DIGITAL LOGIC CURRENT FLOW

By
Henry W. Ott
Henry Ott Consultants

www.hottconsultants.com

hott@ieee.org

INTRODUCTION

Many Engineers and Designers Are Confused About How And Where Digital Logic Signal Return Currents Flow, and What is the Source of the Digital Logic Currents.

Is it Better to Have a Digital Logic Trace Adjacent to a Ground Plane or a Power Plane?

What About a Trace Between a Power and a Ground Plane?

Would it be Better to Have the Trace Between Two Ground Planes, or Possibly Two Power Planes?

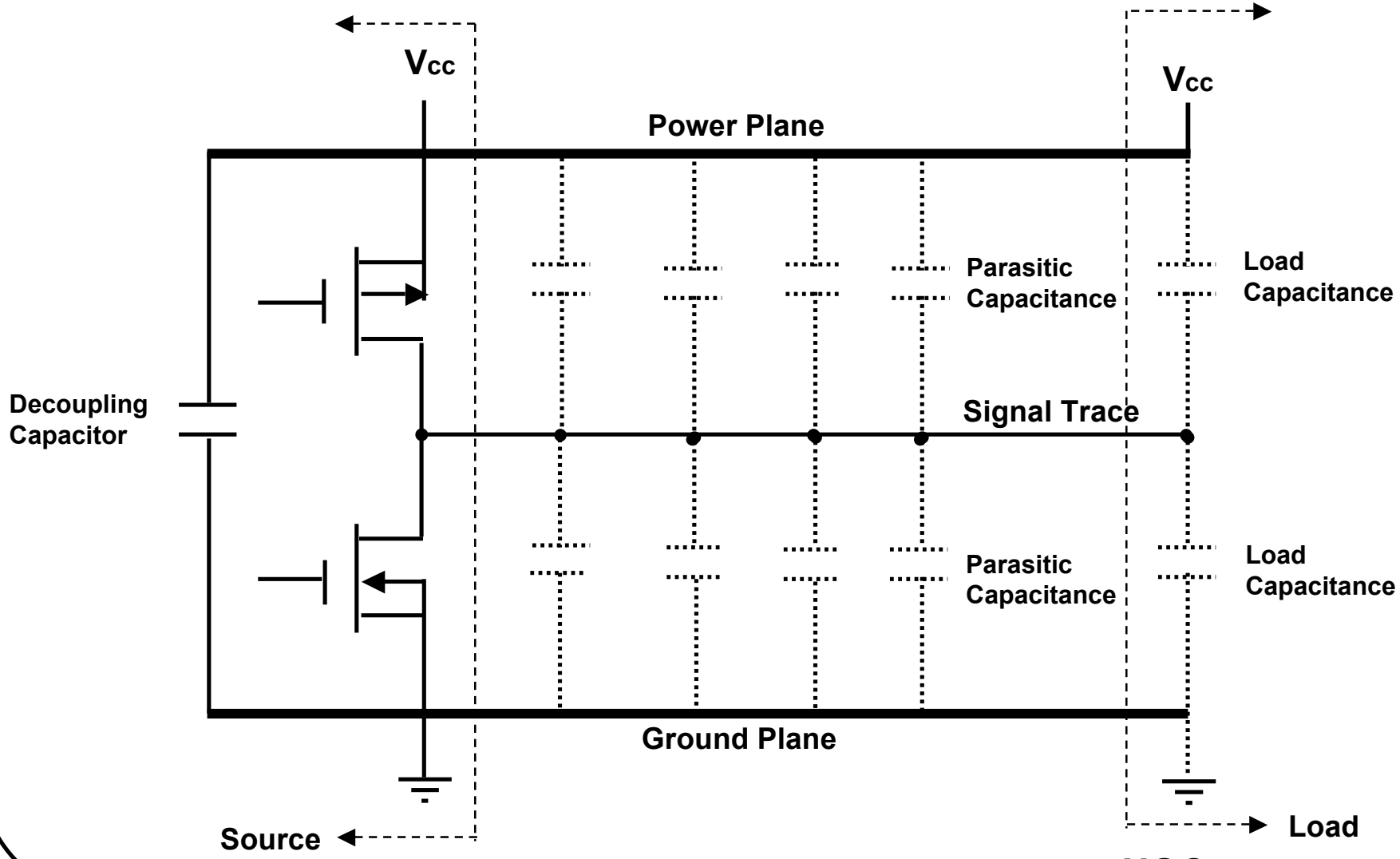
To Answer All These Questions, One Must Know Two Things:

(1) What is the Source of the Current, and
(2) What is the Path Taken by the Current When Returning to the Source?

DIGITAL LOGIC RETURN CURRENT PATH

- First, Let Me State, That the Logic Gate is Not the Source of the Current
- The Logic Gate Only Acts as a Switch
- The Source of the Current is:
  - The Decoupling Capacitor, or
  - The Trace and Load Capacitance
- Only the Transient (Switching) Current is Important
- The Transient Current Flow Does Not Depend Upon the Existence of a Load at the End of the Line
- The Output Trace Capacitance Exists (Mostly) Between the Trace and The Closest Plane
- What Then is the Return Current Path?
- The Return Current Path is a Function of (1) the Trace Configuration (Microstrip or Stripline), (2) What is the Adjacent Plane or Planes (Power or Ground), and (3) What is the Logic Transition (Low-to-High or High-to-Low)?
- There Are Ten Different Cases to Consider.

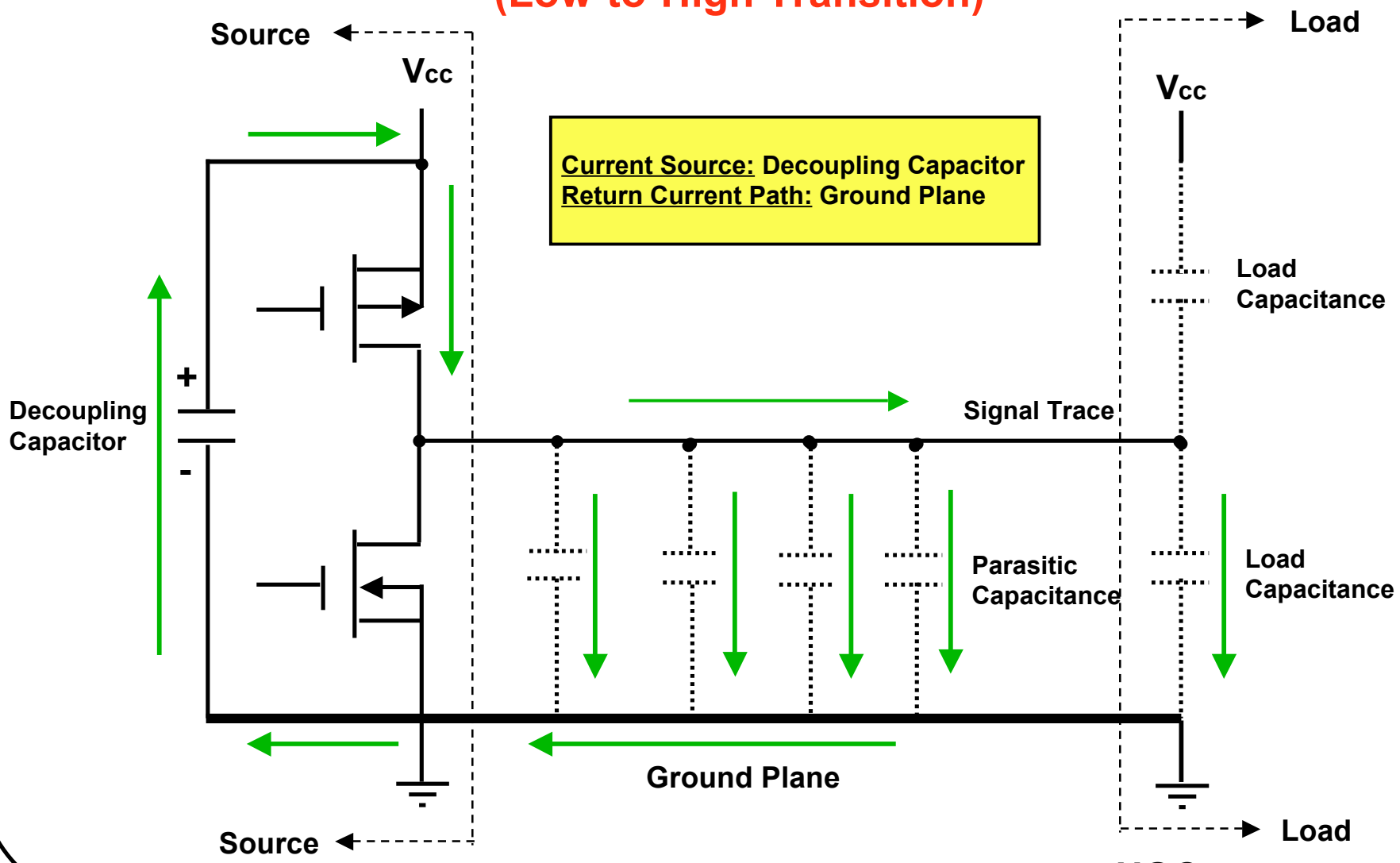
GENERAL CASE–CMOS LOGIC GATE DRIVING A LOAD



Slide #5

DIGITAL CIRCUIT CURRENT PATH

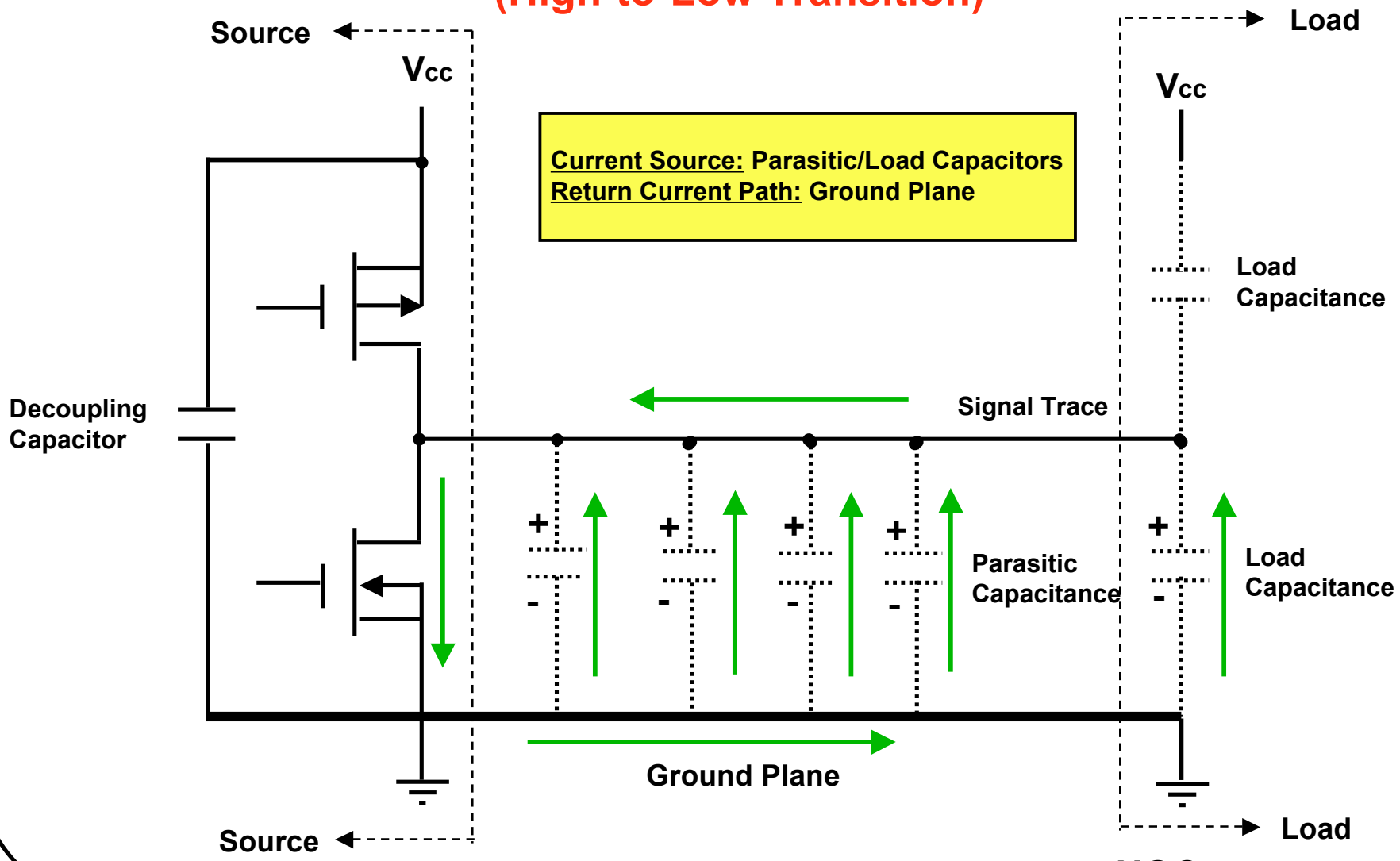
Trace Adjacent to a Ground Plane (Microstrip)
(Low-to-High Transition)



Slide #6

DIGITAL CIRCUIT CURRENT PATH

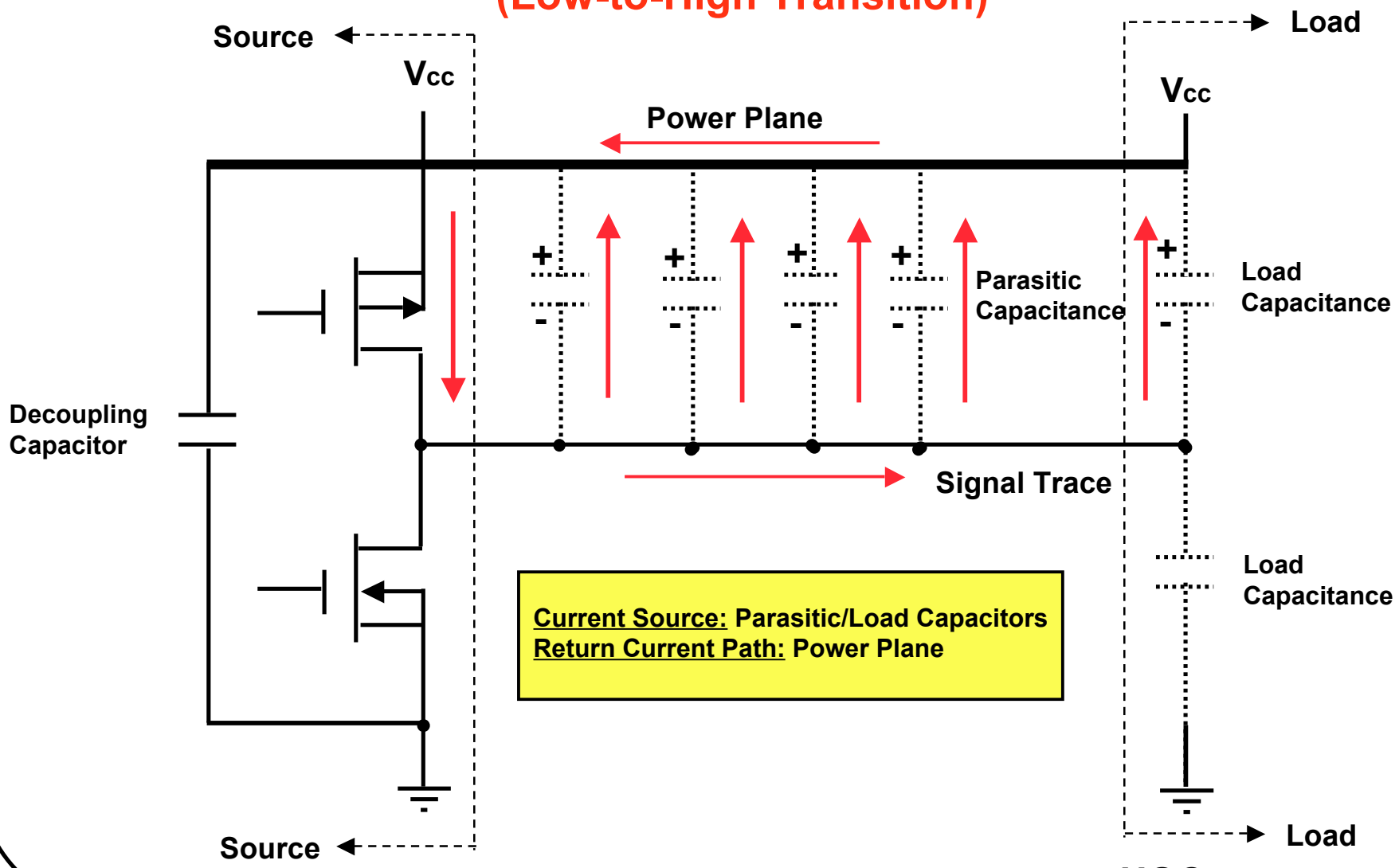
Trace Adjacent to a Ground Plane (Microstrip)
(High-to-Low Transition)



Slide #7

DIGITAL CIRCUIT CURRENT PATH

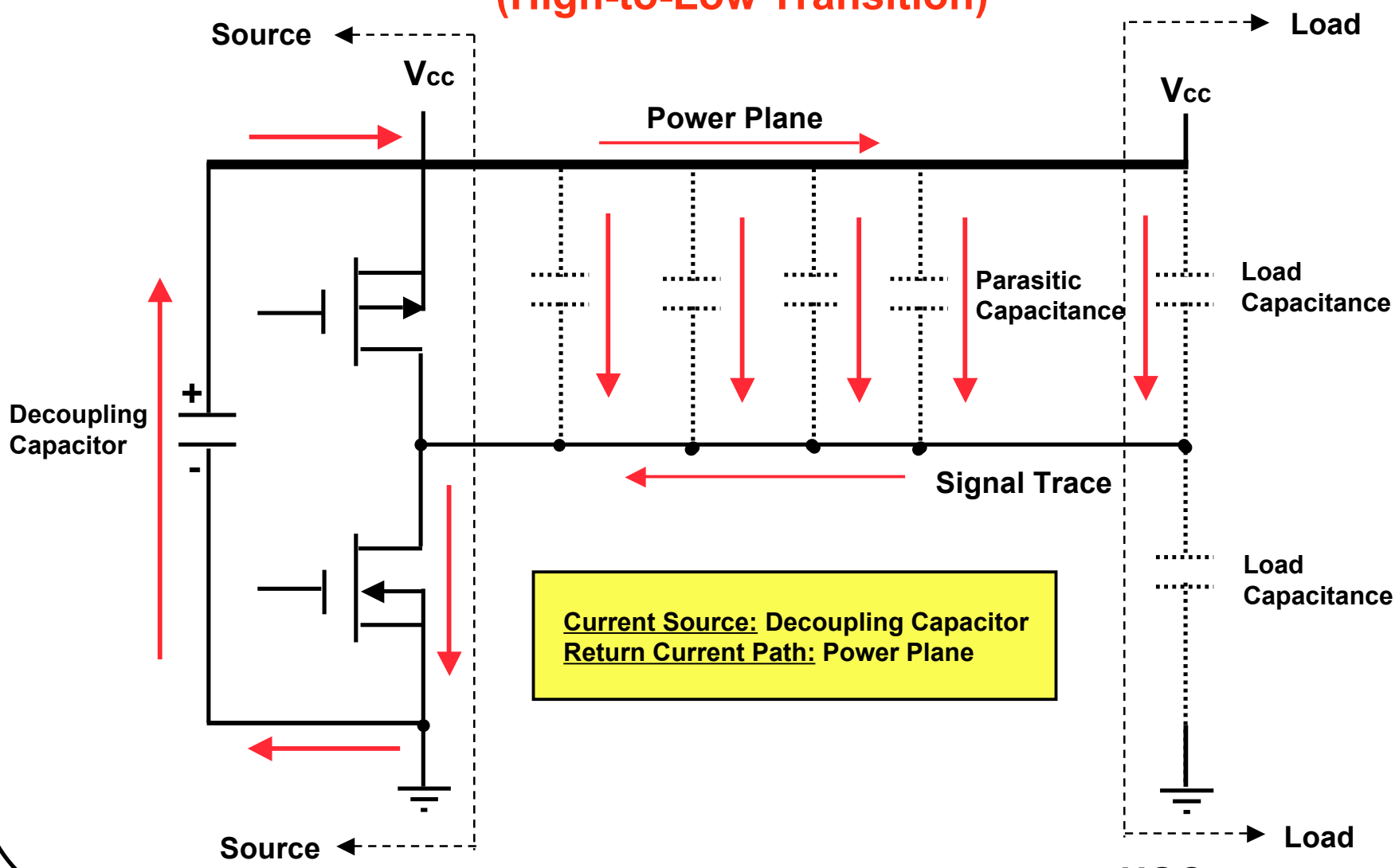
Trace Adjacent to a Power Plane (Microstrip)
(Low-to-High Transition)



Slide #8

DIGITAL CIRCUIT CURRENT PATH

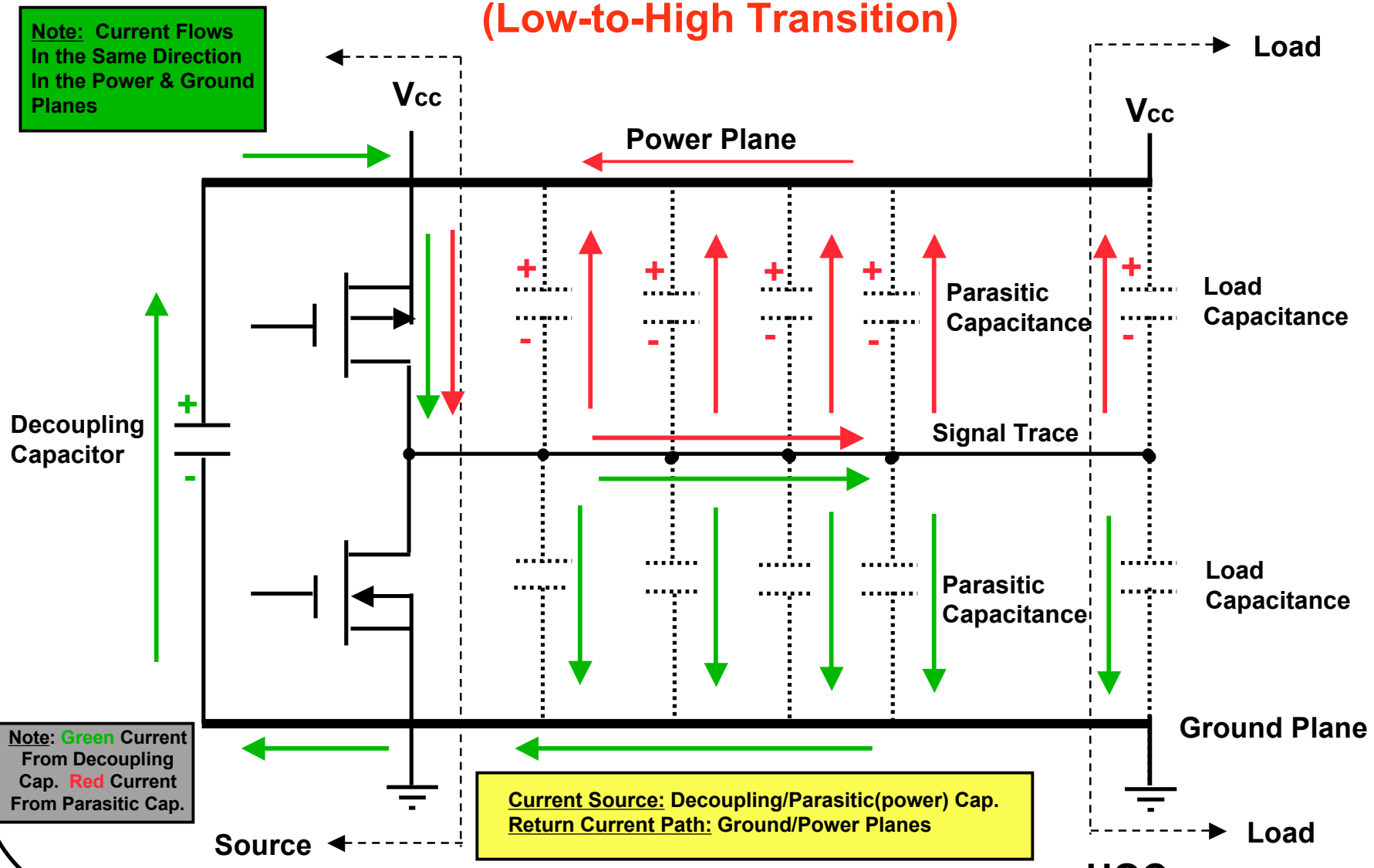
Trace Adjacent to a Power Plane (Microstrip)
(High-to-Low Transition)



Slide #9

DIGITAL CIRCUIT CURRENT PATH

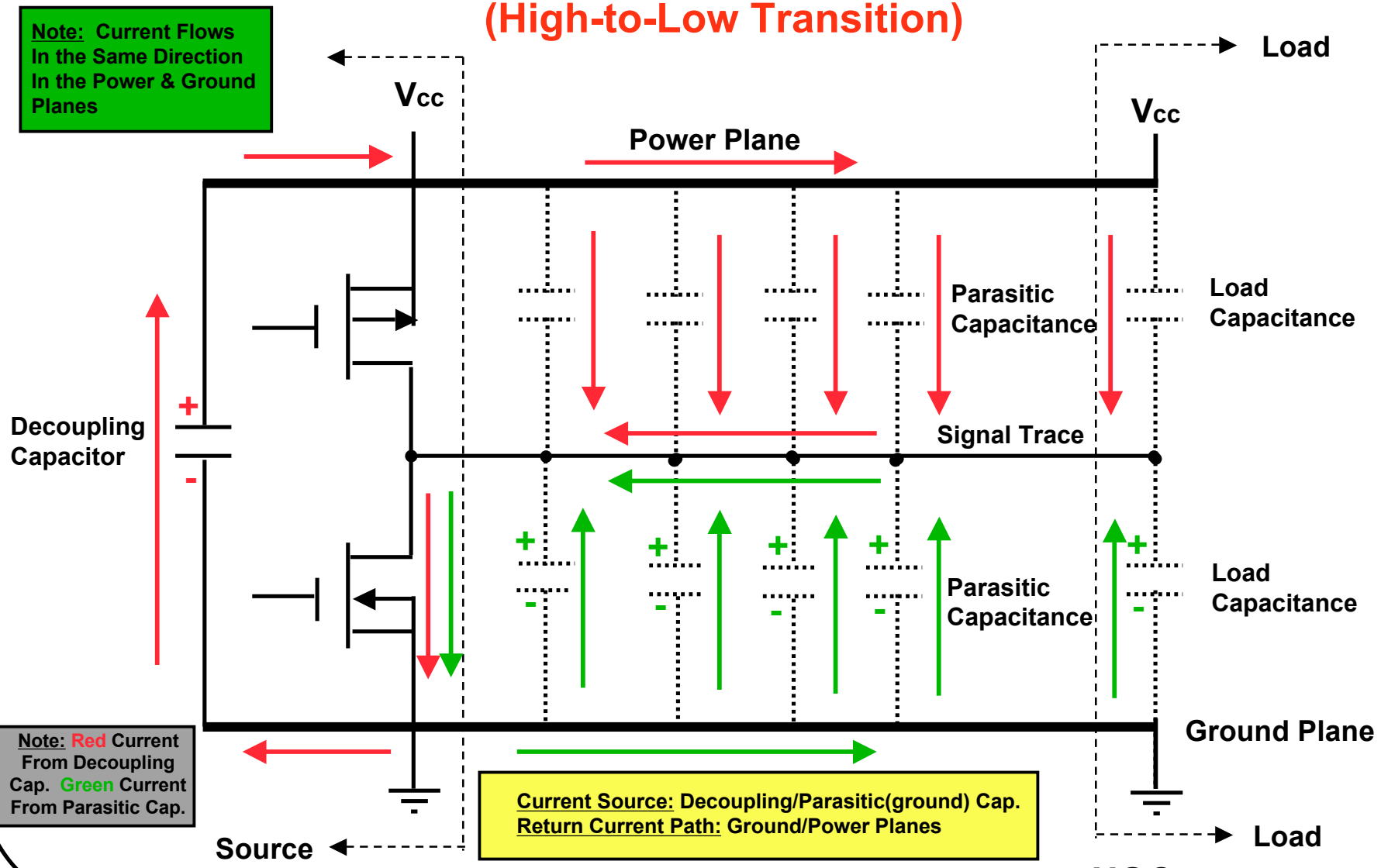
Trace Between a Power & Ground Plane (Stripline)
(Low-to-High Transition)



Slide #10

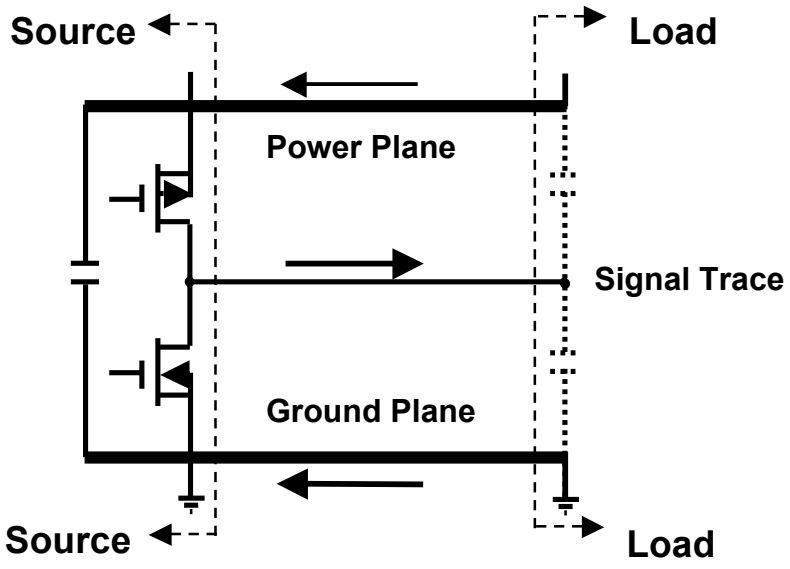
DIGITAL CIRCUIT CURRENT PATH

Trace Between a Power & Ground Plane (Stripline)
(High-to-Low Transition)

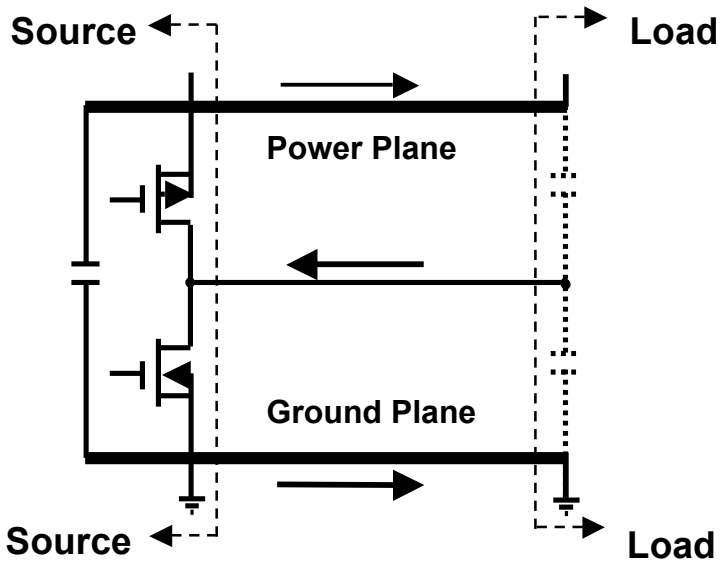


SUMMARY–DIGITAL CIRCUIT CURRENT PATH

Trace Between a Power & Ground Plane (Stripline)



Low-to-High Transition



High-to-Low Transition

Note: Return Currents Flows in the Same Direction in Both the Power and Ground Planes

DRIVER IC CURRENT

- Low-to-High Transition

  — In all Cases, Current Enters the Driver Through the Power Pin and Exits the Driver Via the Signal Pin

- High-to-Low Transition

  — In all Cases, Current Enters the Driver Through the Signal Pin and Exits the Driver Via the Ground Pin

SUMMARY

Configuration	Reference Plane	Transition	Current Source	Return Current Path
Microstrip	Ground	Low-to-High	Decoupling Capacitor	Ground Plane
Microstrip	Ground	High-to-Low	Parasitic/Load Capacitance	Ground Plane
Microstrip	Power	Low-to-High	Parasitic/Load Capacitance	Power Plane
Microstrip	Power	High-to-Low	Decoupling Capacitor	Power Plane
Stripline	Power & Ground	Low-to-High	Decoupling & Parasitic (Power) Capacitance	Power & Ground Plane
Stripline	Power & Ground	High-to-Low	Decoupling & Parasitic (Ground) Capacitance	Power & Ground Plane

Note: For Stripline Referenced to Two Ground Planes, See Microstrip Referenced to a Ground Plane, Except Each Plane Carries Only One-Half the Current. Similarly For Stripline Referenced to Two Power Planes, See Microstrip Referenced to a Power Plane.

CONCLUSIONS

(1) From the Previous Examples it Can Be Concluded That it Makes No Difference Whatsoever to the Digital Logic Current if the Reference Plane, or Planes, Are Ground or Power. In All Cases the Current Returns Directly to the Source Through a Small Loop. In None of The Cases Does The Current Have to Go Out of its Way, or Flow Through a Large Loop in Order to Return to the Source.

(2) The Answer to All Questions On Slide 2 is, It Does Not Matter! All Are Equally Acceptable Configurations.

(3) Stripline, However, Will Always Be a Better Configuration Than Microstrip, Since Two Current Loops Exist. In One Loop the Current Flows Clockwise, and in The Other it Flows Counterclockwise (see Slide #11). Therefore, Radiation From the Two Loops Will Cancel.