The introduction of electronics into jewellery design: an examination of priorities established throughout the design process

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THE INTRODUCTION OF ELECTRONICS INTO
JEWELLERY DESIGN: AN EXAMINATION OF
PRIORITIES ESTABLISHED THROUGHOUT THE
DESIGN PROCESS.

by

J. W. MORLEY

A Thesis submitted in partial fulfilment
of the requirements for the award of

Master of Philosophy

of the Loughborough University of
Technology.

1984
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I would also like to thank Stuart Hicking for all photographic material and Pat and Kate for proof reading and typing the manuscript.
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ABSTRACT

The research is concerned with exploring the possibilities of introducing active electronic circuitry into jewellery design. It is concerned with the cataloguing of functional and aesthetic decisions in two main ways. Firstly, those decisions relating to the combination of dissimilar technologies, this involves the discussion of appropriate materials, functional problems and the emerging technical aesthetic. Secondly, and implicit to this development, the detailed examination of the contexts in which solutions to problems emerge; the particular consideration of the extent to which these are defined by the technical problems, or organization of them to establish a particular emphasis in design.

The thesis catalogues these decisions in the development of five prototypes and illustrates through these the increased awareness gained during research of the elements limiting or contributing to eventual solutions. These factors include firstly, the intention to design jewellery as an expression of practical constraints. Secondly, to design jewellery as a symbolic response to the technology. Thirdly, the increasing knowledge of electronics gained throughout the research, and finally, the search for methods of modelling appropriate to the development of electronic jewellery designs.

The thesis concludes by discussing the degree to which these factors have been allowed to influence the five prototype designs, through the organization and negotiation of sub problems and the implications of established priorities on the emerging styles.
The possibilities of future developments are discussed indicating where new priorities might be established to produce new forms.

The research culminates with an exhibition, a record of which will be included in the thesis after submission.
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INTRODUCTION

The text of the thesis will consist of two identifiable emphases, the first descriptive of technical decision making and innovation, the second a development of philosophical points relating to my preference for the emerging visual alternatives by engaging in the former. Both elements are dealt with concurrently in order to identify through which aspects of emerging designs philosophical points arose. However, the reader will be guided by identifiable differences in the type-face, illustrative of these two main emphases. The thesis is written in the first person acknowledging an appropriate degree of subjectivity.

References to the material of others will be made where it is illustrative of principles and approaches emerging in the research. A number of architectural analogies are drawn which are also used to indicate the emergence of design priorities in the work. The choice of architecture as a parallel reference to electronic jewellery is on the basis of the presence of functional and visual components in each design form and it is in the illustration of emphases between these major factors that these analogies are drawn. All architectural references are well known.

I came to this research with experience of jewellery design and manufacture but none of electronics beyond an interest in its visual potential. My initial recognition of this can best be illustrated in the words of Peter Hinks:

There is something gem-like about the electronic paraphenalia of bulbs, fuses
resistances and the like, tiny ampoules of glass protecting minute whiskers of metal as though they were holy relics, ...(1)

Though these qualities were part of my initial interest my emerging preference was to incorporate active electronic circuitry and the notion of working in an area where some of the parameters would be defined by the electronic circuitry and others by purely visual priorities. It was in the belief that the balance established between these elements might generate new ideas, that most potential seemed to exist. The fusion of the modern technology of electronics with the traditional craft of jewellery making offered equally interesting technical and aesthetic possibilities.

My preference was not merely to recognise the qualities of these technologies in the work but to assimilate these elements and produce new forms.

I was aware that my unfamiliarity with electronics would bring problems in the early stages of research, whilst the advantage this represented was a unique view of electronics uninhibited by prescribed knowledge of assembly systems.

My research began by considering the links between the two technologies.
CHAPTER I

THE FIRST PROTOTYPE
1. Immediate potential

Possibilities combining decorative and functional requirements emerged prior to specific jewellery designs. The use of exposed silver wires to carry the electricity was perhaps the most significant. This idea seemed to offer the best possible balance or fusion of two prescribed elements to one purpose, and whilst doubtful that such a perfect fusion could be achieved with all elements, this provided a precedent in establishing an effective amalgamation of two technologies.

Use of silver as conducting material naturally led to the consideration of insulation which offered possibilities as decorative features and will be examined later in the context of actual designs. Plastics, Acrylic, Epoxy and Polyester resins all of which are used in jewellery for their decorative qualities and in electronics for insulation, offered exactly the combination of technical and decorative qualities I was looking for.

The wearability of jewellery had not been considered in detail. However, early on it became obvious that a similar balance between use and electronic elements could be achieved as seemed to be available between the electronics and traditional jewellery materials. I was already considering the combination of fastenings with the operation of switching pieces on and off.

Other early thoughts which appeared to offer possibilities, involved the use of 'fibre-optic' materials. Though a number of sizes, shapes and
colours of light emitting diodes were available, potential visual interest might be increased by splitting the light from a single source. Initially, I achieved this by use of 1 mm fibres interfaced with a 5 mm L.E.D. Seeing the possibilities I experimented with acrylic rod and sheet, producing a number of light guides interrupted by incisions which would allow some light to become visible on the light guide surface, (Fig. 1.). Experimentation revealed the most successful cut profile and led to the juxtaposition of dissimilar light colours down one rod.

The first jewellery design began to emerge when experimenting with the integrated circuits 555 (Timer) and 4520 (Dual Binary Up-Counter). The binary up-counter is capable of counting fifteen different binary combinations when clocked by the 555, which can be made visible by connecting four L.E.Ds to one stage of the counters outputs. In terms of light therefore, it can produce a combination of fifteen different light patterns from four light-emitting diodes. The circuit was developed and later reduced in components to a second version, which was facilitated by the low voltages used, (Fig. 2.). Due to the number of components and complexity of electrical connections I began to adapt this circuit for use in a 'neck piece'.

2. The Design (modelling)

The process of translation, from test circuit to visualisation of a working 'piece', produced difficulties unique to the subject matter.
Polished acrylic light guide employing principles of total internal reflection.

**Fig. 1** Principle of the Light Guide.
Fig. 2  Circuit Diagram (First Prototype)
The functional requirement of making electrical connections from the pins of the integrated circuits began to dominate, since without them the circuit could not function. In effect what was emerging was a three dimensional puzzle which demanded its own format for solution. My first attempts were on paper, but producing small scale drawings of the integrated circuits to establish the functional juxtaposition of parts, and then re-drawing the circuit a number of times to achieve a satisfactory visual impact, was time consuming in the extreme. Even with the aid of grids and isometric paper, the development of my ideas seemed inappropriate on paper at this stage.

The frustration of searching for ways to solve this problem led me to consider a number of alternatives. Drawing seemed fraught with problems, though the system of orthographic projection was designed to cope with complex three dimensional details.

Viewing the design from predetermined angles, as prescribed by orthographic projection, appeared to offer solutions to my problems. However, this was not a convenient approach. The mental processes necessary to form a complete image from three or more flat views of the design were too unwieldy for the ease of recording changes in the visual or functional emphasis required at this early stage of design.

An alternative which offered an attractive solution to this problem, from both visual and functional standpoint, was the use of a computer.

Two advantages seemed evident. Firstly a computer with sufficient power and resolution of image could
move my design into different visual positions, accomplishing a speedy solution to the normally laborious and demanding mental processes outlined.

Secondly, the idea of using a computer appealed to me, since there appeared to be a natural link with the area of technology I was introducing into jewellery. The three dimensional problems created by the necessity of separating wires of opposite polarity, seemed justification for using the computer in this unusual context. Though this idea was discussed briefly in the University, there were evident problems. My progress throughout the year was already partially dependent on gaining increasing confidence in an area unfamiliar to me. To introduce a further element at this stage would perhaps be unwise.

I adopted a three dimensional approach to the problem, where the third dimension allowed me to model clearly the separation of wires, which on a two dimensional surface would otherwise have looked connected. The 'mock-up' was made in copper wire to the dimensions I intended and the integrated circuits were made in wood, drilled and sprayed black to give a visual approximation of the D.I.L. packaging of such circuits. Working in this way allowed me to visualise a design and also to anticipate problems of manufacture in the final piece.

The illustration (Fig. 3), a front elevation of the three dimensional model, shows the complexity of the connections.
Fig. 3. Front Elevation of Wire Model
3. Selection of Materials

A number of problems from the model became evident which would not have emerged from design by drawing alone. Although technically the circuit would work and the visual quality was desirable, critical wires of opposite polarity could still come into contact with each other. This raised the question of either insulating wires with sleeving, lacquer, or separation of critical wires with 'spacers' of insulating material. The first two alternatives were not in my view appropriate. Sleeving the wire would cover a feature I wished to expose and lacquer, though allowing the wire to remain a strong visual element, is prone to discolouration and flaking. Thus, a light acrylic structure was adopted to both separate and strengthen wires by tying them together. This structure which by itself would be light and prone to breakage, would gain its strength and rigidity from the bonding of one structure to the other, (Fig. 4).

The acrylic frame became the means by which the piece was hung and the light bars which form the optical guide for the four L.E.D's became an integral part of this structure.

I hoped the fusion of visual, structural and electronic elements here would enable the production of a design of increased integrity, and an economy of form which the individual consideration of these elements might not produce.

Until this point I had assumed that the conducting wires would be made of silver, but other jewellery materials offered equally good electrical properties.
Acrylic Frame separates wires of opposite polarity.

Fig. 4  Front and End Elevations of the First Prototype.
and of these white gold offered a particular hardness and rigidity desirable for my use. For reasons of economy I deferred a decision on this and examined other alternatives. Nickel silver offered desirable structural and electrical properties and the yellowness of its surface and tendency to oxidise more rapidly than silver and gold, could have been avoided by silver plating. However, ultimately, neither electrical or structural qualities alone helped me to my final decision, but a third and equally important element of construction. Of the metals so far considered all become soft and ductile after heating.

Annealing temperatures are exceeded in hard soldering operations which means after complex wire structures are joined they would be soft. This would pose a considerable problem in design, since the rigidity I required could only be returned to the structure by work hardening, an operation out of the question in this design. The solution was to adopt the use of a silver, alloyed with small quantities of magnesium, (see Table 1) which hardens after specified heat treatment, (Table 2) and this hardness is not affected by subsequent heating operations. This silver is one of a number of special alloys developed by Johnson Matthey Metals Limited, its qualities being exactly what I required and its cost significantly lower than white gold.

Though the system of silver wire conductors was initially suggested by the package of the integrated circuit itself, the connection of the integrated circuits to the wire and other electrical components proved problematic. Direct soft-soldering (lead) to the pins of the integrated circuits posed three
<table>
<thead>
<tr>
<th>Material</th>
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<tr>
<td>Fine Silver (99.9%)</td>
<td>35</td>
</tr>
<tr>
<td>JMM 'N' Quality Hardenable Silver</td>
<td>60</td>
</tr>
<tr>
<td>Annealed Brass</td>
<td>61</td>
</tr>
<tr>
<td>Annealed Standard Silver</td>
<td>75</td>
</tr>
<tr>
<td>9 carat DF</td>
<td>120</td>
</tr>
<tr>
<td>Annealed Mild Steel</td>
<td>130</td>
</tr>
<tr>
<td>65% Cold-worked Standard Silver</td>
<td>130</td>
</tr>
<tr>
<td>JMM 'P' Quality Hardenable Silver</td>
<td>135</td>
</tr>
<tr>
<td>9 carat Hard White Gold Max Annealed</td>
<td>150</td>
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Table 1 - Comparison of Hardness (JMM Hardenable Silver)
<table>
<thead>
<tr>
<th>Thickness of Strip (or dia. of wire) mm (in)</th>
<th>Time at 650°C h</th>
<th>Time at 730°C h</th>
<th>Time at 800°C h</th>
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<tr>
<td>0.25 (0.010)</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>0.75 (0.030)</td>
<td>9</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>1.0 (0.040)</td>
<td>-</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>1.25 (0.050)</td>
<td>-</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>1.50 (0.060)</td>
<td>-</td>
<td>16</td>
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Table 2 - Minimum Times for Heat Treatment (J.M.M. Hardenable Silver)
problems. The first was the heat penetration to the microscopic circuitry in the plastic package. The second, a silversmith's reservations about the presence of lead and therefore the risk of contamination of silver should the silver's temperature subsequently be raised. The third reservation concerns the unwanted electrical discharge of some soldering ions through the tip which could cause damage to low voltage C.M.O.S. circuitry. After experiments to determine the viability of soft soldering (using 'earthed' 'heat sink' crocodile clips) to various degrees of success, a system emerged which appeared to present the most suitable working compromise. I chose to push-fit and soft solder tiny sleeves on to the legs of electrical components. On to these I sleeved small silver elbows which in turn had been silver soldered on to the main wire frame.

This system appears to work adequately allowing some components (for example the transistors) to be plugged in and out of the circuit. By using a system of two sets of sleeves, chances of lead contamination of the silver are also reduced.

The silver elbows have contributed a further visual element to the design which could have been more dominant had I elected to employ effects obtained as a result of sulphurdising tests to darken the silver (Table 3). As an alternative to this I used a glass fibre brush to texture these components.

4. Selection of Power Source

Towards the completion of the piece one fundamental
Table 3  
Colour Treatment of Silver

Dark Grey  
Solution: Potassium Sulphide (Liver of Sulphur K₂S)  
- ¼" cube  
Water  
- 1 pint  
Method: Dip into heated but not boiling solution.

Gold colour  
- also crimson, purple and brown -  
dependant on temperature of solution and length of immersion in solution.

Solution: Ammonium Sulphide (N.H₄S)  
- 1 G.  
Water  
- 7 oz  
(or: 0.5% Solution)
problem had yet to be resolved satisfactorily. This was the selection of a suitable power source for the piece. Though I was convinced that the cell technology existed, (partly as a result of experiments I had carried out) I was not entirely happy that an effective solution to the problem, as I desired, could be achieved.

Part of my unease in this respect stemmed from my lack of electronic experience.

My first experiments to test the operation of the circuit were conducted with two 1.5 v Alkaline Manganese batteries. The circuit worked well with these, but they were not considered for actual use due to their large size. Lithium and Silver-Oxide cells were also tried, both being designed for low rate applications in watches and calculators and not for the continuous higher rate demands I required. However, these button cells were an appropriate size and format for use in jewellery. Used in the circuit (Fig. 2) the continued current drain proved to be too much for them individually. Full load voltage could be as low as 2.1 v from 3 v cells.

Experiments with series and parallel connection proved to increase voltage and capacity, but the cost of using this power was a worrying factor, Silver-Oxide to an even greater extent, Lithium systems are expensive. Could I justify six to eight hours use at a cost of £3.00?

In the context of a mass produced article the cost of power at this rate would certainly be prohibitive.
However, the pieces were going to be individually made and would in a market context, through this factor alone, be expensive. Perhaps in this context the energy cost could be justified, but was eight hours operation time enough?

Following consideration of Silver-Oxide and Lithium, I considered Mercury systems. These are also available in button cells and still represent a small scale package appropriate for jewellery, though not in such high voltage units. However it was obvious from the variation between no load and full load voltages in previous tests, that series or parallel connection of such small cells was inevitable.

I chose to use three RM13H Duracell Mercury cells in series, nominally rated at 1.4 v each and having external dimensions of 7.9 mm diameter and 5.3 mm in depth.

Judging by the typical discharge characteristics quoted by Duracell (Table 4) and taking into account the higher rate demand I would require, each cell would operate at 1.2 v approximately, achieving a combined voltage of 3.6 v. At 5 mA this would provide 17 hours use at a cost of 30 pence per cell.
Typical discharge characteristics

<table>
<thead>
<tr>
<th>Current at 1.25 Volts</th>
<th>mA</th>
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<tr>
<td>500</td>
<td>2.5</td>
</tr>
<tr>
<td>1.25k</td>
<td>1.0</td>
</tr>
<tr>
<td>2.5k</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Hours of Service at 20°C

Table 4
The current in the circuit of 5mA could only be achieved by choosing carefully the light emitting diodes used. Standard red lamps operate at 1.5 v and typically at 10mA, before an effective light output is evident. Lamps are now available which are highly efficient at low current. Hewlett Packard, the American Optoelectronic component designers, claim brightness up to five times greater than standard units at currents as low as 2mA.(6)

Initial reductions in power to 3 v were accomplished by using integrated circuits of the C.M.O.S. rather than the T.T.L. type. Among the differing characteristics is the ability of C.M.O.S. circuits to operate at 3 v (in some instances lower) in comparison with the 5 v T.T.L. devices.

A running test of the circuit with three 1.4 v Mercury cells revealed new disturbing problems. The increased full load voltage caused a disproportionate current strain of up to 15 mA. This resulted in a running time of six hours only. It appeared that the reason for the circuit sinking more current with only relatively slight increases in voltage, was because of the disproportionate current to voltage curve of the light emitting diodes. Once identified the problem could be solved functionally by inserting a resistor to limit the current flow in the circuit. However the visual implications for the piece of jewellery which was almost complete at this stage, could have been significant, as the components in the circuit formed a visual balance which could be disturbed. Two alternatives were clear. To split the value of the resistor and place two new balancing visual elements
into the circuit, or find an area where the insertion of one more element did not destroy the overall visual effect. The latter course of action proved to be possible and a single 220 ohm resistor was incorporated into the circuit to limit the current drain to 5 mA.

The selection of a Mercury cell system enabled me to complete the design of the battery compartment. My intention from the beginning was to combine the switching of the piece with the fastening device at the back of the neck. This also proved to be the most convenient location for the battery compartment. I therefore sought one solution combining these three functional elements. Each had its own functional requirements. The fastening must locate the piece around the neck and must incorporate some locking or hooking device. Electrical contact is made at this point and so conducting material must be used. The battery compartment must provide location for three series cells, with good electrical contact between them, but clear insulation of opposite poles. The compartment must also provide loading and fastening in location, and removal of the cells.

Fig. 5 illustrates the solution to this problem. In adopting silver for the compartment one set of problems were solved, others created. Silver allowed integration of the case into the whole visually, but being highly conducting required careful insulation with a P.V.C. lining and acrylic insulator-spacer, to prevent contact of opposite poles.

The upper outer casing of the compartment is
Fig. 5 Fastening and Cell Housing. (First Prototype).
positive in polarity. Positive contact with the cells is made via a spring, soft soldered into the cap of the battery compartment. Negative contact is achieved through the elliptical pin at the base of the compartment, on which the cells rest and insulation from positive is accomplished using a black acrylic spacer.

The 'spacer' is also set at an angle to both reduce the possibility of a short circuit as the piece is being put on, and to ensure that the positive and negative halves of the neck piece are visually 'in-line'. To remove the cells, a pin is inserted through the centre of the negative contact pin, which also provides the male component of the catch. The female element is the keyhole component soldered to the negative half of the neck piece.

5. Design priorities

The most dominating elements in this design remain the integrated circuits which by their form suggest the arrangement of the wires which transmit the 'energy'. The packages which house the circuits are designed with ease of connection into electronic systems in mind. I have sought to achieve an alternative system suggested by components but influenced by their use in jewellery. Other components could have become visually dominant, for example, the colour coded resistors and capacitors. However, the overall quality of the piece could have been adversely affected by too many different visual elements. In this design I have allowed
some components obvious aesthetic qualities to remain anonymous by encapsulating them in epoxy resin and silver shells. In other pieces different visual priorities may be established. It is through this manufactured balance between the functional and visual that I am looking for new forms.

The problem of allowing enough articulation of the neck piece for wearability, at the same time preserving electrical contact for efficient conductivity from the battery compartment, represents another fusion of functional elements.

The visual lightness of the main circuitry indicated the choice of a light silver tube for the neck piece. Because of its lightness, hinging mechanisms had to be a larger scale to both prevent a hinge being worn through and enable an increased area of electrical contact.

Two sets of hinges were adopted, (Fig. 6.) (allowing the opening of the neck piece and its connection on to the acrylic frame). The circular shape and increased scale of these hinges allowed a visual 'tie-in' with the 'brushed' silver shells, covering the discrete components.

The functional requirements of fastening, hinging and electrical contact, in conjunction with the possibilities of the material itself, led to devices which owed some of their inspiration to engineering. Whilst some of this came about simply because of such a unique combination of requirements, my 'minds eye' preconception was that hinges and
Fig. 6 Details of Components. (First Prototype)
fastenings should take on an 'engineered feel'. It was my opinion that these forms would lend themselves well to the technical nature of the rest of the piece.

The devices were all handmade and, though borrowing from engineering, required less attention to tolerances normally found in engineering, but perhaps greater attention than many traditional jewellery or silversmithing techniques. Perhaps the battery compartment and fastening at the back of the neck best illustrate this. The pin and keyhold device borrows its inception from an 'engineering feel', but lends itself most appropriately to the hand making processes used in silversmithing. (Fig. 5)

I have tried to be careful in describing my priorities to point out that it is the surface quality, colour and sometimes form of components that I have hidden in order to control the visual appearance. In this sense my approach to this design could not be described as truth to material. However I have preserved, and indeed sought, to declare a truth to function.

The function of components is not hidden and can be recognised and understood from the open three dimensional wire frame. The piece visually declares the technology from which it has been evolved even though it bears little relationship to conventional systems of electronic assembly.

The integrated circuits are almost completely hidden but their dual in-line packaging is suggested by the parallel format of conduction wires.
The transistors are completely covered but their use and size dictate that they occupy a certain position in the circuit. As I decided to have the transistors visually in line as a group of four, this determined the path, spacing and shape (particularly 'end on',) of wires in the piece. Therefore the way the components work and their integration into a functioning whole has been the main influence in this piece.

In the same way, the functional requirements of the Pompidou Centre dominate its unusual visual appearance. Bryan Lawson, architect writing on design strategies says:

*The Pompidou Centre in Paris seems to have been generated by a concentration on the expression of practical constraints.*

This statement illustrates neatly the philosophy evident in its visual appearance and could also be applied to the design of this piece of electronic jewellery, though in both instances this does not reflect the basis for all decisions. Even where constraints are so dominant by necessity or choice, there are always decisions and choices available which are not generated by functional or practical constraints.

For example, how was the striking colour scheme of the Pompidou Centre chosen?

Even here, the colours could relate to coded functions of the exposed pipes, but I suspect that this did not relate so much to function as an aesthetic preference in the mind of the designer. In all approaches to design there are still large negotiable areas foster-
ing design which is purely the designer's personal response or exaggeration of features that already exist. David Pye, architect and industrial designer and for many years Professor of Furniture Design at the Royal College of Art, would call this the useless work of the designer:

Design is done to get results, but the useless work, the freedom of choice about what the thing designed shall look like, matters as much as getting the result and sometimes even more. (8)

These decisions are made all the time by designers and cannot be justified by quantifying their effect as one could by measuring effectiveness of function, but David Pye is in no doubt that there is an effect and that this work and these decisions are no less important in designing.

Where have I made purely visual, aesthetic decisions?

My use of electronics is ultimately for decoration and visual effect, 'useless' but not valueless.

The functional aspects of my design within the context are that the circuit operates and be seen to operate in terms of light patterns and that the system be wearable. I have chosen to express these functional constraints in the form of the piece, but even within this framework decisions were taken on a purely aesthetic basis. The integrated circuits were responsible for the parallel arrangement of wires back and forth, though they need not have been arranged three-dimensionally. The third dimension helps in spacing electrical connections but also
extended the purely visual possibilities in the design. In Fig. 7 the two bottom connections need not have taken such a long route to the positive rail (top). In Fig. 3 the front elevation of the model shows two curved wires (x and y). These emerged in that form purely as a decorative device at the model making stage. Many other decisions, to varying degrees of objectivity, were based on aesthetic judgement and not on functional requirement.

New technologies and the development of new materials bring forth new functional possibilities and practical constraints. Eventually, as their qualities become more familiar, they may give rise to new aesthetic possibilities and standards. If this does not happen and one adopted David Pye's evaluation of decoration, workmanship and aesthetic content of design, perhaps you could conclude that the technology itself is worthless. In the context, in which I am using technology, it is only useful if it not only fulfils a function but creates a range of desirable aesthetic qualities or visual possibilities worth pursuing. I suspect this philosophy could and should be applied to a great many other areas of design that by popular definition would be thought of as 'useful'.

6. Summary

It is attention to tolerances in fitting pieces together which has made this piece difficult and time consuming to manufacture and in no greater instance than the functional juxtaposition of wires carrying the electricity (and particularly
Fig. 7  Detail of Electrical Connections
their connection to the integrated circuits).

The scale in manufacture of the silver 'elbows' and other connecting and sleeving devices has proved time consuming, as has the necessity to solve many problems that were unique to me, on the workshop bench.

The fine electrical tolerances created by my insistence on small scale low power sources also created problems in developing this circuit. Had I not found manufacturers who produce low power, high efficiency solid state lamps, the piece would not have been viable at such low power. Increasing the power would not have ruled out the application of this circuit in jewellery entirely, but would have had significant repercussions on scale and visual form.

A great deal of time in this design was spent in adapting components to interface the electronics with the silver conductors. Discrete components were sleeved with silver so that they would push-fit into the circuit and though the form of the integrated circuits was retained, some 'surgery' on the pins was essential. The latter modification had to be carried out on a handling tray to earth potentially damaging static charges. Working the 'chips' in the vice, necessitated the modification of a multicored lead, adding small 'heat-sink' crocodile clips to earth each pin.

Perhaps I could be accused of over-adapting the electronic connections... This was certainly a significant drain on my time and at first I thought
these modifications would produce less than efficient contacts. However in the event this did not prove to be so and contacts appear to work satisfactorily. However, I shall certainly look at the possibilities of adapting already existing sockets in future pieces where integrated circuits might be used. Investigation into this for reasons of economy of time alone, would be entirely justifiable.

The circuitry used in this piece is not complex in the context of electronics, but is when combined with quite rigorous targets of scale and low power to be applied in jewellery. Certainly progress throughout manufacture was characterised by a continual solving of problems created by these demands. In my next piece I intend to use a simpler circuit which I hope will allow greater freedom for exploration of alternative forms. Perhaps greater experimentation with the formal of the conducting material, since this is always likely to form a major part of any electronic jewellery design.

From the point of view of the user, the piece might demand a little extra care. For example, it must never be placed on a metal tray in either operating or non operating modes since short circuit damage could occur. In terms of handling and wearability, I could have designed a little more strength into the piece where the neck piece meets the light acrylic frame. However the piece is not designed for all occasions or indeed regular wear and I feel the effects possible and visual forms that have emerged justify the inconvenience.

Whilst remarking on visual form, some of the
functional devices such as hinges and sleeving of silver wire with textured silver elbows have proved to be quite interesting visual devices in themselves and could be explored further, quite outside the context of electronic jewellery.

My early involvement led to some doubt that the effects possible in electronic jewellery might not alone justify this research. At this point I feel happier with the light effects that can be produced, than I felt I would be.

However it is the combination of a new technology with a traditional craft which can produce unique problems and interesting new forms, which continues to offer the most potential. To this extent I feel the pieces should justify themselves in the non operating mode.

The problems have already become more subtle in nature. My ideas are no longer initiated by the visual appearance of components, but rather by decisions about which elements should be allowed to dominate the form of a piece (which should be given visual priority).

What is technically possible may turn out to be a limitation on the range of light functions I can produce at this scale. However by varying the visual dominance of components, effective and interesting possibilities may exist in greater numbers than the technology alone might suggest.
Fig. 8  The Completed Piece
(1) Peter Hinks, Twentieth Century British Jewellery, Faber and Faber, London, 1983, p. 158.

(2) Johnson Matthey Metals Limited, Precious Metals Products and Services, 1980, Section 1805, p. 3

(3) p. 3


CHAPTER II

THE SECOND PROTOTYPE
1. The potential of reactive jewellery

An area of enquiry was established looking into switching to relate the electronic activity of pieces to either environmental factors or the movement of the wearer. Components are available that are touch or movement sensitive, or respond to environmental factors such as temperature and light. This seemed to provide another profitable area for investigation of not only 'active' electronic jewellery but pieces that 'react' to situations.

Though the concept was quite attractive enough to merit investigation, practical considerations of economy arising from previous research led to a more detailed examination than might otherwise have occurred. Previous ideas for electronic jewellery utilized fastening devices to complete the circuit and therefore turn pieces on. However this means that pieces are active continuously while worn unless their power source is removed. This is a significant limitation on the situations in which pieces can be worn effectively for example they would only be considered for evening wear since to wear them throughout the day would be an ineffective use of energy. Whilst the extended wearability of the first prototype is not really in question,(due to its delicacy and scale it would rarely be considered for anything other than evening wear), the viability of electronic jewellery could be extended by switching at previously defined periods.

Temperature sensitive devices (thermistors) could be used so that differences between indoor or outdoor environments could be perceived. Seasonal changes
would prove to be a difficulty in that differences in temperature between inside and outside environments would be less noticeable in the summer months. Nevertheless temperature related devices offered possibilities.

Light dependent components which couple switching to levels of environmental brightness appeared to offer far greater potential. Since the maximum effect of electronic jewellery which produces light is only fully evident in darkened environments, it seems wholly appropriate to have pieces 'turn off' when effectiveness would be minimised by bright or day-light conditions.

One of the prevailing difficulties in designing electronic jewellery has been the optimum use of small power units. The requirements for cells which are of a scale appropriate for use in jewellery has led to considerable constraints in designing pieces which will run for long periods of time at low cost. The potential of electronic jewellery 'reacting' to appropriate environmental circumstances in terms of purely energy conservation seemed a profitable line of enquiry.

To exploit the practicalities of 'reactive' jewellery I established that a number of devices familiar to me could be used. One such example was the 555 timer which could be exploited in touch sensitive circuits. The circuit diagram for this is shown in Fig. 9. Here the timer is activated by a very small static charge from the body which switches on a second circuit connected across the output (pin 3) of the timer and the negative rail. The period 'on' of the timer, and therefore the active time of the
Fig. 9  Diagram of the Touch Sensitive Circuit.
circuit this is used to switch, is determined by the resistor (RA) and capacitor (C) in the diagram.

Through initial investigations it seemed entirely possible to time a particular sequence of light effects, determining accurately the start and finish of the sequence. I envisaged using the complete sequence of fifteen light effects from the 4520 'up-counter' previously used and then have the circuit turn off. In practical terms this proved to be impossible for the same reasons that ultimately prevented the development of this circuit into a final prototype. The difficulties emerged from the very criteria I had determined were to 'activate' the electronic jewellery. The temperature of the environment in which the circuit was being tested proved critical and made the length of the operational time of the circuit impossible to predict. Hence timing of light sequence to the "last Flash" was out of the question. More serious than this however, was the discovery that small changes in voltage (the difference between full and no load for example) affected the touch sensitive area of the circuit. Lengths of wire used to connect both within the touch control circuit and to the circuit to be timed also affected dramatically the operation of the switch. Equally difficult to predict was the level of static charge in the body of the operator. After physical activity (as little as walking around the room), the circuit would switch satisfactorily; at other times the charge required would be too low. Many variations in the values of the components were tried, to stabilize to an acceptable level of predictability the reaction of the circuit. Though the circuit was developed to a point where it would work
excellently sometimes, it provided an almost impossible task in designing a final piece, where lengths of wires and values of components could only be determined in the actual piece.

2. The light sensitive circuit: The perception of pattern in the electronics.

The most successful reactive circuit developed at this stage was achieved using a light dependant resistor. This development accompanied the use of a transistor astable circuit as the light producing element. The circuit diagram is shown in Fig. 10. The astable produces its effect lighting two lamps alternatively. The light dependant resistor is part of a potential divider which allows the potential at 'X' to alter according to light levels. This in turn allows current to flow either through the L.D.R. or to the base of transistor 'Y' turning on the astable circuit.

With this circuit there are not two clearly defined states. As the current to the base of transistor 'Y' increases the gain of the transistor increases proportionally until maximum current is available to the astable.

The diagram of the astable component of the circuit, the numerical balance of devices and its operation, a balance of changing potential, began to suggest a visual approach to the design of a piece of jewellery. Equally dominant was my wish to experiment with the form of the conducting material, to move away from the use of wires and explore conductivity through layers.

Drawings and wire models were used to establish the
Fig. 10  Diagram of the Light Sensitive Circuit.
visual balance I was trying to achieve, reflecting the electronic function of the circuit.

Modelling and a particular style of drawing emerged again from the problems of working out final designs.

Models and drawings were both used, but because the circuit and number of components presented a less complicated whole than my first piece, I was able to adopt a slightly different system which both reflected the visual effect I was hoping to achieve and the necessary separation of critical conducting paths. This approach consisted of an amalgamation of conventional elevations with some of the symbols of electronic circuit diagrams. I can best illustrate this approach and its similarity with the eventual visualization of a piece in the diagram in Fig. 11. Diagram A is the visualization of the design and B is a development of the same piece showing essential electronic information.

3. Manufacture

The transistor astable circuit incorporating the light sensitive switch was eventually developed from wire models into flat shapes which could be pierced out of sheet silver.

The illustration (Fig. 12) shows this development and the attempt to achieve a balance which is almost symmetrical, reflecting by intention the underlying form of the circuit.

The separate shapes represent different layers of the piece and were drawn on tracing paper so that they could be laid one layer onto the next to model
Fig. 11

(A) Visualization of a Design.
(B) Visualization Combining Essential Electronic Information.
Details (A & B) of silver conductors.

Discrete Components sleeved in rectangular silver shells.

Fig. 12 Plan of Components (Second Prototype).
the separation of the conducting paths. In visualizations which had to be more complete than this to establish the final form of the piece, separate layers were represented by cross-hatching where the frequency of lines was increased for each layer. Ultimately a card model was made so that no doubt remained about the eventual functioning of the circuit. The model also allowed the facility of writing on it the connections to the electronic components, resistors, capacitors and transistors, ensuring correct polarity.

The overriding requirement that the visual whole should reflect something of the balance of the circuit initiated the decision that discreet components had once again to be sleeved. This time it was not appropriate to encapsulate them in the cylindrical forms previously used, but to fit in with a visual format which by now was firmly established, they were sleeved in rectangular tubular shells. These were made in two sizes to accommodate the difference between the capacitors and other electronic components. This in turn meant that to interface these components with the circuit, the conductive paths (silver layers) had to be different widths. This was not the only instance where the components influenced the visual form of the design. Transistors used previously were of the TO18 cylindrical package type, where the three pins are positioned in a triangular format. This was unsuitable for the layered design I had in mind. I knew that transistor packages existed that presented the pins in an 'in line' format and on this basis the 'E' line package was adopted. Had I not known of this package type, a design using layers of conducting material may not have developed however the position in line of the base collector and emitter of the transistor, entirely dictated the relative
positions of the layers.

The manufacture of the piece presented its own particular problems. The layers were pierced out of sheet silver and filed to shape with an accuracy demanded by the relative positions of the electronic components. Small pins were soldered on to the layers to allow them to be eventually 'plugged in' to components. The encapsulation of components and establishing the relative position of pins and sockets was an extremely difficult process. A transistor with sleeves soldered on to it was used as a jig to correctly space the sockets on the ends of component leads as they were encapsulated in the epoxy resin. The interfacing of two- and three-pin components demanded care to ensure correct separation.

4. **Summary**

As the piece took shape I was satisfied that the layered approach was producing an interesting visual form but worried that the scale of the construction was taking on a heavier feel than anticipated. The body of the piece was almost complete when I diverted my attention to other areas of research, in order eventually to return to the piece to make a more dispassionate assessment of its worth. Ultimately I decided that the piece would not be continued. I felt that I had achieved many of my intentions. The visual balance reflecting the underlying form and function of the electronic circuitry had been profitable parameters within which to work. A number of new working methods had been established. Experiments with different shapes of conducting
material had evolved into interesting possibilities which if not resolved here indicated potential for future work. Equally, new ways of modelling eventual solutions to both visual and functional electronic problems were explored profitably, revealing alternatives which might later be used in research. The eventual termination of the piece therefore, was a decision based entirely on my opinion that the scale and weight of the piece was wrong and for use in a neck piece as intended.

Its potential seemed more appropriate for use in other contexts.

If lightened visually it may have fulfilled my original intentions, but adaptation was now out of the question and my time could more profitably be spent in other areas of research.
CHAPTER III

THE THIRD AND FOURTH PROTOTYPES
1. Establishing new priorities (prototype three)

Having completed pieces of jewellery with electrical characteristics and complexities which determined to a large extent their character, I decided on a contrasting approach with a piece which originally owes more to the visual idea of technology than the constraints the electronic technology might impose. In short and to return to the architectural analogy used earlier, a design based less on the expression of practical constraints analogous of the Pompidou Centre, and more like an expression of forms which embody the 'idea' of technology, perhaps like the futurist drawings of architecture by Sant Ellia.

The choice of brief for the research and my initial belief that electronics would embody interesting visual forms was initiated to some extent by an already established interest in the visual manifestation of technology, quite apart from their purpose. I sought to exploit this interest free from the intricacies and constraints so dominant in the first piece.

The fact that the final piece looks as though it owes its inception to the study of science fiction is not coincidental, since science fiction itself is constructed from an idea or expression of futurist technology.

I chose to use a simple electronic circuit with components few enough to be subservient to my design requirements feeling that the symbolism of technology I wished to achieve would be enhanced by the inclusion of an 'active' electronic circuit. The effect of this
circuit would be visible but in contrast to the first piece, its generation would remain anonymous.

2. The electronics

The circuit I chose to use was based on the integrated circuit LM 3909 (L.E.D. Flasher/Oscillator), a device capable of producing pulses of over 2 v from a 1.5 v cell at a current drain of less than 0.5 mA. A very economical performance when compared to devices previously used. However its function is also more limited in terms of light effect. It is capable of flashing one or more lamps simply on or off simultaneously. The decision was made to pulse one lamp only but maximise this one light source by splitting it down an acrylic light guide, employing principles used before (Fig. 1). The circuit diagram is shown in Fig. 13. In addition to the components in this diagram I chose to add a further 1.5v cell to increase the supply voltage to 3 v knowing that the working characteristics of L.E.Ds allow them to be pulsed at much higher rates than they would normally be capable of for continuous running. As the pulse width of this device is very short the lamp will function satisfactorily.

The increase of a further cell was a determining factor in the size of the piece of jewellery. On this occasion two 1.5 v Silver oxide cells measuring 7.6 mm in diameter by 3.6 mm approximately were used. These are a more expensive form of energy than the Mercury cells used previously, but justified in the context of low current drain expected and the low volume to power ratio which would enable me to keep
**Fig. 13**  Circuit Utilising Flasher-Oscillator.
the scale of the piece small. Additionally the L.E.D. I chose to use was supplied by Stanley Optoelectronic Components and is one of their new family of Hi-Super Bright L.E.Ds, (1) with a higher luminous intensity than the Hewlett Packard Hi-efficiency devices previously used. The reason for using this considerably more expensive device was to maximise the effect of the flasher/oscillator unit.

These were my constraints, a circuit with dimensions which would have to be taken into account in the production of the piece but with fewer components, less complexity and therefore less dominant in the design process. However, inevitably the function of this small circuit would have influences on the resulting form.

3. Functional and visual priorities

The design of this piece of jewellery is illustrated in Fig. 14. It is difficult to establish what direct influences led to this design. It is not directly accountable to the electronic circuitry though undoubtedly the form exhibits a degree of convenience for containing it, as illustrated in the drawing.

It is impossible to establish the degree to which experiments with these shapes were influenced subconsciously by the demands of size, shape and function of the circuitry, (which I was at least aware of prior to the design of this piece). Difficult though such influences are to identify, they no doubt existed.
Fig. 14(A) Details of the Third Prototype

- LED & tapered light guide
- Silver Conductor to connect cells in series
- Cell Compartment
Fig. 14(B) Details of the Third Prototype

Details of Components.
Full Size.
Other functional requirements of the piece evolved as designing progressed. The semi-circular components (horizontal in front elevation) were originally developed as a visual device and only later adapted to become the means by which the bottom acrylic battery case could be removed. When the possibility of using this visual feature was first considered, I had intended that it become the switch and brooch pin. Though the usefulness of this component was developed and this in turn led to modifications of my original visualization, it was not initially intended to be a functional component.

These aspects of this piece illustrate the emphasis in my thoughts, concerned as throughout the work to achieve an economy and integrity of design by the combination of visual and functional elements where the chance was offered, but the initial conception of the whole was not consciously visualised around these. Indeed it could be argued that had I not adapted the piece in the ways illustrated to incorporate functional aspects, it would have been necessary to add further devices to the piece. These would have been noticeable 'add-ons' and as such a distraction from the visual effect intended. In this sense the combination of usefulness with the purely visual served to disguise the function and not express it as in the first piece.

The eventual combination of electrical switching and fastening of the brooch to the clothing was achieved as follows. The internal circuitry was linked by means of a small silver pin to the silver shell of the piece. The shell is therefore live in the operating mode. The brooch pin itself becomes a
conductor by virtue of its housing within the shell structure, and transmits the electrical charge back into the main circuitry via a small silver pin insulated by acrylic from the main shell. In no sense does the design visually declare that the pin is the switching device.

Subservient though the functional requirements are in this piece to a visual concept, they still demanded ingenuity through which they could be incorporated into the whole. The most difficult problem to solve technically was the incorporation within the piece of a battery case to house the two 1.5 v cells. The silver shell had in fact been made before this problem was fully solved (a risk, and evidence of my insistence on a particular visual form). The alternatives were to create a single cylindrical battery compartment housing both cells in series, (similar in principle to the compartment design in the first piece), or to look at ways of designing a compartment with the cells in series but in a 'side-by-side' position. The latter alternative seemed to offer the most economical use of the limited space. The use of coloured acrylic for the bottom of the silver capsule was an advantage in the eventual insulation of the compartment from the rest of the piece. The final design of the compartment shown in Fig. 14 consists of a box with the cells separated by an acrylic spacer with positive and negative ends of the two cells respectively uppermost. Contact from positive of one to negative of the other is accomplished by a silver sliding lid which serves the dual function of retaining the cells and providing enough downward force from the 'springyness' of the material, to ensure an efficient electrical contact. The positive and negative connections to the circuit
are through the bottom of the battery compartment, through two pieces of silver tube on to which silver pins have been soldered. These pins travel between two layers of red and green acrylic and emerge inside the capsule of the piece significantly away from other conducting material.

Initially it was my intention to allow the positive and negative connection wires on the bottom of the piece to be visible, since it was a feature with some visual interest. However the fitting of the battery compartment into the base of the piece necessitates the addition of a thin layer of green acrylic to cover this feature for reasons of strength. The only visible evidence of the battery compartment when the piece is assembled are the holes underneath each cell which have been opened out to allow the convenient removal of cells from the piece with the tip of a pencil or pen.

The importance of using the space within the capsule carefully was helped by inlaying the battery compartment into one layer of the base. However the remaining space was still small and necessitated the modification of the integrated circuit, 'slimming down' its dual-in-line package. After previous experiences with modification of components I had hoped to avoid this. In the event this was not a complex or time consuming process and left enough room for the electrical wiring and capacitor to be housed in the capsule.

The removal of the battery compartment is accomplished by the detachment of the acrylic base from the piece. Two silver brackets either side of the
silver capsule provide access, and the base is located on to the mountings for the brooch pin (Fig. 14).

Finally the light guide itself is channelled down the silver 'U' section and tapered both for economy of space and to provide a converging path to intensify the gradually weakening light source (Fig. 14). Electrical connections to the lamp are made with extremely small diameter single core plastic wrapped wires, on to which are soft-soldered small silver sleeves which can be push-fitted on to the anode and cathode of the lamp. All other electrical connections follow the same format allowing the removal of any length of wire or component within the circuit.

4. **Summary (prototype three)**

The shape of the light guide housing is another example of the indistinguishable link between the need to accommodate a functional element and a form pre-determined for its visual qualities. It is not obviously associated with electronics, indeed the whole piece is not, other than in its operating mode.

Possibly the use of the red and green colours give a visual hint, since they traditionally have electrical associations. However I believe the piece exhibits a technical feel analogous of aspects of our technological world which are obviously a strong part of my visual vocabulary. The fact that the piece was not evolved from rigorous abstraction of any particular source is perhaps an indication of how much I respond to the technical aesthetic and is arguably a further indication of the reasons for my
Fig. 15. The Completed Piece
selection of parameters for my work this year.

5. Consolidation of the new priorities (Prototype 4)

As with most of the work undertaken this year, the completion of one piece does not adequately illustrate the breadth of ideas either considered or generated before the process of selection has taken place. In each area of activity there have been by-products, visual possibilities, perhaps mistakes which could have provided endless hours of development which for the sake of pursuing my involvement with electronic jewellery have been shelved. Many of these ideas are developments concerning the recognition of possibilities of materials or forms quite outside the use of electronics. However occasionally ideas incorporating similar circuits to the piece being developed at the time emerge and offer profitable avenues of involvement within the parameters of the study. The ring design is an illustration of a case in point.

The ring incorporates exactly the same electronic circuitry as the brooch previously completed and is only modified in respect of a lower power requirement and the incorporation of a smaller lamp. In essence it employs all the same components and principles of design as the brooch. Where then is the development which justifies its inclusion in the study?

In retrospective consideration of the third prototype (the brooch), the most significant developments were the expression of a response to technology and the subsequent incorporation of the functional considerations of electronics and wearability, in a highly
pre-determined form. The ring embodies these principles but represents new challenges, particularly the problems of miniaturisation, storage and switching of the power source. (A particularly difficult assimilation of technical and visual elements). The emergence of the design in purely visual terms was a continuation of the forms used in the brooch. Shapes are re-orientated in a way still evocative of technology but complying with a heightening of demands made upon them by wearability.

The consideration of housing the electronic circuitry was not initially examined in detail beyond the assumption that it could be retained within the capsule which was a non-negotiable element of the solution image.

The eventual design evolved around a firm set of visual priorities well established in the brooch design. Again it would be difficult to identify to what degree my knowledge of the electronic requirements in terms of space and layout had on my initial visualization.

I can say that they were not consciously examined in detail until satisfactory forms were emerging. Proof of this lack of influence of practical constraints on the design at this stage emerged later when it became clear that a number of features would have to be removed or modified to allow the ring to work. The most obvious features were the removal of a curved cross member which would have obscured part of the light guide, (this was to be a purely visual device in the ring and owed its origin to the green and red cross member holding the battery case in
position on the brooch) and the deepening of the circular acrylic discs (analogous of cooling fins) to accommodate the integrated circuit.

These modifications did not threaten my solution image significantly enough to make them unsatisfactory, indeed the deepening of the acrylic discs improved the purely visual impact of the piece. This approach compares with the brooch, where some anonymity of functional demands was desirable so that the piece presented a visual coherence.

6. **Functional and visual priorities**

The design of the ring is illustrated in Fig. 16. The exploded drawing shows its component parts and the organisation of the space to incorporate the electronic circuitry.

Throughout the visualisation of the design I had assumed that the location of the light guide would be across the top opening of the silver shell. There were no problems in incorporating this functional element into the visual whole.

The light guide uses exactly the same principles of total internal reflection within an acrylic rod, used in previous pieces, but in a far smaller form demanded by the scale of the piece and enabled by a small high efficiency lamp from Hewelett Packard. The light guide is tapered over its length to intensify the light.

The position of the integrated circuit presented
Fig. 16 Details of the Fourth Prototype.
a number of considerations of which the insulation of the pins from the silver shell was perhaps the most important. A number of alternatives were examined, most employing the space within the shell vertically in some way. All methods required that the integrated circuit be thinned down and pins bent flat to reduce the volume of space required. Ultimately the vertical position of the integrated circuit was abandoned since space was being wasted on either side of it. Its housing in this position did not offer any obvious solutions for insulation of the pins in very close proximity to the silver shell. Both problems were resolved when the position of the integrated circuit was changed to horizontal, with the pins radiating from the centre of the ring. The shell dimensions alone could not accommodate the integrated circuit in this position but extra width could be gained by positioning it within the acrylic unit made up of discs, removable from the centre of the ring (Fig. 16). In visual terms it is not obvious that extra space has been gained. This is largely due to the use of clear frosted acrylic spacers between the main green discs retaining a lighter appearance than might otherwise have been achieved with an opaque colour.

This solution was ideal visually, had gained more space and immediately provided the required insulation of the integrated circuit from the silver shell. Space now available in the silver dome at the top of the ring could house the capacitor insulated from its silver surroundings with plastic sleeving.

The remaining major problem was the housing of the silver oxide button cell and integral to this
consideration, a method of switching the piece on
and off. A number of solutions were considered
including a device which would house the cell in
the side of the ring incorporating hinge and switch.
These possibilities whilst offering functional
features which could have been exploited visually,
threatened to become dominant and change my original
visualisation. The alternative eventually chosen
did not involve significant visual changes and was
adopted because of this.

The cell was housed at the bottom of the silver
capsule, between the integrated circuitry and the
ring through which the finger would pass. A silver
contact with a small pin soldered on to it was
inlayed into the lowest of the three acrylic discs to
afford contact between the negative pin on the inte-
grated circuit and the negative pole of the cell.
Positive contact is through a removable inner ring,
which both secures the cell in position and conducts
through the shell to a wire linking it to the positive
contact of the integrated circuit. The housing for
the cell is made of acrylic to insulate positive from
negative poles. When the ring is not being used in its
operating mode the inner ring is simply removed and
the cell released.

In the final assembly of the piece one completely
unforeseen problem arose. Though I established that
all the components would fit within the spaces I
had provided including an allowance for the volume
of wire, when the components were assembled, I found
that the wires resistance to bending made it almost
impossible to locate the components in their allotted
spaces. I had significant problems with this manag-
ing only to position components correctly to discover
a connection had pulled loose or broken off a component. Even at this advanced stage of research this illustrates an unnerving ability to overlook important factors, relating to the electronic content of my work. Eventually the components were re-wired using a thinner enamel clad copper wire, covering this with plastic sleeving to ensure effective and lasting insulation. The components were then located but by no means easily. Had I envisaged this problem the design of the ring would have been radically different. Alternatives might have included a "lift off" top allowing components and wires to remain undisturbed as access is gained. This system would have been preferable, and could have been employed with insignificant changes to the appearance of the piece.

The problems encountered here are unique because of the scale of the piece. It is illustrative of one extreme possible using integrated circuits manufactured in standard dual-in-line packages.

7. **Summary of new emphases**

Throughout the development of designs for the third and fourth prototypes the need to liberate myself from the constraints of the first two pieces seemed important. I could justify this since the parameters for my research were entirely self-generated. The change in emphasis was to create a context for design, which would allow greater freedom to respond to a fusion of jewellery with the idea of technology and not entirely the working demands of electronics. Though an individual approach cannot fail to be
evident in any piece of work, whatever the constraints, ultimately I sought more control in establishing the solution image. This gave me something identifiable to work towards and was probably a need created by the challenge to my confidence initiated by the unfamiliarity of electronics. It is interesting however, that in supposedly creating greater freedom our perceptual system immediately seeks to impose a new order and ultimately a new set of parameters within which we can work. It is through this highly individual process that our preferences and influences become particularly visible.

The pieces of jewellery initiated by liberating them as far as possible from at least one determining technology, reflect therefore an assimilation of features owed to a more general technical aesthetic. These are obviously part of my visual vocabulary and might be regarded as symbols of technology. In his book 'Thoughts on Design', Paul Rand says:

It is in symbolic, visual terms that the designer ultimately realises his perceptions and experiences and it is in a world of symbols that man lives. (1)

In so far as there were some self imposed intentions to make a visual statement about the influence of technology, this could be regarded as a symbolic constraint. Where the priority of intention to symbolise or express a particular influence exists in design, other constraints often become subservient. Symbolic design involves us in measuring practical constraints against our visualisation. If the two do not match, one of two things occurs. Either the visualisation is discarded completely as impractical,
or is modified without destroying the designer's image. This process occurred frequently throughout the evolutionary stages in the brooch and ring, where modifications had to be considered in order that they would work or be wearable. These remaining practical constraints were the only ones that could not be ignored within the parameters of electronic jewellery. Had I failed to incorporate these functional elements into the design in a way that did not interfere with the established visual emphasis, the design would have been abandoned. As it was, they were incorporated without appearing to be additions and, where modifications were necessary, they did not interfere with my solution image.

Whilst I have had the freedom to change the emphases in design in the ways described, some areas of design and particular problems will inherently suggest constraints. However, even in architecture an area of design which, broadly speaking, has to meet the needs of the client or user, practical and internal constraints can become subservient to the wish to generate symbolic associations in external appearance. Perhaps an excellent example would be the design of the Sydney Opera House, where many practical constraints were considered after the external form was generated. The design owes more to its visual association with sailing than to many other possible determinants of form.

Both the brooch and the ring represent an approach which I feel could be adapted to a more robust and general use of electronic jewellery, remaining individual but presenting less challenges to the wearer than the open wire structure of the first prototype. Additionally, these pieces can be handled
and enjoyed through this handling in a way the
delecacy of the first prototype would not allow.
This was a factor in my decision to develop this
particular approach. The constant handling in
manufacture was a welcome and satisfying experience
not present in the first piece.
Fig. 17: The Completed Piece
(1) Stanley, *Optoelectronic Components*, Catalog No. EB2-1, Japan, 1982, p. 1

CHAPTER IV

THE FIFTH PROTOTYPE
1. The circuit design

The fifth prototype was initiated by an investigation into the potential of counter-decoder circuit (40178). Reasons for assuming a piece using this device would be worthwhile were based on experience gained using the binary-up-counter in the first prototype. This counter was used to produce fifteen light combinations using the principle of total internal reflection in acrylic, to provide light mixing when lights of different colours were on simultaneously. The effect was pleasing but embodied inherent difficulties in terms of the available power. These difficulties were not understood at the time. The demands on power varied according to how many lamps were on at any one period. Since this could be anything from one to four, the full and no-load voltage variations were greater than I would have liked.

It would have been possible to increase the capacity of the cells to accommodate this variation, achieving a higher rate capability but only at the expense of increasing the size of the power unit. I was not prepared to do this and ultimately had to sacrifice some effectiveness of the piece for a scale I found acceptable. The results of voltage variation were evident as numbers of lamps on increased, causing the light output to decrease. This was an unavoidable 'trade-off' in the first prototype and was inevitable to some degree within the parameters of the available power and the light mixing effect desired.

The proposed use of the counter-decoder did not present the same problems.
The device can be used to light ten different lamps but unlike counters designed to produce binary patterns, it lights each lamp individually.* This makes the question of current drain from small power units a more predictable and controllable element. However, one could justifiably argue that the effects possible using this are limited, or less exciting because of this. Certainly this was a consideration but a limitation I was happy to work with, looking for other factors to increase the visual interest.

Speed and switching were two elements I adopted to increase interest in the effect possible. From earlier research into coupling the response of electronic jewellery to environmental conditions or wearer activity, I became interested in the use of mercury switches. The notion of positioning a mercury switch so that the piece would be on for approximately 50% of the time appeared to have potential. Movement or body position could activate the switch for long or short periods determined entirely by the wearer. If it was possible to turn on the piece for only very short periods of time, in order that the effect be noticeable to any greater extent than the flash of perhaps one or two lamps, the speed of the counter must be relatively fast. This was entirely possible electronically by

* It is possible to source more than one light emitting diode from each output of the device, or wire the integrated circuit into the 'sinking' mode which would light up to ten lamps simultaneously.
setting the high and low time of the timer in the circuit using appropriate values of capacitor (C1) and resistors (R₁ and R₂) (Fig. 18).

Figure 18 shows how this piece eventually evolved. It uses the familiar format of the 555 timer to provide the 'square edged' trigger to the counter. Component values were adjusted for timer speed and operation at 5 v, a higher voltage than previously used.

The selection of a more powerful battery was based on my gradual appreciation of the difficulties of working at three volts which is theoretically the lowest voltage at which most C.M.O.S. integrated circuits will work efficiently. Five volts would accommodate voltage drops across the integrated circuits and light emitting diodes without threatening the effectiveness of the light output. This decision had to be paid for, its cost being the increased size of the power source which would have visual and weight implications to be solved later on. However with knowledge gained of electronics throughout the research, I now recognised that it was better design practice to select the power unit at this early stage. (Something that didn't occur in the first prototype and subsequently caused unforeseen problems).

The power unit selected was the Duracell PX27, nominal 5.6 v, with capacity of 150 mAh at 5v (Table 5)(1). My intention was to run the L.E.Ds at 5 to 6 mA which because of the high efficiency lamps used, would provide a bright display. This resulted in the circuit in its entirety sinking no more than 8mA. If the piece was to run continuously, which of course it would not because of the mercury switch, it would run for approximately 19 hours.
Fig. 18  Circuit Diagram (Fifth Prototype)
Typical discharge characteristics

<table>
<thead>
<tr>
<th>Ohms</th>
<th>Current at 5 Volts</th>
<th>Hours of service at 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1k</td>
<td>5 mA</td>
<td>15</td>
</tr>
<tr>
<td>2k</td>
<td>2.5 mA</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 5
Experiments revealed that I could run the L.E.Ds at between 2 and 4 mA for quite an effective light which meant that the overall current drain would only be 5 to 6 mA. This would allow 25 to 30 hours battery life. I decided against this economy for the sake of effect, particularly as the speed of effect I desired might not be so obvious at lower light output.

The increase in voltage had implications for the circuit design which contrasted significantly with the design of the first prototype. Transistors were used from each output to increase the available current to the lamps, but unlike the first prototype it was necessary to limit the source current from the counter-decoder to the manufacturers recommended output current. This was not necessary in the first circuit due to the extremely low voltages used. The implications of this for an eventual jewellery design were that I could have up to ten additional resistors to accommodate visually. Also it would be normal practice to limit the current flowing through the lamps using series resistors (the possibility of more components).

My first reaction to this was to consider using resistor networks, compact enclosed plastic packages containing four or more resistors of the same value (sometimes available in the same dual-in-line format as the integrated circuits). However the introduction of resistors in such package formats whilst representing a considerable saving in space, threatened to reduce the flexibility needed to orientate components in a satisfactory visual whole. Equally the idea of more small black plastic packages represented a degree of anonymity of function that I was not willing to accept. Part of my problem was solved when I discovered
capability of the device should be used. This became quite a severe and unexpected limitation on my thinking. I had unknowingly defined the parameters within which an eventual design could emerge. It is perhaps unusual to be limited by the extent of a device's capabilities, it is more often the limitations which give the designer problems.

Electronically there was no particular reason for setting the circuit to count ten identifiable stages and by simply connecting any one of the circuits outputs to the reset pin the circuit will count up to any pre-defined number between one and ten. This flexibility was eventually recognised and used in later stages to the final prototype.
2. The parameters of the problem

Inevitably the format of this report may indicate to a greater extent than was actually so, a separation of the development of the electronics from the visual designs proposed. Whilst this had to be so to some degree to establish some predictability in component numbers, it was not unusual for the electronic components to be changed in package style to fit a particular visual image, or indeed for the extent of a circuits capabilities to be revised as an overall design emerged. A case in point was the recognition that perhaps a number of the outputs of the counter decoder need not be used in a more successful rationalisation of electronic effect and visual layout of the piece. Making these changes I realised how firmly I was holding on to notions of just what sort of problem it was I was involved in. It was a shock to realise that the way I had defined the problem had become quite a severe limitation to my progress.

This was very important not least because the whole study was initiated by setting my own parameters. Thus a careful examination of my constraints within the problem, particularly those self generated 'to find a way in' to designing (a quite legitimate way of establishing 'land marks' to make a start), seemed to be essential.

Could I be objective enough to establish the parameters within which I was designing? If so was I happy to remain within them or had categorisations initially adopted for convenience become so dominant that I should relinquish them?
In the fifth prototype, I had accepted the upcounter-decoder as the functional centre of the piece, the associated electronics were developed in the ways described in the preceding section. The limiting parameters of the electronic circuitry were accepted since I hoped and was searching for a solution that would be an expression of these. This may have been the basis for failing to question the extent to which the device should be used, but generally these constraints were acceptable, even desirable.

Early in the consideration of an approach to the design of the fifth piece, I had established a preference for an open wire conducting structure, similar to the first piece. How influenced I was by a degree of success already achieved working this way and not willing to establish quite such new and challenging territory late in the study, might also be factors to consider.

I prefer to refer back to the very strong image established at the beginning of the study of a perfect fusion between the visual qualities of jewellery materials and their excellent electronic properties, as still being the most dominant factor in the choice of format. It is true to say that I wanted to continue to explore this way of working incorporating features which might represent functional improvements including a little more emphasis on wearability. Equally some conclusions drawn from the completion of the first piece were not entirely resolved. I wanted to re-look at the adaptation of components, about which I expressed concern earlier in this report, particularly the possibility of using existing sockets for the integrated circuits. From this point of view, the exploitation of a wire format, since
this was what had initially thrown up these problems, seemed completely appropriate.

The format imposed on the piece through the exploitation of the circuits light capability was perhaps another area where parameters were unwittingly established and accepted. The use of acrylic light guides to the same principles assumed throughout the research was undoubtedly an influence strongly assimilated from successful use in previous pieces, but not consciously adopted as one of the constraints in the design. Alternatives using the light in various ways were considered. The potential of the light output from the electronics, its single, sequential operation, presented opportunities for creating the impression of movement within a piece. Also the possibilities of creating a three dimensional light effect or one doubled by the use of light reflective material, were considered. These ideas were given a low priority for reasons of scale, particularly the depth required within a piece to create an effective result. Similar limitations postponed a more thorough investigation into the potential of optical fibre. Though these practical limitations were significant it was probably the acceptance of other priorities such as those described in the previous paragraph, that appeared to make developments on this area less important than they might have otherwise been.

The dangers implicit in the acceptance of the parameters of a design problem can be great, if they are not continually re-examined. Once established it can be difficult to remember that many if not all, are of the designers making and can as such be re-defined. Bryan Lawson, architect and psychologist, refers to
the pitfalls of such classification of problems as
the 'category trap'. Comparing the initial percep-
tion of design problems with the analogy of establish-
ing one's position in an unknown forest, Lawson says:

Initially the real secret of good
designing lies in how to begin search-
ing the forest as it were, so as to
piece the whole together. The designer
is always on the lookout for ways of
simplifying or subdividing the problem
in order to make his task more manage-
able, but there are many pitfalls or
traps for the unwary here. (2)

3. The identification of sub-problems

Becoming more aware of alternative approaches to
problem solving, it was easy to be led to the
assumption that a specific amount of time and honest
effort must lead to solutions. This of course is
not the case. Design still involves large amounts
of time which appear unproductive, where time and
effort are frustrated by lack of perceivable pro-
gress. Progress actually made during these apparently
fallow periods is difficult to assess and if this
were possible the negative effects and feelings pre-
sent whilst undergoing them could be dispelled.
Progress towards a fifth prototype was indicative of
this, and in order to establish why this was so I
have had to examine my approach within the parameters
established in the previous section.

The problems presented were very similar to those
inherent in the first piece of jewellery, but my
approach to them was identifiably different in a number of ways. This difference was partly due to a growing awareness of approaches to the solution of problems in design in general terms and partly due to a knowledge of electronics (albeit still immature) which had not been present at the beginning of my research.

My first piece was the result of looking for order where initially I found it difficult to perceive any. Also I had some notions of what electronic jewellery could look like but certainly fewer than I have now. These factors characterised an openness in my approach which with some pieces behind me and problems satisfactorily solved, could no longer exist in quite the same way.

The patterns generated by the ways electronic components are combined were not obvious to me at the beginning of research, nor could I recognise the underlying form or logic in the electronics. My initial process of design therefore consisted of picking out elements as they presented themselves and not obviously working within recognisable sub-patterns and problems which became characteristic of my later approach. The fact that pattern is perceivable in the form of the first piece is evidence of the strong influence of functional constraints within which I was working and my ability to assess sub-problems as I was dealing with them. It is interesting to note that in the evaluation of the first piece I had become aware of and able to identify the design problem with some perception of its parts.

The increased appreciation of patterns that are
inherent in circuit design, is now a large part of the framework through which I perceive current design problems. Once such knowledge is established it provides the means by which sub-sections of the problem can be identified and analysed working through these until the complete picture is assembled. Whilst this approach is of enormous value and a legitimate approach to designing, there are inherent dangers which must be acknowledged.

The electronically established pattern of output, limiting resistor, transistor and lamp respectively, was one such pattern or sub-section in the fifth prototype which could be negotiated separately. Functionally it could be analysed in terms of keeping critical wires separate and visually to achieve a satisfactory visual impact, before other elements within the whole need be considered (Fig. 19). Another identifiable element which immediately suggested possible visual pattern was the essential linking of all collectors of the transistors to the positive rail.

Whilst this approach can be useful and sometimes the key to successful resolution of the many component parts of a design problem, it can foster its own severe limitations. Bryan Lawson is an advocate of the value of 'land marks' and subdivisions of problems using understandable features in order that more sense can be assimilated of the whole. However, he identifies traps which can occur in over defining the parameters of such problems. He calls these the puzzle trap. The nine dot, four line problem is illustrative of the pitfalls of this type of thinking. Presented to students, they often over define the parameters of the puzzle to the extent of precluding any possible solution (Fig. 20)(3). Effectively this
Fig. 19 Pattern in the Electronics.
Join all the dots with only four straight lines without lifting the pen from the paper.

Fig. 20 Nine Dot, Four Line Problem.
involves looking for solutions within the boundaries formed by the nine dots. However the puzzle can only be solved by escaping these self-imposed limitations and looking outside the pattern. A further trap inherent in the identification and subsequent solution of sub-problems is that success with any one of the pre-defined parts might inhibit their eventual combination into the whole. If the designer has a solution to the problem of one part he might be reluctant to relinquish his success which may ultimately be necessary to fit together the parts. Lawson illustrates this with the jigsaw puzzle test (4). Students are presented with two puzzles separately from which they must make two squares or rectangles. When this is accomplished the students are asked to combine the pieces of both puzzles to form one square or rectangle. It was discovered that students often had great difficulty in relinquishing the success achieved with the two separate puzzles, which they must, to achieve one successful solution. Obviously problems within design are rarely so clear cut but the examples illustrate the degree to which our thinking can become inflexible, simply as the result of over prescribing our problems. Referring to the identification of sub-problems as a design strategy, Bryan Lawson says:

Such a technique is undoubtably an excellent way of getting to grips with a problem so long as the designer remembers that the original assumptions which defined the puzzle were of his own making and are therefore open to question later. (5)

It is therefore very important to analyse our own implicit rules and boundaries in order to avoid the traps of over defined problems, initially continued merely for convenience.
4. Negotiation of the sub-problems

The identification of sub-problems within the many elements proposed for the fifth piece initially provided me with a more sure footed approach than was present at the outset of my research, but from a confident start, frustration accumulated when as discussed earlier, time and effort were not rewarded with acceptable solutions to my problems.

In the previous section the elements within the problem that were obvious enough to be negotiated separately were identified. The idea of using existing sockets for the integrated circuits prompted a fundamental acceptance of certain positions for these quite different from the position in the first prototype. Because of the increase in depth of circuit plus socket, they were positioned back to back with pins in line with the intended length of the piece (Fig. 21). This did not present problems in itself, in fact it initially offered a number of advantages. For example the wires from the outputs of each chip, were facing away from each other which offered distinct advantages for the eventual separation of exposed wires of critical polarity. From a visual point of view, the idea of two circuit modules had potential.

The established sub-section to the electronic problem of output, limiting resistor, transistor and lamp (indicated in Fig. 19 by O,R,T and L respectively) and its subsequent negotiation in both visual and functional terms, gave rise to the pattern illustrated. The 'E' line transistor package was selected in order that collector base and emitter would occupy different
FIG. 21  First Design (Fifth Prototype).
levels within the piece. This format contributed to the functional separation of wires and to the visual pattern illustrated.

It was still my intention to use all available outputs of the counter decoder, to light ten individual lamps. My thinking was limited by this for some while, associated with it was the notion that the light effect from these should be visually sequential forming a running pattern within the piece. As the outputs of the integrated circuits were on two different levels and not in sequential order, the intention of creating any pre-defined light pattern, whether it be sequential or symmetrical presented enormous problems of potentially crossing wires. My attempt at negotiation of this problem can be seen in the copies of sketches which are the mapping of the output wires of the transistors to their conclusion, in the lighting order indicated by numbers 0-9 (Fig. 22).

After some attempt at resolving the problem, I re-defined its parameters so that a more profitable way forward could be established. I decided that the non-negotiable element of the problem was the open exposed wire structure. This as indicated in the previous section was a strongly held part of my approach established when the potential in electronic jewellery was first being assessed.

The result of establishing this priority was the emergence of a symmetrical pattern in the wiring of the outputs which ironically produced an asymmetrical or random light effect. Although the visual symmetry represented a logical order which I
All wires at X originate from the outputs of 4017B. Numbers indicate lighting order of LEDs.

Fig. 22  Mapping of Wires (Fifth Prototype).
found initially satisfying, on repeated returns to the drawing board, I was not sure if I liked it or not.

Even though the front elevation (Fig. 21) does not indicate the levels defined by the position of the integrated circuits, which admittedly add an element of interest, I was beginning to feel the problems I had identified had over rationalised the design to the point of anonymity. At this stage of the design the feeling was not as clearly formed as the previous paragraph indicates, but was sufficient to make me re-assess my priorities and constraints, particularly in response to other problems emerging.

The different levels of the output wires within the piece began to create problems which were noticeable as the result of model making. It was becoming clear that my adherence to principles adopted to guide me in to the design were producing more problems than solutions. From a purely visual point of view the depth of the piece was unsatisfactory. It was exaggerated further when the vertical resistors (the only position that these could be incorporated into this format), were placed into the model. Equally there were problems of mounting the transistor cases into an acrylic supporting structure intended to create stability and ensure spacing of wires. These problems were made more difficult by the negotiation of two different levels.

It was clearly the time to re-negotiate some of the implicit boundaries that had led to what was now an attempt to combine incompatible elements.

By this stage in the design process, I felt a solution
had almost been reached and for a long time I resisted the thought of alternative approaches until I felt the battle with the problems was an unproductive one. It may have been possible to complete the design but with doubts that the visual effects were less than those I hoped for, I began again. As Bryan Lawson says:

The designer is on the horns of a dilemma in that he cannot expect to arrive at an integral synthesis of all the needs of a problem until he has a comprehensive grasp of the constraints. On the other hand he is unlikely to appreciate many of the constraints until he begins to propose solutions.\(^{(6)}\)

David Pye illustrates this further:

When we modify our prototype, it is, quite flatly, because we guessed wrong. It is eminently true of design that if you are not prepared to make mistakes, you will never make anything at all. Research is very often a euphemism for trying the wrong ways first, as we all must do.\(^{(7)}\)

5. Summary: Re-definition and solutions of sub-problems

In retrospect the position I had adopted for the integrated circuits was perhaps the most significant constraint, yet the solution of two problems previously encountered in the first prototype by adopting this format, made it hard to relinquish, as were other parts, successfully negotiated in isolation of the whole.

The re-think involved my return to the pattern
established in the first prototype, integrated circuits with pins uppermost. As a result of this it was unlikely that ready made sockets would be used as their size would foster larger dimensions than intended. However this immediately solved the problems of output being on two different levels even though they were positioned on opposite sides of the integrated circuit.

Problems of allowing enough space for resistors which in the plan of the discarded design were accommodated by creating a right angle bend from the outputs, were incorporated into the three dimensional nature of the wire frame. Output wires initially quite close together were taken the length of the piece, angled in end elevation and passed back under the integrated circuits in parallel format, but with increased space between them.

In order to create a focal point the light guides were to be positioned as near as possible over the inverted integrated circuits. Light production was not an inflexible parameter to my re-definition of the design problems, but the central position eventually assumed created a pattern in the wire structure which also added to the visual effect of the piece. In a sense this was a re-affirmation of the open wire frame approach to electronic jewellery which had always been strongly held.

The perception and identification of electronic form in the relationships between output, resistor, transistor and lamp, was still important but applied to a new framework, resolved itself in different ways. Because of the numbers of resistors and transistors, their positions had to be rationalized so that
their visual impact was not too dominant. In the case of the transistors they were effectively combined with an acrylic component which would support the light guides, some of the wires, the mercury switch and an acrylic bolt which was to become both a visual feature and the means by which more security could be built into the wearability of the neckpiece (Fig. 23).

The mercury switch employed was selected for its visual interest, in that it was encapsulated in a clear package so that the mercury movement was visible. The size of the component threatened to be more dominant than I wished, but the spacing of acrylic supporting veins between the transistors provided just the device to incorporate the switch into the whole, allowing it to become partially anonymous.

At this point in the design process the working potential of the counter-decoder was reassessed. As stated earlier, implicit in the use of the device was its potential for producing ten light outputs. As drawings were produced of the format that was eventually to be accepted, my only reservation was the number and density of the wires. This could only be resolved by increasing the scale and therefore opening the structure out, or as was initiated, the removal of a number of the outputs, lightening the visual feel, resulting in less wires and components. Once realized this modification was accepted since I felt the light effect would not suffer extensively. Throughout the research I have been willing to compromise on light, if the visual quality of the piece over all has been improved. Six out of ten outputs were ultimately utilised (outputs 0-5). Their positions though not
sequential were conveniently grouped and added to the resolution of problems within the piece.
Fig. 23 The Completed Piece
Fig. 24  Detail of Fastening and Battery Case


(3) p. 156

(4) p. 158

(5) p. 157

(6) p. 152

CHAPTER V

CONCLUSION
1. The recognition of design constraints in the determination of style.

While a number of self generated constraints were analysed and re-defined when their limitations in providing usable solutions were realized the text illustrates where other parameters remained and were central to the work that emerged. Many of these constraints were born out of principles I regarded as so strong that I had no wish to challenge them. The example I have used of this throughout the text is the adherence to exposed silver as the main electrical conductor, which features to some extent in all prototypes. There were others, the assimilation of both electronic and functional elements into one rationalized whole was also a perspective throughout. This can be illustrated by the switching of pieces related to their attachment to the body. In the case of the brooch, a pin which would both secure the piece to the clothing and switch it on by providing an electrical link. The neckpieces are activated by the device which secures them to the neck and in which the cells are housed. Where other devices were needed to hinge or join elements, I have sought to express their function within the context of the piece.

These were constraints self-generated and adhered to throughout. In addition, midway through research, other emphases emerged which help illustrate my initial choice of electronic jewellery as an area for research activity. I can illustrate this using the words of Anton Cepka, a Czechoslovak sculptor and jeweller whose work I admire:

The fantastic precise calculation and inventions in any scientific field of the over technicalized world of today
contain something special, apart from their purpose, which we have to take for beautiful. (1)

The judgement implicit in his use of the words 'over technicalized', is a view that I would not necessarily subscribe to but his reaction to technology and his symbolic expression of it, acknowledging the aesthetic of technical things, is a view I understand and sympathise with.

The brooch and ring are almost entirely expressions of technology which are the result of sensitivity to and enjoyment of a technical aesthetic.

Earlier in the text in more close discussion of these designs I indicated that they were not born put of specific abstractions of mechanical or scientific devices, but were, I assessed, more general manifestations of these influences on me. I refer to this again to illustrate how strong this influence is and to suggest that this may have been the motivation for choosing electronic jewellery for the area of development this year.

While the two identifiable areas of electronic jewellery to foster working prototypes were born of a different emphasis in the constraints, both reflect a search for a technical aesthetic. The designs of the first and fifth prototypes evolve largely out of an expression of internal and practical constraints. The third and fourth prototypes of brooch and ring respectively, are a symbolic expression of technology where working constraints have been suppressed to a greater extent, in the interest of working towards a strong solution image.
What all show very clearly can be illustrated by Bryan Lawson:

We have seen that constraints whatever their function, radical, practical, formal or symbolic can be used as generators of form. How they are actually used, in what sequence and with what emphasis is what differentiates one designer from another. [2]

It is important to acknowledge that constraints are not always of a designer's making and whilst my parameters have been initiated entirely for the purposes of this study, the need for designers to meet certain needs are constraints in themselves.

Even here the evidence of one architects work differing from another in a similar situation, none perhaps so marked as when they compete for the same commission, illustrates the different emphasis placed on manipulation of the same constraints. David Pye illustrates the freedom to be found within the design of 'useful things':

When any useful thing is designed the shape of it is no way imposed on the designer or determined by any influence outside him, or entailed. His freedom in choosing the shape is a limited freedom, it is true, but there are no limitations so close as to relieve him or the maker of the responsibility for [3] the appearance of what they have done.

What I believe has emerged from this research is an appreciation of a designer's manipulation of constraints imposed or self-imposed. Among those self defined will be some implicitly accepted without question nor objectively identified, which will assume an importance to the designer regardless of whether he is totally
aware of this or not. This I think gives rise to a style which is not a flippant change of fashion but something that evolves from highly internalised ways of working and an inevitably unique view of problems.

While some constraints may be consciously manipulated to provide new perspectives (a knowledge of this must be a worthwhile pursuit for any designer), others will be so internalised that the degree to which they are being exercised can never fully be established, but these are arguably the most valuable ones, since they are the mark of the individual, the design personality, the style.

David Pye suggests that style is another constraint:

It can be argued that design has invariably exhibited styles because some clear limitations on freedom of choice are psychologically necessary to nearly all designers. When design gets too easy it becomes difficult. Styles provide these desired limitations ...

The identification of style in the context of David Pye's words, could easily be mistaken for something which is recognised, perhaps in the work of others and ultimately something that is sought. What I refer to is style which is unavoidable, the individuality which cannot be repressed, even when the minimum condition for the design of a 'useful' object are stipulated. I accept David Pye's assertion that style becomes a necessary psychological constraint on choice particularly in a completely open situation, but would question whether this applies to 'nearly all designers', as he states. I do not think it can be avoided.
2. 'Modelling' as a determining system in design

In discussion of parameters to designs established or emerging throughout the project, it is important to remember that the drawing or modelling of solutions was another determining system which added to constraints in design. I have referred to this element of the work in the text where it has been relevant to the progress made in particular prototypes.

The question of appropriate 'modelling' techniques which could be used to develop and record ideas occurred initially in the evolution of designs for the first prototype and again in the second and fifth. The source of the problem was the effective representation of ideas where both electronic function and visual effectiveness of pieces had to be considered together.

Limitations of existing drawing connections took on new significance where the crossing of lines could indicate serious electronic problems. This was negotiated in three ways. The first was the use of three dimensional wire models to check electronic viability and visual interest. The second alternative, was to incorporate into conventional elevations some of the electronic drawing language which models the separation of critical wires. Thirdly, the use of tracings to differentiate levels of activity within pieces.

The second alternative relies on an amalgamation of established conventions within technical drawing to resolve problems. It would probably be possible to extend this idea to the creation of a drawing system to cope with the complexities that the separation of
critical wires would demand.

The problems inherent in this approach are that it could require so much mental agility to continually translate the established system into a working reality, that ideas might be lost. What was needed with each of the prototypes were ways of rendering ideas which would lend themselves to change as quickly as ideas occurred not systems that would demand reading and interpretation through which at best, ideas might be limited by the constraints of the system, or worse, lost in 'reading' and interpretation.

Elements of this approach were successfully applied to the touch sensitive circuit. Here the circuit was relatively simple and a mental image of the working and visual requirements could be negotiated simultaneously.

The third method employed was the use of tracing paper to model layers of activity within a piece and was extensively used in designs for the second prototype. Though a layered appearance was implicit in my aims to experiment with the conducting format within this piece, it is undoubtably true that the system within which the idea evolved, determined to a large extent its eventual appearance. The 'flat feel' of the piece owes something to its development on paper and through the perspective of one elevation in particular.

The first and fifth prototypes owe their initial format to a front elevation drawing to explore the visual potential from what would after all, be the predominant view of them in use. Whilst wire model making solved practically all of the problems of simultaneously coping with the electronic function and visual effect of
these pieces. the problem here was that in comparison with methods of working out ideas so far illustrated, the freedom was so great that limitations had to be imposed in order to establish a starting point. The option of having the third dimension to work out the ideas, actually provided too many alternatives and there was a tendency because of this to solve some of the problems in a more limited context. This ultimately and ironically was often a return to two dimensions where perhaps certain details could be considered. This may also have been another reason why key visual priorities were established on paper before models were actually made. In no instance throughout this research is there a better example of the principle that where few constraints exist they are manufactured by the designer himself.

The influence of three dimensional model making in the prototypes however, was considerable and many visual devices, bends, angles and changes of direction in the wire prototypes, were as a result of exploiting the third dimension. It is true to say that the systems employed to promote the development of designs, influence eventual solutions. As Bryan Lawson says:

\[
\text{Drawings and models then can impose their own grammar on the designer's thought processes...}(5)
\]

David Pye takes this one stage further arguing that drawing instruments themselves are determining systems in design. Our use of them for convenience in particular operations, makes us susceptible to their influence.
3. Establishing priorities in the emergence of a technical aesthetic.

The initial interest in electronic jewellery has been examined and references to an interest in a technical aesthetic, referred to throughout the text. It is not surprising therefore that the work of other jewellers I admire exhibits a degree of interest in technical things. Peter Hinks in his book 'Twentieth Century British Jewellery' identifies these aspects in contemporary work in a sub-section entitled, 'Science Fiction and Space Age Technology'.

All those jewellers he groups together within this classification reflect with different emphasis some aspect of our technological world or future. In describing Eric Spillers work he uses the words:

... bangles of multicoloured discs neatly bolted between hoops of bright metal. Almost precision engineered.

Referring to the work of Joel Degan, he uses evocative imagery describing:

... tiny ampoules of glass protecting minute whiskers of metal as though they were holy relics, ...

Beyond the scope of Hinks book on British Jewellery, there are other jewellers whose work both reflects and suggests strong associations with the technological world. The work of Claus Bury and Fritz Maierhofer exhibits influences analogous to engineering. German born Bernd Swegebrecht draws his inspiration from industrial landscapes, oil refineries or science fiction. All are responding in visually sensitive...
ways to their individual perceptions of the technological world in which we live.

The visual impact of technology is important, in David Pyes words:

All the works of man look as they do from his choice and not from necessity.(9)

The argument earlier in the text was, that given the same sets of constraints designers will evolve different solutions, even where a similar result in terms of use was intended. The implication here is that large parts of things designed to get results are negotiable. This negotiable element is perhaps the best indication of a designer's expression of preference and style. It seems to me therefore, that it is not unreasonable to search for beauty in technical things. Whether we will find it depends on the sensitivity of the designer and the perceptual process of the onlooker.

The work of the artists so far considered shows they have found this beauty and have sought to express it. My sympathy with and involvement in this aspect of technical things, had already been illustrated and is I think evident in aspects of my work.

There are however artists and designers who recognise a technical aesthetic not only in the ways things look but the way they work. These people include in their work devices which perhaps owe their inception to the search for particular results. Removed from the contexts in which these devices were evolved they still generate considerable interest. Perhaps the most general affirmation of this phenomenon is the
long standing fascination of model engineering or the commercial explosion over the last ten years of executive toys. The work of kinetic sculptors and jewellers has exploited this interest. Fredrich Becker is an interesting illustration of this. His perception is obviously and inevitably related to his early studies in aeronautical engineering before his apprenticeship as a silver and goldsmith. He says of his own work:

I have worked on kinetic jewelry since 1965. My efforts consist of pieces of jewelry which record, reinforce and transform accidental movements on the part of the wearer into new and differentiated movement configurations. (10)

The visual elements in his work are extremely simple and geometrical, relying on the movement generated by the wearer to bring them to life. Becker isolates small engineering systems and makes them work for effect and not as they were originally intended for some pre defined use.

Here there is a parallel with the development of electronic jewellery, particularly those pieces generated from an expression of working and practical constraints. The evidence of the electronic circuits working potential is produced in terms of light effect. There is no intended result other than an interest generated by its performance and its being. In different contexts these circuits are components of systems which are designed to get particular and useful results. In the jewellery the aesthetic created by the exposure of a system that merely creates an effect and the evidence of this potential displayed in light are the important things.
Harder to explain is the importance of knowing that these pieces perform in their various ways even when the evidence is not visible, i.e. they are turned off. Though I hope the pieces have a visual interest in the 'off mode', it is very important to me that they are working systems. I am sure that there is an interest inferred by the knowledge that things work.

Perhaps the numbers of people who enjoy looking at and working with technical things, is evidence of this. It is interesting that people are perhaps more inclined to look at things that are systems designed to produce a result, (perhaps in museums), than forms generated without this sort of pre-requisite (for example most sculpture). Perhaps the knowledge that systems produce effect, is important to us even when the effect is not useful as in the jewellery. It may be that the effect helps us perceive the organisation and order in these things (an underlying form).

There is another parallel I wish to draw from Fredrich Beckers work. He designs pieces of jewellery which in his words:

... consist of pieces ... which record, reinforce and transform accidental movements on the part of the wearer into new and differentiated movements on the part of the wearer into new and differentiated movement configurations. (11)

There is undoubted interest in systems which not only perform in some way but react to changing circumstances. Though the parameters of such reactions are well defined by the designer, the suggestion that a system has achieved some 'life' beyond this control is great. My interest in 'reactive' electronic jewellery is
particularly due to this phenomenon though there were also good economic reasons for exploring these ideas. There is also a manufactured relevance but non-the-less an appropriate one between the wearer and the movement of the jewellery in Beckers work, this is another area that has proved to have interesting possibilities in electronic jewellery. The fifth prototype incorporating the mercury switch, is the only piece that reflects this approach, though sound transducers could be equally effective in responding to the wearers speech.

Mary Scherr an American jeweller is concerned with the functional possibilities of jewellery. She has created belts and bracelets that contain crystals to detect air pollution and necklaces that monitor the wearers heart-beat. Many of these are collaborative works with electronics and chemistry experts. It is clear that her intention at least in part, is to design useful objects. However, the pieces are illustrative of a new significance through this organisation of her priorities. What I think is particularly interesting is the imposition of functional constraints on an area of design traditionally free of any pre-defined need to achieve results (other than a moderate degree of wearability). Throughout discussions of how designers work within constraints particularly where they are determined to some extent by getting pre-defined results, I have been anxious to establish the degree of freedom that still exists in decisions about what the thing designed shall look like. Mary Scherr's work may well be perceived as something of a reversal. Perhaps in no other instance does it become more obvious that approaches to design rely entirely on assuming particular sets of priorities, not just in the solution of design problems but as illustrated in this section, the creation of a desirable aesthetic.
4. **Future development**

Though my own priorities were well established throughout this research, this has not prevented me from recognising other departure points and emphases that could have been pursued.

The following are examples of thoughts that have occurred during the research. For example, it might be possible to produce a circuit board composed of transparent plastic on to which a thin layer of silver could be bonded. This could subsequently be etched using standard electronic working methods. The visual potential of this would seem to be very promising but careful investigation into glues and appropriate plastics would have to be undertaken.

Throughout the research I have become aware of materials that have suggested ideas in themselves. Conducting glue and paint might suggest ways of working in less permanent ways using paper and card. An idea analogous to the heaters on rear screens of many cars suggested the sandwiching of conducting foil between layers of heat sealed polythene. This could perhaps be developed in a fashion context.

There appears also to be more potential in the use of light than has so far been exploited. Use of reflective material would certainly seem to be a worthwhile departure.

Quite apart from these ideas, the pursuit of a technical aesthetic through a number of non-electronic devices adopted during the research offer many possibilities of articulation, hinging and fastening.
which have their own inherent interest.

To establish new forms I recognise I must adopt a new emphasis in my priorities and through this new constraints, generating new sub-problems.

The reasons that more variety has not been adopted in my approach has been due to two main factors. The first is undoubtably time. I have been genuinely surprised at how long it takes in David Pyes words, 'trying the wrong way first'. (12)

Equally dominant and perhaps related to this has been the establishment of a style which has been to some degree successful. It is difficult often to relinquish an approach which has been found to work. The influence of the known is very great and combined with pressures of time, perhaps I became less experimental than I had initially intended. However the known can never be entirely left behind, nor should it and I have been happy to take this new knowledge and emerging style to generate other prototype ideas in what has turned out to be a gradual development rather than a series of experiments, (I feel the former is infinitely preferable).

My interests for the immediate future are still governed largely by a desire to refine the approaches already initiated. This is perhaps a reflection of a personal trait to establish a high degree of control in my work, not an altogether worthy reason. Certainly more important to me is to strive for a combination of the two approaches to yield working prototypes. I feel there is a lot of potential in
both the expression of practical constraints largely fostered by the electronics and producing three dimensional images evocative of technology in a more general sense. Each approach would seem to benefit and reinforce the other. Within these criteria it would certainly be my intention to make pieces a little less challenging to wear. The first and fifth prototypes are extremely experimental and have limited wear-ability because of this. Coupled to this I remain very interested in the linking of electronic effects with environmental situations or wearer activity. The potential for this generated in the research that is as yet unused, is certainly worth pursuing.

5. Evaluation

Throughout this research the unknown element of electronics has helped make visible many of the choice and preference points exercised in the design process which may have remained un-rationalised had I worked from an entirely familiar skill base. The hypothesis that the combination of the dissimilar technologies of silver and electronics and the contrasting priorities inherent in creating working systems in jewellery (a highly visual form), have produced the tension sought. I believe this is evident in the prototypes.

It would be easy completing such a study to be 'glib' about the discovery of a way of approaching design problems. In a sense the more we categorise and identify both advantages and disadvantages of approaches, the more we might be inclined to seek and accept an approach as the definative way. In the context of design activity identification and rationalization can appear to become more finite then they
really are, taking on an importance that can be misleading.

The real importance is the recognition of many approaches to design. Forearmed in this way, we can increase our capability of generating new perspectives on design problems that do not readily yield to our attention. Because of elements in designing that cannot be explained, design remains an activity where we have to try many of the wrong ways first. The ability of being able to shift our attention increases the chance of making the right association, recognising an unusual analogy, perceiving a previously ignored pattern. Ultimately the more ways we can propose solutions the better designers we are likely to be.


(4) p. 35.

(5) p. 166.


(7) p. 158.

(8) p. 158.


(10) Ralph Turner, p. 112.

(11) p. 112.

(12) David Pye, p. 27.
GLOSSARY OF TERMS

CHIP      Integrated circuit

C.M.O.S. Complementary Symmetry Metal Oxide
Semiconductor (Integrated circuits, used throughout this research, whose working qualities include performance at low voltages, typically 3 v).


Discrete Components Components packaged individually, e.g. resistors, transistors, diodes etc.

I.C. Integrated Circuit.

L.E.D. Light Emitting Diode.

T.T.L. Transistor Transistor Logic. Integrated circuits with robust qualities but only operating above 5 v.
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