FUSE[1] Consortium

MANAGING SUBCONTRACTORS

IN FIRST TIME USE OF MICROELECTRONICS

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INTRODUCTION

In the first time use of any technology, particularly microelectronics, companies are well advised to subcontract some or all of the critical portions of the project to experienced professional design consultants. There are a number of advantages, including a minimisation of risk, since the experienced professionals are responsible for the most difficult problems, and better technology transfer, since the First User's[2] own technical staff can learn from the same experienced professionals. It is important that the First User carefully manages the interface with the design subcontractor[3], from the outset of the project, and should allocate time for that purpose. The comments apply equally to independent design houses and those who are tied to a manufacturer or foundry.

THE BENEFITS

The benefits of working with an experienced subcontractor when introducing a new technology into a product or process are very considerable[4]. Most obviously, the subcontractor can carry out tasks that require skills or other resources that are not available within the First User's company. Because of their relevant experience, the subcontractor will be quicker, more cost effective, more reliable and produce a more 'professional' result, than the First User. The First User can also benefit from the subcontractor's experience in choice of technology, in specifying the new product, in choice of other subcontractors (for production or testing, for instance) and in planning the project [See AE357 for instance]. The First User's staff will learn by working with experts.

The First User may chose to outsource (or subcontract) many different aspects of the project. Where the company has no prior knowledge of microelectronics and the technology step is large, it is quite

[1] FUSE is an EU programme to promote increased use of microelectronics in European manufacturing companies.

[2] In this document a First User is a company which introduces a microelectronic technology for the first time into its product or production processes. The first user is the client who contracts a subcontractor to do some work.

[3] The subcontractor is a company that has contracted to do work for the First User.

[4] The First User in AE 357 says "External expertise is essential if an SME wishes to expand into a major new technical area". See also the comments from AE1403 in the appendix.

common to subcontract much of the design and production. On the other hand, where the technology step is smaller, the subcontractor role is often limited to that of advisor or consultant on the novel aspects. In some instances two or more subcontractors are used, with one in the advisor role and others doing the main design or production. [See AE 410, 2212]. The net effect is that the First User can save great amounts of time through the judicious use of subcontractors. Because outsourcing can be so important to the success of a project, the First User must manage it carefully.

THE RISKS

A development project can go wrong in three ways, namely 1) the final product may not meet expectations, in terms of performance or manufacturing cost, 2) the project may take too long to complete, resulting in the First User missing sales opportunities and 3) the project may run over budget. If any of these happens the company loses valuable time and money. In fact, the problems can be so severe that the whole project is cancelled. There is no way to guarantee that none of these unfortunate outcomes will occur. With careful management, the risk can be reduced to acceptable levels [AE 418]. The purpose of this document is to give advice to the First User on how to ensure that the subcontractors are not a source of these problems.

In the experience of the FUSE programme, the major risk factors are:

1) Insufficient specification of the product at the start of the project
2) Over-optimistic project plans which don't allow for delays
3) Technical difficulties which could not be anticipated at the start
4) Subcontractors who are themselves over-committed and cannot apply all of the resources that they had originally planned. Often this is a consequence of delays in prior projects, or an underestimate of the technical difficulty.
5) Poor contingency planning.

The first user and subcontractor should plan together to make sure that these problems do not arise, and should have specific contingency plans for dealing with them if they do. The first step is to choose the subcontractor carefully.

SUBCONTRACTOR SELECTION

First Users are advised to get design quotes (proposals) from more than one potential subcontractor [see AE 240 for a discussion on subcontractor selection]. This helps the First User to get the best value for money. Apply normal caution to any quote that seems exceptionally good value. Has the subcontractor underestimated the size of the project? The First User will suffer, at least in lost time, if the subcontractor underestimates the difficulty of the project. Apply similar caution if it appears that only one subcontractor is capable of doing the work at a reasonable price, as this means that you have no contingency plan if this subcontractor gets into trouble. For that matter, you have the opinion of the other companies that it cannot be done!

It is difficult for a First User to assess the relative technical competence of design houses in a discipline where the First User, by definition, has little expertise. The First User can ask to see C.V.s of the staff who will manage or work on the project. Have they designed something similar, using the same specific technology? It also helps if they have some experience dealing with the First User's industry. Some First Users (e.g. AE29392) employ a special subcontractor whose role is restricted to technical management and take the advice of that company in choosing the subcontractor who will carry out the main design work or production tasks.

The First User should ask the subcontractor to provide names of clients who are happy with the work that they have done. Check with those companies how the subcontractor reacted when difficulties arose in the project - did they try to solve the problem or did they try to blame someone else? If ‘design support’ is a significant portion of the service to be provided by the subcontractor, it is very important to ask their existing clients if they think that the ‘design support’ has been satisfactory. If more than one subcontractor is involved - one for design say, and another for manufacture or characterisation - then check that they can work together. It is very difficult to resolve a conflict where two subcontractors blame each other for problems on the project.

When selecting a subcontractor, make sure that they are not (and that they will not become in the future) potential competitors to your company. Through the development they would have access not only to the technical details of the product but also to the technical expertise of the company and even worse to your market details and strategy. A way to avoid this possibility is to choose a subcontractor operating on a different industrial sector or on a completely different line of business.

PRODUCT SPECIFICATION

Inadequate specification is a common source of problems in the development of complex projects. It can cause trouble in a number of ways. Try to ensure that both the First User and the subcontractor's assumptions about the design are explicit in the specification. If there is too little detail, the subcontractor will be forced to assume parts of the specification, and may make incorrect assumptions. When these are corrected, time, and possibly money will be wasted. The importance of this is underlined by the fact that some design houses insist that they revise the specification in the first phase of the project. In practice, the writing of the detailed specification must involve collaboration between the First User and subcontractor. Discuss with the subcontractor how much time and effort you, as First User, will need to spend during the specification phase.[5]

In certain technologies, such as mixed signal design, this specification phase has a second important role. Once the subcontractor has studied the design sufficiently to provide detailed specifications (in collaboration with the First User) the subcontractor may wish to revise the project plan, because previously unforeseen technical problems come to light. Such an initial design and specification phase is often paid for by the client. In other technologies, such as microprocessor/microcontroller design, unexpected problems that make the project impossible, or too difficult, are rare. The First User should discuss this with the subcontractor, before the project starts, and discuss how it should be dealt with if it arises.

In technologies, such as IC design, where prototype production is expensive, it is common practice for the subcontractor to insist that the specification be frozen at some named milestone in the middle of the project. In particular, the client will be shown a set of simulation results at the time when the design is scheduled to freeze. These simulation results then become the product specification - not the original written description, so the First User must be sure that the simulations cover all the important requirements.

PROJECT PLANNING

It is more difficult to plan and execute a project involving many partners in many locations, than one where all the people involved work in the same office. Unexpected delays occur when one group completes a piece of work and another starts, or just because distance reduces the flow of information (however the availability of e-mail can improve the information flow). It is unreasonable to assume that all the resources required for a project will be reserved 100% for the project – the First User's project may have to join the queue like everyone else. The project plan should include extra slippage to allow for this.

The subcontractors work should be detailed explicitly in the overall project workplan. There should be sufficient milestones that progress can be reviewed on a regular basis.

A specific problem occurs in IC design, where prototypes are made on multi-project wafers. These are produced in lots that are scheduled to start every two to three months. They are very convenient in a number of ways, including cost reduction, but the scheduling can have an unfortunate impact on overall project deadlines. Consider what happens if the design phase runs a week or two late, resulting in the project missing the multi-project wafer submission deadline. If the next submission deadline is three months later, the whole project is delayed by three months.

[5] The demonstrator document of AE 2212 advises "Time spent compiling accurate specifications and controlling revisions bears dividends later in the smooth execution of the design and assembly stages of the project."

UNEXPECTED TECHNICAL DIFFICULTIES

In a very small number of cases, the detailed design work on a project will uncover a technical difficulty that could not be foreseen. It is a good idea to discuss with the subcontractor, before the project starts, how such an eventuality could be addressed. How will the extra work be costed, and who will pay? [See AE 418]

Subcontracting agreements generally refer to “reasonable endeavours” or “best effort”. While dealing with advanced technologies even experienced/capable contractors may be unwilling to fully quantify the technical risks involved. However, it can be too easy for a subcontractor to “hide” a lack of technical ability behind the banner of “reasonable endeavours”. Talk to previous customers of the contractors and find out if they are able to deliver as they promise.

DELAYS

Sometimes the subcontractor will encounter delays that have a negative impact on the First User's product introduction plans. Unfortunately, in some cases it is clear that the subcontractor is over-committed, and has given insufficient priority to the First User's project. There appears to be no sure-fire way to ensure that this does not happen. The following ideas can help:

1) Review progress with the subcontractor on a regular basis, so that any problems can be identified early on. In the demonstrator document of AE 1023 they advise “To get a good result, it is necessary to have regularly meetings (e.g. 1-2 weeks) in the design phase and to underline the critical points.” Compare actual progress with the milestones planned in workplan. If it is a big project, you should consider contracting an independent consultant who will monitor technical progress at the same time as you monitor the other aspects. The agreement with the subcontractor should have enough technical milestones that delays will be evident.
2) Check with the subcontractor's other clients, before the project starts, to see if they are on time in their other projects.
3) Provide a specific, contractual, financial incentive for the subcontractor to finish quickly. This may take the form of an ‘agreed damages for delay’ clause (the subcontractor is paid less if the project is late) or a performance clause (the subcontractor is paid more if the project finishes sooner). Examples are given in the appendix 1. See also AE 418.
4) If the management of the subcontractor is forced to allocate scarce design resources between competing projects, they will probably favour their most important customers. This may be a reason for a First User to choose a smaller design house subcontractor, or one that is close by.
5) If the subcontractor is a very small company, then they may not have sufficient internal resources to catch up, if any delay occurs.

QUALIFIED STAFF

A specific problem can arise where the subcontractor has underestimated the technical difficulty and gives the First User’s project to a junior engineer or one without direct experience in the of the specific requirements. The First User should check, at the project meetings, that at least one engineer who is actually working on the project has directly relevant experience.

Currently, and due to the extraordinary growth of the electronic industry in Europe, companies are experiencing extreme skills shortages. As a result, companies are finding hard to hold to key personnel and to replace them with suitable staff when they leave. The loss of some key personnel can undermine the company’s ability to deliver and jeopardise the success of a development. It is important to talk to your potential subcontractors about this matter during the negotiation phase. Identify those individuals who are essential for the project to succeed, and include their names in the contract if necessary. The contractor must have contingency plans to deal with the departure of one or more of them. If this happens, they must be replaced by someone with similar experience and skills or the subcontractor will be fully responsible for any delays or failure to deliver.

PHASED PAYMENT

The amount and phasing of payments from the First User to the subcontractor are matters for negotiation. The First User should ensure that any stage payments (other than the initial payment) are

tied to clearly defined and tangible deliverables [AE 240, AE 194, AE 29412]. Take outside advice about which deliverables are worthy of stage payments - they should represent completed parts of the design, which could be used as a starting point by some other competent designer. Be sure to reserve a large portion of the payment for successful completion of the whole design.

INTELLECTUAL PROPERTY RIGHTS

The First User should have a written agreement with the subcontractor describing the ownership of the work done on the project by the subcontractor. Examples are given in Appendix II-B (AE 194). See also AE 418. Pay particular attention to the terms describing patenting and exclusivity. Can the subcontractor use parts of the design in a different project? Can the subcontractor work for a competitor of the First User during the project? If not, then how soon after the project end can the subcontractor work for a competitor? In the course of the project, the First User may need to provide proprietary information about their business or technology to the subcontractor, in confidence. This information should be clearly identified as confidential. The contract should make clear that such confidential information remains the property of the First User.

Some contractors will keep the IP rights on the design but guarantee exclusivity to the First User in exchange for a “royalty” fee for each unit sold. This is a standard practice and, if properly negotiated between the company and the contractor, can be very beneficial for both. However the First User has to take this extra cost into account when analysing the economic benefits of the development and the return on investment. Even if the contractor keeps the IP rights, a clause should be included in the contract preventing its sale to the First User direct competitors, at least for a pre-determined period of time.

CONTINUITY OF SUPPLY

Continuous supply of all the components in a new design must be guaranteed for the lifetime of the product. This should include guaranteed manufacturing of the modules at an agreed price. An increase on the price of a component can have a detrimental effect in the final cost of the product, making it un-competitive or jeopardising the projected return on investment. Always identify alternative suppliers before going into full production. In some technologies, such as ASICs, MCMs and microsystems, portability of a design to an alternative supplier/manufacturer is generally not possible. In these cases, conditions for the continuity of supply should be included in the written agreement between the First User and the subcontractor (see Appendix II-B).

CONTRACT TERMINATION

The First User may need to terminate the contract prematurely, perhaps because the First User's own business priorities have changed, or because of dissatisfaction with the subcontractor. Terms and conditions for doing so should be agreed before project start. There are examples in the appendix II-B.

CONTRACT IN WRITING

As discussed above, the agreement between design contractor and client can be quite complex. Be sure to have all the terms of the agreement in writing before the project starts, as this will simplify the resolution of any subsequent conflict. Many design houses have standard terms and conditions that are appropriate. Examples of both styles are given in Appendix II. Whatever your agreement, make sure that it is included, in writing, with the contract or with the documentation accompanying the purchase order.

WHEN IT GOES WRONG

If the First User feels that the project is going badly at the subcontractor, then it is best to say so to the subcontractor sooner rather than later. If the problem is deep, and the subcontractor has to withdraw, then it suits the First User that this happens early. On the other hand, it may just be a question of the subcontractor assigning a higher priority to the project, which is more likely to happen if the client has expressed concern. If there is a formal mechanism, such as a Customer Complaint in ISO9000, warn the subcontractor that you intend to make a complaint. If the client is sufficiently dissatisfied that a change of contractors is being considered, then this dissatisfaction should be conveyed to high level

management in the subcontractor. Remember that the lower level managers in the subcontractor may not always convey client dissatisfaction to their bosses.

CONCLUSION

Subcontracting a significant portion of the design is a proven strategy for a company acquiring a new microelectronics technology. To ensure success of the strategy, the management should plan their interaction with the subcontractor, monitor it until completion of the project and develop a contingency plan in parallel.

APPENDICES

APPENDIX I

An Analogy from House Building

Some of the general issues which arise in subcontracting electronics design also arise in other fields, so drawing a analogy with house building may be of benefit.

Consider that you want to build a new house or extend, or renovate your existing house. The sum of money involved, say between 20,000 and 1,000,000 Euros, depending on you lifestyle, is similar to that involved in subcontracting electronics design. The experience of dealing with the building contractor is very different from that of, say, buying a new car. When you buy a car, you choose a model, haggle a little over the finances, pay the money and off you go. With a house it is different, you must do some work to get it right. You can define the outline specifications quite easily - you have after all lived in a house for most of your life. You may choose to get a technical expert, an architect, to help with the overall management. You are most likely to outsource the actual building work, to a reputable building contractor.

Contractor Selection
How do you select your building contractor? You will probably get quotes from two or three contractors, giving them an outline specification (or preferably a detailed specification). While you will select the one who is best value for money, you will be suspicious of any contractor who is very much cheaper than the others. You will ask to see work they have done for other clients, to see the quality of the work, but also to ask that client what the working relationship was like. You will also try to check the contractor's reputation for being dependable.

Detailed Specification
If you cannot provide a detailed specification, the builder will include some margin in the price to cover your uncertainty. Since you don't build houses every day, you can't get the specification exactly right. It will change at least in some details and the builder knows this. Your contract should include provision for changes in the specifications. Clients should know that builders are entitled to a new price if the specifications change, but also know that some builders make profits by charging a lot of money for small changes.

It is a good idea for the client to develop a relationship with the builder so that both understand the reasons for any changes and agree them at an early date.

Unexpected Technical Difficulties
Occasionally unexpected technical difficulties arise. The site and foundations may be more difficult than expected. For renovations to an old house, structural problems or rotten timbers may be uncovered. It should be discussed beforehand if this is likely. It should be agreed in writing who pays for the extra work. If the client pays, then who decides how much money is owed?

Delays
Delays are common in building. If the building contractor promises completion by June 30th, it would be wise to have alternative accommodation available in early July, purely as a matter of contingency. In an economic boom, plumbers, electricians and carpenters will be hard to find, leading to delays outside of the control of the builder. Frequent review of progress on the building helps to encourage the builder. There is no way to guarantee that no delay will occur, but if delays are likely, then it may be worthwhile for the client to give a financial incentive for completion on time, perhaps in the form of an agreed damages clause for late completion. The builder may not be interested in such a contract.

Qualified Staff
Even a good builder will be tempted to get skilled staff to do occasional jobs that they are not skilled in, to save time or trouble - say to ask a brick layer to plaster some corner. In my case we had to tell our builder to stop painting in the kitchen, and paint it ourselves. It turned out that the 'painter' was a trainee carpenter, and a good one, but a terrible painter!

Phased Payment
It is common practice to phase the payments so that the builder only receives money for work completed. In particular it is important that final payment is made after the so-called 'snag list' of outstanding problems is completed.

Contract In Writing
It is good practice to have all the terms of your agreement with the builder in writing, before you hand over any money, as this will help to resolve disagreements later on.

Conclusion
Houses get built, of course, and the great majority of clients are happy with the end product. The few hard cases where the client is dissatisfied tend to occur when the client hasn't taken adequate care to ensure a successful outcome.

APPENDIX II-A

Sample Terms and Conditions for Electronics Design Subcontracting

1. This agreement covers only that work set out in this proposal and any additional work will be undertaken only on the basis of a mutual exchange of letters.

2.The Contractor will not undertake for a third party, during the course of the project (and for six months thereafter), work of such a similar nature as would in the mutual opinion of the Contractor and Client conflict with the interest of the Client in the project.

3. (1) This agreement may be terminated as follows:

(a) By either party by 14 days notice in writing addressed to the other party in the event of a serious breach by that other party of the terms of this agreement.

(b) By agreement between the parties:

(2)In the event of termination of this agreement the Client will pay the Contractor for all work done and services rendered and liabilities incurred to the date of such termination.

4. Fluctuations in costs arising from additional or alternate instructions or requests from the Client will occasion a revaluation of the project fee which will be subject to notification to and acceptance by the Client in writing before the additional or alternate work is undertaken.

5. Special equipment or material required for the conduct of the project will be charged as an addition to the project fee and will become the property of the Client at the termination of the project unless otherwise mutually agreed.

6. The cost of overseas travel and subsistence of Contractor staff, where agreed with the Client to be necessary for the conduct of the project, will be charged as an addition to the project fee.

7. The Client will pay to the Contractor the project fee and any additional costs arising under this agreement as and when invoiced by the Contractor. A credit period of thirty days will be allowed.

8. The Contractor will keep records of its work on the project and will as required and agreed deliver progress reports to the Client. The Client will not withhold any pertinent information necessary for the success of the project.

9. Information and reports received by the Contractor from the Client (and not received from any other source) will be confidential unless otherwise mutually agreed or unless such information or reports have become public knowledge.

10. The Client will not directly or indirectly associate the Contractor with any advertising, publicity or promotional material or litigation relating to the project without the prior written consent of the Contractor.

11. Without prejudice to Clause 10 hereof the Contractor will be entitled to hold itself out as the designer of the project.

12. Any discovery or invention made during the term of the project, relating to the subject matter of the project, by staff members of the Contractor employed on the project, will become the exclusive property of the Client subject to the limitations contained in Clauses 13 and 14 hereafter, and the Client will cause patent searches to be made and/or patent applications filed as he will deem fit at his own expense.

13. If for any reason the Client does not notify the Contractor within six months of becoming aware of any patentable material relating to the project, of his intention to apply for patent protection in respect thereof and effect such application within the said period, the Contractor will be permitted to take out such patents as it deems fit free from any claim by the Client other than royalty-free use of such patents in the Republic of Ireland during the life thereof.

14. Subject to Clauses 8 and 9 hereof, the Contractor will be entitled to the free use of any material not patented or patentable.

15. Any or all Patentable inventions made by the staff of the Contractor engaged on the project during the course of the project, which in the opinion of the Contractor are not directly concerned with the project, will become the property of the Contractor.

16. The expressions Client and Contractor will include the successors and assigns of the Client and Contractor.

17. The Contractor will carry out the project without responsibility in law on its part, and it will not assume any duty of care, in relation to it, or in regard to any representation or description accompanying same. And further the client will at all times keep the Contractor indemnified against all actions, proceedings, claims or demands whatsoever, which may be brought or commenced against it, and also against all costs, damages and expenses which it may in any wise pay or incur in defending or settling the same in consequence of its having rendered any service for the Client.

18. In case any dispute or difference will arise between the parties to this agreement then either of the parties may give notice in writing of such dispute or difference to the other and such dispute or difference will be and is hereby referred to arbitration and to final decision of an arbitrator to be appointed by agreement between the parties or in default of such agreement to be appointed by the (President for the time being of the Incorporated Law Society of Ireland or equivalent). The award of such arbitrator will be final and binding on both parties and he will determine by whom and to whom the costs of the dispute will be paid.

19. The Contractor will deliver to the Client such prototypes, components, drawings, reports or other items as are set out and agreed in the document herein, or which will be agreed in any subsequent agreed specification document. The Contractor will undertake to repair, replace, redesign or rewrite any items or item delivered by the Contractor to the Client which in the opinion of the Contractor and the Client do not meet with the requirements set out and agreed herein due to a fault in design, fabrication, programming or documentation on the part of the Contractor PROVIDED THAT Notice in writing in regard to such alleged default or defect will have been given by the Client to the Contractor within 90 days from the delivery of the said item to the Client, such Notice to set out fully the nature and extent of such alleged default or defect, and any obligation incurred by the Client under this Clause will in no way effect the provisions of Clause 9 herein.

20. Notwithstanding and without prejudice to the right of the Contractor to hold itself out as the designer of the project, any components, equipment, material, reports, drawings, information or other items of any kind generated, invented or acquired by any means by the Contractor in the course of working on the project, will remain the property of the Contractor subject to Clause 9 herein until the project fee as set out in the accompanying quotation has been paid in full. If payment in full has not been made within the credit period prescribed in Clause 7 herein, then the Contractor will have free and unrestricted ownership of such items and will have the right to dispose of or otherwise deal with the said property as it deems fit.

21. The Client will satisfy itself in regard to the necessity, commercial or otherwise, that any design, product or information supplied by the Contractor to the Client in the course of the project should comply with any national or international standard or standards, and will notify the Contractor of such requirements prior to the execution hereof, unless otherwise agreed.

22. If the contractor anticipates that he will not be able to deliver the product at the time of delivery, he will forthwith immediately notify the client thereof in writing, stating the reason, and if possible, the time when delivery can be expected. The client will consider the acceptability of such revised schedule before invoking any rebate clause.

If delay in delivery is caused by an act or omission on the part of the client the time for delivery will be extended by a period which is reasonable having regards to all the circumstances in the case.
If the product is not delivered at the agreed time for delivery the client is entitled to agreed damages from that date of delivery, invoking a rebate of 1% of the value of the delayed goods per week up to maximum of 15%.

23. If the contract is terminated before completion, the contractor will invoice the client for work done to date. The contractor will deliver the results of that work to client, in the form of documentation, schematics or prototypes.

APPENDIX II-B

Sample Contract from an AE

AGREEMENT

for the Tool-up, Qualification and Production of ASIC "Hand Held Monitor"

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Following documents are working papers under the agreement:

PREAMBLE

AGREEMENT, made this *1st day of October 1997* by and between *The Company* having its principal place of business at *Company's Town* (hereinafter referred to as TC), and *The Subcontractor* (hereinafter referred to as CONTRACTOR).

WHEREAS, TC wishes to have the CONTRACTOR to perform prototyping, qualifying and production of electronic integrated circuits (hereinafter referred to as the "PRODUCT") which is defined in the document B142.

NOW, THEREFORE, the parties hereto agree as follows:

1. PROTOTYPING, QUALIFICATION AND PRODUCTION

1.1 CONTRACTOR will perform prototyping, qualification and produce the PRODUCT, and will provide all the technology, labour, material, tooling, facilities and other expertise necessary for such activities.

1.2 CONTRACTOR will meet the schedule for each phase of the project set forth in the document B140.

1.3 CONTRACTOR will produce prototypes as specified in document B140. In the event that the prototypes meet the mutually agreed PRODUCT specification document B142, TC will, pursuant to section 5 below, approve the prototypes by an acceptance in appropriated document.

1.4 Upon the acceptance by TC of the prototypes produced by CONTRACTOR, CONTRACTOR will deliver to TC or third parties, or other locations as agreed between TC and the CONTRACTOR, final plastic prototype units of the PRODUCT in the volume specified in document B141. Such final prototypes will conform to the PRODUCT Specification, document B142 and/or any other functional performance or other specification agreed to between TC and CONTRACTOR provided that such specifications, and any amendments or modifications therefore, are set forth in a document signed by authorised representative of TC and CONTRACTOR.

1.5 Unit pricing for the production is based on the document B141 agreed between TC and CONTRACTOR.
Pricing is stipulated in document B141. Against such purchase orders CONTRACTOR agrees to produce, ship and bill the PRODUCT.

1.6 CONTRACTOR will regularly apprise TC of the result of the tool-up work in regular written reports, which will normally be supplied on a monthly basis.

2. PRICE

2.1 The price model stated in document B140 is firm, according to the yield calculated in document B141, fixed price, unless a written agreement on price adjustment is made. The price includes costs for packing and packing material.

2.2 The production price is based on document B140 and document B141.
It may be necessary from time to time to effect a unit price change based on substantiated change in cost elements as specified in B141. All changes of prices will be mutually agreed.

3. PAYMENT

TC will pay CONTRACTOR in milestone billings during the tool-up in accordance with the pricing schedule set out in document B140.

General Terms of Payment is 30 days net after receipt of invoice.

4. DELIVERY

4.1 The scheduled dates of delivery are those defined in the documents B140 and B141 for the date of the presentation of the goods in the place of delivery.

4.2 CONTRACTOR will promptly notify TC when each shipment is made. This notification should contain, as a minimum, the packing list (detailing part number, value and quantity), TC's purchase order number and, if applicable, the original bill of lading or express receipt.

4.3 Delivery Terms are *FCA Hoersholm* according to *Incoterms 1990*. Partial shipment can be agreed.

4.4 CONTRACTOR's normal lead time for the PRODUCT is 12 working weeks. The parties will implement a rolling forecast system to ensure secure deliveries.

4.5 The delivery in tool-up phase and production of the PRODUCT is based upon TC responding to the stated activities specified in document B140. CONTRACTOR can not be held responsible for any consequential delay caused by TC not meeting its commitments.

5. ACCEPTANCE AND TRANSITION INTO PRODUCTION

Acceptance of prototype ICs and transition into production will be performed over a period of 8 months. The acceptance and production start-up criteria are specified in documents B140.

6. CHANGES

6.1 TC will have the right to request changes to the PRODUCT Specification, document B142. The request for changes will be submitted by TC in writing to CONTRACTOR. If needed, CONTRACTOR will then provide a quotation for any additional costs and time that would be incurred and any changes of components pricing. CONTRACTOR will request TC's written approval of the additional payment, development time and any new component prices.

6.2 Upon receipt of such approval, implementation of said changes will proceed; the PRODUCT Specification, document B142 will be updated to reflect the said changes; document B140 will be updated and agreed by TC to reflect new dates and TC will be invoiced by CONTRACTOR for any additional payment resulting from changes in accordance with the revised document B140.

7. COMMITMENT

7.1 In order to minimise delays it is the intent of both parties to quickly respond to questions of information required from each other relating to the Tool-up for production of the PRODUCT.

7.2 CONTRACTOR will have full responsibility to effectively take whatever reasonable steps necessary to achieve strict compliance during all phases of prototyping and production with all specifications and requirements of the Agreement.

7.3 CONTRACTOR will secure the availability of all materials, labour, tooling and components required for the production of the PRODUCT. In the event of any disruption of materials, labour, tooling or components supply, CONTRACTOR will immediately notify TC and take whatever steps necessary to overcome the disruption.

7.4 CONTRACTOR will maintain all drawings, specifications, technical and commercial documents, data and similar materials prepared or used in connection with CONTRACTOR's performance hereunder during the validity of the Agreement or as a minimum 5 years from last delivery. TC will be notified prior to destruction of any such material.

7.5 The CONTRACTOR will within 1 (one) week after receipt of separate orders per this Agreement order acknowledge delivery time for each order.

8. RIGHT OF ACCESS

TC will have right to attend the site of manufacture/test for the purpose of establishing progress. This will be by prior arrangement and giving reasonable notice. TC will be entitled at such time to request the expedition of CONTRACTOR's manufacturing process and CONTRACTOR will use all reasonable efforts to comply with the request. Such actions will not in any manner limit the responsibilities and liabilities of CONTRACTOR.

9. DECLARATION

CONTRACTOR declares that it has title to all material to be furnished to TC pursuant to this Agreement. Title is transferred to TC when product is delivered *FCA Hoersholm*.

10. QUALITY

10.1 A quality system conforming with the requirements set out in ISO 9001 will be maintained by the CONTRACTOR.

10.2 TC will have the right to perform Quality Surveys and Audits as deemed necessary. Pre-notice of one week.

11. MATERIAL AND SOFTWARE

Material and software furnished by TC to CONTRACTOR will remain TC's property and CONTRACTOR will keep this separate from material and software of CONTRACTOR and identified with an appropriate legend or marked as TC's property. It will be supervised, maintained and cared for by at CONTRACTOR risk until redelivered to TC.

The above rule will also apply to any manufacturing equipment, tools, software and patterns belonging to TC being in the possession of CONTRACTOR. Such equipment, tools, software or patterns may not be used for any other purpose than performing work on behalf of TC. TC will have the right at any time to take possession of manufacturing equipment, software, tools, test patterns etc. belonging to TC.

12. DISCLAIMER OF LIABILITY

Under no circumstances except as stated in paragraph 16 and 19 will CONTRACTOR or TC be liable to the other or to any other party or parties for any special, incidental or consequential damages, however caused, whether for breach of contract, negligence or otherwise, except where the supplier has been guilty of gross negligence.

13. INTELLECTUAL PROPERTY RIGHTS

13.1 As used herein, the term “Inventions” will mean any improvements, or ideas (whether or not patentable or copyrightable), which are developed or discovered during the work performed under this Agreement.

13.2 Both TC and CONTRACTOR agree (at the expense of the requesting party) to provide information and do all other acts necessary to assist the other party in filing any applications for patents, copyrights or Registered Design Rights, or to maintain any patents or copyrights or the like which are issued to the other party or any Inventions, after mutual agreed fee.

13.3 To the extent that applicable law permits, each party hereto will require its employees to assign to such party any intellectual property right, title and interest in and to any Inventions, copyright or copyright application relating thereto.

14. CONFIDENTIAL DISCLOSURES

14.1 All drawings and technical documents relating to the product or its manufacture submitted by one party to the other, prior or subsequent to the formation of the Agreement, will remain the property of the submitting party.

14.2 Drawings, technical documents or other commercial or technical information, including but not limited to information that can be derived from equipment, tools, samples, etc. will if clearly identified by the disclosing party as company confidential by an appropriate legend or if orally disclosed identified as confidential at the time of disclosure be treated as strictly confidential by the receiving party. This means that the receiving party will unless otherwise stipulated herein or expressly agreed in writing:

A. not use company confidential information received from the other party otherwise than for purposes allowed by the specific agreement or as otherwise expressly authorised by the disclosing party in writing;

B. restrict access to and only to disclose the company confidential information, to those of its employees to whom disclosure is necessary for the purposes set out in paragraph A above;

C. treat all company confidential information as strictly confidential and not disclose it to any third party; and

D. be responsible for ensuring that its employees fulfil the above confidentiality restrictions.

14.3 The confidentiality obligations set out above will not apply to any company confidential information which the receiving party can prove:

- is in the public domain otherwise than by breach of these confidentiality conditions; or
- was in its possession prior to receipt from the other party; or
- was received from a third party free of any confidentiality restrictions.

14.4 Notwithstanding the above, CONTRACTOR agrees that TC will be entitled to use drawings, technical documents or other technical information received from the CONTRACTOR for the purposes of erection, commissioning, operation and maintenance of the Product.

14.5 The CONTRACTOR will always provide TC free of charge with such information, documents and drawings which are necessary to permit TC to erect, commission, operate and maintain the Product. One copy of the documents containing the information and drawings will be supplied. If TC requires further copies this will be mutually agreed.

14.6 The CONTRACTOR will not without TC's prior written consent give publicity to or otherwise publish the existence of this Agreement with TC.

15. CONTINUITY OF SUPPLY

15.1 CONTRACTOR undertakes to inform TC in writing at least 12 (twelve) months in advance of any intent to suspend or close down manufacturing of Product.

15.2 CONTRACTOR will inform TC in writing giving 12 (twelve) months notice of any plans to suspend or close down this facility.

15.3 In the event that CONTRACTOR goes into liquidation (except for amalgamation or reconstruction) or commits an act of bankruptcy, or has a receiver appointed for any or all of its assets, then:

(i) TC will automatically have right and title to any manufacturing tools, test equipment and computer programs directly charged to TC intended for use under this Agreement.

(ii) TC will automatically be granted an irrevocable, world-wide royalty free licence to use, reproduce, modify, or disclose such information as provided by CONTRACTOR as a deliverable item under this Agreement, for the purpose of manufacturing the PRODUCT, and having the PRODUCT manufactured by third parties, for use by TC in its present or future products. This information will include such drawings and manufacturing know-how as are necessary to enable TC to source manufacturing of the PRODUCT.

15.4 Volume changes

Delivery of products to TC will be in accordance with the rolling forecast every month on a 6 month basis. From this rolling forecast the first six weeks are binding for both parties. Product volume change within 50% will be possible within a rolling six week period. Major volume changes must be noticed in writing 6 months ahead.

16. DELAYS IN DELIVERY AND TERMINATION

16.1 If the CONTRACTOR anticipates that he will not be able to deliver the PRODUCT at the time of delivery, he will forthwith immediately notify TC thereof in writing, stating the reason, and if possible, the time when delivery can be expected. TC will consider the acceptability of such revised schedule before invoking any rebate clause.

If delay in delivery is caused by any of the circumstances mentioned in paragraph 21 or by an act or omission on the part of TC the time for delivery will be extended by a period which is reasonable having regards to all the circumstances in the case.

If the PRODUCT is not delivered at the agreed time for delivery TC is entitled to liquidated damages from that date of delivery. Invoking a rebate of 1% of the value of the delayed goods per week up to maximum of 15%.

For delivering the prototypes the CONTRACTOR is entitled to a 4 week grace period. If the delay in delivery of the product exceeds more than 4 weeks the penalty is calculated from week one.

If the delay in delivery exceeds 50 days and if the PRODUCT is still not delivered, TC may in writing demand delivery within a final reasonable period which will not be less than one week. If CONTRACTOR does not deliver within such final period and this is not due to any circumstance for which TC is responsible, then TC may by notice in writing to the CONTRACTOR terminate the Agreement in whole or in part.

CONTRACTOR will be responsible for any extra freight charges as a consequence of CONTRACTOR being in a delay in delivery. If PRODUCT is delayed, TC will be entitled, at the expense of CONTRACTOR, to request shipment by express service.

16.2 For other reasons TC may terminate an order in whole or in part whenever it determines, that such a termination is necessary. Any such termination will be effected by the delivery to the CONTRACTOR of a Notice of Termination, specifying the extent to which performance of the work under the contract is terminated and the date upon which such termination becomes effective. All work completed and on hand at the CONTRACTOR's plant, ready for delivery on the effective date of the termination will be delivered as directed by TC. Upon the effective date of the termination the CONTRACTOR will immediately stop performance of work (including work being performed by subcontractors) to the extent specified in the Notice of Termination. Within two (2) months after the effective date of the termination, the CONTRACTOR will submit to TC its claim for the costs set forth in paragraph 16.3.

16.3 In the event of any termination under paragraph 16.2 and 21 the CONTRACTOR will be paid:

a) If TC terminates the Agreement during the Tool-up phase of the PRODUCT then TC will fully reimburse CONTRACTOR the phase in progress.

b) Other reasonable settlement expenses arising from termination. The total sum to be paid to the CONTRACTOR under a) and b) of this paragraph will not exceed the total purchase order price reduced by the amount of payments otherwise made.

16.4 The following paragraphs of the Agreement will survive expiration or termination of this Agreement: Paragraph 13 and 14.

17. CO-OPERATION WITH OTHER CONTRACTORS AND TC

17.1 Subject to paragraph 17.2, CONTRACTOR will co-operate with TC and with any other subcontractor to TC and provide all assistance reasonably required by such subcontractor for the purpose of ensuring the timely progress of the contract.

17.2 CONTRACTOR agrees for the contractual period not to knowingly offer a product with the same specification to other potential customers prior to the written approval of TC.

18. NOTICE

Any notice herein required or permitted to be given will be in writing and may be personally served or sent by first class post and will be deemed to have been given: if personally served on the day of delivery or if mailed on the fifth business day after being posted prepaid and properly addressed.

For purposes hereof, the addresses of the parties hereto (unless a notice of change thereof is given) will be as follows:

CONTRACTOR	TC
Mr. Joe Bloggs *Division Manager* *The Subcontractor* *Subcon Park* *DK-98765 Copenhagen* *Denmark*	*Mr. A.N. Other* *Purchasing Director* *The Company* *New Industrial Estate* *Sometown, A12 34B* *United Kingdom*

19. GUARANTEE

This guarantee is limited to defects which appear within a period of 12 months from the date of delivery. When a defect has been replaced, CONTRACTOR will be liable for the replaced part under the same terms and conditions as those applicable to the original PRODUCT for a period of 12 months.

TC will without undue delay notify the CONTRACTOR through an agreed procedure of any defect which appears. The notice will contain a description of the defect. On receipt of the notice in writing CONTRACTOR will promptly remedy by replacement the defect at its own cost and risk. The CONTRACTOR has fulfilled his obligations in respect of the defect when he delivers TC a replaced PRODUCT. If TC has given such notice as mentioned above and no defect is found for which the CONTRACTOR is liable, the CONTRACTOR will be entitled to compensation for the direct reasonable costs incurred as a result of the notice.

Unless otherwise agreed, necessary transport of the PRODUCT from and to TC in connection with the replacing of the defects for which the CONTRACTOR is liable will be at the risk and expense of the CONTRACTOR. TC will follow CONTRACTOR's instruction regarding such transport.
Defective parts which have been replaced will be made available to the CONTRACTOR and will be his property. If the CONTRACTOR does not promptly fulfil his obligations under this clause, TC may, by written notice, define a final time for completion of the CONTRACTOR's obligations. When a defect has been successfully replaced, the CONTRACTOR has fulfilled his obligation.

The CONTRACTOR is not liable for defects arising out of materials provided by, or a design stipulated or specified by TC.

The CONTRACTOR is liable only for defects which appear from proper use of the PRODUCT.

20. COMPLETE AGREEMENT

This Agreement, along with the referenced Documents hereto and the terms and conditions incorporated herein and the Mutual Confidentiality Agreement between the parties dated *1st October*

1996 constitute the entire Agreement between the parties as to subject matter hereof, and supersede and replace all prior or contemporaneous agreements, written or oral, regarding such subject matter, including but not limited to all provisions of TC's purchase order or any other document issued by TC. No amendment or modification of this Agreement or of the Mutual Confidentiality Agreement will be valid except if set forth in writing stating that it is such an amendment or modification and signed by an authorised representative of each of the parties hereto.

21. FORCE MAJEURE

A case of release from obligations (force majeure) is deemed to be caused by impediment or occurrence that delays or prevents the fulfilment of the agreement and which the effected party had no reason to take into account when entering into the agreement and which is independent of any action by either party and could not be averted or prevented without unreasonable expense or loss of time. Such cases may result from war, mutiny, internal unrest, expropriation or confiscation from public needs, embargo, acts of God, discontinuation of public transportation or supply or energy, labour conflict or fire or other events beyond the effect of the parties control which delays or prevents the fulfilment.

Delays on the part of CONTRACTOR constitute a case for release from obligations only when caused by force majeure as set out above and when another subcontractor can not be engaged without unreasonable loss of time or expense.

Should the relevant party fail to give written notice of a requirement for an extension of time for fulfilment of the contractual obligations within 14 days of the emergence of force majeure, it will forfeit its right of extension. The party will also inform the other party in writing within an equal period of the termination of the force majeure.

22. DISPUTES AND APPLICABLE LAW

All disputes arising in connection with the agreement will be finally settled in accordance with the Rules of the *Copenhagen Chamber of Commerce*. The arbitration will take place in *Copenhagen* and be conducted in the English Language.

This Agreement will be governed by the substantive law of *Denmark*.

IN WITNESS WHEREOF, the parties have caused this Agreement to be executed by their authorised representative.

The Company		*The Subcontractor*	
Name:	_____	Name:	_____
Title:	_____	Title:	_____
Signature:	_____	Signature:	_____
Date:	_____	Date:	_____

B140 Production of ASIC for Hand Held Monitor - Price Model

This document specifies the production of the device and the procedures to be carried out by CONTRACTOR and its subcontractors in order to produce the ASIC called HHM version 1.1.

For price quotation we have used following parameters:

Part IQTV 2.0	
Device complexity:	40 mm, die area 40 mm
Type of device	Mainly digital 4 ADC (10 bit) 2 DAC (8 bit)
Package type	PLCC84 or QFP80
Volume to customer	1 K , 10K or 50,000 per year
Lifetime	1-5 years
Technology	0.8 UCMOS DP/DLM
Test time at wafers	7 sec.
Test time at ICs	10 sec.
Total fabrication yield	Variable (60, TBD)

Below please find our parameter for calculation based on subcontractual agreements and the work performed by CONTRACTOR:

Wafer prices/wafer	1500	USD
Encapsulation fee/device	0.85	USD
Shipments per batch/way	185	USD
Importation tax to EU	0%	USD
Start fee per batch	100	USD
Test price per hour	850	USD
Rate of exchange	USD/DKK	7.00
Rate of exchange	GBP/USD	1.67

If the parameters are changed the total component price will change. The prices are based on the activity level for a total of 2500 components delivered within 18 months.

Below please find hour calculation versus volume with a chip size of 40 mm:

	Fabrication yield		
Delivery end user	1 K	10 K	50 K
QA-programme	K	1 K	5 K
To be produced	1.2 K	11 K	55 K
To be encapsulated	1.5 K	12 K	60 K
Electrical test IC	4 hrs	40 hrs	200 hrs
Starts per year	1	2	10
Chips to be produced	2.5 K	20 K	100 K
Chips per wafer	118	118	118
Number of wafers	21	169	847
Wafer test hours	7 hrs	53 hrs	265 hrs
Start per year	1	2	5

The following assumptions give production costs as indicated below:

Wafer investments	128 K	726 K	2904 K	900 DM/ 850 dm
Capital cost 1%	1 K	13 K	43 K	
Shipment 10 lots	1 K	2 K	10 K	

Wafer test:

- start fee	1 K	1 K	1 K
- wafer test	7 K	53 K	212 K
Encapsulation	8 K	67 K	210 K
Shipments	1 K	2 K	10 K
Final electrical test:			
- start fee	1 K	1 K	1 K
- electr. test	4 K	38 K	190 K
QA- programme	15 K	15 K	50 K
Production cost	168 K	918 K	3631 K
Risk and overhead	17 K	91 K	361 K
Sales prices in DKK	185 K	1009 K	3992 K
Price per unit DKK	185.00	100.90	79.84
Price per unit GBP	16.09	8.78	6.95

Please note that since CONTRACTOR has no control over the design phase a fixed price cannot be given and price variations for the component may be the result of:

* Change in die area (40 mm is assumed)
* CONTRACTOR has quoted in DKK but for comparative reasons the price in GBP has also been stated
* Change in subcontractual costs (actual price, rate of exchange)
* The actual yield of device (lot by lot)

CONTRACTOR has negotiated sub contractual prices to be fixed over a period of 22 months, after which the contracts with wafer foundry and encapsulation houses have to be renegotiated.

The delivery time of components will be 12 weeks from fixed orders. Since the actual production flow is a little bit higher CONTRACTOR plans to have a 15% storage on agreed annual volume. In order to secure the constant flow of components to your production facilities a forecast for the next 3 months (updated every 2 weeks) will be installed.

In order to give you an overall picture, CONTRACTOR is pleased to present the actual time schedule for production:

No of weeks in production	Action
0	Fixed orders received
1	Acknowledgment of orders
8	Wafer production finished
10	Wafer test performed
12	Encapsulation performed
14	Devices ready for shipment

B141 Development and Tool-up for Production of Mixed Signal ASIC for Hand-held Monitor

This document specifies the development and the tool-up for production for a mixed signal ASIC to your product Hand held Monitor. Based on discussions the development and tool-up for production will contain 15 major steps:

Task 1	Specification done by *The Company* (TC) or *Design Contractor* (DC)
Task 2	Library importation performed by TC or DC
Task 3	VHDL/ Verilog done by TC or DC
Task 4	Synthesis performed by TC or DC
Task 5	Simulation performed by TC or DC
Task 6	Test vectors performed by TC or DC
Task 7	Simulation of test vectors performed by TC or DC
Task 8	Layout Routing performed by CONTRACTOR
Task 9	2. sign of CONTRACTOR/TC/DC
Task 10	Exportation to Europractice by CONTRACTOR
Task 11	Prototypes performed by *Foundry*
Task 12	Test Solution implementation performed by CONTRACTOR
Task 13	Prototype qualification performed by CONTRACTOR and TC or DC

This means that CONTRACTOR will offer services inside task 8 to 13 only and will support TC with technical questions inside task 1 to 7.

The overall major time schedule for the 5 tasks will be tasks are:

Task 2	:	Library delivery	week 43
Task 8	:	Netlist importation	week 45
Task 9		Place and route	week 48
Task 10:		Europractice exportation	week 49
Task 11:		Silicon implementation	week 07
Task 12:		Test solution	week 44
Task 13:		Prototype delivery 20 pieces	week 08

The schedule is based on shipment of netlist tape to CONTRACTOR in week 45. After this a manufacturing process of 14 weeks is expected.

In order to fulfil our payment requirement and to obtain neutral cash flow CONTRACTOR will follow the below invoice schedule:

Invoice schedule:

Week:	
45	2 600.-
50	24 750.-
05	6 280.-
07	2 700.-

All prices are in Euros.

For further specification of the technical contents and milestones we refer to the specification of the individual tasks shown below:

Task 8 Layout Routing performed by CONTRACTOR
To be defined when final specification is finalised

Task 9 2. sign of CONTRACTOR/TC/DC
To be defined when final specification is finalised

Task 10 Exportation to *Foundry* by CONTRACTOR
To be defined when final specification is finalised

Task 11 Prototypes performed by *Foundry*
To be defined when final specification is finalised

Task 12 Test Solution implementation performed by CONTRACTOR
To be defined when final specification is finalised

Task 13 Prototype qualification performed by CONTRACTOR and TC or DC
To be defined when final specification is finalised

B142 Development of Mixed Signal ASIC for Hand-held Monitor - Specifications

(Detailed specifications for Mixed-signal ASIC for hand-held monitor)

APPENDIX III

Some Hard Cases

The following are summaries of some hard cases from the FUSE portfolio. They are included in order to give prospective First Users examples of what can go wrong, in extremis. Please be assured that they are the worst cases of First Users being let down by the subcontractors, and do not represent typical experience. They are reported in summary, and solely from the viewpoint of the client. The examples mostly come from the 'higher technologies', because this usually represents a large technology step for the First User.

High Accuracy IC

A company in Northern Europe commissioned a mixed signal design. The noise and power dissipation requirements indicated that a mixed signal IC was needed. With advice from a consultant, the company sought quotes from three well known design houses, choosing the best one on the basis of price and experience. In fact, the subcontractor had a limited number of staff with the experience of that particular field, and did not put any of them working on the project. At a design review it became clear that the IC would fall very far short of expectations. At the crisis meeting that followed, the subcontractor said that the project was much more difficult than originally estimated and that their fee would need to increase substantially (in excess of 50%) to fix the problems. After discussions with an independent consultant the company agreed to pay the extra fee. The subcontractor put a specialist onto the project to design a revised prototype. This had a significant positive impact. However, the prototype, which arrived about a year after the original planned date, also fell short of the target specification (perhaps because the specialist left the project before completion).

In retrospect, this design appears to have been too difficult. The client might have discovered this earlier, and cancelled the project, or otherwise minimised the risk, with the following strategies:

a) Contract an independent consultant to monitor the project, checking both technical progress and the experience of those working on the project. The consultant might have identified that the experience of the staff on the project wasn't good enough.
b) Fund a detailed feasibility study or architectural design as the first phase of the project. The detailed report should have identified most of the problems and risks.
c) Add performance clauses to the contract when the first prototypes failed.

The subcontractor might not have accepted these conditions, but that might be a sufficient reason for the client to withdraw.

Initial discussions with the subcontractor should have identified that there was a finite possibility that the project might turn out to be very difficult. If the client could not afford this risk, they could have withdrawn from the project.

Medium Volume IC

A small company commissioned an analog IC design. Some of the main requirements were low power consumption of the circuit and good performance under extreme conditions. The subcontractor was in charge of both design and production of the chip, but with significant design input from the client. The design was first simulated and then breadboard tested. The results of the breadboard test were not successful, but the contractor blamed it on the problems associated with this technique. When the first prototype was produced, this design worked fine at normal conditions, but had unacceptable power consumption problems for slightly above normal conditions. The subcontractor was unwilling/unable to improve the design so the first user had to get an independent consultant to improve the design. There were long delays to produce the second prototypes based on this improved design because the subcontractor didn't have enough resources (they had more work than they could handle) to incorporate the changes. When the new prototypes arrived, a year behind schedule, they didn't work properly. After careful study of the prototype, it was identified as a fault with the fabrication process. The subcontractor accepted this as their fault and agreed to produce a third prototype. Again big delays were caused by the lack of resources at the subcontractor. Finally the new prototypes arrived, 18 months behind schedule,

with exactly the same fault as the second ones. When approached by the First User, the subcontractor no longer wanted to know about the project. The First User has invested a lot of time and money into the project, has orders waiting for the new product, but has nothing to show.

The subcontractor has very good experience on this type of design and the experience of previous customers was very positive. In this case it appears that the subcontractor did not allow sufficient margin for error in the design estimate and did not have sufficient internal engineering resources to complete the project on time. It also seems clear that if the client had been a major customer, the subcontractor would have dedicated more resources to the project and prototypes would had been turned around in much shorter periods of time. Performance clauses or financial incentives for early return of prototypes could have worked in this case.

A Microsystem

A company planned to minaturise one of its products through the use of microsystems. It approached a number of potential suppliers, but only received a proposal from one of them. The other potential suppliers declined to bid. The project met technical difficulties early on. Eventually, the subcontractor accepted that they no longer believed that the project was technically feasible! The First User's investment of time and money was wasted, as they had no alternative, i.e. they had no contingency plan.

In retrospect, the main warning sign was that only one of the vendors approached actually made a proposal to do the work. This meant that the First User did not have a contingency plan. It was also an indicator that significant technical/financial risk was involved.

An Advanced Microsystem

The objective of this Application Experiment was to produce a physically much smaller and cheaper component using microsystems technology. The subcontractor was a major supplier of microsystems who has been at the forefront of this technology since its inception. Some delays occurred during the project due to technical difficulties at the subcontractor. However, following a formal complaint from the First User, the subcontractor allocated more resources to overcome the difficulties. Despite this, the final product did not meet the agreed specifications due to a problem with the contractor process. After several months, and due to the lack of progress, the development was finally abandoned.

The subcontractor was not able to deliver what they had originally promised, as their process was still being developed. Contacting previous customers could have help to identify what parts of the process had already been used and were proven and what ones were still under development. When dealing with new/advanced technologies, all innovations must be considered as a potential risk during the initial risk assessment and contingency plans must be prepared to minimised their negative effects.

Power Electronics

A mechanical engineering company planned to introduce some power electronics into their product. They engaged two subcontractors, the smaller of which, employed two people. The smaller company had a well earned reputation based on the technical expertise of one of its two staff. They also spoke the same language and were located quite close to the First User, which offered several advantages. No contingency was made for the possibility of the expert becoming unavailable.

Unfortunately, the expert became involved in another project, and spent very little time on the First User's design. The project became delayed. When the First User began to look for other experts, they found that such experts were rare and that is was not really practicable to work with another. Further delays occurred when the expert became ill for a few months. These delays caused knock-on delays within the second, larger subcontractor.

Three distinct lessons can be learnt here. Firstly, the critical role of *one individual* working for a subcontractor should have been identified as a risk factor at the start. Secondly, when problems arise in a small subcontractor, it is very difficult for them to recover without causing inconvenience to the client. Finally, if the contract had included significant financial incentives for completion on time, this would have put more pressure on the expert to support the First User's project.

APPENDIX IV

Examples of the Subcontractor Role

The following are direct quotes from Demonstrator Documents of successfully completed FUSE application experiments indicating the benefits of outsourcing some or all of the development project in t he first time design of microelectronics.

AE240

"The first user, having taken the decision to use three sub-contractors to provide design, training and production services went about contacting a number of potential sub-contractors. The most important was sub-contractor 2 who would be performing the synthesis, simulation and final verification of the design. A request for tender was sent out to 4 potential companies who could fulfill this role. Three of the four companies proposed solutions and in all cases they would liaise with the foundry to manage production of the silicon prototypes. The factors that contributed to the selection of the sub-contractor were, fixed consultancy cost, foundry NRE cost, most suitable technology, MOQ and gate array pricing structure. The successful company satisfied the first user under all of these categories and was the best candidate under most of them. In addition, the successful sub-contractor spent much effort in understanding the nature and scale of the project and as a result was in the best position to quantify the work involved and hence deliver the most competitive fixed quotation. Sub-contractor 3 (the foundry) had a good fit in terms of the gate array technology available with important technical features such as embedded RAM, flexible manufacturing with competitive pricing on low volumes. Sub-contractor 1 provided training services as a well recognised center of learning in the field of IC design."

Subcontractor 1

Company size: 200 employees

Company business description: The subcontractor offers a full range of services to industry and is involved in leading edge electronics research covering several areas such as IC process, packaging devices and basic materials research. The centre has two semiconductor fabrication facilities which process both Silicon and Gallium Arsenide.

Expertise of the company: The subcontractor has expertise in most areas of microelectronics including CAD, IC design, IC packaging, materials research, test and characterisation.

Experience of the company: The subcontractor was founded in 1981 and has 15 years experience in microelectronics research. Most of their staff hold higher degrees or doctorates in relevant disciplines. The centre has an impressive list of international clients for which it has carried out research and development consultancy.

Work Performed for First user: The subcontractor provided the VHDL training course to the first user. The course was 3 days in duration and was tailored to the first user's requirements. The course was specifically aimed as an introductory course to VHDL since the first user had no previous experience with VHDL based design. The course did not include IC design but was strictly confined to VHDL based design and good practice.

Subcontractor 2 – Excel Consultants

Company size*:* 4 employees

Company business description: Excel Consultants offer a range of consultancy services for IC design to industry. Ranging from specification to full blown design, EXCEL can tailor their service to the needs of the customer. The company is well equipped with the latest in CAD tools and TEST facilities.

Company's market(s): IC semiconductor design consultancy

Expertise of the company: IC design, Digital, VHDL, Simulation, Test Vector generation.

Experience of the company: Excel have provided design services to a number of clients. They are approved by Chip Express to supply technical support and design services to companies using Chip Express gate arrays.

Work Performed for First user: Excel consultants provided design consultancy services to the first user. They were the most important sub-contractor as they were charged with the task of taking the first user's VHDL code and test bench and providing a fully verified gate level net list to the foundry. Chip Express performed the layout and routing of the design and returned post layout timing information to Excel. Excel then performed post layout timing verification of the design before signing off. There were a number of technology specific issues that were handled by Excel. The first user had provided a high level RTL description of the ASIC but Excel had to convert this to a working gate array. Issues such as the clock tree structure, fanout, power dissipation, scan path insertion, fault simulation and other IC design specific expertise were all handled by Excel.

Liasing with Excel was a surprisingly simple process. They provided a fixed cost quote for the Job. This was arrived at in a number of stages. Firstly, the first user estimated the complexity of the design with approximate calculations and identified a target gate array. Excel then gave a guideline quotation based on a man effort estimate. The first user generated the VHDL and sent an early draft of the code to Excel. They then performed a trial synthesis of the design and spent some time examining the design to see if good coding practices were used. Based on this information they supplied a final fixed quote for the design stipulating that it was based on the VHDL code supplied. They allowed quite an amount of leeway in terms of changes that were made to the VHDL without revising the quote. The first user ran into quite a few problems with the design but Excel provided much guidance in conjunction with Chip Express (The 3rd sub contractor). The testbench supplied by the first user was considered by Excel to have very high fault coverage and was supplied in their 'ideal' format. They had to perform minimal translation of the vector files and as such had a fully packaged design with a working test harness.

By the end of the application experiment, Excel had underestimated the work involved in converting the VHDL into a gate array design. Their fixed quote meant that this did not affect the budget of the first user. Excel Consultants is based in the U.K. while the first user is based in Dublin, Ireland. This geographical difference had no negative impact on the work performed. All of the interaction was by either telephone or EMAIL. All of the design and technical information was exchanged using EMAIL. Excel handled most of the interaction with Chip Express. Any technology specific queries from Chip Express were handled directly by Excel and the communication was copied to the first user. This was a very efficient way of managing the sub-contractors. Commercial concerns and final sign off procedures were performed by the first user. There was no written contract specifically between the first user and Excel consultants. Instead, there were terms and conditions set down by Excel which the first user implicitly agreed to in retaining Excel as design consultants. Payments were made on a phased basis according to agreed deliverables with the final payment made after final sign off of the design.

Subcontractor 3 – Chip Express

Company size: >100 Employees with turnover >$18 in 1995

Company business description: Chip Express are a provider of fast turn around gate array solutions aimed at the low to medium volume ASIC market. The company uses a one mask wafer level process on a 0.8 micron 3 layer metal gate array technology to produce a low NRE medium volume product. The company has established a niche market for companies with volume requirements between 1K and 100 K pieces per anum. Using a laser machining process, chip express can produce one off prototypes in as little as three days for design testing and field trials prior to production. The one mask wafer level process allows for low to medium quantities (100 to 3K pieces) to be produced. For medium to high volume applications (>3K pieces) Chip Express offer a 'Hard Array' migration path with no re-engineering requirement on the part of the customer. The company will shrink the design down to a smaller die size for a small NRE fee and hence the unit cost is reduced.

Company's market(s): The company's markets are in ASIC gate array production for telecommunications, multimedia, Instrumentation and computer applications.

Expertise of the company: The company has expertise in taking a gate level net list and converting it to their gate array architecture. They can manufacture one off prototypes using their proprietary laser machining process and they also can test the devices using customer supplied test vectors.

Experience of the company: Founded in 1989. Chip Express have been producing gate arrays for 7 years. They have an impressive customer list including Hewlett Packard, IBM, Philips etc.

Work Performed for First User: Chip Express are the gate array foundry for the first user. They took the gate level netlist supplied by Excel Consultants and performed IC layout of the design. They then extracted back annotated timing information from the post layout design and returned the data to Excel. They then waited for final sign off of the fully verified design and manufactured 2 prototypes. Both prototypes were tested using the vectors ultimately supplied by the first user. Excel had made some modifications in order to increase the test coverage to 95%. Finally, the prototypes were sent to the first user for evaluation and testing. Chip Express charged a fixed NRE fee for the provision of the prototypes. There is no further NRE fee for production runs unless the First User either changes the design or migrates to another gate array technology offered by Chip Express.

Chip Express dealt with the first user under its terms and conditions of sale. They charge a fixed rate dependant on the size of the design. The first user had to complete a design interface form which includes an authorisation to proceed with manufacturing after the design has been signed off at various stages. NRE had to be prepaid before final layout was performed by the sub-contractor.

Summary
Working with the subcontractors turned out to be a very straightforward process. The interfaces and the work to be performed was clearly defined. This was because the first user supplied a VHDL model and a working test harness that defined the behavior of the working model. The test harness was crucial in identifying that the work was performed as agreed. The fixed cost basis for performing the work by the sub-contractors assured the first user that this element of the project would stay within the planned budget. Contingencies for delayed work or work incorrectly performed were lacking in this arrangement. The first user had only a financial lever in terms of paying for work that was verifiably correct. However, in this instance, the sub-contractors performed very well. There was definitely a strong element of 'good will' between the parties with the common aim of performing the work successfully.

AE 357

"The main support for the Application Experiment came from Euro-Projects Ltd. They provided both management and technical expertise, without which the project would not have run so smoothly. Specifically they assisted us:

- in evaluating a range CAD tools available,
- following selection of the Proteus CAD system they provided training in its use, with particular emphasis on 'Good Design Practice' for PCBs.
- they also provided substantial technical input into the design of the analogue section of the PCB".

"Particular emphasis was placed on how to mix these technologies on a single PCB; and avoiding the analogue signal degradation that can result from noise coming from nearby high frequency digital components."

The subcontractor "provided guidance at an early stage in the programme, on the control implications in moving from the AT-MIO-CARD to the proposed new analogue I/O card. His assistance ensured that the target spec for the new card was adequate for the closed loop control needs of the final Application Experiment. This is demonstrated by the complexity of the PI control algorithms that were finally adopted, and have been discussed earlier."

AE 418

"The subcontractor should offer the following capabilities:

- packaging: mounting, bonding, housing.
- qualification of processes, components and packages
- testing according to standards
- process development, including automation
- process evaluation by modelling and monitoring
- laboratory-scale and prototype series production
- compact courses, workshops and seminars, also in-house

"*Contractual safeguards*: The success of an MCM development project depends to a large extent on the precise definition of the obligations and responsibilities of the individual project partners. The party responsible for redesign – and therefore the associated costs – in case of problems must be clearly defined. Without this definition, a project such as this can easily turn into a bottomless pit. To avoid delays in the project, a contract penalty could be agreed for late delivery. Even if it proves difficult to come to a contractual agreement regarding this issue, the effort will pay off since it will reduce the risk of delays and additional costs. It should also be understood that all resulting designs would become the exclusive property of the FU. This is one of the prerequisites for handing the design over to another design partner if desired.

"In our experience, the contract definition is of greatest importance."

AE 1016

"The company has selected subcontractors to support the development of this in-house embedded ASIC design capability. One subcontractor was selected for the design of the hearing aid DSP-chip. In addition to the design of the circuit, packaging and assembly was a major problem, which had to be solved. In order to use the chip in a hearing aid, the overall size has to be as small as possible. Therefore the TÜRK+TÜRK selected one design-house and a specialist for micro-assembling as subcontractors. The subcontractors were selected for the following reasons:

- Prior experience of developing ASICs, especially in low-power design.
- The ability and agreement in the objective of transferring knowledge via a co-operative development process
- As a local subcontractor the company is able to provide technical support throughout the introduction of the design to manufacturing
- Cost effectiveness
- Vicinity to the FU and between the subcontractors
- Subcontractor (Micro-Assembler) was already known by FU "

"A contract was made between the FU and the subcontractor. This contract includes one redesign and further assistance in future problems and questions. Other terms of this contract are:

- Contractual co-operation
- Guarantee and liability
- Rights
- Remuneration
- Durance of contract and termination "

"First user and subcontractors agreed on a contract with clear responsibilities. The subcontractors were responsible for presenting only design alternatives that would allow to reach the functional objectives. TÜRK+TÜRK was responsible to define the functional requirements according to a list of parameters, requested by the subcontractors. The subcontractors were responsible for correct operation of the chip according to the specification, which the parties agreed on and have to pay re-design costs from their budget. The first user learnt that most design companies plan at least one redesign and consider it in their budget, but try to offload the responsibility to the customer, especially if design decisions are taken by the customer. "

AE 1403

"Subcontractor advice and assistance throughout the project helped avoid many pitfalls particularly in the following technical areas:

Specification
"We were able to incorporate a higher specification than originally intended at this correct stage at the expense of extending the project a little.

Training
"Training in the new technology is essential and the choice of subcontractor appropriate.

Design
"We were not competent to undertake the design using microelectronics and needed independent advice and expertise.

Staff availability
"In-house staff availability can be very variable and unpredictable. The use of a subcontractor alleviates this during important phases of the project and allows a degree of freedom in the deployment of resources."

"Ruskinn Technology were very happy with [the] subcontractor. Apart from underestimating the time required to help us develop the microcontroller, the quality of work and hand over of information proved to be first class".

"The aim is to provide independent and impartial advice and solutions to companies on a cost effective basis by providing access to a highly qualified multi-disciplined techno-commercial team of expertise. The unit also provides access to public (i.e. DTI and EC grant-aided assistance) finance and specialise in training and are able to manage projects from the feasibility stage through to the design and prototype stage."

Subcontractor Role in the Application Experiment
"The main support for the Application Experiment came from [the subcontractor]. They provided both management and technical expertise, without which the project would not have run so smoothly. Specifically they assisted us in the evaluation of a range CAD tools available on the market. After the selection they provided training in use of 'C', with particular emphasis on 'Good Design Practice'. They also provided all the technical input into the design of the component. Particular emphasis was placed on how to mix these technologies."

"External expertise is essential and selection of subcontractors was a careful process. We believe they need to be able to be involved in the specification, design and training workpackages for the First User. "

"Ruskinn Technology recommends that any company undertaking a new, to them, technology should seek clear advice and opinion on the essential specification aspect of the experiment before commencing the project. Ruskinn have discovered that getting it wrong can delay progress and cost more money than allocated in the budget. "

AE 2212

Engineering and design aspects of any future projects will be sub-contracted. The decision to use subcontractors should be taken at an early stage if there is any possibility of directly employed staff being diverted from the project by other business demands. Formal project planning, management and control has been shown to work, and will be applied in future to other similar contracts.

Time spent compiling accurate specifications and controlling revisions bears dividends later in the smooth execution of the design and assembly stages of the project. External advice and expertise (e.g. a TTN) is essential if an SME wishes to expand into a new technology.

Bolton Institute TDU provided both management and technical expertise for the project. Specifically they assisted Westin Ltd in the evaluation of a range CAD tools available.

After the selection they provided training in use of 'C', with particular emphasis on 'Good Design Practice'. They also provided the technical input for the component design. Particular emphasis was placed on how to mix different technologies.

Subcontractor contribution
The Bolton Institute TDU, Microelectronics Design Centre, was responsible for the design of the microelectronic components of this Application Experiment. The TDU provided and produced:

Checking/commenting on the initial Westin functional specification.
Detailed System and Technical Specifications.
Design and procurement of the microelectronic hardware.
Microelectronic System and Circuit Design and implementation to prototype.
PCB circuit details using EDWIN CAD system.
Printed Circuit Board (PCB) layouts for manufacture by Lyncolec Ltd.
Software design and implementation for the microelectronics.
Prototype assembly.
System documentation, for presentation to Westin including:
- Functional, system and technical specifications.
- Circuit diagrams.
- Sample boards fully populated and working to the agreed specifications.
- Design notes.
- Software listings and disk containing source and compiled code.

"The TDU Microelectronics provided the training course in addition to working with the staff of Westin during the specification and design phases of the Application Experiment. The following courses were delivered to three Westin staff".

- Introduction to microcontrollers, managing and specifying microcontroller projects.
- ANSI 'C' course.
- ANSI 'C' on microcontrollers."

AE 24586

DCB technology for production of voltage regulators in motorcycle applications a chip on board solution to regain competitiveness.

Subcontractors role
The subcontractor's role in the development programme was to supply initial training on the DCB technology (DCB substrates, soldering of bare dies and connections on DCB, tests on die and wire bonding, quality and reliability of DCB assembled products), built and supplied 20 prototype of the DCB circuit. ABB and IDM have continuously exchanged information, solutions to resolve problems concerning the mounting of surfaces material, choice the correct materials and test the new board.

Subcontractor information
By visiting international fairs of the sector and evaluating competitors' products, IDM S.r.l. defined the technology that was strategic to acquire. As a matter of fact the FUSE support motivated the company to begin a prototype development. IDM S.r.l. started to plan the AE without any internal expertise on the matter, but we thought it a primary point to know as much as possible on the technology from different areas in order to be skilled enough for choosing the right subcontractor. We believe that the right choice of the subcontractor is the most important step of the AE.

In our case this is firstly due to the small size of our company and consequently to the small contractual power if scheduled time or results would not be reached. At the very first beginning of the AE we found several subcontractors that were interested to process only a small part of our project: theoretical studies and seminar, die attach, wire bonding, SMT applications, but their different working areas and their intrinsic diversities soon revealed to be a problem for scheduling the development time and the economic cost of the operation.

At the end and with the help of the TTN, we succeeded to find a unique subcontractor with good acquaintance with the technology we pursued. The subcontractor has a foundry, where they can produce and sell DCB substrates and they have a product line, called modules, where they assemble their chips on their ceramic. We evaluated some other European supplier for MCM services with the help of our TTN, but we concluded that no one of them had an high power dissipation technology available at the moment of the decision.

Moreover our choice was also motivated by the fact that the subcontractor seemed very interested in becoming our future supplier for DCB substrates. So they were motivated in helping us to acquire the technology.

For what concern the payment of the subcontractor we divided it in three steps. We considered that only the seminar could be paid in advance. The production of the substrates and the prototypes have been paid 30 days after their delivery to us. We consider also very important to have a good relationship with subcontractor personnel both in Italy and in Germany so that they can easily co-ordinate and improve the different subcontractor's teams involved in the AE.

AE 24675

Mentec have no ASIC design experience and this will be the company's first venture into the world of ASIC design. To this end Mentec contracted Silicon Systems Design (SSD) to help in specific ways where Mentec Limited was lacking in the particular knowledge areas required for this project. SSD are an ASIC design house and have in-depth knowledge of ASIC design. They provided Mentec with valuable design guidance and training during the project design phase. They provided further consultancy and help with the task layout, floor planning, routing of the ASIC. Working with SSD provided the Mentec design team with invaluable knowledge about ASIC development flows and toolsets. Mentec planed a close working relationship with SSD as they were situated about fifteen kilometres apart.

Expertise and experience of the company
SSD have the capability for design of full custom digital, analog, and mixed signal devices. 80 Design engineers are currently employed each with access to full layout facilities.

Description of personnel and Rationale for choosing SSD
80 Design Engineers, 20 Sales staff, 20 Administration staff. SSD's design centre HQ is in Dublin Ireland. They also have additional design centres in San Jose and Cork. They provide full custom IC design and support for Digital, Analog, DSP and RISC technologies. Their experience expertise and location made them an excellent choice as consultants on this Application Experiment.

Mentec Limited chose ATMEL/ES2 as its ASIC manufacturer. ATMEL's ability to deal with small projects, (Mentec's volume requirements were low) the time scales they offered, costs and flexibility were all advantages in choosing them as a sub-contractor. Mentec Limited agreed a contract for the supply of ASIC chips with ATMEL and in that way the risk of manufacture was shared. The cost of unpredictability was factored into the contract with a higher unit price agreed for risk samples. The contract that was made with ATMEL incorporated sign-off procedures, non-performance penalty procedures and a purchase order details.

ATMEL/ES2 Ltd. – Profile

Company size: 3000 people

Relevant expertise and experience of the company: ATMEL manufactures a broad-line of high-performance non-volatile memory ICs, microcontrollers and logic devices. The highly differentiated nature of ATMEL's product lines results in greater profit margins and more secure customer relations than commodity semiconductor manufacturers. The company's products are used in telecommunications, computer and consumer automotive systems. The company's non-volatile memory products consist primarily of EPROMs, EEPROMs (parallel and serial- interface) and Flash memory devices, and its logic products consist of programmable logic devices (EPLDs and FPGAs), application specific integrated circuits and microcontrollers. Headquartered in San Jose, California, ATMEL has

manufacturing facilities in Colorado Springs, Colorado and Rousset, France, where it fabricates silicon wafers using its proprietary CMOS technologies, and manufactures circuits having feature sizes as small as 0.35 microns.

Rationale for choosing / evaluation of this subcontractor: ATMEL's earnings and revenue growth rates exceed that of the industry, reflecting the company's strong new product acceptance. In the most recent second quarter, revenue continued to be driven by expanding international demand for ATMEL's products in the telecommunications and consumer markets. ATMEL's assorted product offerings and extensive list of customers dramatically reduce the risk of individual customer or product line brinkmanship.

AE 25956

Multiswitch for satellite receiver. Hirschmann decided at the start of the project that they would not develop design expertise in-house to enable them to carry out a detailed design of an ASIC. Their aim was to be able to give a functional specification for an ASIC, which thus meant that they would use a design house to prepare the detailed design of the ASIC and liase with the foundry. There were therefore two sub contractors for the ASIC work. As with all specialist design and manufacturing projects where the First User does not possess, nor wish to acquire detailed knowledge of the work being outsourced, it is essential that the sub contractors are capable of carrying out the tasks assigned to them, and can work effectively with the First User. In this project, Hirschmann discussed with their local TTN potential design houses and foundries, which included Maxim and Hisys. Hirschmann then contacted the foundry, Maxim, and asked them to recommend a suitable design house for their application. Maxim advised that Hisys were a small design house located near to Hirschmann, who were used to dealing with 11 high frequency design applications, similar to that required for this project. Based on these recommendations, a meeting between the TTN, Hirschmann and Hisys was arranged, and from this it was agreed that Hisys would act as the design sub contractor, with Maxim as the manufacturer. Hirschmann only had a contract with Hisys, who in turn had a separate contract with MAXIM to manufacture the devices. Hirschmann had an initial contract with Hisys to cover the feasibility study, and then a separate contract to cover the development and sub contract manufacture. It was stated in this contract that if the circuit did not work exactly to specification, then Hirschmann would have to pay for a design iteration.

HiSys was contracted to develop and optimise the circuit according to the specification given by Hirschmann. As results, all required circuit and layout information (schematics) was delivered in written form (plots) to Hirschmann and MAXIM and additionally in electronically readable form to MAXIM. The simulation results were delivered as plots and tables to Hirschmann. A written test specification for prototype evaluation as well as for the series test was delivered to Hirschmann and MAXIM. Hirschmann ensured that they maintained all Intellectual property Rights (IPR) regarding the overall design in the contract drawn up between themselves and Hisys. However, the masks and tapes are owned by MAXIM. The design can not simply be transferred to another manufacturer, because it is a complete analogue design, which depends on Maxim's process parameters. Details of the sub contractors chosen to assist Hirschmann are given below:

Subcontractor 1 Hisys Design House
In this project, Hisys were responsible for producing the ASIC design to the specification agreed with Hirschmann, and then ensuring that samples were correctly manufactured and tested by Maxim, the foundry. The company was founded in 1996 and comprises 3 design engineers, with collectively 15 years design experience. The company develops monolithic integrated circuits exclusively designed for their customers. They have available to them the necessary state-of-the-art software tools for high frequency system and circuit design. The range of support covers all tasks from system definition, through design, to volume production. It includes specification development, circuit design, layout creation, prototype evaluation, and transfer to production.

The personnel have specialised knowledge in high frequency integrated circuit design. Focused on high speed communication applications, Hisys covers all required medium independent system knowledge for high-speed transmission. Hisys have established strong links to dedicated silicon vendors, including Maxim, who offer silicon bipolar and BiCMOS processes, which are optimised for high-speed analogue or mixed signed circuit and system design.

In this project Hisys developed the mixed signal ASIC design using bipolar processes offered by Maxim, to the specification supplied by Hirschmann. Hisys acted as the intermediary between Hirschmann and Maxim, and prepared all the necessary contracts and specifications for Maxim regarding the fabrication of the ASIC. Hisys were aware that the simulation of high frequency components and the isolation between them on silicon would be very difficult. Therefore the contract signed between Hisys and Hirschmann gave a target specification and clearly stated that if a design iteration was necessary, the cost would have to be met by Hirschmann. Hisys also had a similar agreement with Maxim.

Subcontractor 2 Maxim
In this project, Maxim were responsible for manufacturing the ASIC devices for Hirschmann, using the design information supplied by Hisys. In addition, they were tasked with designing and manufacturing a suitable test fixture, in order that each ASIC could be functionally tested before dispatch.

The company was founded in 1983 in Sunnyvale, California to design, develop, manufacture and market a broad range of analogue and mixed signal integrated circuits for use in a variety of electronic products. Maxim now provides over 1000 different products to a customer base of 35,000 businesses world-wide. Around one third of Maxim's current $450 million annual sales are made in Europe and the company provides direct engineering support throughout Europe with a field applications team of more than 30 engineers speaking at least 10 European languages. In 1994 Maxim acquired the integrated Circuits Division of Tektronix, located in Germany, and it was this foundry which produced the ASICs for this project. In addition to increasing manufacturing capacity for Maxim's eight different analogue CMOS processes, this acquisition provided a portfolio of state of the art bipolar processes aimed at high frequency applications. These are supported by a design philosophy and unrivalled device modelling that have allowed the company to extend access to customer hardware engineers for the definition of ASICs for high performance, low power, RF applications. As software tools for logic simulation have advanced it has become commonplace for systems companies to design their own digital and even low frequency analogue and mixed signal circuits but the RF domain has, until recently, remained the preserve of semiconductor design specialists. By providing a stable well defined process, powerful analogue simulation tools and accurate component models Maxim is able to offer competent RF transistor level hardware design engineers the opportunity to realise their design directly in silicon. The Maxim GST2 process has a transistor f1 of 27 GHz. This and high functional packing density now provides the possibility to integrate RF applications at frequencies up to 2.5 GHz. Pre-diffused, application oriented tile arrays have been developed to allow the sharing of a large part of the tooling and complex manufacturing process between a number of different designs. This reduces both the development costs and time to market of an ASIC design. Maxim were able to use, within this project, the pre-diffused, application orientation tile array. Their design support and model libraries fitted well with the Hisys modelling tools.

Subcontractor 3 University of Stuttgart
There are 15 engineers in this University with experience in electromagnetic field simulation for optimisation of mobile phone systems and waveguide design. One engineer qualified to PhD was involved in this project. The connection line structure and layout was modelled, simulated and optimised in order to try and maximise specific knowledge and simulation tools for RF design, and the fact that they were local to Hirschmann were two main reasons why they were chosen for this task.

GENERAL COMMENTS

[AE 26139]: "Our unique new product, its complexity, its flexibility, and its innovative operation, is as much a testament to our subcontractor dedication to the project as it is to our own." "The fact that the project has been successfully completed, that we have a finished product and that we have the staff to implement it, is proof that they were unquestionably the right company for us to use for this job."

[AE 26243]: "To use an appropriate subcontractor is many times the right solution and the way to accomplish targets which would not have been feasible by just lying on the company's know-how and expertise."

[AE 26608]: "The professional expertise of the Company combined with the professional expertise of the subcontractor that can lead to results that each of the partners alone would not be able to achieve, in reasonable time and cost."

[AE 27026]: "We would like to put emphasis on the importance of choosing a good subcontractor. We had our life made much easier due to the level of support we received from ours."

[AE 27489]: "For a successful project it showed to be of great value to have selected a good subcontractor with great care, which especially proved to be advantageous to find solutions to problems that were not foreseen at start of the project."

[AE 27535]: "One of the most important factors in a new project success is the choice of consultants. This choice is as much important as using a new technology for the first time. In this case, the subcontractor can introduce the company to the new technology rapidly and without causing trouble to the company's day by day activities."

[AE 27675]: "It is very important to work together with the technical expertise and assistance of third parties. Relying upon external expertise can save of a lot of time and cost, and can significantly shorten the development time for new products."

SUBCONTRACTOR EXPERTISE AND EXPERIENCE

[AE 26033]: "For a 'First User' it is crucial to work together with a consultant or subcontractor with excellent knowledge in the areas not known by the Company!"

[AE 26243]: "The chosen subcontractor had the ability to deal efficiently with small projects of this type, proven by the subcontractors' previous successful works in the area of interest." "Indeed the careful selection of the most suitable subcontractor is of outmost importance for the success of such an experiment, since if the specific subcontractor were not so well qualified the project's outcome would be doubtful."

[AE 26655]: "The reference list that the SC presented to us gave reason to believe that the project would be carried out in a professional manner."

[AE 26682]: "One of the main reasons why this SC was selected were the references he brought from the companies that had worked with him in the past."

[AE 29412]: "Try to integrate the know-how of your individual subcontractors in a very close way into the design of the soft- and hardware which will directly build up your knowledge."

[AE 29749]: "The selection of subcontractors understanding problems related to your own company product and application field is a key factor."

[AE 29813]: "To realise the AE, it was fundamental to select an expert and reliable subcontractor, whose qualified services were required as necessary to minimise the risk of not achieving the expected results of the project within the scheduled timeframe." "The Subcontractor referenced a wide typology of projects and products realised with the microelectronic technologies. It demonstrated a wide range of links with other suppliers and board manufacturers."

CO-OPERATION AND COMMUNICATIONS

[AE 26033]: "The interfacing was done through regular meetings. At the beginning the meetings took place every two weeks, at a later stage it was switched to communication through e-mail and the meeting interval were expanded to one to two months."

[AE 26171]: "Developing a good relationship with subcontractors was very important so that the we could feel free to ask questions at any time to gain help and assistance. This relationship allowed us to complete the hardware development on schedule and produce prototypes that worked to specification."

[AE 26608]: "Communication and involvement are very important. The subcontractor should feel like part of a team with the customer, working together in solving a common problem."

[AE 27436]: "A key factor of success working with external partners is the good quality of the documentation exchanging, specification and design data between the parties. The management job may suffer a lot due to inefficient communication skills."

[AE 29412]: "Make sure to manage your subcontractor to work on your goals not on theirs."

[AE 29531]: "All parties involved, including supplier and subcontractor, must be committed to the project and good communication channels between each party are essential to maintain good project management."

[AE 29738]: "The basis for a successful co-operation between subcontractor and First User is the specification of the new product and the selection of technology with the support of the SC. Of high importance is the common design work between the layout designer and the First User."

[AE 29749]: "The most important feature of this Experiment that avoided the problems encountered in the past, was the useful collaboration between the subcontractor and the company. The responsibility shared, each task has been carried out with the suitable skills and continuous check has been done on each phase."

[AE 29759]: "Another very important point for a small company like SITRONIC is the subcontractors intention to work in close co-operation with us, that includes that the subcontractor considers the development to be important for themselves." "Make sure to manage your subcontractor to work on your goals and not theirs."

[AE 29813]: "The subcontractor collaboration is fundamental to successfully finalise the project. Active collaboration with them before and during the project execution was important to avoid practical errors that would result in loss of time and productivity."

[AE 30107]: "The needs of working together with people with different culture and interest in a continuous exchange of information and a confrontation with different experiences produces good results; especially during the contract definition it could give additional benefits to the FU."

CONTRACTUAL MATTERS

[AE 25962]: "For the subcontractor prototype development work we arranged stage payments linked in with key training and initial deliverables at the early stages throughout the project, under terms and conditions associated with the company purchase orders."

[AE 26566]: "We agreed on a basis of a fixed price contract; this revealed to be an important item as the project lasted longer than planned."

[AE 26662]: "A fixed price contract proved in the end to be valuable. If redesigns had to be paid for, together with the extra time for testing of the components and system, the ROI of the project would have been jeopardised."

[AE 27771]: "The company also imposed a very tight clause: in case of failure of the functionality of the first prototypes the subcontractor would have been charged with the costs of a second foundry run."

[AE 29412]: "Fix the tasks, time schedule, milestones and payment in the contract and keep in touch with the subcontractor to check the observance." "The contract was made with accurate schedule for tasks and payments: 30% of order on signing of specification and start of the design; 30% on Delivery of functional prototypes (20pcs.), and 40% after finishing of all qualification tests."

[AE 29494]: "The payments were agreed to be made on completion of every deliverable as stated in the experiment workplan."

[AE 30095]: "SUPERAUTO and our subcontractor signed an agreement of collaboration for the specific development, ruling the modalities with which the activities of on job training, design and test of the board would have been carried out on going the project. Contents of this document mainly establish the duration, the costs and responsibility, other than the way in which to conduct the job. The Company imposed also a tight clause to the Subcontractor in case of failure of the functionality of first prototypes due to errors related to the design activities under the Subcontractor's responsibility."

INTELLECTUAL PROPERTY RIGHTS (IPR)

[AE 26535]: "A good industrial property strategy gives an edge in contract negotiation. Other organisations should recognise the importance of this aspect of subcontract negotiation. During contract negotiation, obtaining several years of exclusivity on the Company's markets to give an initial competitive advantage should be considered."

[AE 26682]: "IPR issues should be considered first (is the FU the only fully entitled to exploitation?). If this is not the case, special licence agreement should be settled with the other owners."

[AE 27436]: "A special agreement was made with the Subcontractor. The Company entrusted SC with the design and the fabrication of the related prototype. SC will own the results generated during the project, and related to the field of the project, with the condition that the Company will be free to use and exploit them. SC granted us an exclusive, free of charge and irrevocable license on IPR. The Company granted to SC a non-exclusive, free of charge and irrevocable license on IPR."

[AE 27612]: "In the past, we had made a point of establishing the IPR for all product development work prior to embarking on such a project. However, having done this type of work before, the subcontractor was reluctant to relinquish IPR in this instance. The First User was not put off using them, as we were mainly interested in the knowledge transfer and prototype development. … All the work was satisfactorily completed on a professional basis."

[AE 29494]: "A confidentiality agreement was signed prior to FUSE application with the subcontractor to allow freedom of exchange of information between the party concerned. Salamander exchanged a contract with the subcontractor at the beginning of the project for training and design assistance, in which Salamander reserved their copyright of the completed firmware."

[AE 30095]: "… SUPERAUTO asked for a non disclosure agreement from the Subcontractor and it also retained any right on the product as resulting from the agreed contract."

MISCELLANEOUS

[AE 26208]: "Provide the subcontractor with all the necessary information, without too many confidentiality barriers, in order to enable them to develop the design properly."

[AE 26224]: "Use a subcontractor that has experience not only in the required technologies, but also in project management and training / knowledge transfer."

[AE 26655]: "Also, the AE has taught us how difficult it is to write good specifications for a subcontractor. The significance of such specifications can not be underestimated, as disagreement about how to interpret a set of unclear specifications can cost very much both in time and money."

[AE 27321]: "An ideal subcontractor should be suitable in size. Large enough to have quality assurance programs, personnel education etc. so that you can rely on them and do not have to worry about their progress/results continuously. But not too large since the interest towards small purchasers becomes more marginal the larger the company gets."

[AE 29759]: "When there is more than one subcontractor, try to integrate the know-how of all of them in an efficient way."