x] Command Waiting". Like Figure 10 depicts, once the reset button located near the TI logo on the Printerpack is pressed, the command window should say “Idle" instead. It is at this point that Repetier can properly send print instructions to the LaunchPad or interact with the µSD card.

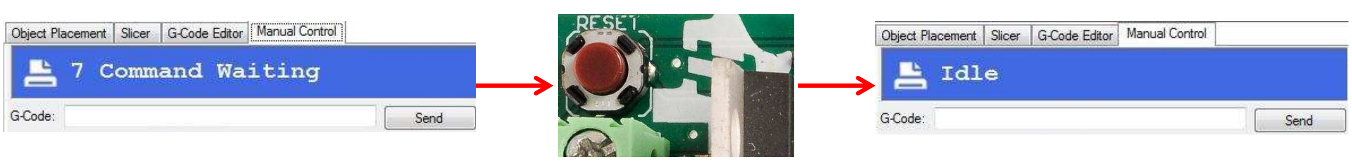


Figure 11. Printerpack Reset to Enable UART Communication

5.3 Component Tests

5.3.1 Motor Movement

Before beginning, verify that all axis locations are not near their boundaries but instead sit somewhere in the middle of the print space. The extruder should also not actively be fed with filament while testing the motors. Starting with the X axis, move in the positive X direction a few units using the GUI's manual control buttons. There are a few conditions to check for at this point:

- If the motor does not move, check for apt motor connection to the Printerpack and that UART communication has been appropriately established between the LaunchPad and the chosen host software, using Section 5.1 and Section 5.2 for reference. It is also possible that the potentiometers need to be tuned as described in Section 3.2.
- If the wrong motor moves, then at least two of the motors are connected to the wrong headers. Turn off the power supply and switch motor connections as necessary, see Figure 6. Re-connect the power supply and try again.
- If the motor moves in the wrong direction, turn off the power supply and reverse the motor connection on the Printerpack. After re-connecting the power supply and trying to move again, the motor should now move in the correct direction.
- Measure the distance the motor moves. If the motor moves too little or far, the corresponding _steps_per_unit variable defined in the configuration.h file of the firmware is probably incorrect and needs to be adjusted. For more information, see Section 4.3.

Always remember to turn off the power supply any time the motors are being disconnected from the Printerpack as failure to do so could cause damage to the stepper motors or their respective drivers. Once the X axis motor is moving as expected, the process may be repeated for all axis motors and the extruder motor.

5.3.2 End Stops

First ensure that all axis locations are not currently at their minimum boundary. Since only the minimum end stop push buttons have been accounted for in the firmware, they will be the only ones tested for operation. With the X end stop push button physically pressed by hand, command the X motor to move in the negative direction. Motor movement here implies incorrect end stop connection to the Printerpack, in which case re-examine Figure 6 for the accurate end stop placement. If the motor does not move, advance to homing the X axis and let the printer's X axis move on its own until the end stop push button is pressed. Repeat this process for all axis end stops.

5.3.3 Heated Elements and Thermistors

Set the extruder heater to anywhere in the range of 150°C to 250°C (this value will be more specific based on the type of filament being used) and turn it on. Carefully handle the extruder for enough time to make sure that it is warming up. Do not touch it again after checking, for the anticipated temperature is sure to cause a burn. Monitor the temperature graphs on the preferred host software and verify that the temperature is rising and plateaus on the selected temperature. If the temperature does not appear to increase at all whereas the extruder is obviously heating up, immediately turn off the extruder and review the extruder thermistor connection. Repeat this process for the heated bed (using a temperature range of 50°C to 80°C instead).

5.4 Calibration Information

Even with all individual mechanisms tested and working as expected, there is still some work to be done before the first print job can be initiated. Several online calibration and development guides are available online that cover a multitude of important topics such as bed leveling and preparation, extrusion, and temperature control. They aid in configuring 3D printers to produce the best works possible and should be thoroughly reviewed before continuing. After all of this is done, the 3D printer is ready for operation. Printer platforms that the Printerpack has currently been calibrated and tested on include the Mix G1 and the Prusa i3. The process for starting the first print in the selected host software is as such: load a stl file, slice it into g-code using Slic3r, and run the job. Always personally monitor the first few jobs to understand how the printer reacts and re-configure or calibrate accordingly.

6 Test Data

Multiple data measurements were recorded over the progression of various tests completed to confirm the rigidity of the 3D Printerpack hardware. Such data is displayed in this section to prove correct use of components and exemplify the board's capabilities.

As is common with stepper motor drivers, microstepping current waveforms were recorded with an oscilloscope to exhibit proper operation. Figure 12 and Figure 13 demonstrate the current waveforms at 500 mA peak (normal operating current for typical 3D printers) and 1.5 A peak (maximum operating current for the DRV8825 without additional cooling), respectively. AOUT is shown in blue and BOUT in green, with AOUT leading BOUT by 90° as is standard for stepper motor drivers. The driver shown is operating at a 1/16th step size, meaning that there will be 16 steps per 90°. For more information regarding operation of the drivers, see the *DRV8825 Stepper Motor Controller IC Data Sheet* (SLVSA73).

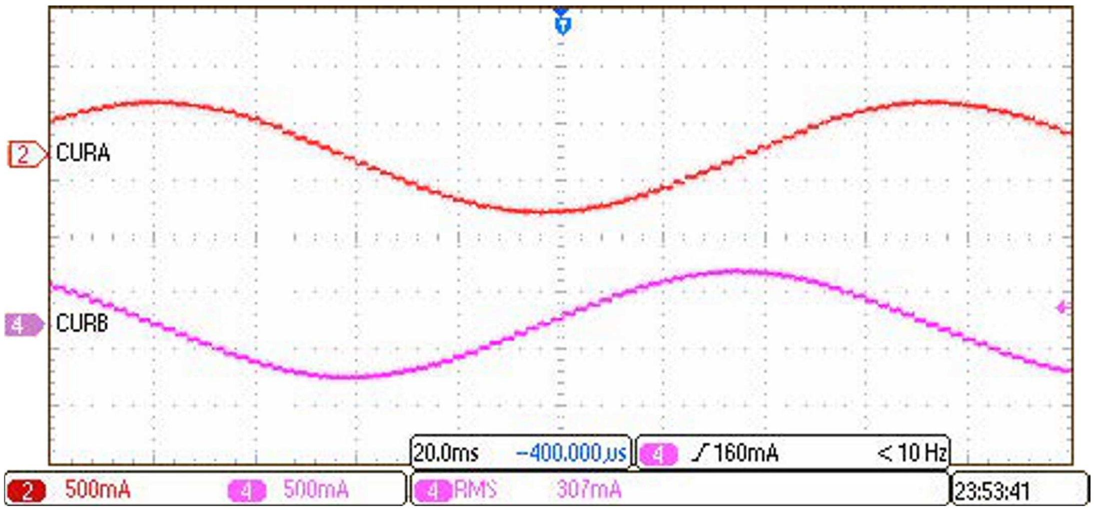


Figure 12. Output Current vs. Step Input for Normal Printer Operation

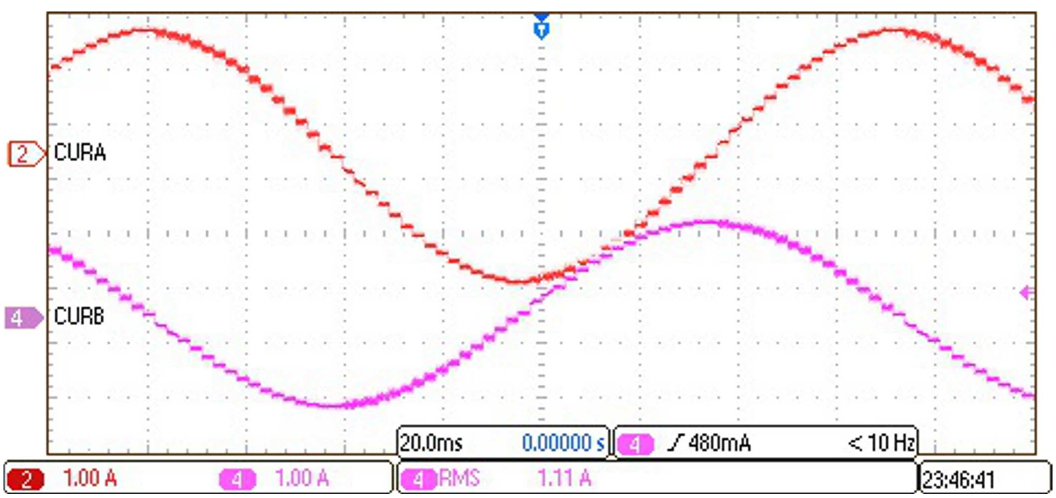


Figure 13. Output Current vs. Step Input for Maximum Driver Operation

Thermal images of a DRV8825 under the loads mentioned were also captured. Driver temperatures while operating at both 500 mA peak and 1.5 A peak are shown in Figure 14. Driving a load of 1.5 A peak, the device temperature was shown to reach as high as 145°C. As stated in the data sheet, thermal shutdown of the DRV8825 will occur if the die temperature exceeds safe limits (usually 160°C) and will automatically resume once the die temperature returns to a safe level. This typically means that if operated above 1.5 A peak, the driver will constantly stutter between normal operation and thermal shutdown.

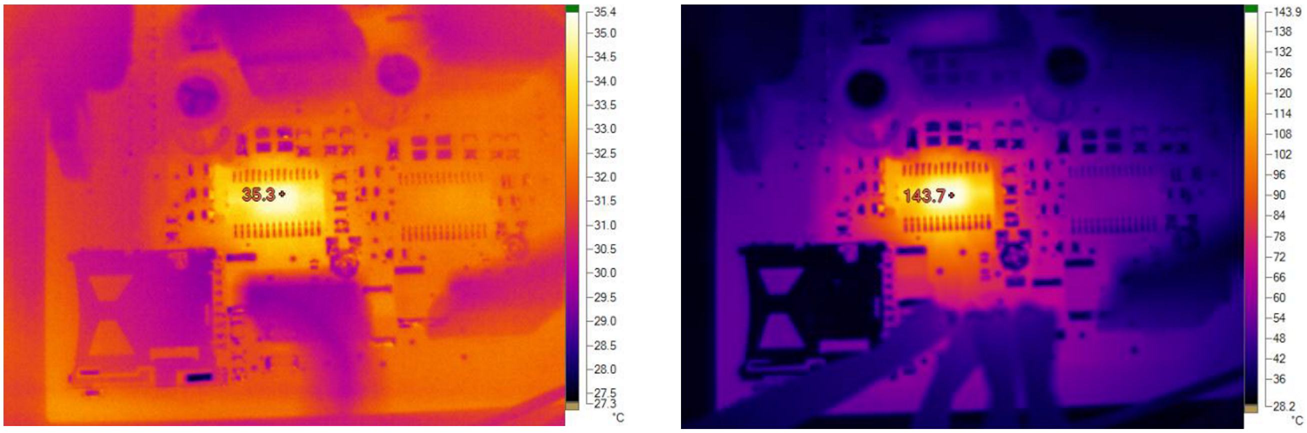


Figure 14. DRV8825 Temperatures, Printer Operation on the Left and Maximum Operation on the Right

Thermal images for the CSD18534KCS FETs driving the heated bed and extruder resistors were also taken. These images only demonstrate the FETs being used for 3D printer applications and do not showcase maximum ratings of the device, which can operate at 60 V and 71 A peak at room temperature. Instead, they are operated through the 12 V supply require 8.5 A and 1.85 A for the heated bed and extruder resistors, respectively. Figure 15 shows the FET temperatures.

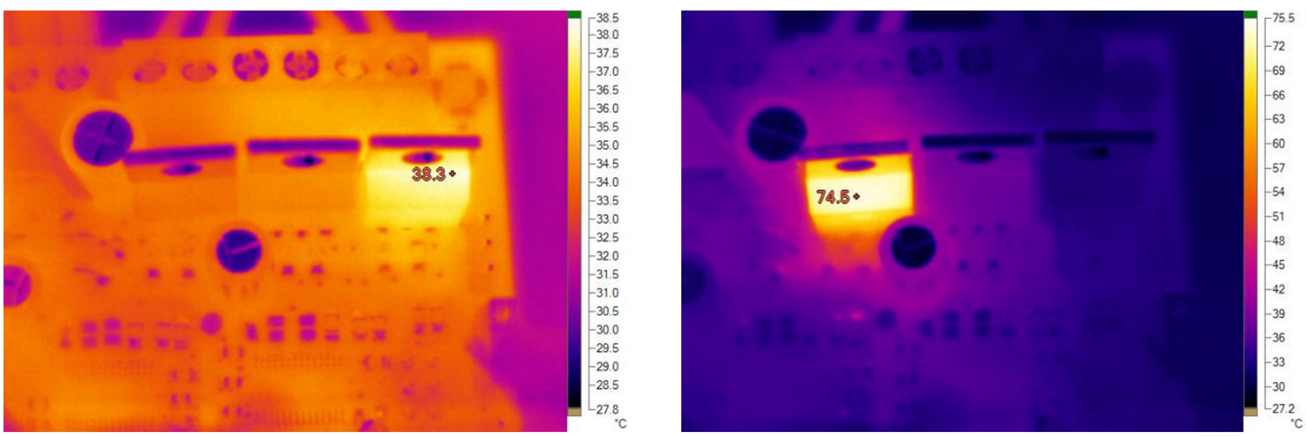


Figure 15. CSD18534KCS Temperatures, Extruder Resistors on the Left and Heated Bed on the Right

Several current measurements were also taken and are displayed in Table 2. Average operational current is difficult to determine due to the continuously changing state of the 3D printer and is also dependent on stepper motor selection, print job, and print settings such as heated bed and extruder temperatures.

Table 2. System Current Measurements

Device	Current (mA)
DRV8825 (4)	500 (peak)
CSD18534KCS (Heated Bed)	8500
CSD18634KCS (Extruder Resistors)	1850
MSP-EXP430F5529LP (powered through USB/eZ-FET lite)	21.7
MSP-EXP430F5529LP (powered through 12 V supply/UA78M33)	22.5
Sleep current (12 V supply connected, no power to the MSP-EXP430F5529LP	3.16

A few example prints that were made with the Prusa i3 printer hardware and TI 3D Printerpack are shown in Figure 16 and Figure 17, with a ruler included for scale. These pictures reflect the accuracy and resolution of the printer with features as small as one to two millimeters being printed using the 3D Printerpack. However, this resolution depends on the setup itself, with possible variables including nozzle diameter, motor step size, and print speed.

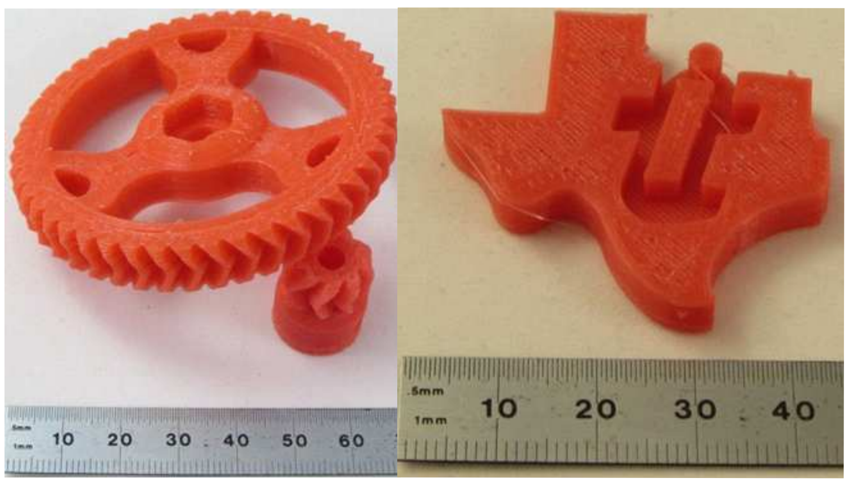


Figure 16. Test Prints Made With the TI 3D Printerpack

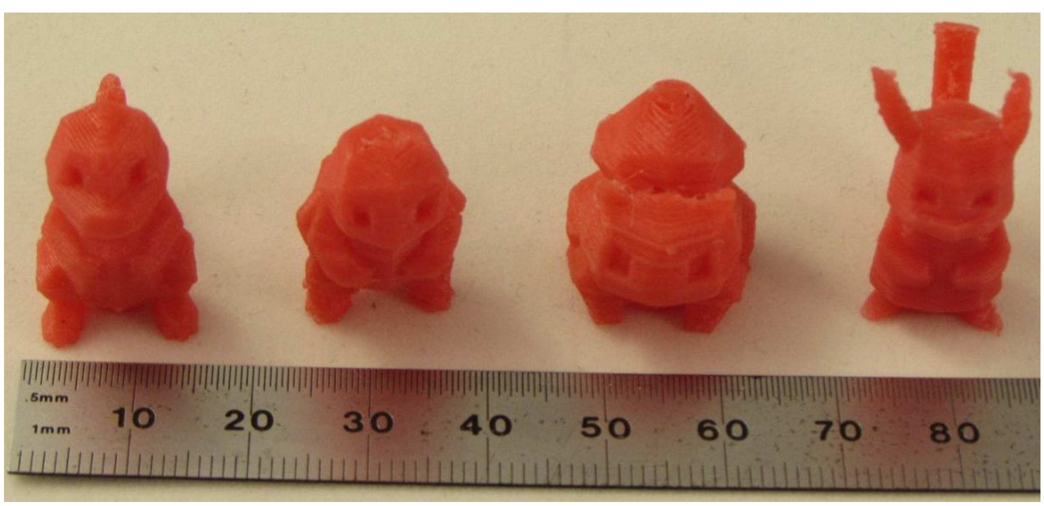


Figure 17. Small Figurines Printed to Demonstrate Small Feature Sizes

7 Design Files

7.1 Schematics

To download the Schematics for each board, see the design files at TIDM-3D-PRINTERPACK.

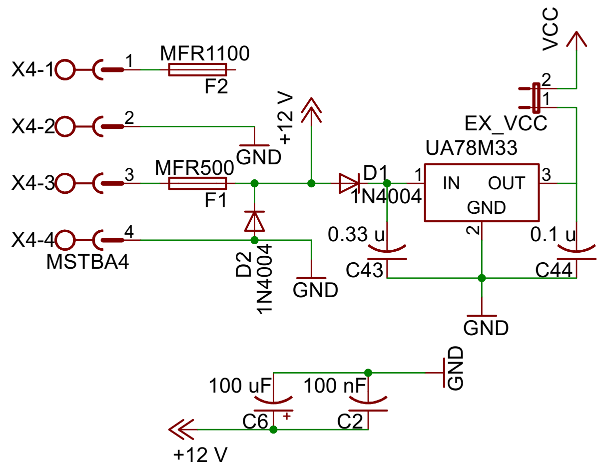


Figure 18. Power and Extruder Resistors Schematics

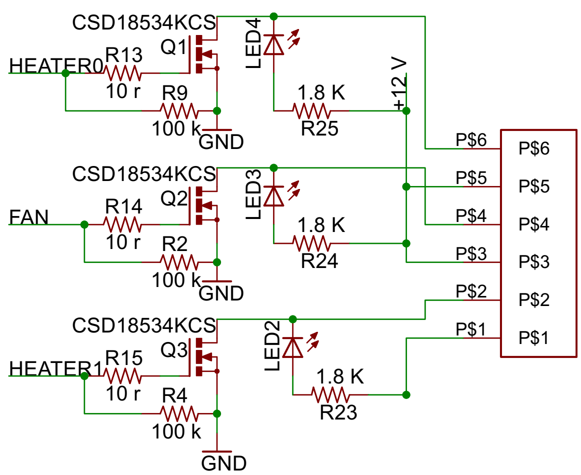


Figure 19. Heated Bed and Fan Schematics

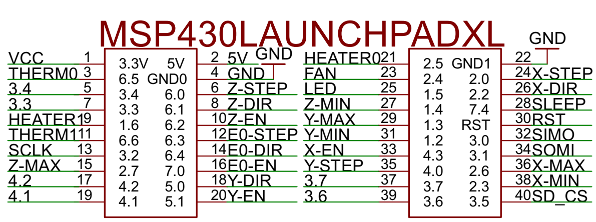


Figure 20. MSP430F5529 Connection Schematic

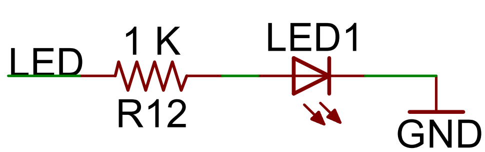


Figure 21. LED Schematic

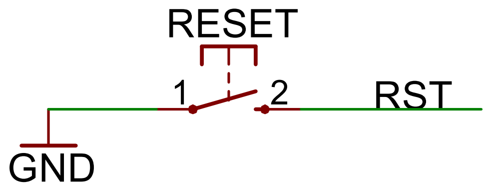


Figure 22. Reset Schematic

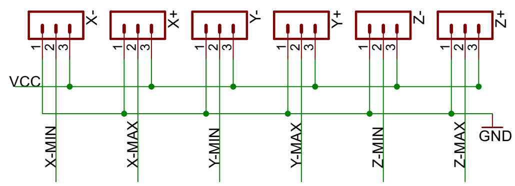


Figure 23. Endstops Schematic

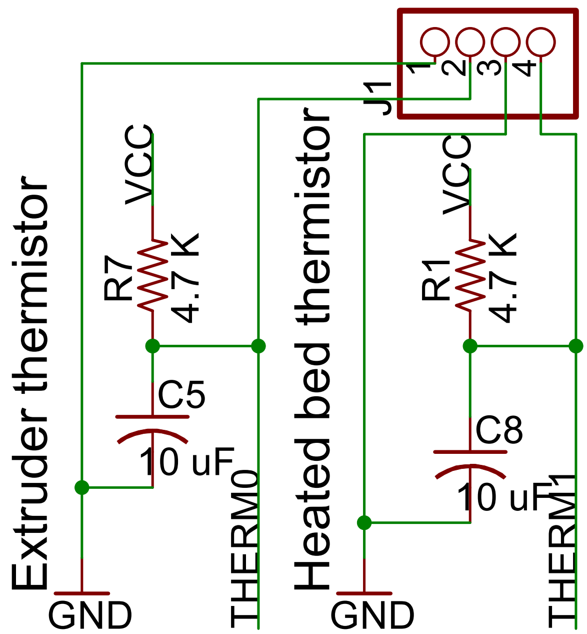


Figure 24. Thermistors Schematic

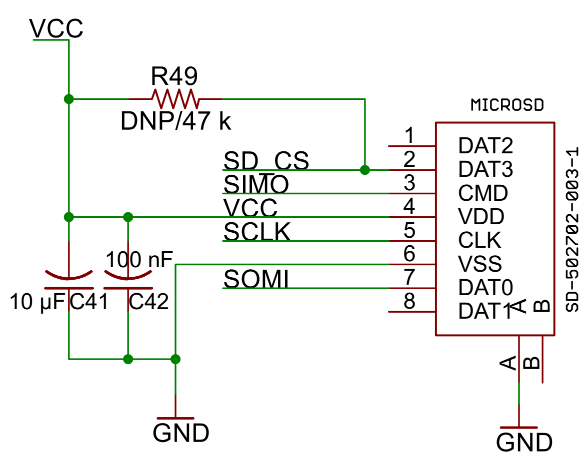


Figure 25. microSD Memory Card Schematic

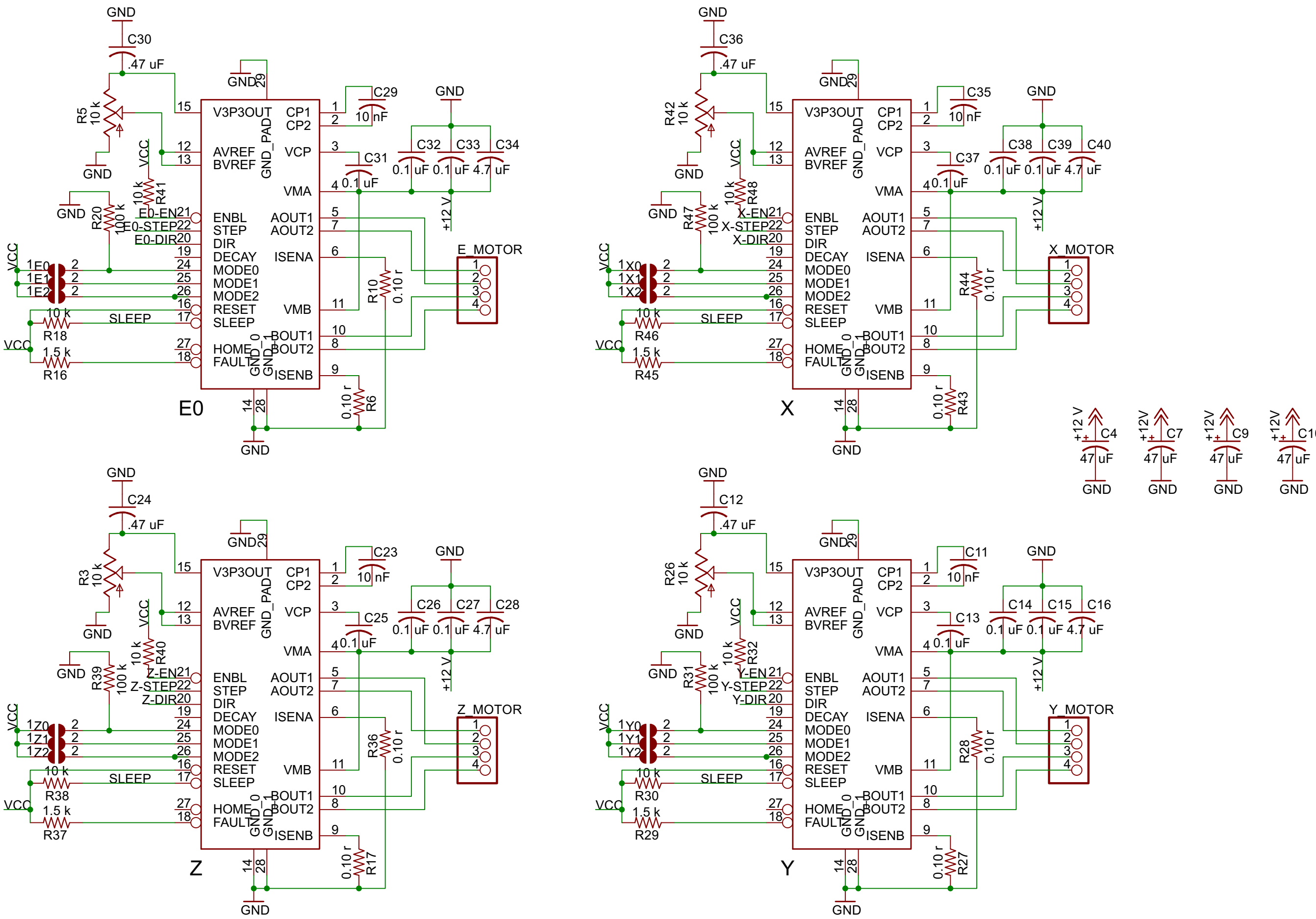


Figure 26. Stepper Drivers Schematic

7.2 Bill of Materials (BOM)

To download the bill of materials (BOM), see the design files at TIDM-3D-PRINTERPACK.

Table 3. Bill of Materials (BOM)

Item	Qty	Reference/Designator	Value	Part Description	Manufacturer	Manufacturer Part Number	Alternate Part	Eagle Footprint
1	4	C11, C23, C29, C35	10 nF	CAP CER 10000PF 50 V 20% X7R 0805	Samsung	CL21B103MBANNNC		C0805
2	4	C12, C24, C30, C36	.47 µF	CAP CER 0.47 µF 50 V 10% X7R 0805	Samsung	CL21B474KBFNNNE		C0805
3	11	C13, C14, C25, C26, C31, C32, C37, C38, C2, C42, C44	0.1 µF	CAP CER 0.1 µF 50 V Y5V 0805	Samsung	CL21F104ZBCNNNC		C0805
4	4	C15, C27, C33, C39	0.1 µF	CAP CER 0.1 µF 50 V 10% X7R 0603	Samsung	CL10B104KB8SFNC		C0603
5	4	C16, C28, C34, C40	4.7 µF	CAP CER 4.7 µF 50 V 10% X5R 0805	Samsung	CL21A475KBQNNNE		C0805
6	4	C4,C7,C9,C10	47 µF	CAP ALUM 47 µF 50 V 20% RADIAL	Panasonic	ECA-1HM470		E2,5-6
7	1	C6	100 µF	CAP ALUM 100 µF 50 V 20% RADIAL	Nichicon	UVR1H101MPD		E3,5-8
8	3	C41, C5, C8	10 µF	CAP CER 10 µF 35 V Y5V 1206	Taiyo Yuden	GMK316F106ZL-T		C1206
9	1	C43	0.33 µ	CAP CER 0.33 µF 50 V 10% X7R 0805	Samsung	CL21B334KBFNNNE		C0805
10	2	D1, D2	1N4004	DIODE general purpose 400 V 1A DO41	Comchip	1N4004-G		DO41-10
11	5	E0-MOT1, JP1, X-MOT1, Y-MOT1, Z-MOT1		Pin header				4PIN-HEADER
12	1	F1	MFR500	FUSE PTC resettable 5A hold	Bourns	MF-R500		MFR500
13	1	F2	MFR1100	POLYSWITCH PTC reset 11A HLD T/R	TE Connectivity	RGEF1100-2		MFR1100
14	1	LED1	RED	LED super red clear 0805 SMD	Lite-On	LTST-C170KRKT		CHIP-LED0805
15	3	LED2, LED3, LED4	GREEN	LED green clear thin 0805 SMD	Lite-On	LTST-C171GKT		CHIP-LED0805
16	1	MICROSD	SD-502702-003	CONN micro SD R/A PUSH-PUSH SMD	Molex	5027020891		SD-502702-003
17	2	MSP430F5529 LAUNCHPADXL	MSP430F5529XL	F5529 launchpad headers	Samsung	SSW-110-23-F-D		10x2PIN-HEADER
18	3	Q1, Q2, Q3	CSD18534KCS	MOSFET N-CH 60 V 100A TO220-3	TI	CSD18534KCS		TO220BV
19	2	R1, R7	4.7K	RES 4.7K Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ472		R0805

Table 3. Bill of Materials (BOM) (continued)

Item	Qty	Reference/Designator	Value	Part Description	Manufacturer	Manufacturer Part Number	Alternate Part	Eagle Footprint
20	1	R12	1K	RES 1K Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ102		R0805
21	3	R13, R14, R15	10r	RES 10 Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ100		R0805
22	4	R16, R29, R37, R45	1.5k	RES 1.5K Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ152		R0805
23	8	R18, R30, R32, R38, R40, R41, R46, R48	10k	RES 10K Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ103		R0805
24	7	R2, R4, R9, R20, R31, R39, R47	100k	RES 100K Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ104		R0805
25	3	R23, R24, R25	1.8K	RES 1.8K Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ182		R0805
26	4	R3, R5, R26, R42	10k	TRIMMER 10K Ω 0.1W SMD	Bourns	TC33X-2-103E		SM-42/43A
27	1	R49	47k	RES 47K Ω .4W 5% 0805 SMD	RΩ	ESR10EZPJ473		R0805
28	8	R6, R10, R17, R27, R28, R36, R43, R44	0.10r	RES .100 Ω 1W 1% 2010 SMD	TT Electronics	LRC-LR2010LF-01-R100F		R2512
29	1	RESET	SPST-NO	SWITCH tactile SPST-NO 0.02A 15V	Panasonic	EVQ-11L05R		PBTH
30	12	SJ1, SJ2, SJ3, SJ4, SJ5, SJ6, SJ7, SJ8, SJ9, SJ10, SJ11, SJ12		SMD solder jumper				SJ
31	4	U$1, U$4, U$5, U$6	DRV8825PWP	IC motor driver par 28HTSSOP	TI	DRV8825PWP		TSSOP-28
32	1	U$2	282837-6	Terminal block PCB 6POS 5.0MM GREEN	Phoenix	1935200		282837-6
33	1	UA78M33	UA78M33	IC REG LDO 3.3 V 0.5A SOT223	TI	UA78M33CDCYR		SOT223
34	6	X+, X-, Y+, Y-, Z+, Z-		PIN HEADER				3PIN-HEADER
35	1	X4	MSTBA4	Terminal block PCB 4POS 5.0MM green	Phoenix	1935187		MSTBA4

7.3 Layer Plots

To download the layer plots, see the design files at TIDM-3D-PRINTERPACK.

7.4 Altium Project

To download the Altium project files, see the design files at TIDM-3D-PRINTERPACK.

7.5 Layout Guidelines

Due to high current consumption required for the heated bed, extruder resistors, and stepper motors, their respective trace widths need to be adequately sized. PCB trace width calculators can be used to estimate the required trace width given current consumption and copper thickness. Utilizing traces on both the top and bottom of the board can effectively aid in increasing current allowance. Keep in mind that when in use for 3D printing, the heated bed may require up to 11 amps whereas the rest of the board could need 5 amps (mostly separated between the stepper motors and the extruder resistors).

Although this will not be achieved with common 3D printer tasks, the DRV8825 stepper motor drivers can handle up to 1.5 A per phase without a heat sink or forced air flow. With this in mind, the driver output traces also need to be an appropriate width to allow for a high current consumption. It is suggested that the motor headers be placed relatively close to the drivers so that the trace distances are minimized.

The DRV8825 includes a PowerPAD™ that acts as a thermal heat sink for ground. It is highly recommended that this pad be connected to a ground plane through the use of multiple vias to correctly dissipate heat from the stepper motor drivers. For more information on how to suitably connect the PowerPAD to a ground plane, see *PowerPad™ Made Easy* (SLMA004).

The µSD card layout does not have to be included for basic 3D printing, but should be if the user wishes to run 3D prints without the aid of a host PC. Firmware including µSD card functionality is currently unavailable but will be provided in future releases.

7.6 Layout Prints

To download the Layout Prints for each board, see the design files at TIDM-3D-PRINTERPACK.

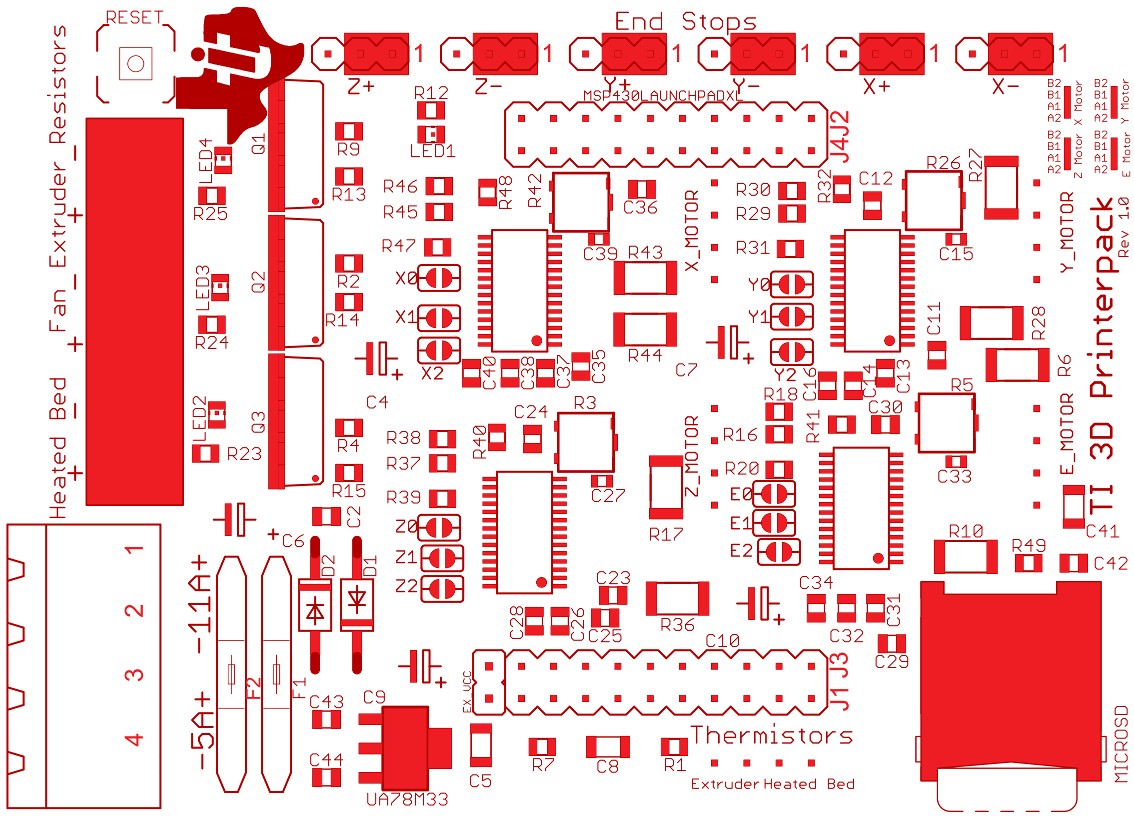


Figure 27. Top Silkscreen

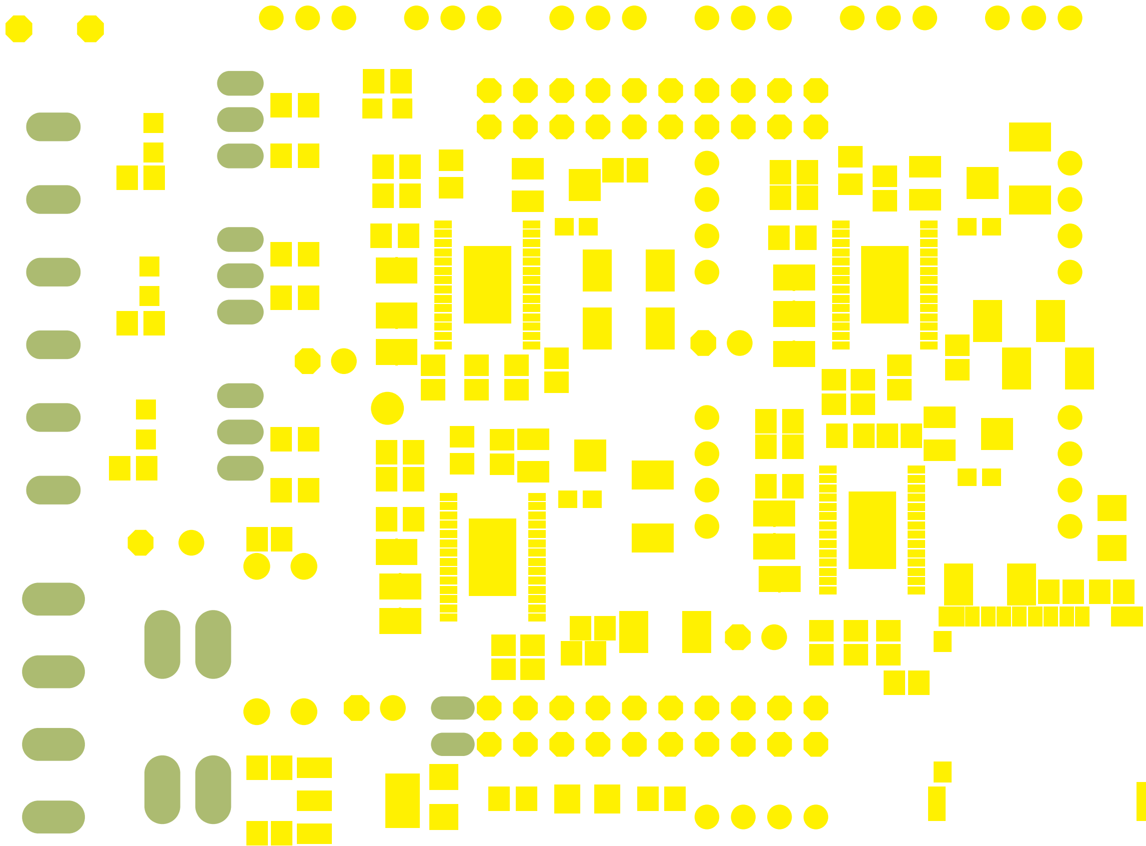


Figure 28. Top Soldermask

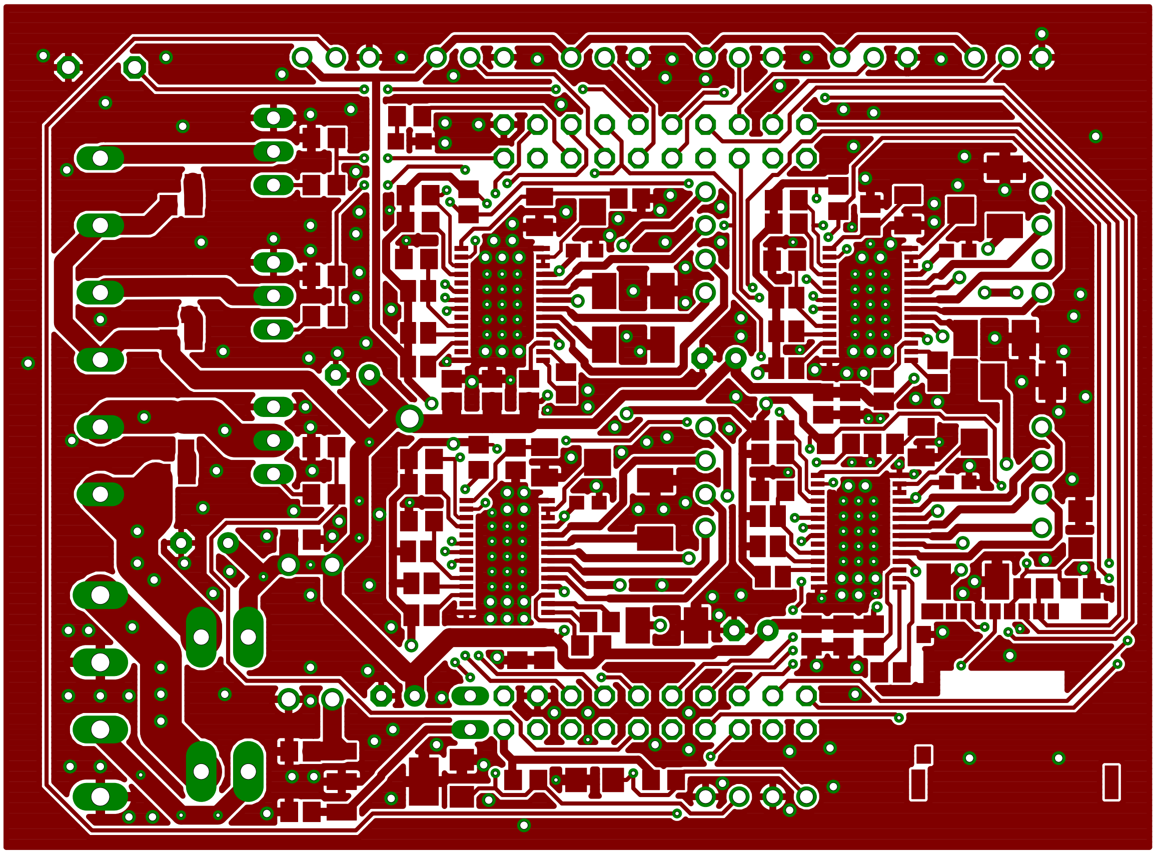


Figure 29. Top Layer

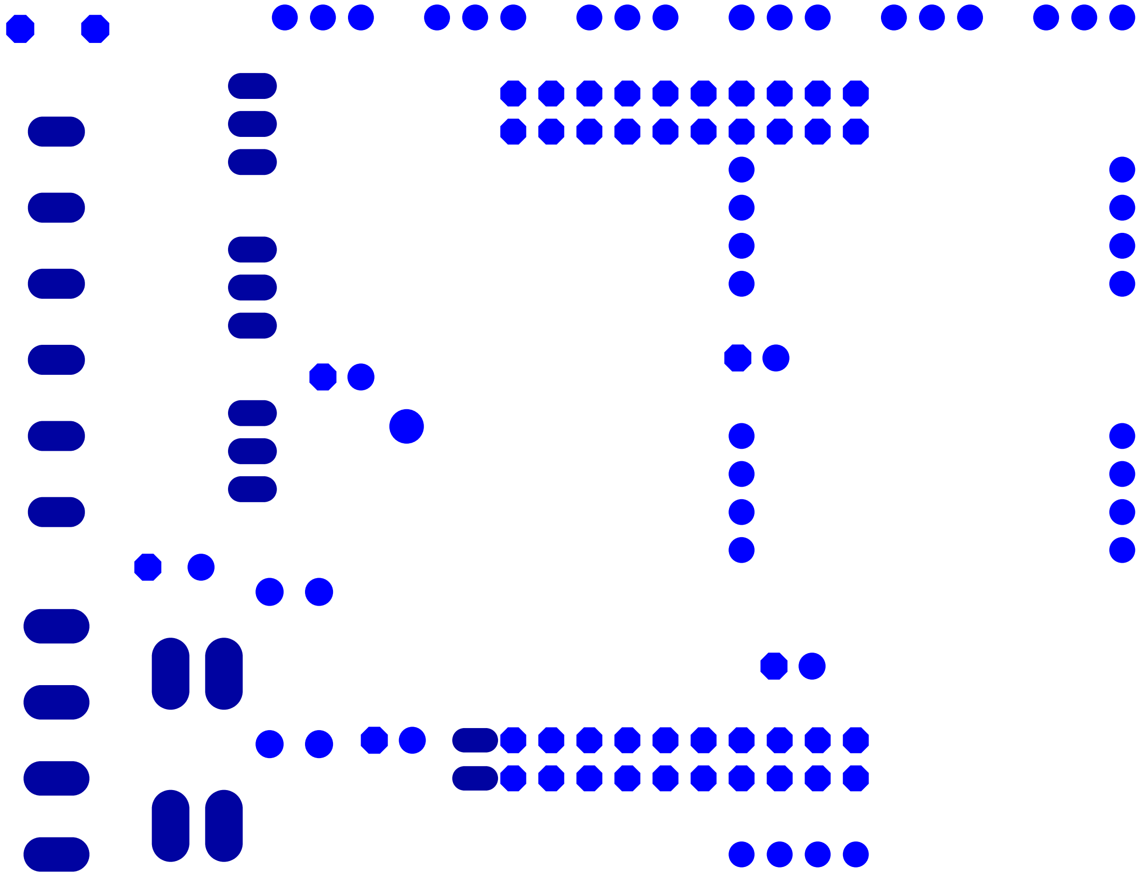


Figure 30. Bottom Soldermask

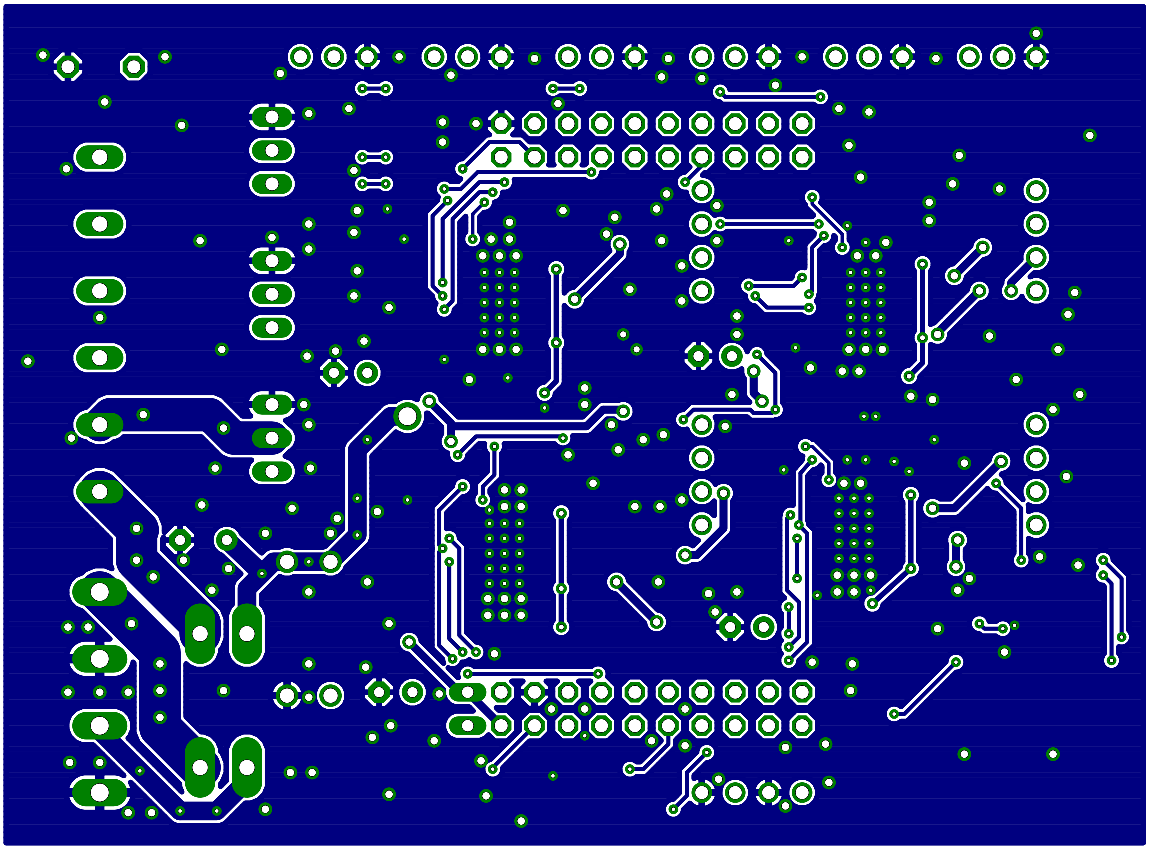


Figure 31. Bottom Layer

7.7 Gerber Files

To download the Gerber files, see the design files at TIDM-3D-PRINTERPACK.

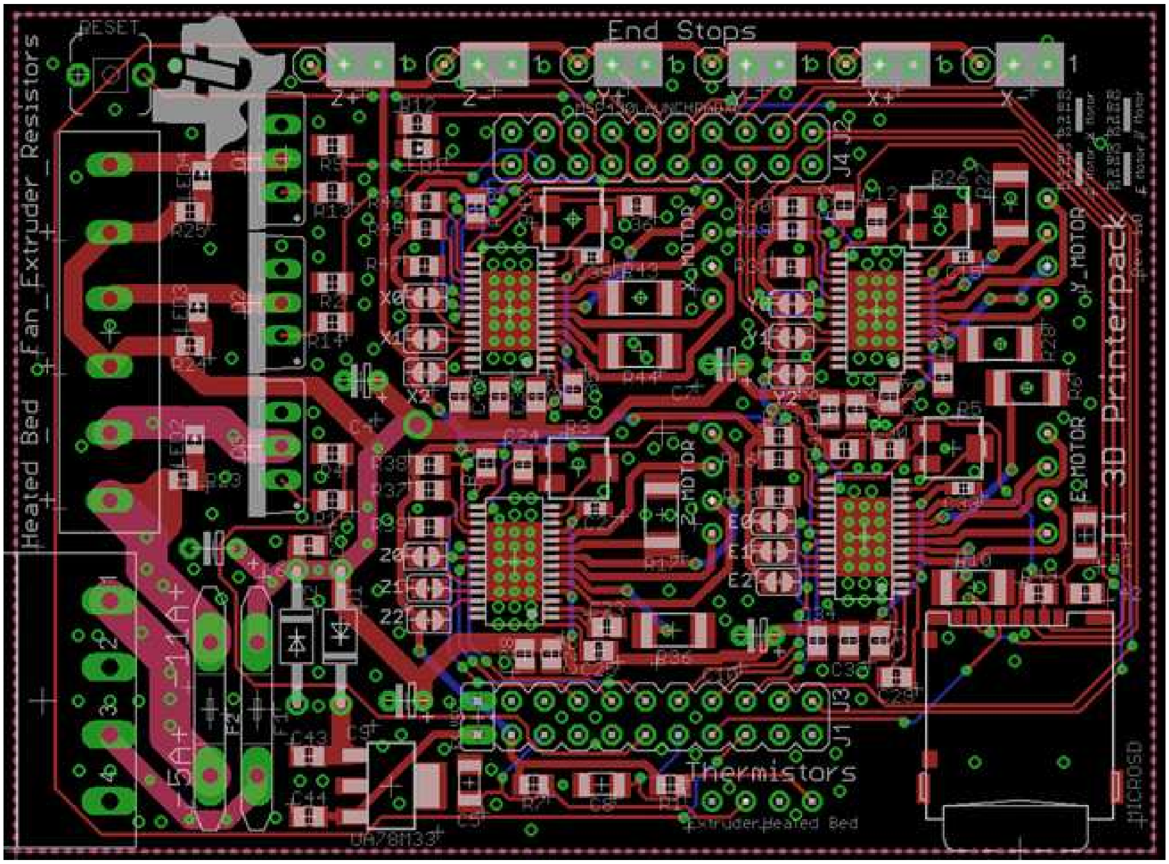


Figure 32. 3D Printerpack Layout

7.8 Assembly Drawings

To download the Altium project files for each board, see the design files at TIDM-3D-PRINTERPACK.

7.9 Software Files

To download the software files, see the design files at TIDM-3D-PRINTERPACK.

8 References

1. RepRap
2. richrap.blogspot.com/
3. CircuitCalculator.com
4. *PowerPad™ Made Easy* (SLMA004)
5. *DRV8825 Stepper Motor Controller IC Data Sheet* (SLVSA73)

9 About the Author

RYAN M. BROWN is an MSP430 Customer Applications Engineer at Texas Instruments, where he is responsible for supporting development of customer designs in various applications. Ryan brings to this role his experience in PCB design software, MSP430 architecture, and LaunchPad and BoosterPack protocol. Ryan earned his Master of Science in Electrical Engineering (MSEE) from Texas Tech University in Lubbock, TX.

Revision History

Changes from Original (November 2014) to A Revision **Page**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.