How Unique Cable and Connector Solutions are Taking 3D Printing to New Levels

This briefing is an executive summary of a webcast sponsored by Heilind Electronics and TE Connectivity.

Introduction

Additive manufacturing, or 3D printing, is decades old but the industry today is quite challenging. 3D printing enables rapid prototyping, quick-turn designs, and the ability to quickly scale in industrial, consumer, and high-risk markets. The industry enables what was only dreamed of years ago.

This paper begins with a teardown of a consumer desktop 3D printer, focusing on answers to questions such as how to make the most sufficient design for a particular end product, and how to move from power to the control to subsystems. How are all these subsystems synched together? How does the printer interact with the user — is it through a touchscreen, switches, or other inputs? How does it interact with the outside world — through Wi-Fi connectivity?

The subject device of the teardown is a consumer desktop 3D printer (Figure 1) broken into five main categories: power supply; main control board; print head carriage; x, y, z access control; and print stage. There are different sizes and separate categories within this device, and they are all controlled or used a bit differently.

Power Supply

The first component in the power supply is the power input and user on/off, which is plugged into a standard outlet and then comes in through a filter attached using axial and quick disconnect. The user input is a toggle switch, also using axial quick disconnect.

The power controller/regulator is a pre-made unit supplied by the printer manufacturer. Everything is attached to the power control regulator using a terminal block and ring tongue terminals on the cable. Power is brought to the main control board using free-hanging terminal blocks, which are very similar to the terminal block used in the power supply. It's a very robust design and gives the user multiple advantages over other types of interconnects.

This printer is an example of a very efficient design for multiple reasons. There are eight different FASTON connectors in this portion of the design, and that enables operator ease of use. The components are aligned quite well with other supply components; for example, there is an on/off switch with FASTON pads on the back, and there is a power filter with the same quick disconnect.

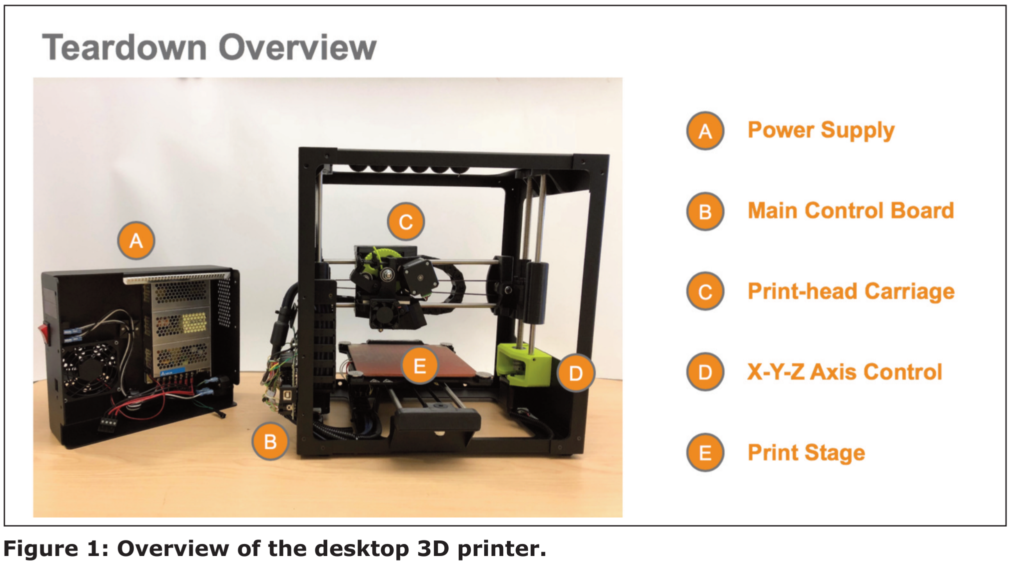

Figure 1: Overview of the desktop 3D printer.

Main Control Board

The main control board is shown in Figure 2. There is a substantial number of components on this small board that control the entire device. Power comes into the board and then out to the various devices. The manufacturer uses the same four-position connector on the board (highlighted at number 1), and then splits it out using multiple different free-hanging terminal blocks.

The same connector is reused, which simplifies the supply chain and the parts required. Indicated by number 2, anything with a blue dot is actually the same connector in relation to the supply components. The various subsystems are connected to the control board; 16 different connectors and cable assemblies using different wire-to-board configurations.

Highlighted at number 3 are the multiple parts reused. These are testing programs — unshrouded stick headers mounted onto the board. There are various points in manufacturing that use these as test boards to make sure the items within the device are working properly.

It's also important to make sure cables are identified and managed properly so they are not mismated or cross-mated in final assembly. From a cable management perspective, there are often opportunities to use different cable jackets to help the operator identify what connector needs to be pressed into what receptacle. Different materials, different colors, and identification labels are used. The physical layout of the printed circuit board can be changed to help the operator determine the order in which the connectors go together.

Other things that can be done to error-proof the process include polarization and keying different options that could be considered in this area. With so many different cables being used throughout the device, consider the strain on these different cables and how they're going to be retained as the device moves. To accomplish this, there are different retention and strain relief options.

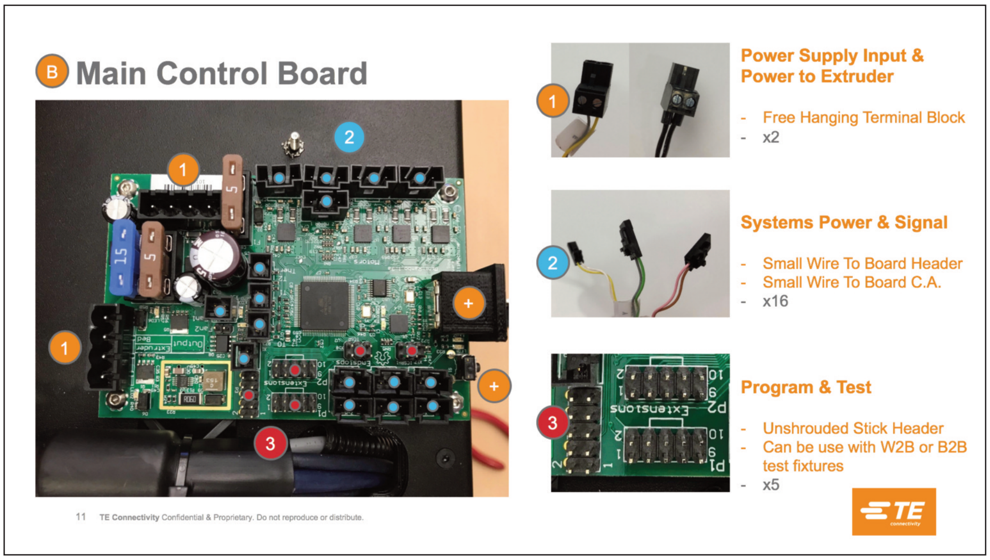

Figure 2: Main control board components of the printer.

Print-Head Carriage

The print-head carriage is a simplified design. The printer sits on a desk, so every square inch counts. The power and signal from the main control board are brought into the print-head carriage through a mixed power signal wire-to-wire connector. This is convenient for field repair and testing.

A drive motor provides filament into the print head. This uses a mixed power signal wire-to-board connection to drive, turn on, and turn off the motor. The fans on the print carriage use a very small micro-miniature board connector.

Key considerations in this area center on the thermal components. How is temperature measured, sensed, and corrected in this area of the unit? A well-regulated thermostat controls the fans, and then ultimately the temperature of the device.

It's very important to keep the position calibrated as this print-head carriage is moving across the device. Air bubble detection highlights any anomalies in the filament as it moves into the print head so as not to disrupt the final print.

X-Y-Z Axis Control

The x, y, z axis control is shown in Figure 3. The print area and stage are able to move in two to three directions. This is important as far as applying the print to the stage and building up the material throughout the print. The x, y, and z motions are controlled by multiple different motors all working together. Each motor is controlled separately and synched electronically by the main control board. Each connector and motor are also connected using the same system for both power and signal, and are used four different times as far as wire-to-board configuration.

A key consideration is the use of mechanical versus electrical calibration. Electric calibration is used in this area but using a mechanical device such as a separate drive to overcome some electrical considerations is an option. A redundant system can be used for the motors to control all three directions.

A final consideration would be if it is appropriate to use internal versus

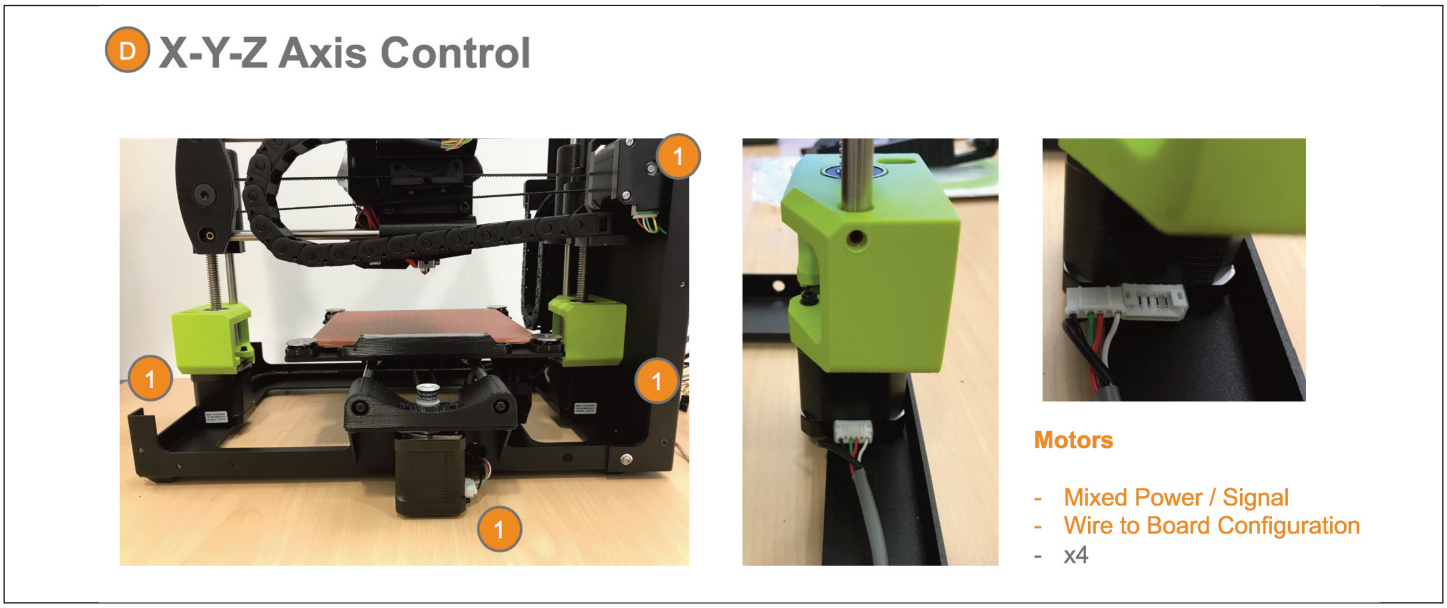

Figure 3: Axes and control of the printer area and stage.

external style connectors. Most of the electronic and connector components are exposed to the outside environment; it wouldn't be appropriate to use the same type of internal connectors in an external environment. Consider the tradeoffs, the risks from a safety perspective, and the reliability of allowing the end user to interface with these systems.

Print Stage

The print stage is heated, which is important for many reasons. The challenge, however, is maintaining the temperature and life of the print stage. It also requires the use of a thermostat with input controls. Considerations include different style connections used on the same device, and field repair and replacement of these systems.

Is a connector system necessary, or can a direct attach method be used? In this case, a direct attachment is used where the wires are directly attached onto the stage. A wire-to-wire connection system is used to remove the entire stage. If the stage had to be repaired or replaced, the item would have to be thrown away, with the new item controlling it as though it was new. A connector system could save some of the components related to the stage, thermostat, and input controls.

Connector Options

Across TE Connectivity, there are more than 75 unique wire-to-board and wire-to-wire product families for different purposes. The printer discussed in this paper used fine pitch discrete wire connector systems that are 2.5 mm and smaller. TE families in this category are CT, Mini CT, HPI, Slim, and Micro SLP (Figure 4).

CT (Common Termination) — This 2-mm wire-to-board family is available in both crimp and IDC termination versions, and can terminate 22 to 30 AWG wire, with a 2- to 30-position range. This device features a free-hanging header and a tester to manipulate and evaluate any component on the board or in the device. A panel-mount header is an advantage when moving through panels and walls, and fully boxed and partially boxed headers enable different polarization options as well as identifying which assembly should be plugged into which board-side header.

Mini CT — This is a 1.5-mm version of the CT. Specifically, this is a top surface mount product. The cable assembly plugs into the bottom of the board through this connector; however, its surface is now on the top side of the board. This connector can be placed anywhere on the printed circuit board where there is room to make a cutout. This connector shortens cable lines and avoids going around the edge of a board where there may not be enough room to route the cable.

HPI — This product is available in 1 to 4 mm and is an industry-standard, footprint-compatible design. Options include different colors and wire-to-wire configurations.

AMP Slim and Micro SLP — These small wire connections have a mated height of 1.4 mm. Micro SLP allows

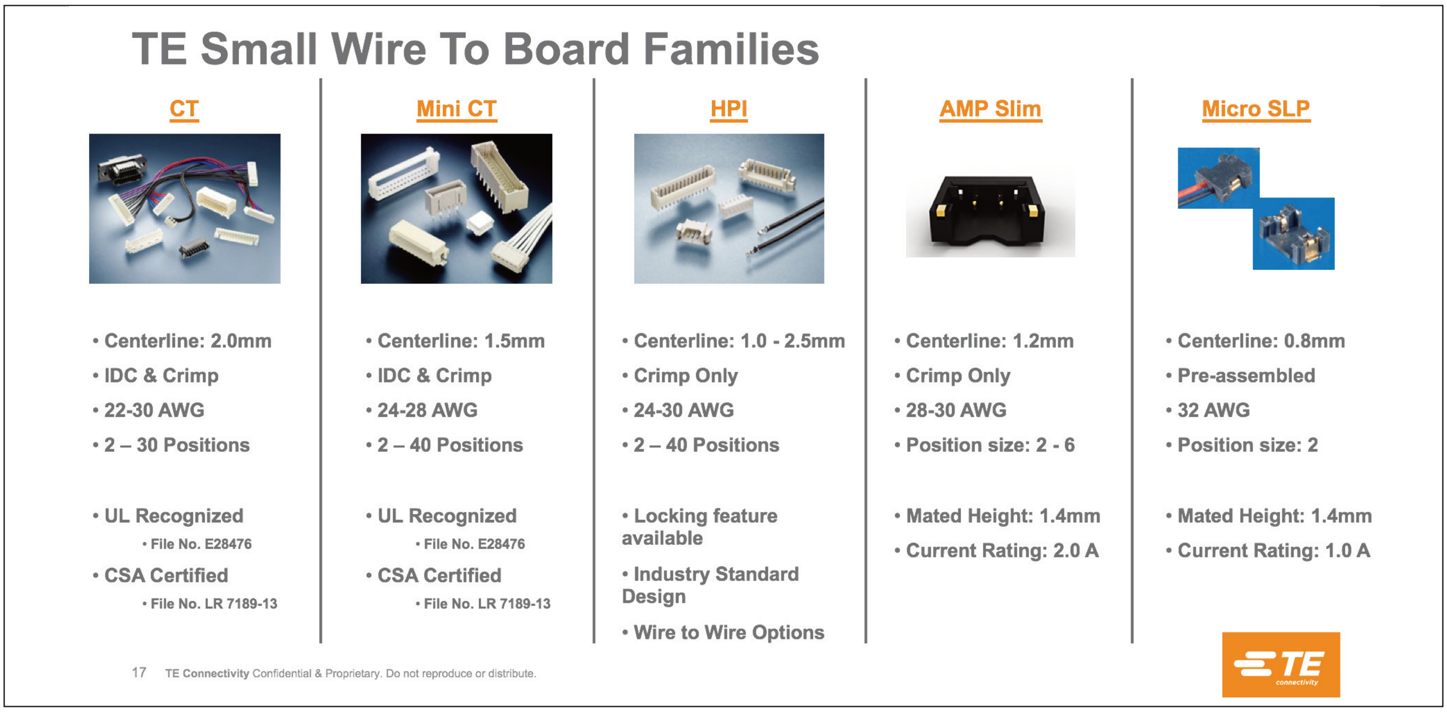

Figure 4: TE Connectivity's fine pitch discrete wire connector systems that are 2.5 mm and smaller.

users to determine a very small 32-gauge wire. It is available in a 2-position size to save as much space as possible. AMP Slim may be a choice if position size must be increased or the power that can be pushed through the connective system increases. It's available in 2 to 6 positions, and can push 2 amps per pin through this connection system.

Flexible Printed Circuit (FPC) connectors were not used in the printer teardown, but they are prevalent in systems using a display or in which operators can interface with a device, whether it's a 3D printer or other machine. Nearly all displays have a FPC jumper to connect with the sub-board; these jumpers attach to the board using FPC connectors.

The key design considerations when choosing FPC connectors are the position size and centerline size to be used for the device; typically, the 0.5- to 1-mm range. This provides a balance among cost, size, and performance. Another consideration is contact position, which relates to how the cable is routed and sent through the device, and how it ultimately arrives at the FPC connector. Contact positions are available in top, bottom, and dual styles.

Finally, some other design considerations for FPCs are the tradeoffs among durability, reliability, size, and cost. These tradeoffs are measured through the use of an actuator, and the connector systems that use this actuator typically referred to as ZIF, or zero insertion force. This actuator provides much higher durability and better cable retention. The tradeoffs are size and higher cost due to the more complex nature of the design.

About the Author

Tyler Madden is Global Product Manager – Data & Devices Business Unit for TE Connectivity. He has been a Product Manager at TE Connectivity for 10 years. Currently, he oversees the team of product managers that manages TE's smallest-sized discrete wire-to-board, wire-to-wire, and flex-to-board interconnect systems.

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