ELECTRICAL PACKAGE DESIGN

Major design tasks & Functions

Design Tasks

- Creating a signal distribution system
- Creating a power/grounding system
- Overcoming parasitic reactance's an obstacle

Functions

- Provide signal/power distribution
- Protection from environment(chemical/ physical)

Thermal mitigation

- Connectivity within package, between layers
- Potential for lumped passive elements

Fundamentals of Electrical Design

- Ohm’s Law
- Skin Effect
- Kirchhoff’s Laws (KVL/KCL)
- Noise
- Time Delay
- Simultaneous Switching Noise (ssn)
- Transmission Lines
- Crosstalk
- EMI

Electrical Anatomy of Packaging

- Dealing with parasitic elements
  - Cause delay, skew, lead/lag, and transient power fluctuations
  - Transmitted signal winds up being degraded
- Primary challenge:
  - Handling non-ideal effects
  - Package design must meet specifications

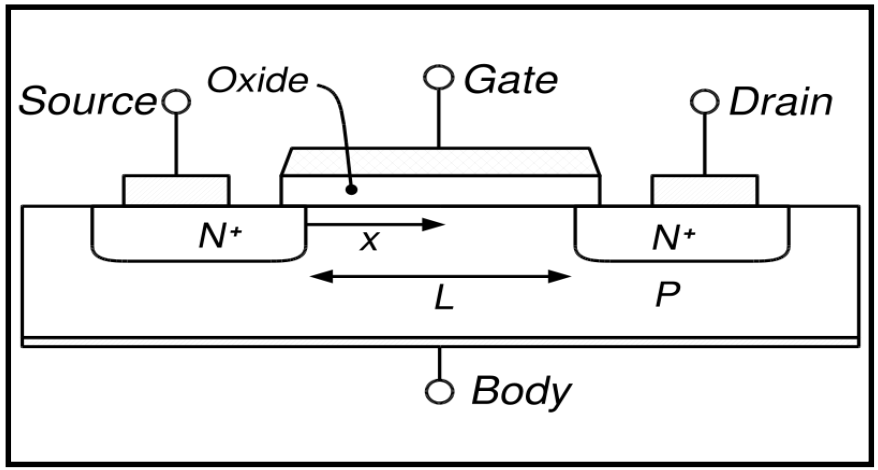
Signal Distribution

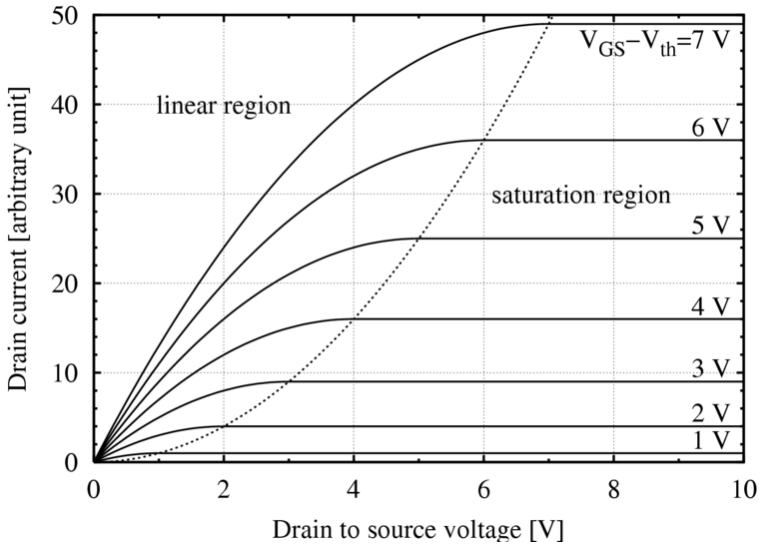
- Devices and Interconnections

  MOSFETs are most frequent devices

  Operated as a switch (cutoff / saturation modes)

  Binary state at the gate determines mode





Signal Distribution

- Non-idealities in MOSFETs

  On-resistance R_{ON}

  - Leads to non-zero voltage drop
  - Thermal losses
  - Potential for other parasitic problems and delays

  Switching delay, rise/fall times

  - Limit speed of packaged circuit
  - Consume energy to charge/discharge gate capacitance

  Capacitive Delay of Interconnections

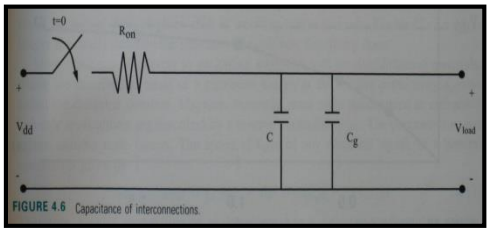


FIGURE 4.6 Capacitance of interconnections.

Signal Distribution

- Kirchhoff's Laws and Transit Time Delay

  Propagation at C (3 x 10^8 m/s) in air

  Propagation at <C in solids

  KVL/KCL fail to account for delays or phase shift

  Time domain analysis

  - *Time of Flight*
  - Frequency domain analysis
  - Main parameter is wavelength
  - $\lambda = c/f$
  - speed in material = $(3 \times 10^8)/(\varepsilon_r \mu_r)^{1/2}$ [m/s]

Signal Distribution

- Transmission Line Behavior of Interconnections

  $L\Delta z$ is total series inductance of equivalent circuit

  $R\Delta z$ is total series resistance of equivalent circuit

- Waves Between Digital Gates

  Parallel strip is common, easy to design

  Microstrip, embedded microstrip, and stripline

    - Microstrip: between air and dielectric
    - E-Microstrip: embedded within a dielectric
    - Stripline: connection between two metal layers

Signal Distribution

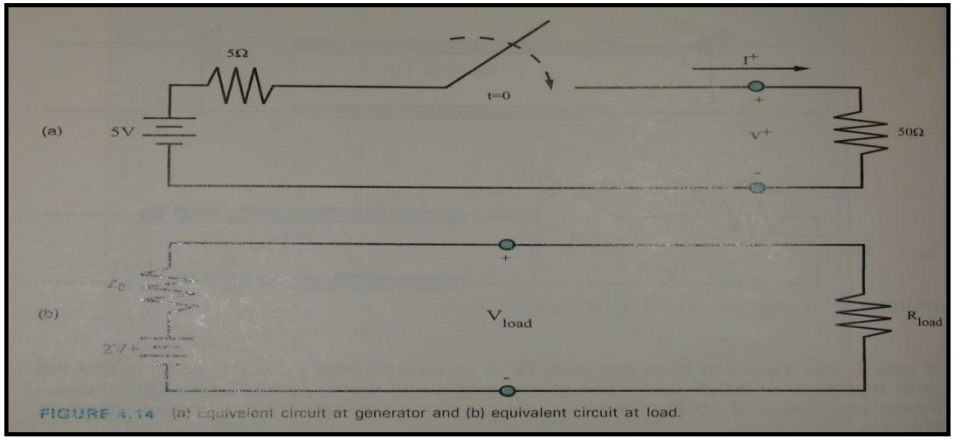
- Signals exhibit a finite velocity

  Output from line is not instantaneous

  $v_p = 1/(LC)^{1/2}$

  Input appears to be a resistance (top figure)

  Load terminated by MOSFET (high resistance)



Equivalent circuit at (a) generator and (b) load

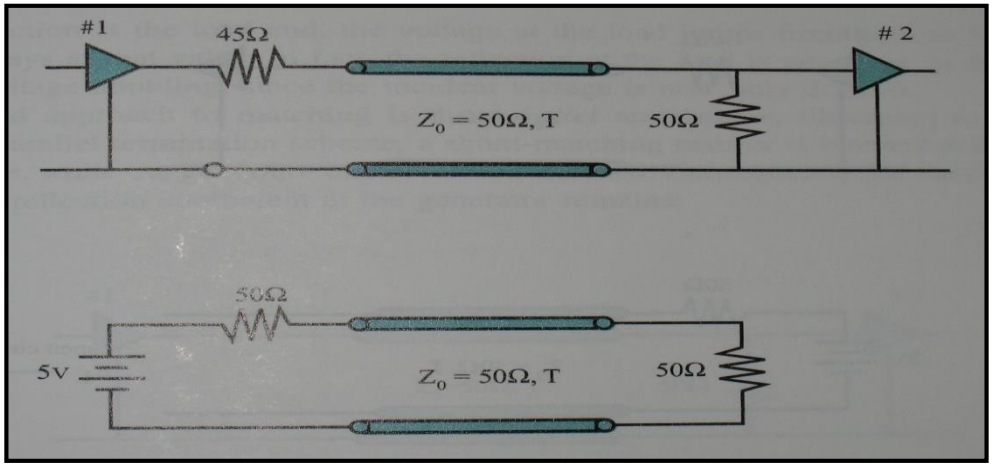
Signal Distribution

- Match the Terminations and Line Impedances

  Basic Electromagnetics

  Unmatched terminations lead to reflections

  How to match previous figure:



(a) Matching by adding 45 ohm series resistance, and (b) Resulting system with matched impedances.

Power Distribution

- Interconnects must also carry power

  Active elements require power to operation

  Voltage drop and inductive effects are main issues

  Supply voltage may not be the same everywhere due to V=IR drops throughout the package

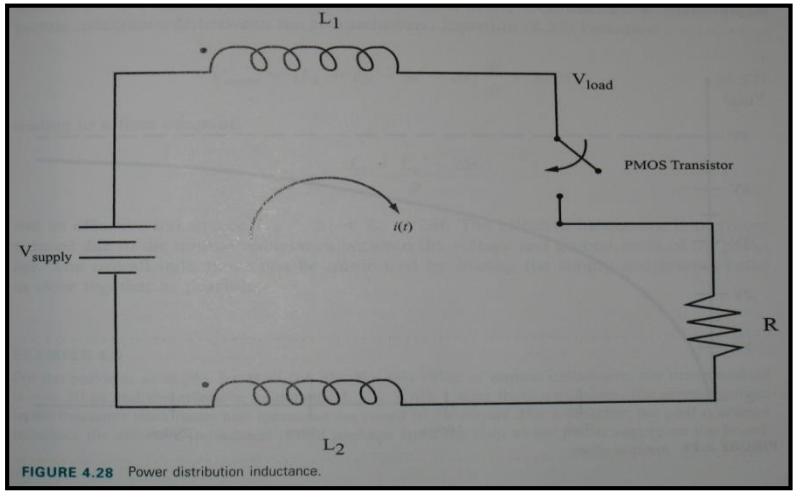
  Parasitic inductance leads to voltage drops:

  - $V_{supply} = (L_1+L_2)(di/dt)+R*i(t)$
  - $V_{load}(t) = V_{supply}(1-e^{-t/T})u(t)$
  - The load voltage is therefore the supply voltage plus the induced time constant parameter

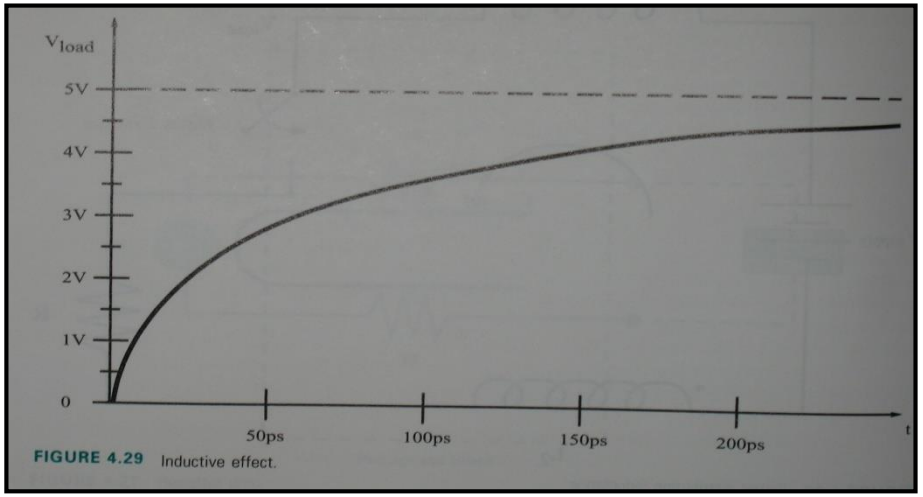
Power Distribution

- Effective power distribution inductances

  Inductances L1 and L2 are for voltage and ground leads for the package



Power distribution inductance



Inductive effect

Power Distribution

- Effective Inductance

  Used to evaluate the power distribution performance of the package

  Contribution can be either *additive* or *subtractive*

  - Additive: currents are in same direction
  - Subtractive: currents are in opposite directions
  - Assuming a mutual inductance *M* between inductors:

  $V_{supply} = (L_1+L_2-2M)(di/dt)+Ri(t)$

  Time Constant: $T = (L_1+L_2-2M)/R$

  Effective Inductance: $L_{eff} = L_1+L_2+M$

  (reduced due to mutual inductance between voltage and ground leads of the package)

Power Distribution

- Power Supply Noise

Local, real supplies source finite current

With series inductances, the local Vdd will drop since the inductor current cannot change instantaneously

  - Result: transient fluctuations in supply voltage
  - $\Delta V = L_{eff}(dI/dt)$
  - Called *simultaneous switching noise (ssn)*

- Effect of Packaging on Inductance

  Minimizing inductance reduces supply noise

  Effective inductance varies from package to package (quad flat pack, QFP, or ball grid arrays, BGAs, etc.)

  Inductance is either due to spheres or planes

Power Distribution

- Inductance and Noise Relationships

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