INTRODUCTION

- **The Role and Place of Modern Mixed Analog–Digital Chips**
- **Very Large Scale Integration (VLSI) Technologies**
- **Over 1 million transistors**
- **From 70’s Digital Computer Era had begun**
- **Analog Signal Processing reduced but not disappeared**
- **The need to interface the computer to the analog world**
- **The need for analog–enhances digital performance**

THE NEED TO INTERFACE THE COMPUTER TO THE ANALOG WORLD

- **Computers work in the real word**
- **Automobile**
  - **Radio, computerized engine control, safety, navigation aids, etc.**
- **Cellular telephony**
  - **Transmission and reception of both analog and digital signals**
- **A/D and D/A converters**

Layout

THE NEED TO INTERFACE THE COMPUTER TO THE ANALOG WORLD

- **Pre–Post Conversion signal condition**
  - **Amplification, filtering for antialiasing or smoothing, sampling, holding, multiplexing etc.**
- **Direct signal processing without A/D conversion**
  - **Medium SNR systems, high speed, low power**
- **Interface with sensors**
  - **Receiving antennas, transmission lines,**
- **Drive for attuators**
  - **Transmitting antennas, transmission lines**

Layout

THE NEED TO INTERFACE THE COMPUTER TO THE ANALOG WORLD

- **MAD circuits have been realized in metal–oxide semiconductor (MOS) technology**
- **Precision ratio capacitor arrays**
- **Internally compensated MOS operational amplifiers**
- **High performances A/D converters**
- **High performances Switched–Capacitor filters**
- **Continuous time filters**
- **PCM encoders–decoders**

Layout

THE NEED FOR ANALOG-ENHANCED DIGITAL PERFORMANCE

- **Analog circuits make possible the high performance of digital systems**
  - **Hard disk drive**
  - **Digital communication links**
  - **High speed digital circuits are analog in nature**
  - **Clock recovery circuits**
  - **PLL**
  - **Charge pumps**

Layout

ADVANTAGE OF MIXING ANALOG AND DIGITAL CIRCUITS ON THE SAME CHIP

- **The size of the system is reduced**
- **The speed of the operation can be increased**
- **The power dissipation is decreased**
- **The design flexibility is increased –> high # of channels**
- **The reliability is increased**
- **The system cost is reduced**

APPLICATIONS OF MAD CHIPS

- **Telecommunications**
- **Consumer electronics**
- **Computer and related equipment**
- **Multimedia**
- **Automotive systems**
- **Biomedical instrumentation**
- **Robotics**

Layout

PROBLEMS IN THE DESIGN OF MAD CIRCUITS

- **Analog circuits are critical to design**
- **Analog voltages are small signals (μV) near digital circuits (V)**
- **On chip interferences**
- **Analog circuits are not amenable to standardization**
- **For analog circuits design automation is not possible**
- **Testing**
- **Mixed circuit designers are not easy to find**

Layout

MECHANISM AND EFFECT OF NOISE COUPLING

- **VLSI MAD chips consist of several subsystems which must be kept from interfering with each other**
- **Sharing of common substrate**
- **Sharing of common connections to the external word**
- **Parasitic coupling from inductance and resistance of power supply and ground wires**
- **Coupling from substrate**
- **Coupling from protection diodes**
- **Coupling from parasitic cap. of adjacent elements**

Layout

MECHANISM AND EFFECT OF NOISE COUPLING

- **Voltages and currents switching cause noise**
- **This noise will increase as:**
  - **Magnitude of switching events increase**
  - **Number of switching events increase**
  - **Frequency of switching events increase**
- **Differential ECL**
- **ECL**
- **TTL**
- **CMOS**

TECHNIQUES FOR NOISE REDUCTION

- **Design system solution**
- **Shielding**
- **Packaging**
- **Chip floorplanning**
- **Chip wiring**

Layout

SYSTEM SOLUTIONS

Even pure CMOS logic design are being limited by crosstalk and inductive switching noise problems

Adding any circuitry with less noise margin than CMOS circuits is very difficult

- **Separate IC's mounted in hybrid packages or Multi–Chip Module (MCM)**
- **Correct timing of signals**
- **Comparators and sampling circuits do not compare or sample when large digital driver switch**
- **Use fully differential circuits when possible**
- **Use of special logic circuits**

Layout

LAYOUT SOLUTIONS

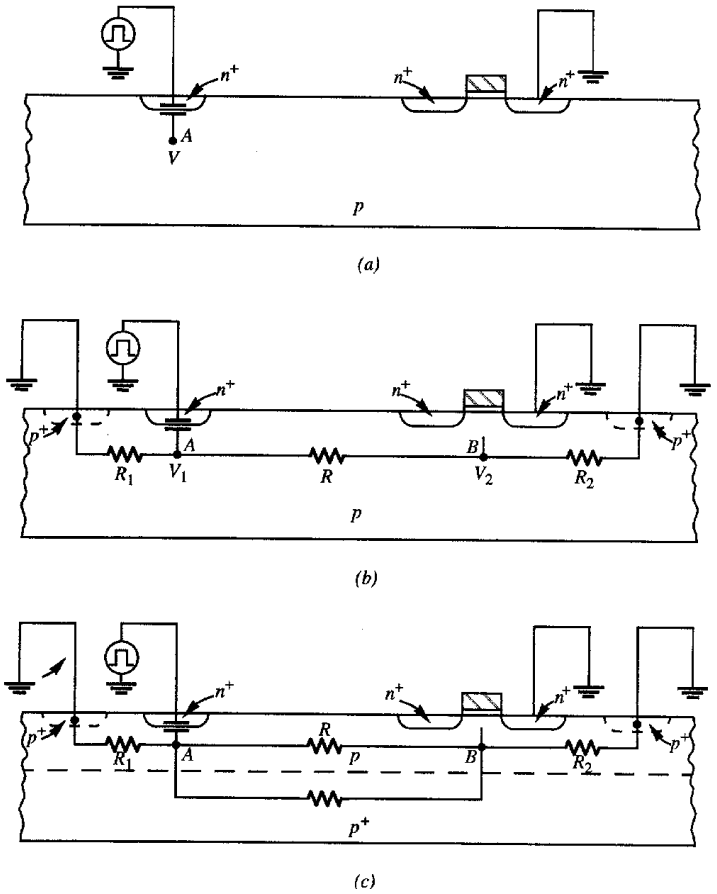
- **Stop thinking of power supply lines and grounds as perfect conductors**
- **Avoid common power supply or ground buses**
- **Use of bypass capacitors inside and outside**
- **Pay attention to the resonant frequency**
- **Also analog circuits require different power supply**
- **VDDDR1, VDDDR2, GNDDR1, GNDDR2, (PAD RING)**
- **VDDDC1, VDDDC2, GNDDC1, GNDDC2, (CORE)**
- **VDDA1, VDDA2,.. GNDA1, GNDA2,.. VSUB1, VSUB2,..**

LAYOUT SOLUTIONS

- **Assign bonding pads wisely**
  - **The package bonding diagram should be anticipated**
  - **Use several pads in parallel for power supply and ground**
- **Make power supply lines and ground wide**
  - **Lines as wide as 100µm**
  - **Use of less resistive metal layer (Metal2)**
- **Use of star VDD**

SUBSTRATE COUPLING

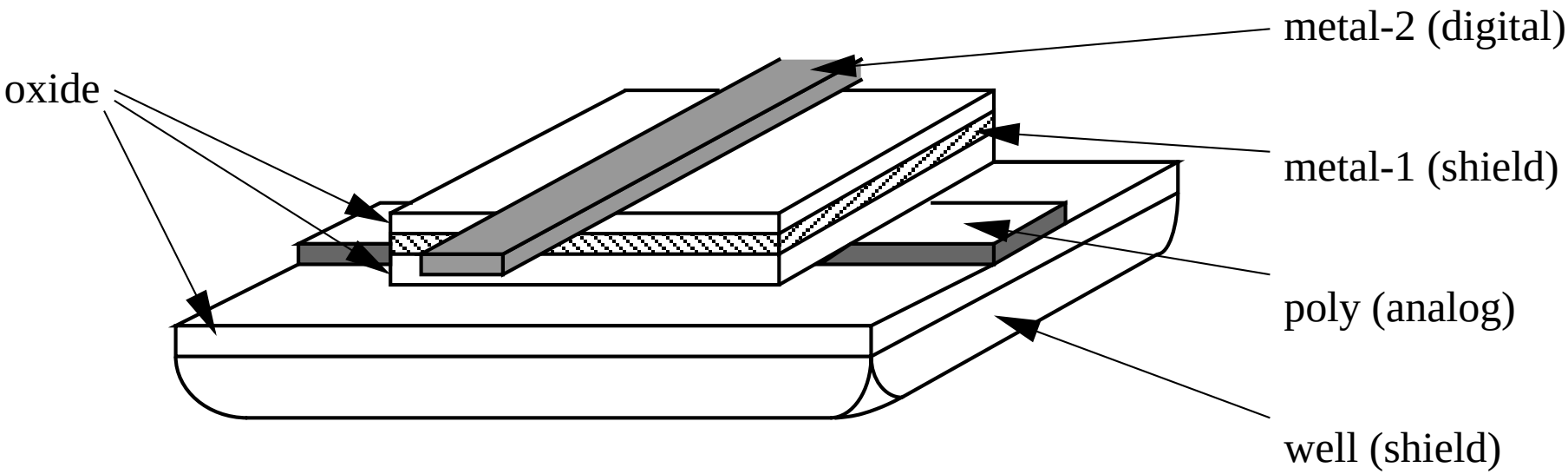
- **Consider substrate coupling carefully and guard against it**



Layout

SHIELDS

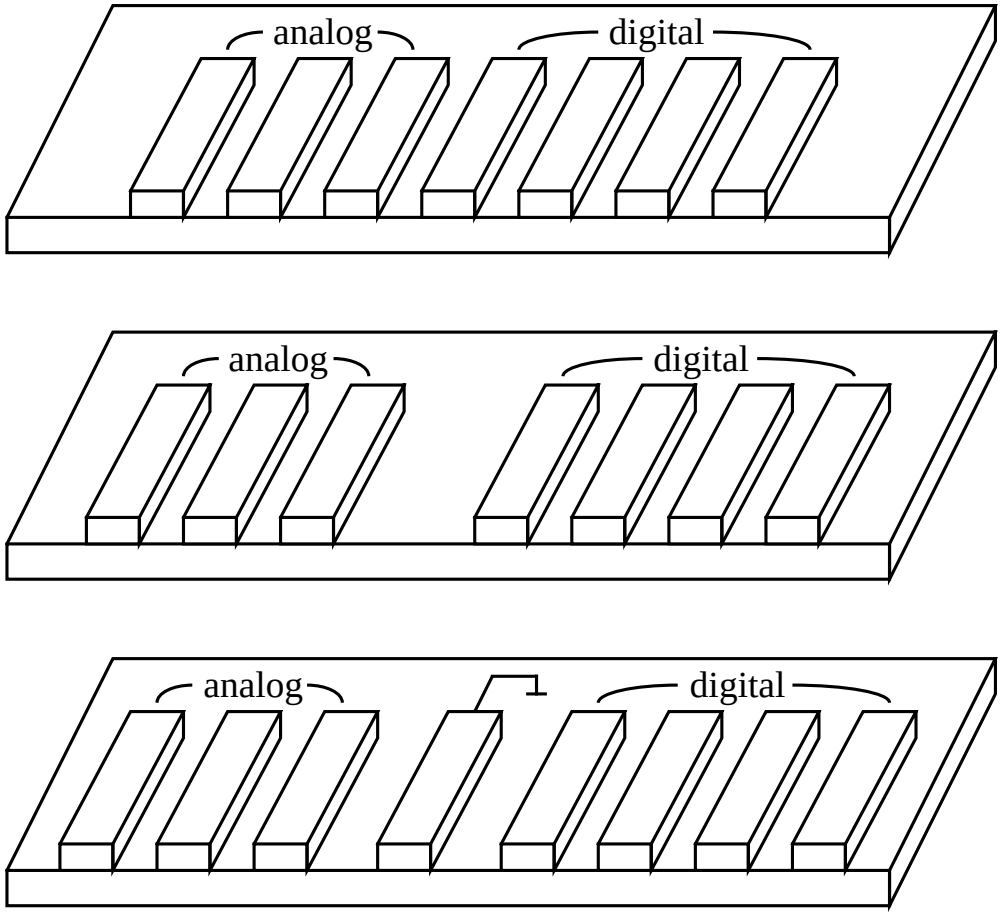
- **Shield all sensitive circuits, devices and interconnections lines**



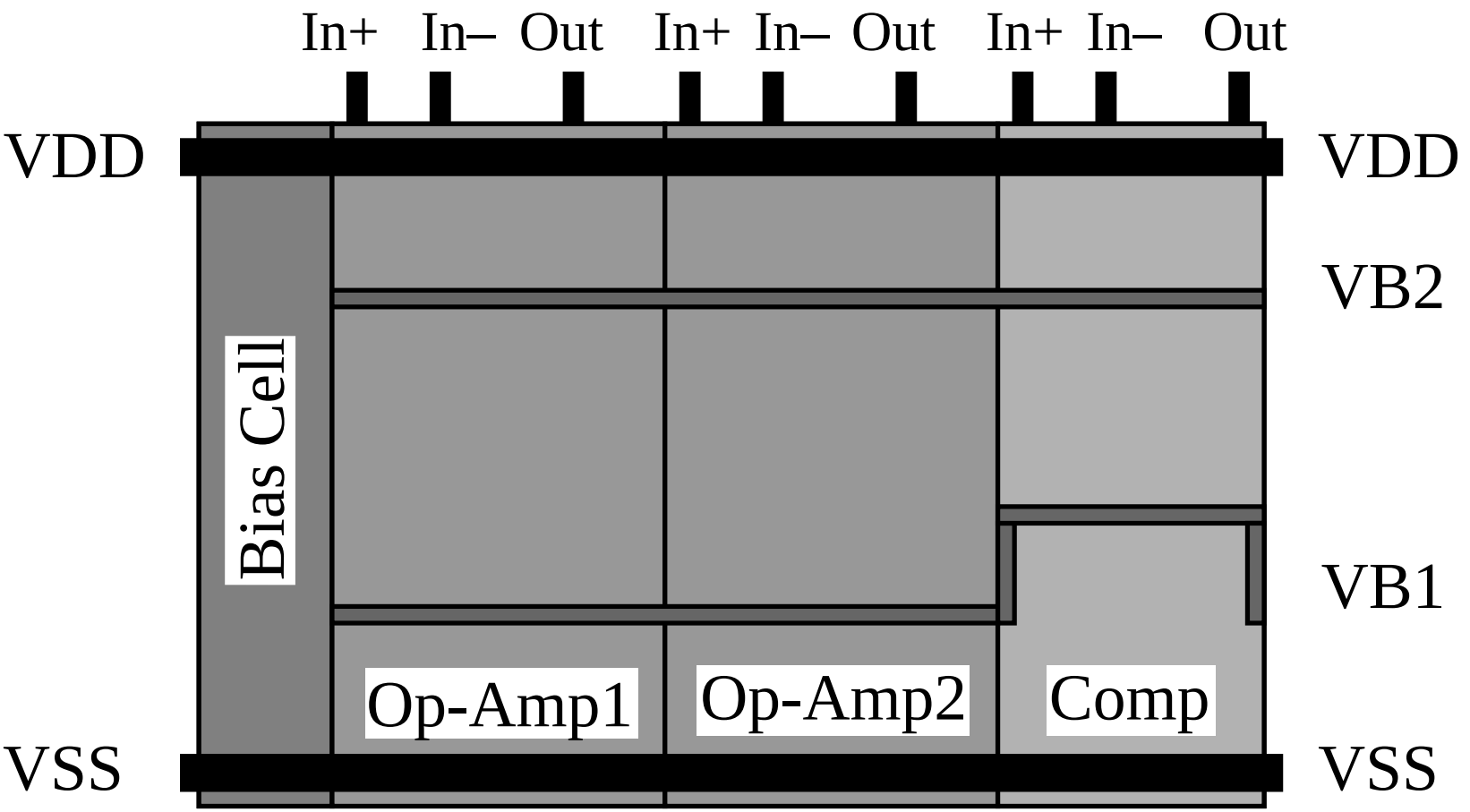
- **Use of metal-1 layer as digital inteferences shield**
- **Use of well as substrate shield**

LAYOUT SOLUTIONS

- **Avoid proximities of circuits, devices or interconnection lines that can interfere with each other**

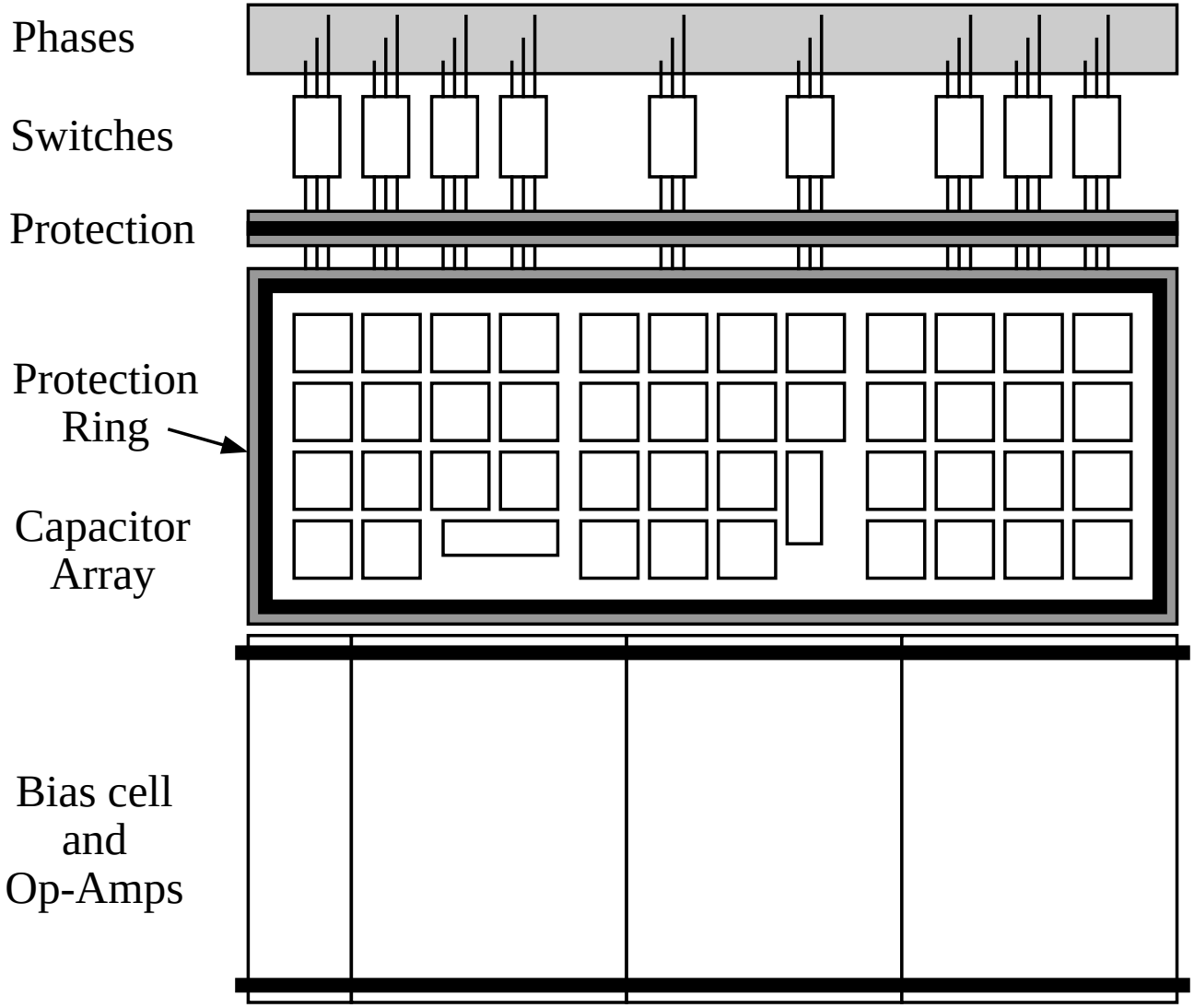


LAYOUT OF SC CIRCUITS



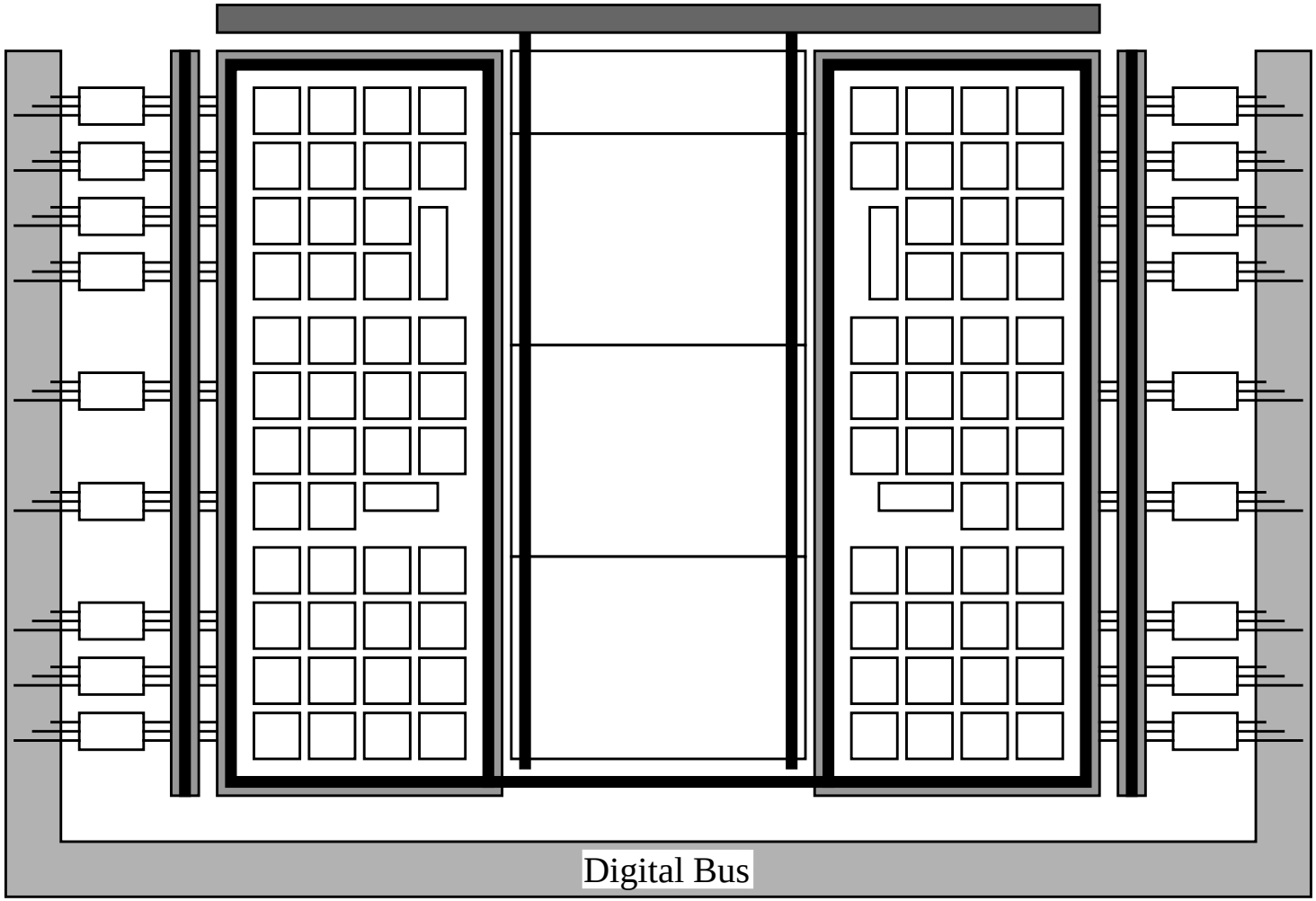
Layout

LAYOUT OF SC CIRCUITS



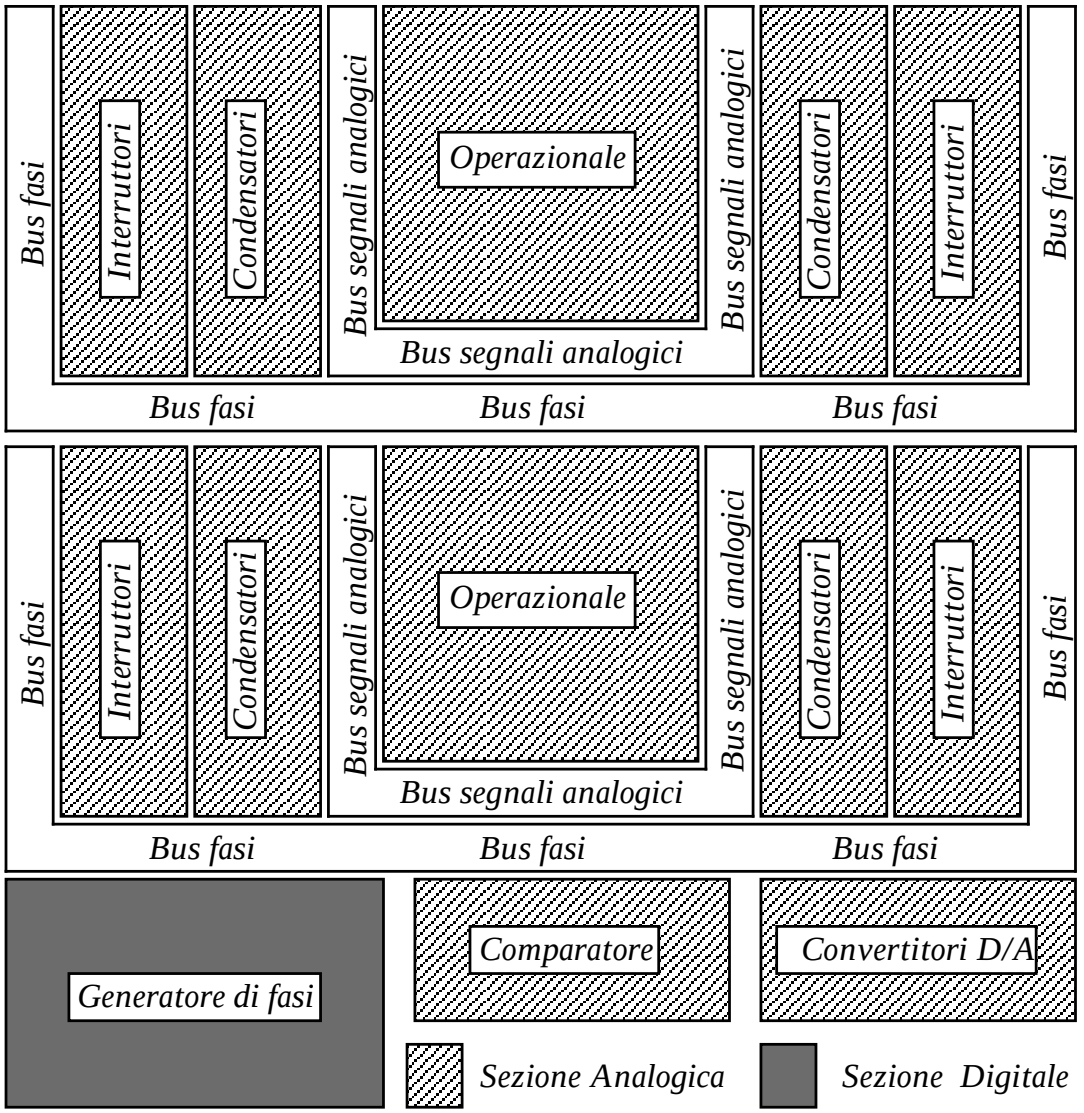
Layout

LAYOUT OF SC CIRCUITS



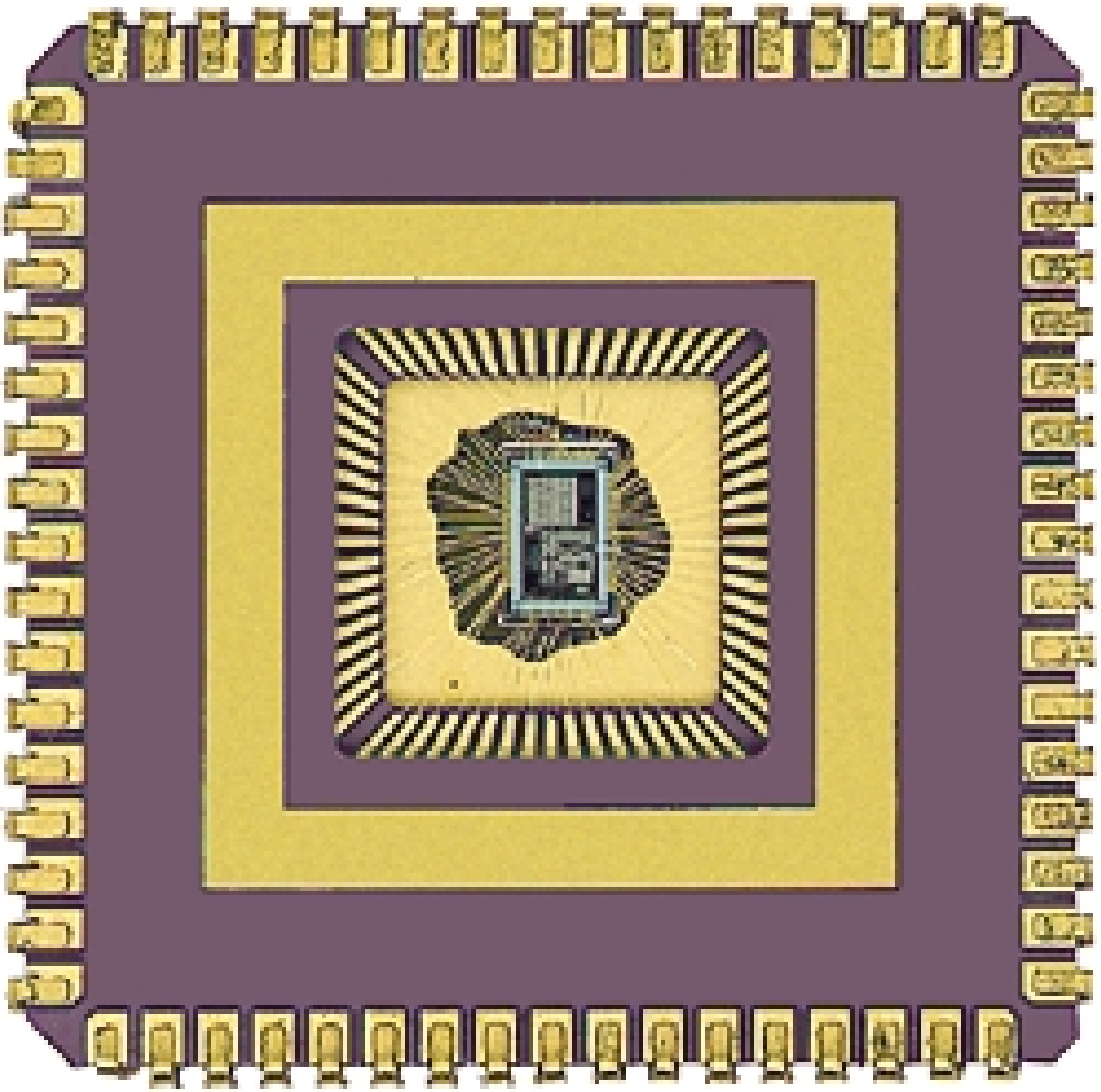
Layout

FLOORPLAN SC CIRCUITS



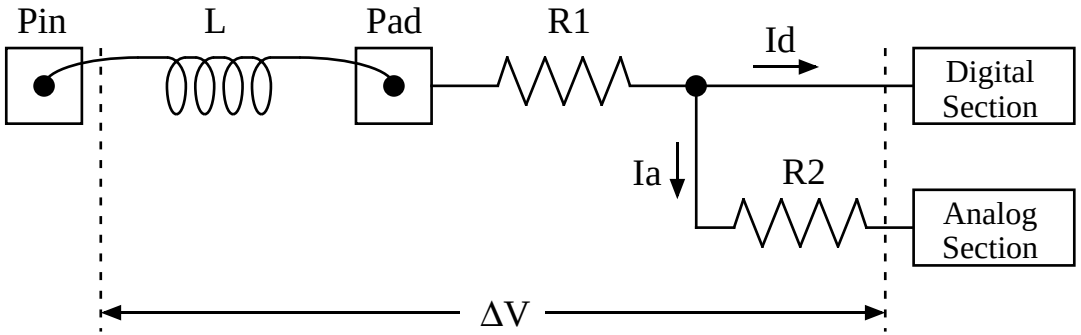
Layout

MICROCHIP



Layout

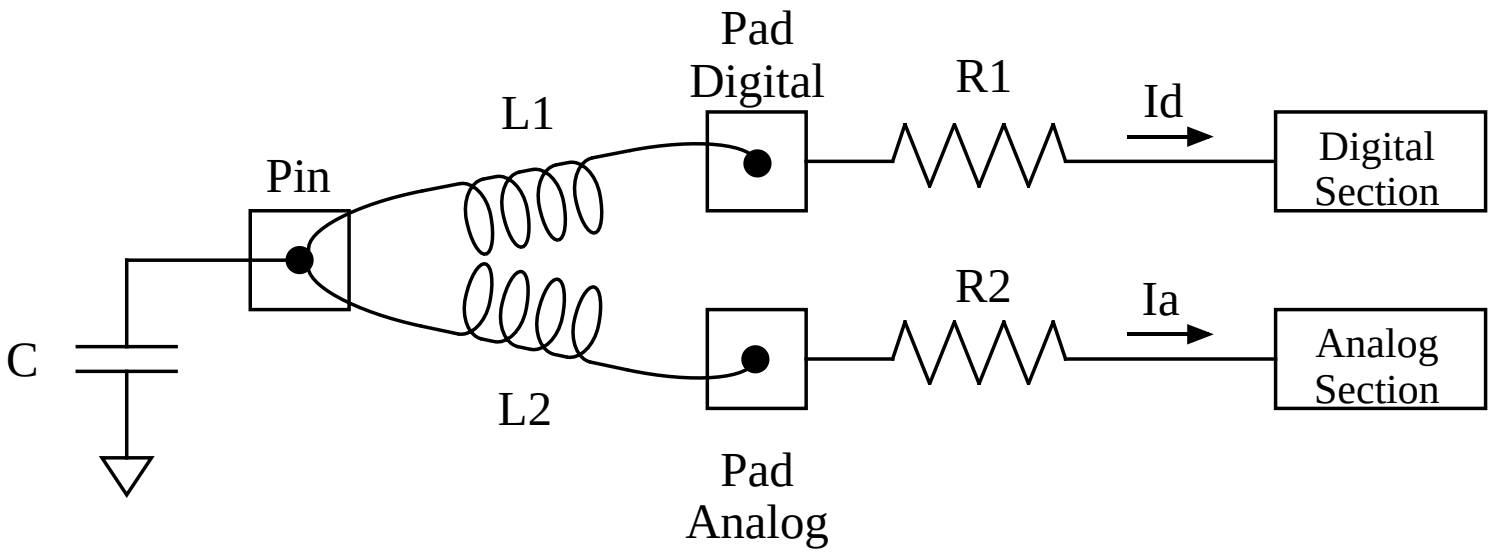
BONDING 1



- **Bad performance**
- **Current in digital section** $i = C\frac{dv}{dt}$
- **Voltage across the inductance** $v = L\frac{di}{dt}$
- **Resonance frequency LC can equal the clock frequency**
- **Transistor level simulation!!!**

Layout

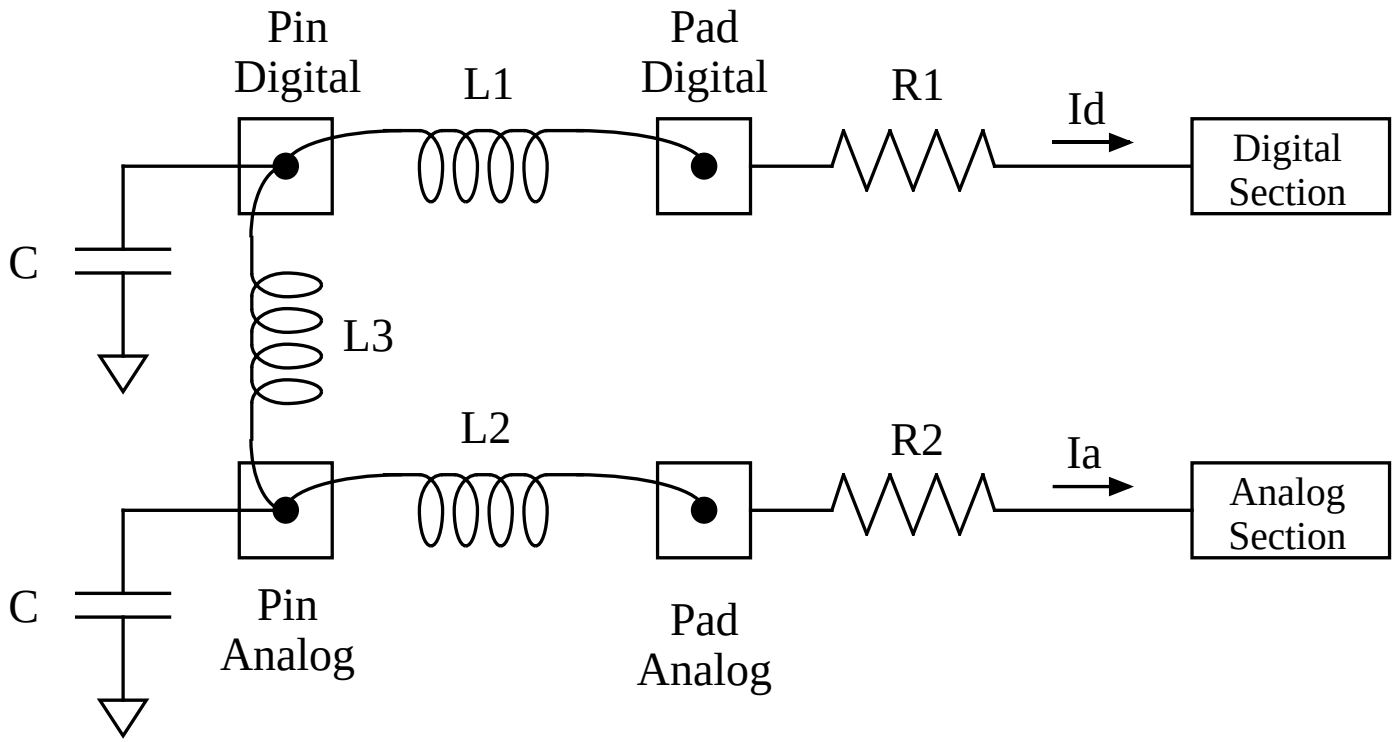
BONDING 2



- **Improved connection**
- **Addition of bypass capacitor to avoid resonance frequency**

Layout

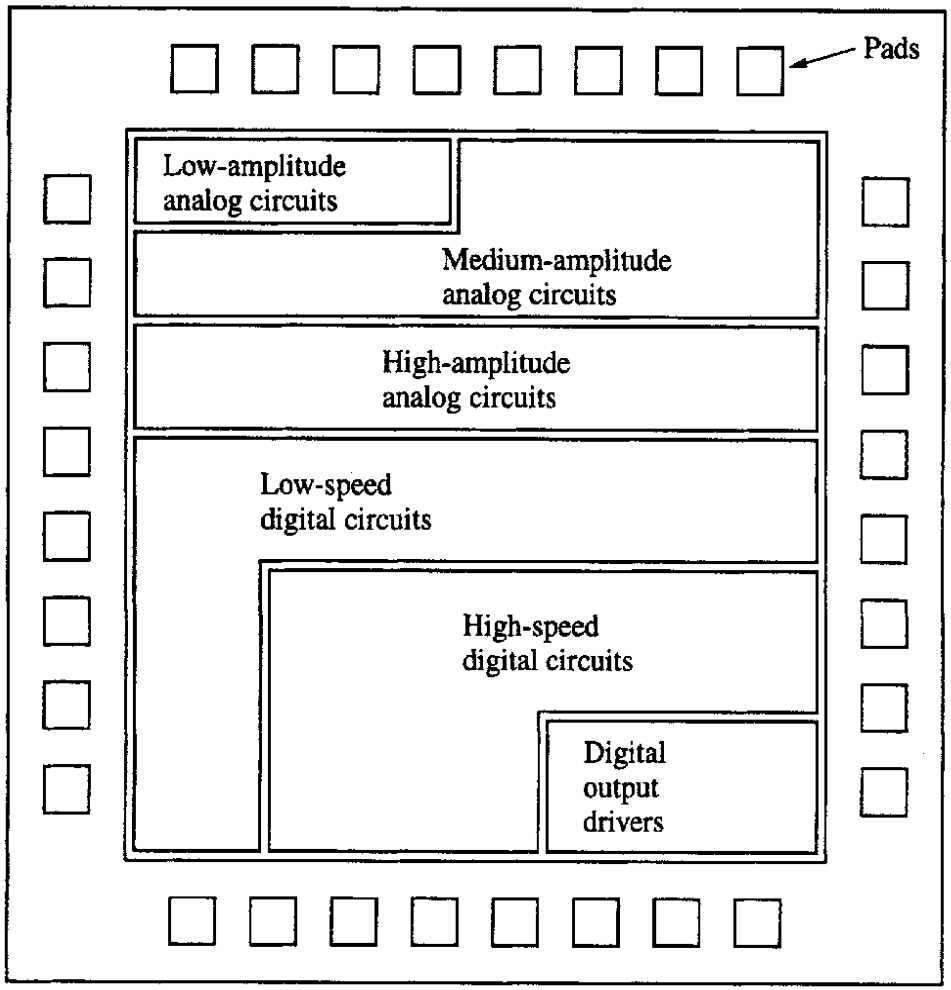
BONDING 3



- **Best solution**
- **Cost**

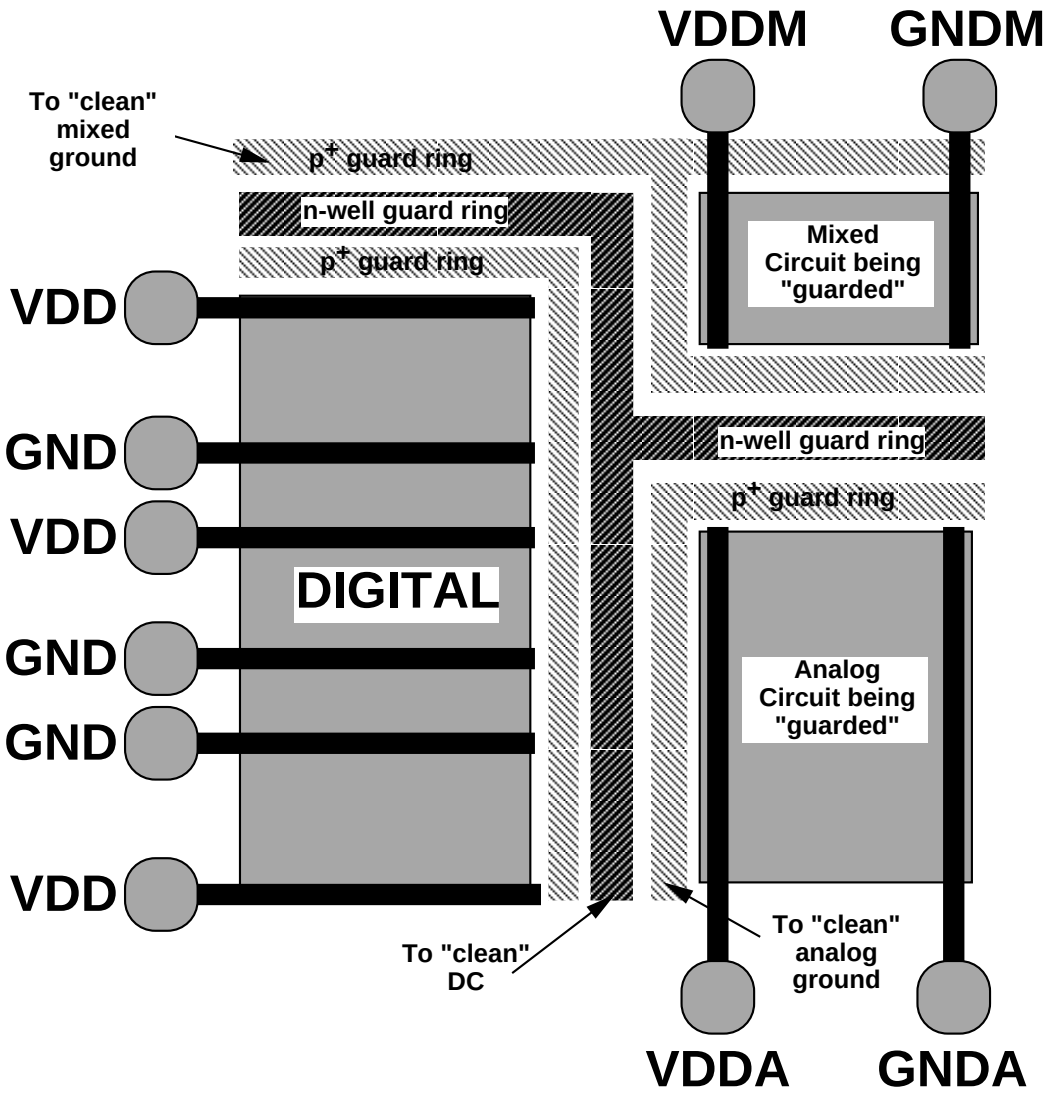
Layout

FLOORPLAN



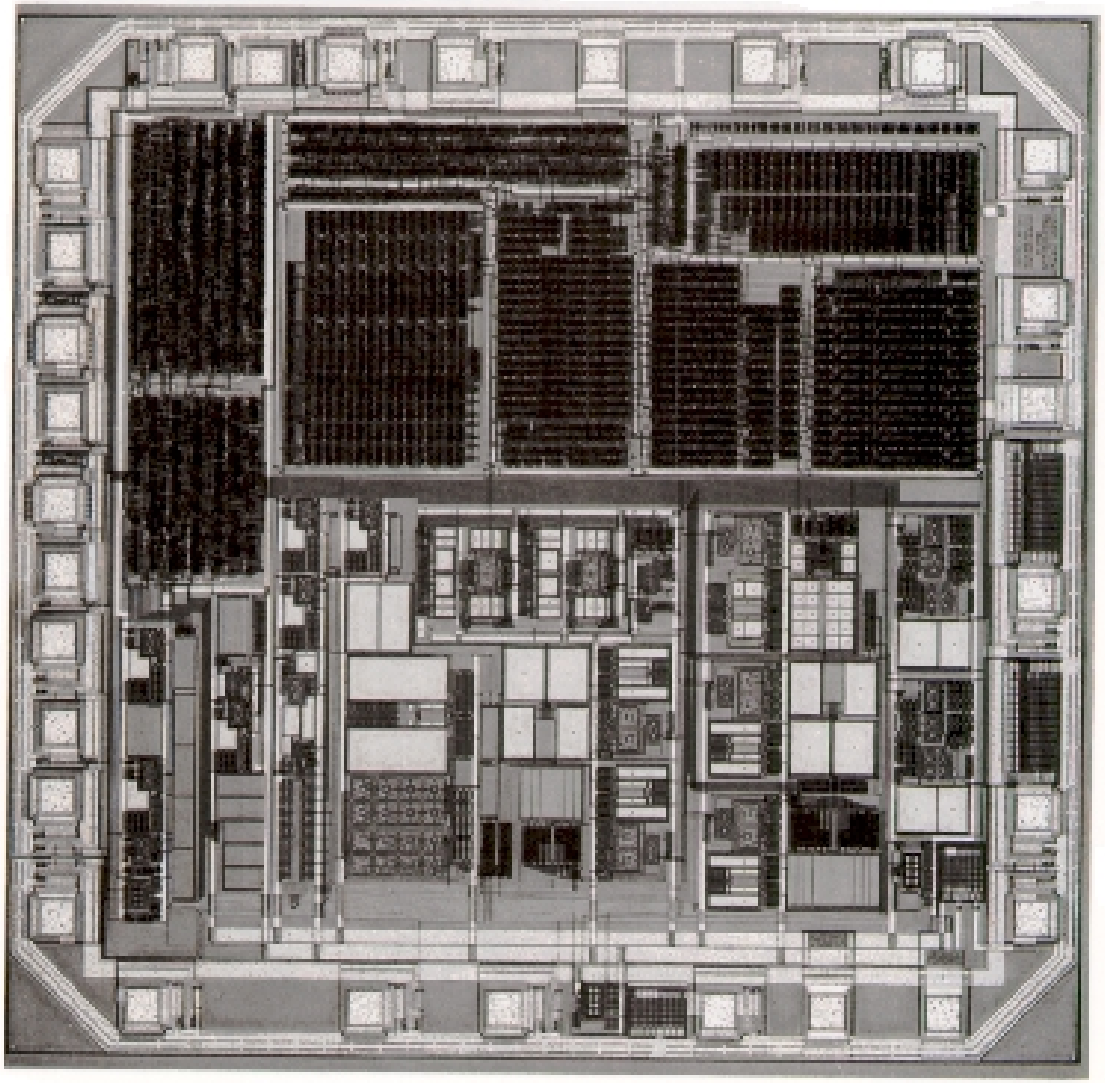
Layout

GUARD RINGS



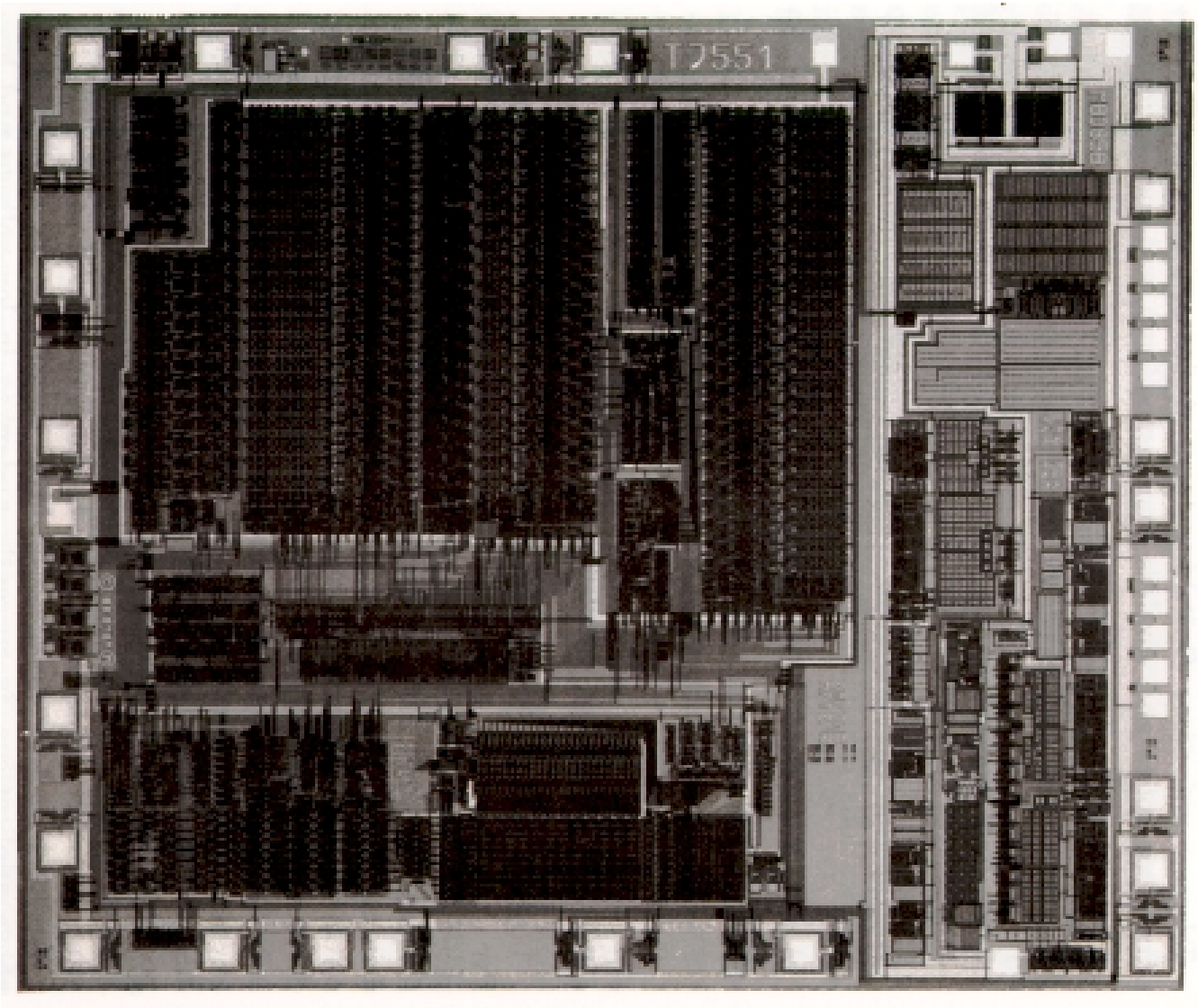
Layout

MAD EXAMPLE 1



Layout

MAD EXAMPLE 2



Layout