# GESTÃO DE PROJECTOS DE I&D - VISÃO GLOBAL DA CANDIDATURA ( INVESTIGADORES )
(R&D PROJECTS - RESEARCHERS )

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**Referência do projecto**
**Project reference**
PTDC/EEA-ELC/68972/2006

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1. Identificação do projecto
1. Project description

**Financiamento solicitado**
**Requested funding**
199.984,00 Euros

**Área científica principal**
**Main Area**
Electrical Engineering - Electronics and Computers

**Área científica Secundária**
**Secondary area**
Biochemistry Engineering and Biotechnology

**Título do projecto (em português)**
**Project title (in portuguese)**
ICONS- Estimulador Neuronal Intra Cortex Visual

**Título do projecto (em inglês)**
**Project title (in english)**
ICONS- Intracortical Neuronal Stimulator

**Palavra-chave 1**
Estimulador Neuronal Microelectrónico

**Keyword 1**
Microelectronic Neuronal Stimulator

**Palavra-chave 2**
Estimulador Neuronal Sem Fios

**Keyword 2**
Wireless Neuronal Stimulator

**Palavra-chave 3**
Micro-Agregados de Implantes Neuronais

**Keyword 3**
Implantable Neuronal Microarrays

**Palavra-chave 4**
Ligação por RF para Aplicações Médicas

**Keyword 4**
RF Link for Medical Applications

**Objectivos sócio-económicos**
**Socio-economic objectives**
Human Health

**Data de início do projecto**
**Starting date**
01-01-2007

**Duração do projecto em meses**
**Duration in months**
36

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2. Instituições participantes
2. Participating institutions

**Instituição Proponente**
**Principal Contractor**
**Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento em Lisboa (INESC ID/INESC/IST/UTL)**
Rua Alves Redol, 9
1000-029Lisboa

**Instituições Participantes**
**Participating Institutions**

**Instituto de Engenharia de Sistemas e Computadores - Microsistemas e Nanotecnologias (INESC MN/INESC/IST/UTL)**
Rua Alves Redol, 9
1000-029Lisboa

**Unidade de Investigação**
**Principal Research Unit**
**Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento em Lisboa (INESC ID/INESC/IST/UTL)**
Rua Alves Redol, 9

1000-029Lisboa

**Instituição de Acolhimento**
**Host Institution**
**Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento em Lisboa (INESC ID/INESC/IST/UTL)**
Rua Alves Redol, 9
1000-029Lisboa

3. Orçamento
3. Proposal Budget

**Instituição Proponente**
**Principal Contractor**

**Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento em Lisboa**

| DESCRIÇÃO<br>DESCRIPTION | 2007 | 2008 | 2009 | 2010 | 2011 | TOTAL |
|---|---|---|---|---|---|---|
| Recursos Humanos<br>Human resources | 25.490,00 | 25.490,00 | 25.490,00 | 0,00 | 0,00 | **76.470,00** |
| Missões<br>Missions | 2.500,00 | 2.500,00 | 2.500,00 | 0,00 | 0,00 | **7.500,00** |
| Consultores<br>Consultants | 2.500,00 | 2.500,00 | 0,00 | 0,00 | 0,00 | **5.000,00** |
| Aquisição de serviços e manutenção<br>Acquisition of services and maintenance | 2.500,00 | 7.500,00 | 5.000,00 | 0,00 | 0,00 | **15.000,00** |
| Outras despesas correntes<br>Other current expenses | 1.000,00 | 1.000,00 | 1.500,00 | 0,00 | 0,00 | **3.500,00** |
| Despesas gerais<br>Overheads | 8.298,00 | 8.198,00 | 7.198,00 | 0,00 | 0,00 | **23.694,00** |
| **TOTAL DESPESAS CORRENTES**<br>**TOTAL CURRENT EXPENSES** | **42.288,00** | **47.188,00** | **41.688,00** | **0,00** | **0,00** | **131.164,00** |
| Equipamento<br>Equipment | 7.500,00 | 2.000,00 | 1.500,00 | 0,00 | 0,00 | **11.000,00** |
| **TOTAL** | **49.788,00** | **49.188,00** | **43.188,00** | **0,00** | **0,00** | **142.164,00** |

**Instituições Participantes**
**Participating Institutions**

**Instituto de Engenharia de Sistemas e Computadores - Microsistemas e Nanotecnologias**

| DESCRIÇÃO<br>DESCRIPTION | 2007 | 2008 | 2009 | 2010 | 2011 | TOTAL |
|---|---|---|---|---|---|---|
| Recursos Humanos<br>Human resources | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | **0,00** |
| Missões<br>Missions | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | **0,00** |
| Consultores<br>Consultants | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | **0,00** |
| Aquisição de serviços e manutenção<br>Acquisition of services and maintenance | 5.000,00 | 5.000,00 | 5.000,00 | 0,00 | 0,00 | **15.000,00** |
| Outras despesas correntes<br>Other current expenses | 3.000,00 | 3.000,00 | 3.000,00 | 0,00 | 0,00 | **9.000,00** |
| Despesas gerais<br>Overheads | 5.940,00 | 1.440,00 | 1.440,00 | 0,00 | 0,00 | **8.820,00** |
| **TOTAL DESPESAS CORRENTES**<br>**TOTAL CURRENT EXPENSES** | **13.940,00** | **9.440,00** | **9.440,00** | **0,00** | **0,00** | **32.820,00** |
| Equipamento<br>Equipment | 25.000,00 | 0,00 | 0,00 | 0,00 | 0,00 | **25.000,00** |
| **TOTAL** | **38.940,00** | **9.440,00** | **9.440,00** | **0,00** | **0,00** | **57.820,00** |

**Orçamento Global**
**Global budget**

| DESCRIÇÃO<br>DESCRIPTION | 2007 | 2008 | 2009 | 2010 | 2011 | TOTAL |
|---|---|---|---|---|---|---|
| Recursos Humanos<br>Human resources | 25.490,00 | 25.490,00 | 25.490,00 | 0,00 | 0,00 | **76.470,00** |
| Missões<br>Missions | 2.500,00 | 2.500,00 | 2.500,00 | 0,00 | 0,00 | **7.500,00** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Consultores<br>Consultants | 2.500,00 | 2.500,00 | 0,00 | 0,00 | 0,00 | **5.000,00** |
| Aquisição de serviços e manutenção<br>Acquisition of services and maintenance | 7.500,00 | 12.500,00 | 10.000,00 | 0,00 | 0,00 | **30.000,00** |
| Outras despesas correntes<br>Other current expenses | 4.000,00 | 4.000,00 | 4.500,00 | 0,00 | 0,00 | **12.500,00** |
| Despesas gerais<br>Overheads | 14.238,00 | 9.638,00 | 8.638,00 | 0,00 | 0,00 | **32.514,00** |
| **TOTAL DESPESAS CORRENTES**<br>**TOTAL CURRENT EXPENSES** | **56.228,00** | **56.628,00** | **51.128,00** | **0,00** | **0,00** | **163.984,00** |
| Equipamento<br>Equipment | 32.500,00 | 2.000,00 | 1.500,00 | 0,00 | 0,00 | **36.000,00** |
| **TOTAL** | **88.728,00** | **58.628,00** | **52.628,00** | **0,00** | **0,00** | **199.984,00** |

**Plano de financiamento**
**Finance plan**

| DESCRIÇÃO<br>DESCRIPTION | 2007 | 2008 | 2009 | 2010 | 2011 | TOTAL |
|---|---|---|---|---|---|---|
| Financiamento solicitado à FCT<br>Requested funding | 88.728,00 | 58.628,00 | 52.628,00 | 0,00 | 0,00 | **199.984,00** |
| Financiamento próprio<br>Own funding | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | **0,00** |
| Outro financiamento público<br>Other public-sector funding | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | **0,00** |
| Outro financiamento privado<br>Other private funding | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | **0,00** |
| **Total do Projecto**<br>**Total of the project** | **88.728,00** | **58.628,00** | **52.628,00** | **0,00** | **0,00** | **199.984,00** |

4. Justificação do orçamento
4. Budget justification

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**4.1. Justificação dos recursos humanos**
**4.1. Human resources justification**

| Tipo | Nº de pessoas | Duração | Custo envolvido (€) |
|---|---|---|---|
| (BI) Bolsa de Investigação (Mestre) | 2 | 36 | 70560 |

Justificação

Team member #1 we will need a scholarship for designing and testing the microelectronic circuits.
Team member #2 we will need a scholarship for designing and testing the microelectronic array and to build the system based on flip-chip technology.

**Custo total:** 70560

**4.2. Justificação de missões**
**4.2. Mission justification**

| Tipo | Local | Nº de deslocações | Custo envolvido (€) |
|---|---|---|---|
| Participação em congressos | Various in Europe and United States | 6 | 7500 |

Justificação

It is expected to obtain scientific results for publication in two international conferences per year, which means a total of 6 communications. These conferences are in the area of Electrical Engineering, Micro and Nano technologies and Bio Circuits and Systems.

**Custo total:** 7500

**4.3. Justificação de consultores**
**4.3. Consultants justification**

| Nome | Instituição | Fase do projecto | Custo envolvido (€) |
|---|---|---|---|
| Dr. Eduardo Fernández | Institut de Bio-Ingenieria, Facultad de Medicina, Universidad Miguel Hernández | For the whole project | 5000 |

Justificação

It is very important to have consultants with expertize in the neurobiology, namely the neurobiological aspects related with the design and implementation of visual neuroprosthesis. Dr. Eduardo has a lot of experience on implanting microelectrode arrays in mammalians and he has performed several experimental studies
related with the effects of charge injection in the visual cortex. We already collaborated with Prof. Eduardo Fernandez in the scope of CORTIVIS project and we will invite him as a consultor for this project we propose now.

**Custo total:** 5000

**4.4. Justificação de aquisição de serviços e manutenção**
**4.4. Acquisition of services and maintenance justification**

| Tipo | Custo envolvido (€) |
|---|---|
| Microelectronic Circuits and MicroElectrodes | 30000 |

Justificação

Justificação

5000€ per year will be needed to cover the respective part of the maintenance of the clean room woned by INESC-MN.

A test circuit (in the second year) and a final demonstrator will be built and tested. This is the main expense of acquisition of services (even through Europractice mini@sic, an integrated circuit costs around 5000 euros). For testing it is necessary to prepare printed circuit boards, and it is necessary to do bonding and packaging of the test chips. Conventional microelectrode arrays will be processed in such a way that it integrates the interface with microelectronic circuits in its back through flip-chip technology. A new type of planar microelectrodes arrays will also be developed and fabricated on glass or Si substrates using wet and dry microfabrication techniques.

**Custo total:** 30000

**4.5. Justificação de outras despesas correntes**
**4.5. Current expenses justification**

| Tipo de despesa | Custo envolvido (€) |
|---|---|
| Acquisition of Electrical components and Books | 12500 |

Justificação

To test the prototypes various additional components are required.
Recent books will be acquired during the project.
Current material for printing, storing data (DVD), etc.

**Custo total:** 12500

**4.6. Justificação do Equipamento**
**4.6. Equipment justification**

**4.6.1. Equipamento já disponível para a execução do projecto**
**4.6.1 Available equipment**

| Tipo de equipamento | Fabricante | Modelo | Ano |
|---|---|---|---|
| magnetron sputtering deposition system | Nordiko | 2000 | 1994 |
| magnetron sputtering deposition system | Nordiko | 7000 | 1994 |
| Ion beam deposition and milling system | Nordiko | 3600 | 2005 |
| Real Time Spectrum Analyzer ((GHz) | Tektronix | RSA3308A | 2004 |
| 250m2, class 10/100 clean room | LUWA | - | 1994 |
| direct write laser lithography | Lasarray | DWL 2.0 | 1994 |
| Direct write e-beam lithography | Raith | 150 | 2006 |
| Ion beam deposition and milling system | Nordiko | 3000 | 1998 |
| Reactive plasma etching | LAM | - | 1994 |
| Annealing furnaces | Home made | - | 2000 |
| Scanning Electron microscope | Hitachi | - | 1993 |
| X ray diffractomer | Siemens | D5000 | 2006 |
| UHV PVD system | Home made | UHV1, UHV2 | 1996 |
| CVD | Electrotech | - | 1994 |
| Photoresist tracks | SVG | - | 1994 |
| Spin On Glass Tracks | SVG | - | 1994 |
| Vibrating Sample magnetometer | Digital Measurement Systems | 880 | 1990 |
| Ellipsometer | Rudolph REsearch | - | 1993 |
| Profilometer | Dectak | Alpha Step | 1994 |
| Electric characterization | KLA | KLA1007E wafer prober | 2001 |
| Wire bonding | - | - | 1993 |
| Pulse generator | Agilent | 33220-A | 2005 |
| Dicing saw | DISCO | DAD 321 | 1995 |
| Atomic Force Microscope | Digital Instruments | Dimension 3000 | 1998 |

**4.6.2. Discriminação do equipamento a adquirir**
**4.6.2. List of new equipment requested**

| Tipo de equipamento | Fabricante | Modelo | Custo envolvido (€) |
|---|---|---|---|
| Oscilloscope | Lecroi | to be determined | 7500 |

Justificação

Due to the project nature a 4-channel oscilloscope with floating isolated probes is required for measuring biological signals. Also, a deep memory size is required to acquire long real time biological signals.

| Tipo de equipamento | Fabricante | Modelo | Custo envolvido (€) |
|---|---|---|---|
| Magnetron (4") | Nordiko | N3600 | 10000 |

Justificação

To introduce an extra target to the existing six.

| Tipo de equipamento | Fabricante | Modelo | Custo envolvido (€) |
|---|---|---|---|
| Magnetron | Nordiko | 3600 | 15000 |

Justificação

This equipment will be installed at the Nordiko 3600 Ion Beam system, to monitor in real time the ion milling steps and achieve a precise control of the etching during the tunnel junction patterning steps. The equipment will be shared among other projects (only

25% of the total cost is supported by this project).

| | | | |
|---|---|---|---|
| PC - laptop | any | Intel Based | 2000 |

Justificação

This PC will be used and shared by the grant holders to use along all the project, namely to store all the information about the project and also to write the papers and the technical reports.

| | | | |
|---|---|---|---|
| PC- desktop | any | AMD | 1500 |

Justificação

An worksation to install all the software required to describe and design the circuits (from Synopsys and Cadence)

**Custo total:** 36000

5. Equipa de investigação
5. Research team

**5.1 Lista de membros**
**5.1. Members list**

| **Nome**<br>**Name** | **Função**<br>**Role** | **Grau académico**<br>**Academic degree** | **%tempo**<br>**%time** |
|---|---|---|---|
| Moises Simões Piedade | Inv. Responsável | AGREGAÇÃO | 25 |
| André Aires Coutinho Guedes | Investigador | LICENCIATURA | 25 |
| Jorge Manuel dos Santos Ribeiro Fernandes | Investigador | AGREGAÇÃO | 15 |
| José António Beltran Gerald | Investigador | DOUTORAMENTO | 15 |
| Leonel Augusto Pires Seabra Sousa | Investigador | AGREGAÇÃO | 10 |
| Marcelino Bicho dos Santos | Investigador | AGREGAÇÃO | 10 |
| Miguel de Lima Teixeira | Investigador | LICENCIATURA | 75 |
| Paulo Jorge Peixeiro Freitas | Investigador | AGREGAÇÃO | 5 |
| Rui Miguel da Costa Chaves | Investigador | LICENCIATURA | 25 |

**Total: 9**

**5.2. Lista de membros a contratar durante a execução do projecto**
**5.2. Members list to hire during project's execution**

| **Membro da equipa**<br>**Team member** | **Função**<br>**Role** | **Duração**<br>**Duration** | **%tempo**<br>**%time** |
|---|---|---|---|
| (BI) Bolseiro de Investigação (Mestre) 1 | Bolseiro | 36 | 100 |
| (BI) Bolseiro de Investigação (Mestre) 2 | Bolseiro | 36 | 100 |

**Total: 2**

6. Projectos financiados
6. Funded projects

*(Sem projectos financiados)*
*(No funded projects)*

7. Indicadores previstos
7. Expected indicators

**Indicadores de realização previstos para o projecto**
**Expected output indicators**

| DESCRIÇÃO<br>DESCRIPTION | 2007 | 2008 | 2009 | 2010 | 2011 | **Total** |
|---|---|---|---|---|---|---|
| **A - Publicações**<br>**Publications** | | | | | | |
| Livros<br>Books | 0 | 0 | 0 | 0 | 0 | **0** |
| Artigos em revistas internacionais<br>Papers in international journals | 0 | 2 | 2 | 0 | 0 | **4** |
| Artigos em revistas nacionais<br>Papers in national journals | 0 | 0 | 0 | 0 | 0 | **0** |
| **B - Comunicações**<br>**Communications** | | | | | | |
| Comunicações em encontros científicos internacionais<br>Communications in international meetings | 2 | 2 | 2 | 0 | 0 | **6** |
| Comunicações em encontros científicos nacionais<br>Communications in national meetings | 0 | 0 | 1 | 0 | 0 | **1** |
| **C - Relatórios**<br>**Reports** | 1 | 1 | 1 | 0 | 0 | **3** |
| **D - Organização de seminários e conferências**<br>**Organization of seminars and conferences** | 0 | 0 | 0 | 0 | 0 | **0** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **E - Formação avançada**<br>**Advanced training** | | | | | | |
| Teses de Doutoramento<br>PhD theses | 0 | 0 | 1 | 0 | 0 | **1** |
| Teses de Mestrado<br>Master theses | 0 | 1 | 1 | 0 | 0 | **2** |
| Outras<br>Others | 0 | 0 | 0 | 0 | 0 | **0** |
| **F - Modelos**<br>**Models** | 0 | 0 | 0 | 0 | 0 | **0** |
| **G - Aplicações computacionais**<br>**Software** | 0 | 0 | 0 | 0 | 0 | **0** |
| **H - Instalações piloto**<br>**Pilot plants** | 0 | 1 | 0 | 0 | 0 | **1** |
| **I - Protótipos laboratoriais**<br>**Prototypes** | 0 | 2 | 2 | 0 | 0 | **4** |
| **J - Patentes**<br>**Patents** | 0 | 0 | 0 | 0 | 0 | **0** |
| **L - Outros**<br>**Other** | | | | | | |
| | 0 | 0 | 0 | 0 | 0 | **0** |
| | 0 | 0 | 0 | 0 | 0 | **0** |
| | 0 | 0 | 0 | 0 | 0 | **0** |

**Acções de divulgação da actividade científica**
**Scientific activity spreading actions**
*(Estimula-se a apresentação e propostas neste âmbito que possibilitem a aproximação da actividade científica ao grande público)*
*(It is strongly desired the presentation of proposals within this subject that will approach science to the general public.)*

We intend to prepare technical material and give talks about the results of the project, namely the for students of electronics and biomedical engineering.

For the public in general, the project will be divulgated through the media. For blind people in particular, we intend to establish protocols with nacional and international associations, such as the ACAPO (Associação dos Cegos e Amblíopes de Portugal) and ONCE (Organização Nacional de Cegos de Espanha). These protocols include information about all around the world ongoing projects in the area of visual prostheses and also about the main objectives and results achieved in this project.

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8. Anexo técnico
8. Technical addendum

**8.1. Resumo**
**8.1. Abstract**

**Resumo (em português)**
**Abstract (in portuguese)**

Nos últimos anos, tem-se verificado um intenso esforço de investigação para aplicações biomédicas. A elevada complexidade destas aplicações deve-se à sua multidisciplinaridade, assumindo a microelectrónica um papel fundamental. Os estimuladores implantáveis mais utilizados em aplicações biomédicas são os para estímulo dos músculos e do sistema nervoso, para o coração, de membros ou para suprir deficiências auditivas. Algumas destas aplicações, tais como o metrónomo electrónico para o coração, requerem sistemas de consumo muito reduzido, para evitar a substituição de baterias, mas a sua operação praticamente não exige processamento de sinal. Implementações biomédicas no campo da reabilitação do sistema visual são introduzidas nas fases iniciais deste sistema. Para lá dos mecanismos mecânicos e ópticos associados à função de visão, que são perfeitamente conhecidos e que podem ser corrigidos por cirurgia ou usando lentes externas, outras mecanismos, tal como o processamento de imagem, que tem lugar entre a retina e o cortex visual, não são completamente conhecidos. Resultados de investigação recente mostram que o estímulo do cortex visual melhora a qualidade de vida de cegos, nomeadamente com cegueira profunda.\nNeste projecto, será desenvolvida uma neuro-prótese visual sem fios, bidireccional e com elevado débito de sinais (vídeo), baseada num sistema integrado de estimulação através de microeléctrodos. Na arquitectura do sistema, apresentada na Fig.3, podem-se identificar dois sub-sistemas principais: um sub-sistema primário, colocado no exterior do corpo, onde é efectuado o processamento, e um sub-sistema secundário, localizado no interior do corpo, que estimula o cortex visual através de um aglomerado de micro-eléctrodos (Fig. 1). As soluções existentes transportam os dados e a alimentação através de fios que interligam os dois sub-sistemas. Requerem um elevado número de fios de ligação e a existência de um conector eléctrico implantado no corpo, o que torna esta solução quase impraticável pois origina a necessidade de combater infecções permanentes associadas à interface conector/corpo.\nCom acoplamento em rádio-frequência (RF), os dados e a alimentação podem ser obtidos no sub-sistema secundário através de um transformador com acoplamento fraco, evitando a ligação física e a utilização de baterias na prótese. Por outro lado, a comunicação bidireccional simultânea permite excitar e, também, adquirir sinais dos microeléctrodos (que podem ser sinais neurológicos ou sinais de monitorização de estado) o que potencia a utilização deste sistema para novas aplicações que requerem comunicação bidireccional de dados a elevado ritmo.\nA solução proposta neste projecto é inovadora e coloca problemas e múltiplos desafios específicos ao nível dos circuitos e dos microeléctrodos. Desenvolver-se-ão os circuitos para quatro diferentes blocos. O bloco de interface com o secundário do transformador, composto pelos seguintes módulos: o módulo de potência, o módulo de recuperação de relógio e os módulos de modulação e desmodulação dos dados (módulos RF). O bloco de processamento dos dados e de controlo é composto pelos módulos digitais de processamento dos dados de entrada e de saída. O bolco de estimulação dos micro-eléctrodos inclui um conversor digital-analógico (DAC) integrado na unidade de acondicionamento de sinal, um circuito adapatador de impedâncias e um conversor analógico-digital (ADC), para monitorar o estado dos micro-eléctrodos. Por fim, o aglomerado de microeléctrodos será desenvolvido no INESC-MN e processado sobre um circuito integrado CMOS, utilizando tecnologia flip-chip para que seja implantável e robusto. O protótipo do sistema será testado utilizando o modelo de retina e o sub-sistema primário desenvolvido pela equipa de investigação deste projecto num projecto europeu anterior

(CORTIVIS) e terá o apoio da equipa do neurocirurgião Prof. Eduardo Fernandez, no que se refere ao teste em animais. O INESC-MN iniciará ainda o desenvolvimento de uma versão do estimulador neuronal com a capacidade de ser simultaneamente excitador e sensor, utilizando a sua tecnologia de sensores magnéticos ultra sensível baseados em junções magnéticas de efeito de tunnel. Estes microeléctrodos podem tirar vantagem da arquitectura de transmissão de dados bidireccional, desenvolvida neste projecto.\nEm conclusão, neste projecto pretende-se desenvolver o sub-sistema secundário para uma prótese visual , utilizando uma aproximação "System on a Chip" (SOC), integrada com o aglomerado de microeléctrodos. Este sub-sistema é composto por múltiplos circuitos projectados com tecnologias diferentes. Apesar da se poder considerar que as especificações individuais de cada um dos blocos não são muito exigentes, as restrições de consumo de potência, dimensão e os aspectos relacionados com o ambiente de funcionamento, fazem do projecto e implementação deste SOC um grande desafio.\n

**Resumo (em inglês)**

**Abstract (in english)**

Biomedical applications have seen an intense research effort in the last few years. Due to its huge complexity it is a multidisciplinary area where microelectronics plays an important role in the feasibility of most systems. Implantable stimulators for biomedical applications, most commonly applied, are in the area of muscular or nerve stimulation, for heart, limbs or hearing diseases. Some of these applications, such as pacemakers, require very low power systems, to avoid the replacement of batteries, but its action requires also almost no signal processing. Biomedical implementations in the field of visual rehabilitation, is integrated in its early stages. Besides the mechanical and optic mechanisms associated with vision which are already fully understood and can be corrected by surgery or external lenses, other mechanisms like the image processing that takes place from the retina down to the visual cortex is still not well known. Recently research results on experiments to stimulate the visual cortex to improve the quality of life for blind or partially blind people have been presented.\nIn this project we address an integrated microelectrode stimulator system for a wireless intracortical neuroprosthesis , with high bit rate (video) . The system architecture is presented in Fig.3 where the system is divided in two parts: a primary system placed outside the human body, where all the processing takes place, and a secondary system placed inside the human head, to estimulate the visual cortex through the electrode array (Fig. 1). The traditional solutions to interface the implant with data and power were by a wired link. However, it requires a large number of wires and an electrical connector implanted in the body, which apart from the discomfort; poses a serious risk of infection. \nWith RF coupling, data and power can be obtained directly from an RF low-coupling transformer discarding the need for batteries or wiring. On the other hand, simultaneous bidirectional communication allows driving, and also acquiring, signals to, and from, the microelectrodes (it can be neuronal signals or signals sensing the state of the system).\nThese characteristics will also open the possibility of applying the system to other applications that require bidirectional high rate communication. \nThe solution proposed here is innovative and poses many application specific problems at circuit level, which are not present in mainstream applications. We intend to address the design of the circuit as four different blocks. The block that interface with the transformer secondary which is composed of the following circuits: the power supply block (power module); the clock recovery circuit; the data demodulator and the data modulator (RF processing modules). The data processing control block which is composed by the input and output data processing blocks (digital modules). The electrode stimulator block which has a digital-to-analog converter (DAC) as a signal conditioning unit, a electrode buffer and a analog-to-digital converter (ADC) for electrode monitoring (analog modules). Finally, the microelectrode arrays to be designed on house and processed over a CMOS integrated circuit using flip-chip technology in order to be fully implantable without external wiring, reducing the risk of infection and increasing robustness. The prototype will be tested using the retina model and primary system (discrete solution) developed by this project team in a former European project (CORTIVIS) and the project has the support of the neurosurgeon Prof. Eduardo Fernandez to perform tests in animals. The INESC-MN institute will develop a new version of the neural microelectrode stimulator with both capacities of exciting and sensing, by using its own technology to develop magnetic junction tunnel sensors. Theses microelectrodes can take advantage of the architecture developed in this project for bidirectional communication. \nIn this project we intend to implement a complete secondary system as System on Chip (SOC) solution integrated with the microelectrode array. This system is composed of various circuits in different technological areas. Although the individual specifications of each block can be considered to be not very demanding, the global solution due to the constraints in area, power, and the issues related with the environment of the application makes the design and implementation of the SOC a great challenge.

## 8.2. Objectivos

## 8.2. Objectives

**Descrição dos Objectivos do Projecto**

**Project Objectives (description)**

The goal is to design and prototype a microelectrode stimulation system for cortical neuroprosthesis (Fig.1). A preliminar version of the system was designed in an European project already finished which led to a solution with discrete components. This solution was able to provide insight and important information on the signals nature. This solution also showed that it was limited in terms of bandwidth, power consumption and size. The solution proposed in this project is to design and prototype an integrated microelectrode stimulator for intracortical neuroprosthesis. The implantable microelectrode stimulator uses flip-chip technology to be fully implantable without wiring (Fig.2), reducing the risk of infection and increasing robustness. It is small enough to be undetectable and has low power consumption obtained directly from the carrier, through an RF low-coupling transformer, discarding the need for batteries. The system architecture and circuit techniques which overcome some of the application issues will be based upon the system architecture (Fig.3).

**Descrição dos Objectivos do Investigador Responsável**

**Principal Investigator Objectives (description)**

Much research work of the IP has been done in the Signal Processing Systems (SIPS) research group at INESC-ID, devoted to the study of high performance architectures and algorithms for signal processing applications.\nThe research activity of the IP has been recently focused on the area of high performance systems based on specific architectures and algorithms to develope microsystems for biological analysis and for neuroprosthesis design. By their nature, these research application areas require an interdisciplinary expertise. This motivates the aggregation of efforts from multiple research areas where it is necessarily included the technological capacity to realize these advanced systems. The IP has been involved in actions to motivate the participation of different research groups of INESC-ID in projects with INESC-MN, believing that there is an explored research potential and that, following this way, we can significantly contribute to develop, in the country, innovative systems at first class world level.\n

## 8.3. Estado da Arte

## 8.3. State of the Art

**Descrição do Estado da Arte**

**State of the Art (description)**

In the last few years there has been a huge effort to develop implantable integrated stimulators for bio-medical applications. Most of these stimulators are in the area of muscular stimulation (e.g. for heart or limbs diseases) [1, 2] and in the area of cortical or nerve stimulations (e.g. for blind/partially blind people or hearing diseases) [3, 4]. With the exception of a few applications (e.g. pacemakers), long time performance of the implanted stimulator implies the power to be furnished by an outside unit. This poses the need for wireless delivery of both power and data.\nIt has been shown that electrical stimulation of individual components of the visual pathway such as the retina, the optic nerve or, directly the visual cortex trough implanted microelectrodes, evokes the perception of points of light spatially located, denominated by phosphenes. The project considered in this proposal is intended to be a continuation of this team work of developing a cortical visual neuroprosthesis for profoundly blind people, the scope of the already ended CORTIVIS project supported by the European Commission [5-7]. Other labs that are also performing research in this area are the Meister Lab [8] and the John Moran Labs in Applied Vision and Neural Sciences [9] at the University of Utah. \nMicroelectronic prostheses which interact with the remaining healthy retina have been developed to restore some vision to those who suffer from eye diseases, such as retinis pigmentosa. This type of prosthesis can use sub-retinal devices [10] (to replace the photoreceptors) or more complex epi-retinaldevices [11], but require that output neurons of the eye and the optical nerves are in a healthy state. When this is not the case, the stimulation has to be performed in the primary visual cortex, directly to the neurons in higher visual regions of the brain. Brindley [12] showed that simultaneous stimulation of multiple electrodes allowed blind volunteers to recognize simple patterns. However, they showed that a cortical prosthesis based on a relatively large number of superficial implanted electrodes requires high currents to produce phosphenes (> 1 mA) which leads to problems such as epileptic seizures. In this cases, deep intracortical neuro-stimulation with long-term implantable deep electrodes should be used, exciting the neurons at a depth between 1 mm and 2 mm, which corresponds to the cortical layers 4 (namely, C ), where signals from the Lateral Geniculate Nucleus (LGN) and C arrive. A first experimental work comparing the performance of different models has been recently published by our research group [13].\nThe development of stable long-term implantable electrodes for nerve recording and stimulation is an absolute need for the success of this type of visual neuroprosthesis. The currently available electrodes fall into two categories: individual metallic wires or planar polyimide/silicon bases with multi-contact metal deposition. Wire-electrodes permit good nerve contact but lack spatial resolution for both recording and stimulating; planar multi-contact electrodes have exceptional spatial resolution but have poor tissue contact. The first neuronal microelectrodes were developed in the end of the sixties and are still the commercial microelectrodes available [14]. Since then, various groups developed new type of electrodes, some with integrated electronics for signal processing. In 1994 the group of Dr. Kensall D. Wise of the University of Michigan developed 3D arrays of active planar microelectrodes [15], which fabrication involves formation of high doped Boron layers by diffusion at very high temperatures for the definition of the needles structure. This electrodes led to the fabrication of arrays of 8x16 electrodes controlled by CMOS circuits integrated in the array [16] for signal processing. Also in 1994, the group of Eng. Gregory T. Kovacs of the Stanford University developed micro-electrode arrays for recording the neuronal activity of peripherical and cranial nerves, [17], fabricated with techniques compatible with the standard CMOS industry. The same group developed in 1997 multi-electrode arrays with more than one electrode per needle for multi-neurons recording [18]. Similar electrodes were developed for cortical stimulation [19]. More recently, a new technique was developed to fabricate similar electrodes to the ones available commercially that doesn't require high temperature diffusions [20].\nOther fundamental component of the system is the wireless radio frequency (RF) link, that must provide both power and bidirectional transmission of data between the outside and the implant. The most common solutions proposed in literature for the RF link are Amplitude Shift Keying (ASK) modulation [6], Frequency Shift Keying (FSK), [21] and Differential Binary Phase Shift Keying (DBPSK) modulation [22]. Within reasonable limits, the FSK and DBPSK receivers are insensitive to the amplitude of the received signal, making these circuits more robust regarding the high variability of the RF channel. Demodulation of FSK and DBPSK is usually done coherently, thus requiring more complex and power consuming receivers. Carrier frequency recovery is important because it allows the implant to operate with a clock which is frequency-synchronised with the received signal. This avoids intermodulation noise and improves the overall system performance. With FSK or DBPSK, the transmitted spectrum does not contain a specific carrier signal; so, carrier recovery is more difficult (requires a narrower Phase Locked Loop or bandpass filter). On the other hand, power extraction is easier with the constant amplitude FSK or DBPSK signal than with the amplitude-varying ASK signal. For monitoring purposes a reverse data link is usually also proposed. One solution is to use DBPSK, which needs a very simple transmitter. Other solution is Load-Shift Keying [22], which is based on the different impedance measured at the primary of the coupling transformer when the secondary is or not shortcut. \nReferences\n[1] Q. Bai, K.D. Wise, .Single-unit neural recording with active microelectrode arrays,. IEEE Transactions on Biomedic Engineering, vol. 48, pp. 911.920, Aug. 2001.\n[2] R. Andersen and C. Buneo, "Intention maps in posterior parietal cortex," Annual Revision of Neuroscience, vol. 25, pp. 189-220, 2002.\n[3] W. H. 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### 8.4. Resultados e Repercussões
### 8.4. Results and Repercussions

**Divulgação de Resultados (descrição)**
**Diffusion of Results (description)**

For the divulgation of result of the proposed project a webpage will be setup including: description, objectives, achieved results, developed circuits and related pages concerning projects with similar goals. Scientific results will be published in tecnical reports and communicated in international conferences and journals. All these documents will be made available in the webpage.

**Repercussões (descrição)**
**Repercussions (description)**

The potential economic and social implications of this project lie with the realistic possibility that it will contribute significantly towards the goal of developing artificial visual systems, partially restoring lost functions due to damage or disease of the visual pathways in humans. The research of new integrated microelectrode stimulator system for intracortical neuroprosthesis is one of the main challenges to developing neuroprosthesis for restoring a limited, but useful, visual sense to profoundly blind people. \nAlthough the full restoration of vision seems to be an impossible task in the next few years, the discrimination of shape and location of objects could allow blind subjects to be autonomous in tasks like: to guide themselves in a familiar environment or to read enlarged text. This will result in a\nsubstantial improvement in the standard of living of blind and visual impaired persons.

### 8.5. Regionalização
### 8.5. Regionalization

| Região<br>Region | Percentagem<br>Percent |
|---|---|
| Norte | 15 |
| Centro | 15 |
| Lisboa e Vale do Tejo | 15 |
| Alentejo | 15 |
| Algarve | 15 |
| Região Autónoma dos Açores | 15 |
| Região Autónoma da Madeira | 10 |

Descrição
Description

The repercussion of this project on Portuguese economy has no relation with any particular region. Instead, application of the output results will require a set-up of industrial know-how to implement and safely implant an active cortical device to provide a functional sense of vision to blind persons. The positioning of the Portuguese and European industry, in the emergent field of neuroprostheses is of great importance for the future. The success of this industry will stress the competency in the field of neurotechnology, without any special advantage from the fact that the research takes place in a particular region.\n

### 8.6. Tarefas
### 8.6. Tasks

**Lista de tarefas** (4)
**Task list** (4)

| Designação da tarefa<br>Task denomination | Data de início<br>Start date | Data de fim<br>End date | Pessoas * mês<br>Person * months |
|---|---|---|---|
| Power supply and RF modules | 01-01-2007 | 31-12-2008 | 65 |
| Microelectrode Array and interface with Flip-chip technology | 01-01-2007 | 31-12-2009 | 47 |
| Input and Output Data Processing | 01-07-2007 | 31-12-2008 | 35 |
| Control Unit and Microelectrode stimulator | 01-01-2008 | 31-12-2009 | 48 |

*(Os detalhes de cada tarefa estão disponíveis clicando na designação correspondente)*
*(Details for each task are available by clicking on the corresponding denomination)*

### 8.7. Referências Bibliográficas
### 8.7. Bibliographic references


| Ano<br>Year | Publicação<br>Publication |
|---|---|
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| 2006 | R.Ferreira, P.Wisniowski, P.P.Freitas, J.Langer, B.Ocker, W.Maass, “Tuning of MgO barrier magnetic tunnel junction bias current for pT magnetic field detection”, J.Appl.Phys., vol.99, pp.08K706-08K708, April |

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**8.8. Artigos Anteriores**
**8.8._ Previous Articles**

| Ano Year | Artigo (endereço na *Internet* - URL) Paper (Link in the Internet - URL) |
|---|---|
| 2005 | 1- Moises Simões Piedade, José António Beltran Gerald, Leonel Sousa, Gonçalo Nuno Gomes Tavares, Pedro Tomás, "Visual Neuroprosthesis: A Non-Invasive System for Stimulating the Cortex", IEEE Transactions on Circuits and Systems I - Regular papers, IEEE, vol. 6, n. 12, pages 2648-2662, December (http ://www.inesc-id.pt/ficheiros/publicacoes/2572.pdf) |
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9. Ficheiros Anexos
9. Attachments

| Nome Name | Tamanho Size |
|---|---|
| figures.pdf | 193Kb |

sexta-feira, 16 de Março de 2012