# Gold Tooled E-Textile Circuits on Bookcloth

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***Abstract*—Gold tooling is the process of applying gold leaf to the bookcloth or leather of a book's cover and is a long established technique within the book arts, an artistic field that encompasses a vast array of works, both practical and expressive, each centred around the book. Experimentation found that applied gold leaf has sufficiently low resistance ( 0.24 Ω/□) to be used for electrical interconnection. While soldering proved difficult, conductive epoxy combined with an adhesive underfill was electrically and mechanically sufficient for mounting components. This introduces the possibility of adding interactive elements to a discipline in which novel forms and functionality are common themes.**

***Index Terms*—Book arts, gold tooling, e-textile circuits**

## I. Introduction

Gold tooling is a long established technique within the book arts, a wide ranging field encompassing artist's works exploring the limits of the book's definition to conservation efforts designed to preserve literary works into the future [1]. Gold tooling is the process of applying micron thick layers of gold leaf to a surface and is used in book binding for titles and decoration on book covers [2]. Gold's colour, malleability and chemical stability allow it to be beaten into the thin layers needed for tooling while also leading to a desirable finished aesthetic that doesn't degrade with time.

Gold is also one of the most conductive elements, raising the question of whether it would be possible to use gold tooling to create electronic circuits. This work explores the possibility of combining traditional gold tooling methods with e-textile circuit building techniques to integrate functional circuits into bindings.

## II. A History of the Book Arts

The discipline of artist's book production begins in earnest at the start of the 20th century [3], but, as an art form, it is entwined with the history of the book itself going back much further than that.

The history of books as a whole extends to the beginning of recorded history, but the book as it currently exists, first took shape with the development of the codex, a series of folded leaves, sewn together and protected with some kind of cover, early in the common era [4]. Codices at this time were predominantly used by early Christians and were spread with the religion throughout Europe and the Middle East [5].

Paper, as opposed to earlier parchments, was developed around the same time in China [4], though only spread to the West after the fifth century CE, through the expanding Islamic Empire, which acquired the technology in central Asia, brought it through the Middle East and North Africa and from there up to Southern Europe.

At this point, books were mainly used for religious purposes. In Europe, this was producing copies of the bible and its exegesis [4]. Likewise in the Middle East, book production was mostly pursued as a way of recording the teachings of the Prophet Mohammed, in what would become the standardised Qur'an [5]. Though book keeping was also used for recording laws and other official records [6].

This period also saw rise of manuscript illumination, the process of illustrating the margins and parts of the text, which was used on up to ten percent of books, those holding particularly revered text or commissioned by wealthy clients [7]. This process would involve several people, specialising in outlines, colouring and in some cases gold gilding using gold leaf.

While in the West, gold leaf was being used for illustration, in the Islamic empire, more attention was being given to the book cover. Islamic bindings of the time were characterised by their leather cases that were decorated using a number of techniques including gold tooling [8]. This would go on to become a standard technique in 19th and 20th century western

bookbinding [9].

Over the following centuries, with the advent of the printing press, rising literacy and the start of the industrial revolution, book production expanded in scale and became increasingly mechanised and commercialised. It was against this backdrop that some of the first precursors to 20th century artist's books were produced.

In the late 18th century, poet and engraver William Blake began producing books of his poetry that he wrote, printed and illustrated himself. This was in part a cost saving measure but was also done in opposition to the exploitative industrial systems of the time which Blake opposed. He developed a means of printing, a reverse version of the intaglio process he had used as an engraver, to produce more than 10 publications between 1788 and 1820. Some consider these not to be true artist's books as Blake didn't bind them himself; the standard practice at the time was for books to be sold as loose leaves and then bound separately [3].

Other works that would feed into the artist's book include Stéphane Mallarmé's 1897 poem *Un Coup de des Jamais N'Abolire le Hasard*, was composed in response to the invention of the Linotype machine and its adoption for news printing. Mallarmé disdained the monotonous formatting of newspapers and was concerned about the effect large volumes of published news would have on literature. His poem used several different font sizes and spread its text out across the page, geometrically conveying the shipwreck alluded to in the text. The layout is aware of the nature of the codex it exists in, often using the seam between verso and recto to echos splits occurring in the text [4].

Similarly to the above examples, 20th century artist's books often sought to redress issues their creators saw in book or artistic production at the time. Some artists used books in an attempt to bypass the exclusionary gallery system; hoping that by producing work cheaply, in large editions, it could be made available to a wider public. The success of this approach has been questioned: the upfront cost of printing many copies was often prohibitive and the cost per item when producing smaller editions or manufacturing by hand meant that the results were not as widely accessible as desired [10].

Another example is Janet Zweig's *The 336 lines currently expurgated from Shakespeare's Romeo and Juliet in ninth grade textbooks* which examined issues of censorship, how the book can facilitate it and how books may be used to combat it [3].

Xu Bing's *Introduction to Square Word Calligraphy* examines the nature of language by using a system of Latin letters arranged so that they appear to be Chinese characters. This gives English speaking viewers an appreciation of the Chinese calligraphic writing system, but also gives Chinese viewers an unexpected sense of isolation upon encountering it [11].

Between the spaces of artist's books and commercial book manufacture, there are those whose bookbinding exists as more of an artisan craft [12]. This includes binders working professionally in small businesses as well as hobbyists such as those who practice fanbinding, a practice grown out of fanfiction. The practice functions both as a means of artistic expression and as a way of preserving works otherwise only available on online platforms which can be subject to censorship or have little commitment to archivism [13]. The economic models used in fanbinding are carefully tailored to the values of its community and the legal risks of commercialising transformative works [14].

## III. Materials and Methods

Experiments for this work were conducted on a custom bound book, made using the case binding technique. In this style of binding, the text block — the sewn together pages of the book — and the case — the boards and their covering which form the covers and spine — are assembled separately, then joined together. This technique was chosen so that the finishing on the case could be done flat, before being folded around the text block.

The process for a typical case binding is shown in figure 1. First the pages of the book are folded into signatures of four to six sheets which are sewn together using linen thread to create the text block. For larger books, linen tape or cords may be sewn across the spine at the same time, increasing the strength. The text block is then rounded and backed, a process that compensates for the extra thickness the thread introduces and ensures the spine takes the proper shape and involves carefully hitting the block with a hammer, before being glued to ensure stability.

The case is made by first cutting three sections of board, typically a solid board about 3 mm thick called binder's board or grey board, to the sizes needed for the two covers and the spine. The boards are laid with approximately 7 mm between them and the bookcloth or leather is cut to a size that will cover the whole area, with about 2 cm extra around each edge. The bookcloth is glued to the boards using PVA with the extra margin folded up and onto the inside.

Typically, the text block would be glued into the case at this point using the endpapers. These are sheets, twice the size of the pages, one half of which is glued to the inside of the cover, the other half being glued in a strip along the spine edge of the first or last page of the book. If tapes or cords were used in the sewing, these are glued to the inside of the covers, under the endpapers.

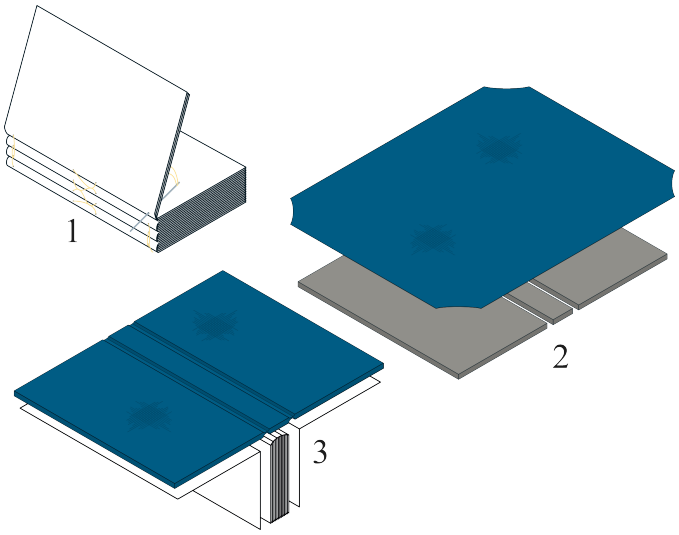


Fig. 1. The process of case binding a book

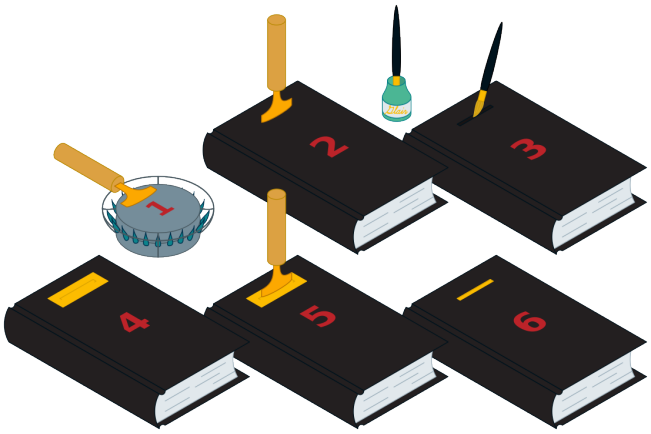


Fig. 2. The steps of applying gold tooling to a book cover

Once the book has been constructed, any designs on the cover are added. When this is done with gold leaf, the process follows that shown in figure 2. Initially, impressions in the shape of the design are made in the surface using a heated tool. This is done both so that when the gold leaf is applied, the pattern is visible and also to give a smooth stable surface for the gold to initially adhere to.

Next, a heat activated adhesive called glaire is applied to the surface. Traditionally, this is made from egg whites, though modern shellac based alternatives exist. The gold leaf is then placed on the surface and lightly pressed down at which point the surface tension of the glaire holds it in place. The heated tool is then reapplied, curing the adhesive and making the bond permanent. Excess leaf can then be rubbed off, leaving just the adhered pattern.

For large designs, this often has to be done in sections and multiple layers are often necessary to ensure complete coverage of a design.

For the conductivity experiments that form this work, two samples were made following the processes described above. The first, consisted of a minimal version of a case: a single spine – cover hinge and no text block which was used to test the reliability of gold tooled connections going over the flexible part of the case. The second was a full case bound book featuring a microcontroller, four LEDs and a push switch to test the feasibility of mounting components.

In both cases, Colorado Rayon bookcloth (FJ Ratchford, Stockport, UK) was applied to 3 mm thick boards. Tooling was done using 22ct, 13g gold leaf (Gold Leaf Supplies, Bridgend, UK). The text block prepared for the full book used 128 leaves (256 pages, A6) coming to a total thickness of approximately 13 mm.

The hinge was tested using the bend testing setup shown in figure 3 [15]. The fixture on the left is moved forward and back, across a range of 10 cm, with the other end of the sample able to rotate around the axle on the right. The maximum velocity of the moving end was 30 cm/s. A Keithley 2000 multimeter automatically measured the resistance along the track when each extreme was reached.

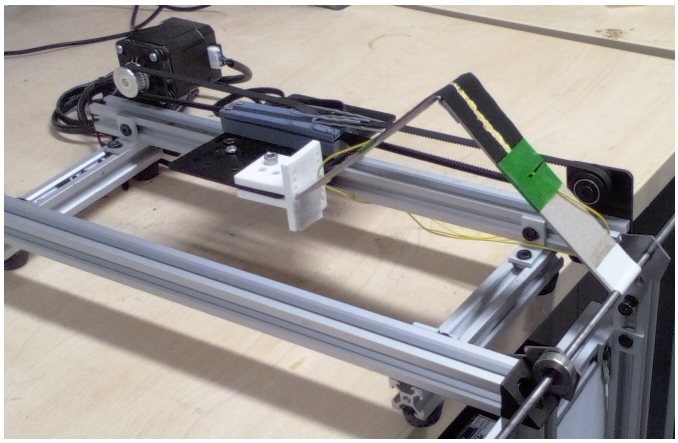

Fig. 3. Bending rig used for hinge conductivity testing.

In the case of the full book, because the tooling needed to connect the spine and the front cover, it was applied before setting in the text block. Additional strips of board were cut to provide support beneath the hinge cloth, allowing the necessary pressure to be applied there. These strips were then removed to allow the hinge to bend.

Due to the manual nature of the process, feature sizes (track widths and spacings) of 0.5 mm were tested. This made it possible to test 0603 and 0402 components and ICs with a pin pitch down to 1 mm. Finer details are theoretically possible; pallets and gouges, the tools used to create lines and curves, are available in thicknesses as low as 1 pt (1/72 in, 0.35 mm), but using them effectively requires far more skill than I have.

## IV. Results

The results of the bending test are shown in figure 4. The resistance of the track is initially 15.5 Ω when flat and 16 Ω when bent. This equates to a sheet resistance of roughly 0.23 and 0.24 Ω/□. Over the course of 1000 bending cycles. The resistance in each case had only risen by 0.2 Ω.

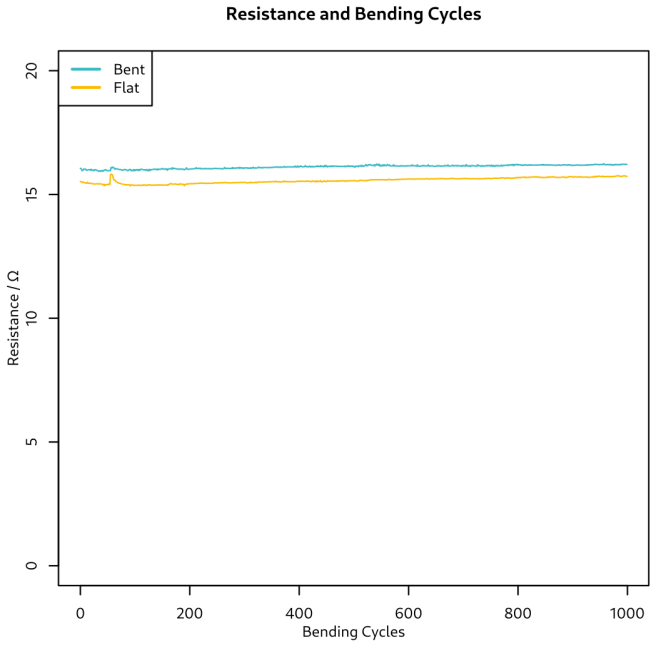


Fig. 4. The resistance of a gold tooled track at its most bent and most flat after up to 1000 bending cycles.

Initial attempts to solder to the gold traces showed that attaching components in that way would be impractical. While both the gold and the book cloth were able to withstand the heat of the soldering iron for long enough, the adhesion of the molten solder to the iron was stronger than that of the gold to the cloth. This made it impossible to remove the soldering iron without pulling up the traces. An alternative is to use conductive epoxy. In this case, Dycotec's DM-SAS-10030-ST silver based epoxy was able to provide a conductive connection for attaching components. Conductive epoxy has a much lower mechanical strength than solder, however this could be compensated for with an adhesive underfill. Applying Loctite 401 to the underside of each component provided the mechanical strength necessary to make conductive epoxy connections practical.

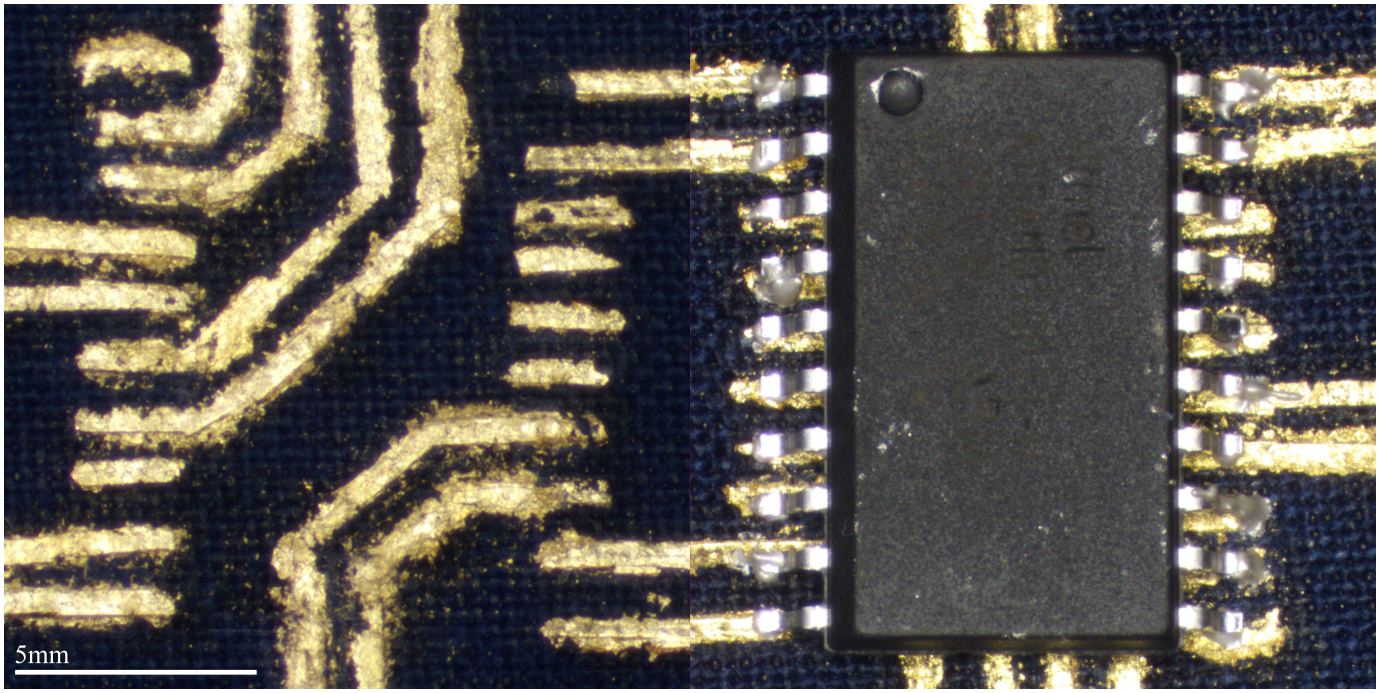


Fig. 5. The tooled footprint for an ATSamD10 microcontroller (left) and the conductive epoxy mounted chip (right).

Fig. 6. The complete, case bound book, featuring a microcontroller, four LEDs and a button mounted to the cover, with connections routed over the hinge between front cover and spine.

## V. Discussion & Conclusion

This work represents a first step in a new avenue for book arts. The ability to combine electronics with traditional book production enables exploration of the relationship between physical and digital literature.

The lessons books can impart about user interface design and human computer interaction are under utilised [16] and these techniques allow for an exploration of the book as an interface within the context of HCI.

The environmental impacts about e-textiles and electronics more broadly are of great concern. These issues stem, in part from a lack of awareness of the number and environmental cost of the components. By incorporating electronics into artistic or artisan works, viewers attention can be drawn to the components involved and the complex processes needed to combine them. This can be used to encourage a reevaluation of attitudes to other electronic devices.

Beyond this, the myriad capabilities of electronic circuits present a vast number of new options of adding functionality or expression to book bindings.

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