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Proceeding Paper

Miniature Flexible Reprogrammable Microcontroller Circuits for E-Textiles †

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Abstract: An e-textile system was developed, allowing USB reprogramming of miniature, flexible, integrated microcontroller circuits which allows for easier development of complex and configurable e-textile circuits. This prototype consisted of a series of five exposed pads on the edge of the PCB and a corresponding clip connector. Mounted onto the clip are a micro-USB port and necessary additional components to facilitate USB programming meaning that no additional components are required on the microcontroller board thus increasing flexibility. This system has the potential to make software development and reconfiguration of the e-textile easier while the small size and flexibility of the connector allow improved textile integration. This work provides a platform for future e-textile system development and increases the operational lifetime, thus reducing waste due to product obsolescence.

Keywords: e-textile; embedded microcontroller; e-waste; sustainability; flexible electronics

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1. Introduction

Microcontrollers are vital components in many e-textile devices [1,2]. Their re-programmability and wide range of peripheral functions means that they can fulfil the digital processing requirements of almost any small electronic product while their small size makes them possible to include in e-textile devices.

The ability to be re-programmed is key to a microcontroller's utility, and most provide some means of uploading new programs while in situ, for example, AVRs' SPI-based "ICSP" protocol [3]. However, such systems typically only work on one brand of microcontroller and require specialised programming circuits to use. The connectors required to use these systems also occupy a large area: the pin header needed to connect the ATMEL ICE programmer to a QFN ATtiny occupies 4 times the area and 12 times the height of the chip itself, see Figure 1.

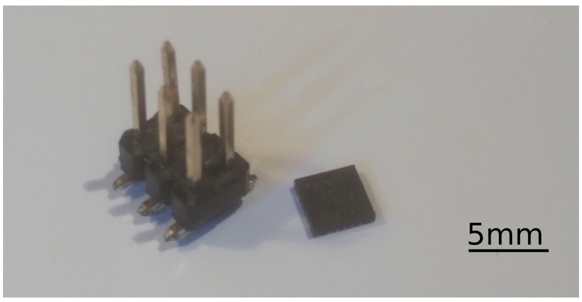

Figure 1. A standard 2.54 mm, 6-pin programming header (**left**) compared to the ATTiny85 microcontroller it programs (**right**).

The first problem can be solved using a USB bootloader. This is a small program which is used to load new software via a USB connection.

However, even micro-USB connectors are relatively large components in the context of e-textiles and restrict the textile integration of a microcontroller circuit. A potential solution to this is to use an edge connector. These consist of a series of exposed pads near the edge of the circuit board. The board itself is then inserted into a receptacle with contacts arranged to connect with the pads. However, existing solutions are for typically thicker (0.3 mm) flat flexible cables (FFC), therefore connections can be difficult and unreliable.

2. Design

The system developed here uses five, 1 mm pitch, pads which need only protrude a few millimetres from the body of a flexible circuit board connect to an external clip. The five connections are used for power, ground, positive and inverted USB data and a button-operated reset line which prompts the microcontroller to run its bootloader. The clip contains all the additional components needed for USB programming: the micro-USB connector, a 3.3 V voltage regulator, a reset button and several passive components. A diagram of this system is shown in Figure 2.

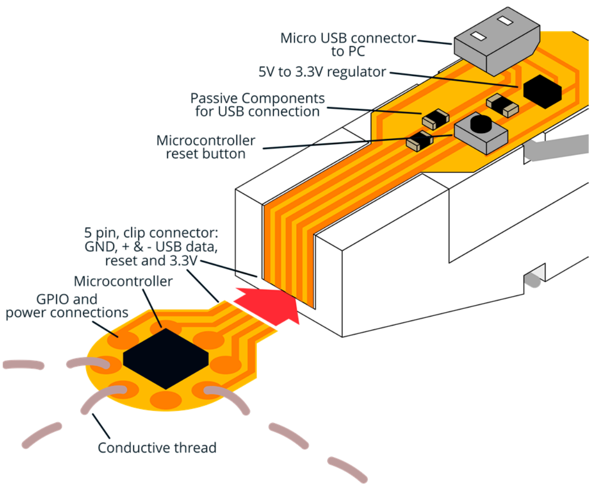

Figure 2. Design of the microcontroller and programmer. Placing the components needed for USB on the programmer clip means that only the microcontroller's IC needs to be integrated into the textile.

The contacts on both sides are tinned with solder to prevent corrosion This system was tested using an ATTiny85 microcontroller [3] with the micronucleus bootloader [4]. Both the flexible microcontroller circuit board and the programming clip's PCB were made using a standard photolithographic etching process described previously in [5].

The contacts on both sides are tinned with a thin layer of solder to prevent corrosion and to raise the contact point slightly, making the connection more reliable.

3. Applications

The test implementation was incorporated into both woven (Figure 3, top left) and stretchable, knitted fabrics (Figure 3, right) by couching the conductive thread soldered to the general purpose input/output (GPIO) pins for the controller. Another version was made by inserting the device and its connecting wires into woven pockets in a custom-made fabric (Figure 3, bottom left).

Because of its small size, the impact on the flexibility and stretchability of the fabric is minor. This is a major improvement over existing prototyping boards designed for e-textile which are much larger and used rigid PCBs (Figure 4).

Figure 3. Microcontroller circuit integrated into the collar of a garment (**top left**), a stretchable knitted fabric (**right**), and a custom woven textile (**bottom left**).

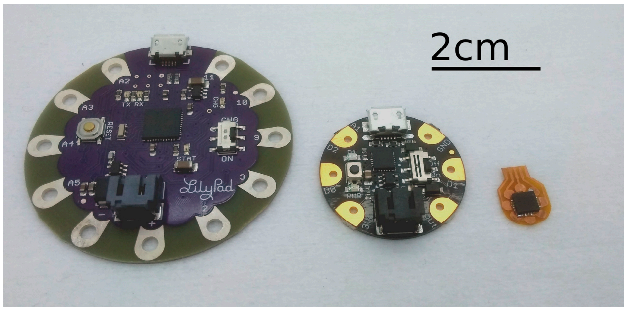

Figure 4. Existing prototyping boards designed for e-textiles, left to right: an Arduino Lilypad (diameter 50 mm [6]), an Adafruit Gemma (diameter 28 mm [7]) and this work (10 × 12.5 mm).

This programming system can easily be adapted to other microcontrollers which are reprogrammable via USB.

4. Conclusions

This work presents an easy-to-use programmer, compatible with many different types of microcontrollers. It occupies significantly less circuit board space than existing commercial equivalents, the prototype displayed here is 80% smaller than an Adafruit Gemma and requires no additional components on the microcontroller board itself.

This is important in e-textile applications where a large size or additional rigid components can compromise the textile's properties of comfort and flexibility.

The small connector size and minor impact on integration mean that, when moving beyond the prototyping stage, the connector footprint may not need to be removed, and if it is, only a small change to the circuit layout is needed. The initial demonstrators also show that this methodology of flexible microcontroller integration and flexible connection point works with both couching into existing garment structures and integration during weaving.

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Conflicts of Interest: The authors declare no conflict of interest.

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