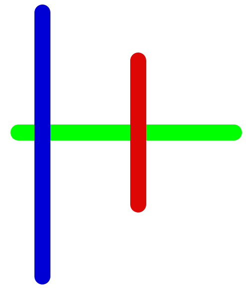
Stick Diagram

Fundamentals



by
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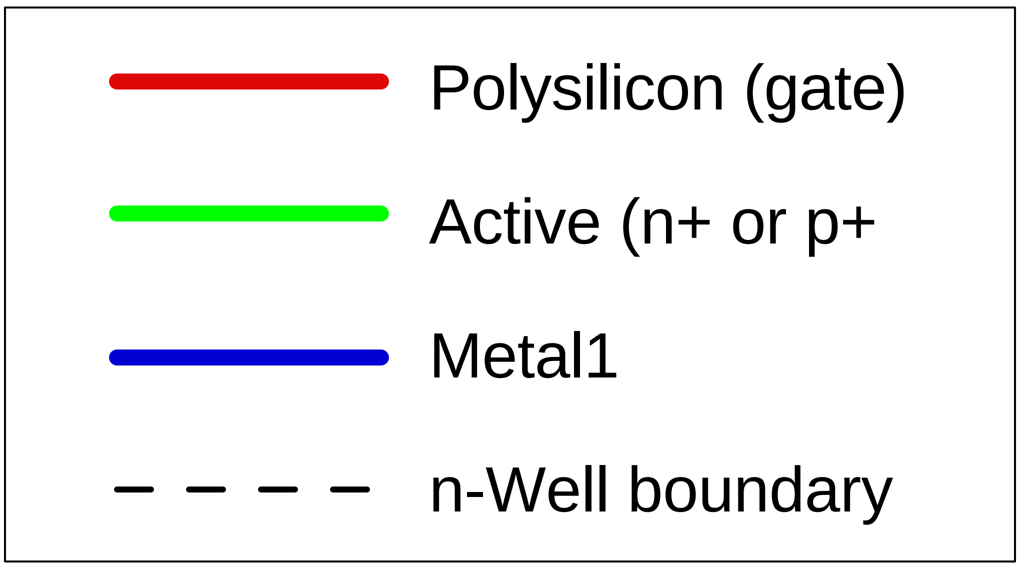
Introduction

Stick diagrams are useful for planning the layout and routing of integrated circuits. In a stick diagram, every line of a conducting material layer is represented by a line of a distinct color. In our study, we will use the basic color coding below:



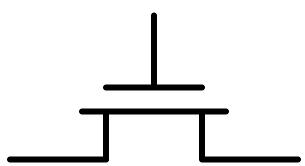
Other layers will be introduced later.

The width of a line is not important, as stick diagrams give only wiring and routing information.

Interpretation

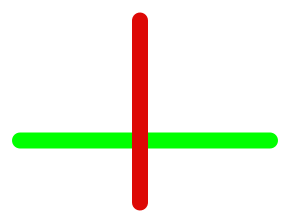
As discussed in the book, a VLSI circuit may be viewed as a 3-dimensional set of patterned material layers. Stick diagrams provide a top view of the patterns. The colors allow us to trace signal flow paths through the conducting layers in a complex integrated circuit.

A stick diagram is thus a schematic representation of a circuit at the physical design level. With a little practice, you will be able to read a stick diagram and translate it into a conventional circuit schematic.



nFET

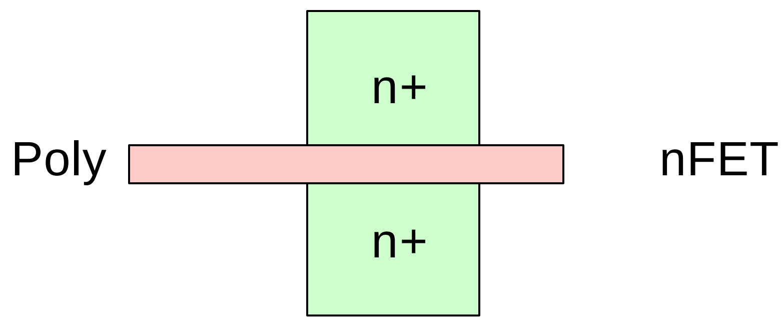
⟺



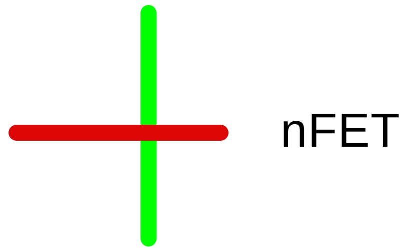
nFET

Origin of the Colors

In the early days of MOS integrated circuits it was noticed that when a chip was illuminated with a white light source, each conducting layer had a distinct coloring associated with it when viewed under a microscope.



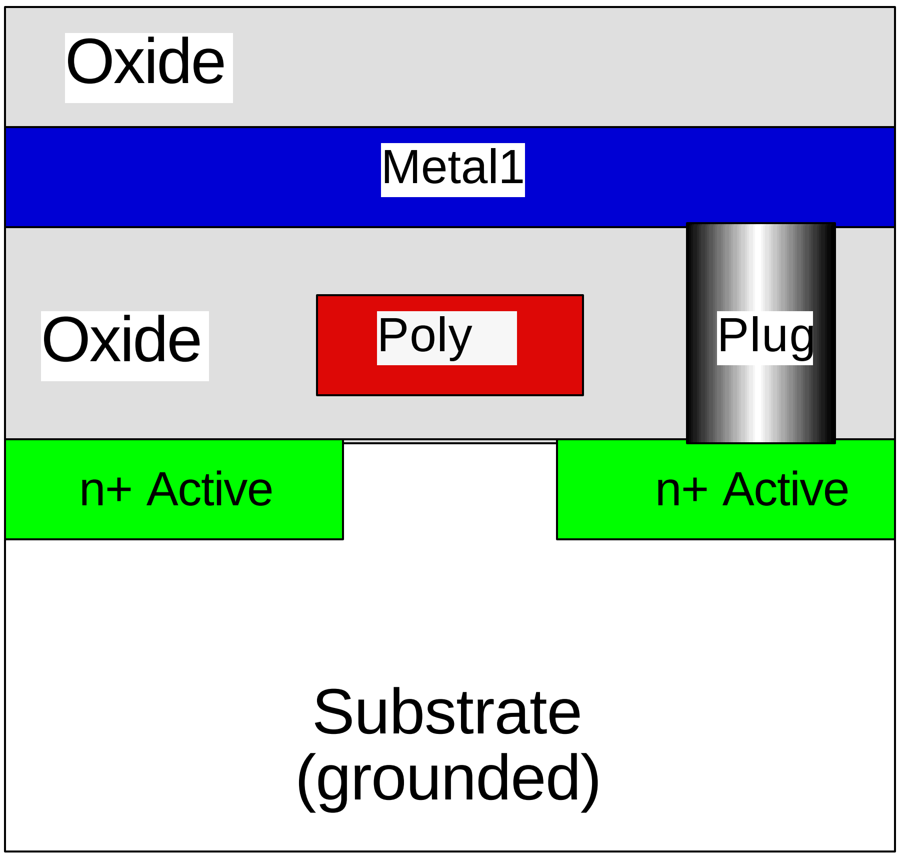
This observation provided the basis for developing the technique:



Oxide layers appeared transparent, so they are not shown.

Basics

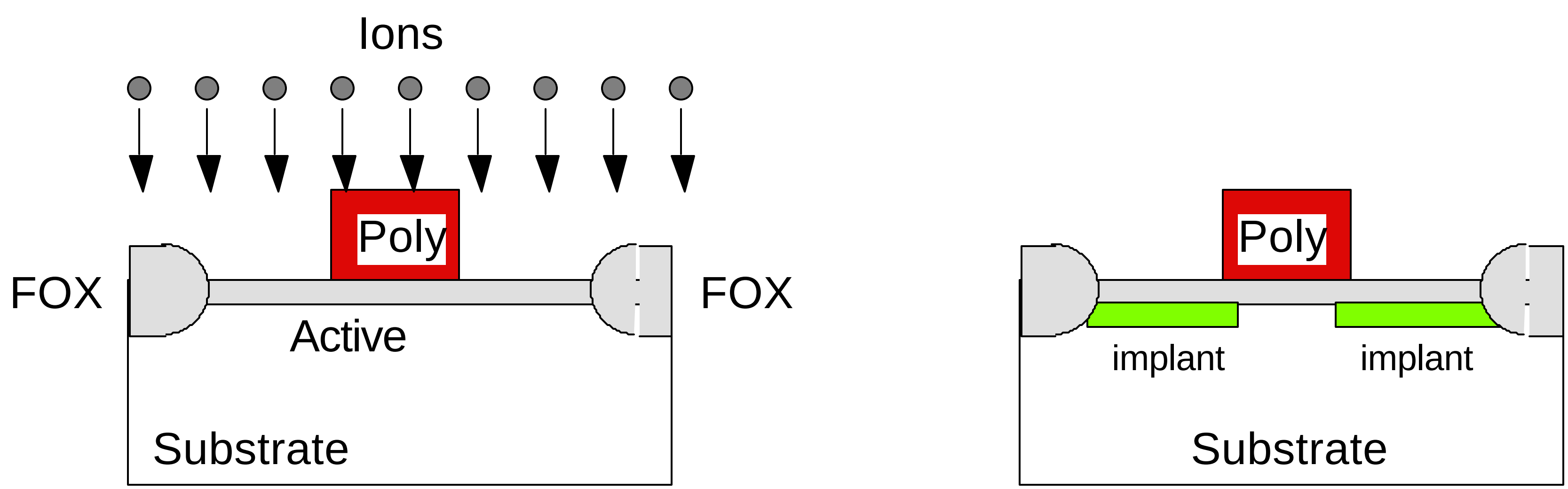
We assume that every conducting layer is insulated from every other conducting layer. This is achieved using either silicon dioxide layers (above the substrate) or reverse-biased pn junctions (in the silicon).



A contact or via is needed to connect two layers

FETs

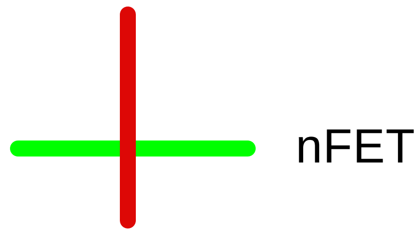
In the self-aligned gate process, the polysilicon gate pattern and field oxide (FOX) act as masks to the n+ or p+ drain/ source ion implant.



We will assume a p-type substrate in our discussion. It is not shown explicitly in the stick diagram. If the ions are donors (P or As), this creates n+ implanted regions and yields an nFET.

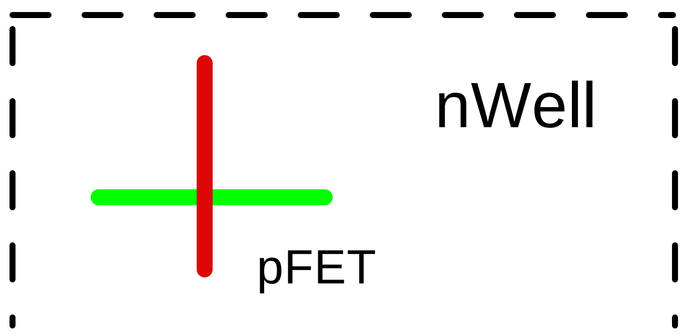
In terms of stick diagrams, we thus say that an nFET is formed whenever

Red (Poly) crosses over Green (Active)



This is consistent with a top view of the transistor.

A pFET is described by the same "red over green" coding, but the crossing point is contained within an nWell boundary

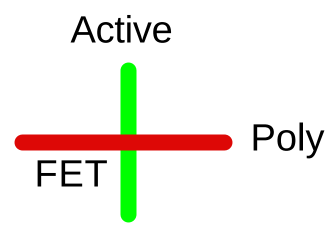


Basic Rules

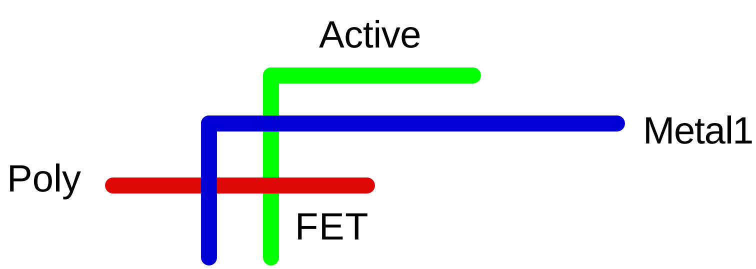
The rules for constructing stick diagrams are based on the characteristics of the conducting layers.

- Only the routing is important, not the line widths

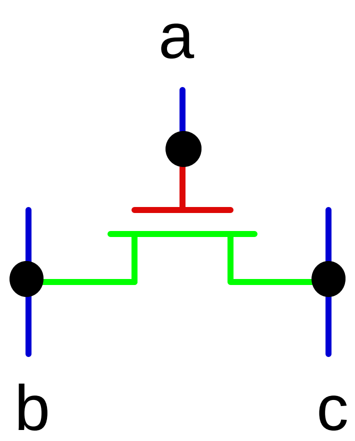
- Red over green gives a FET
  (Poly) (Active)



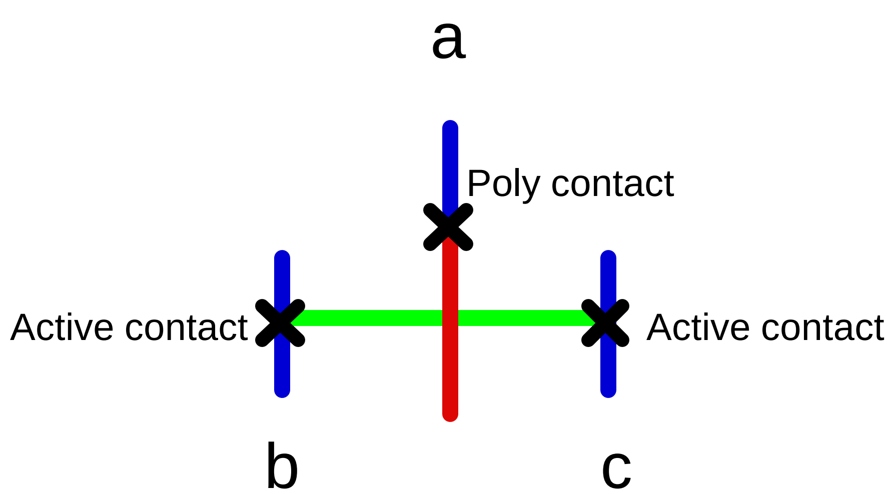
- Blue may cross over green or red without a connection
  (Metal1) (Active) (Poly)



- Connections between layers are specified by ✖
This represents an oxide etch



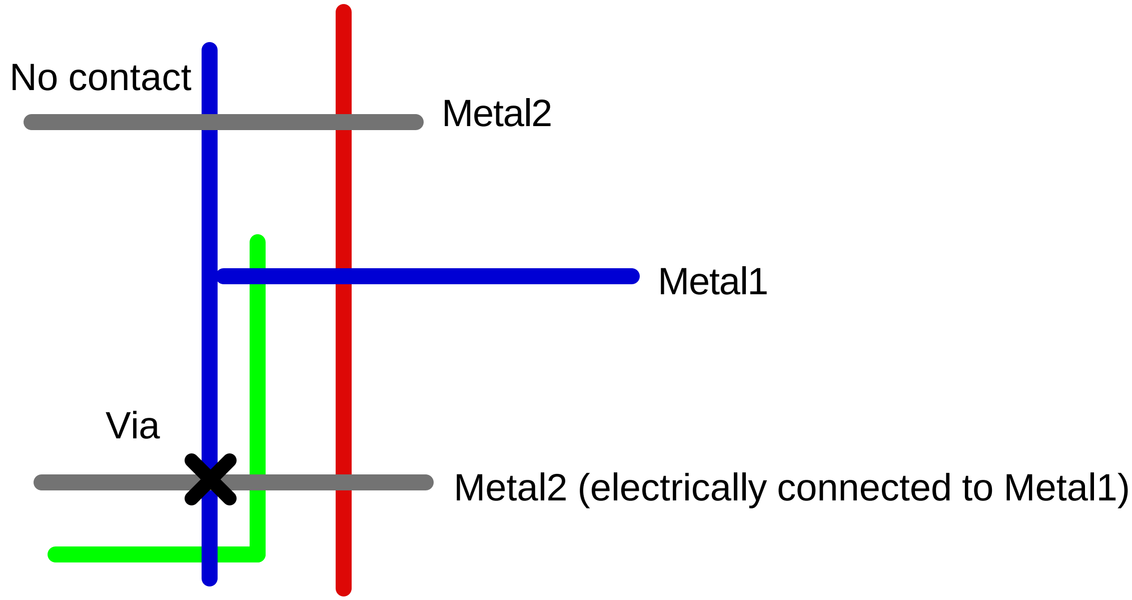
Schematic

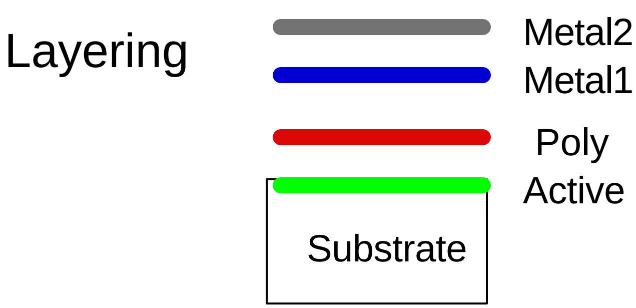


Stick diagram

Poly contact: Metal1-to-Poly
Active Contact: Metal1-to-Active

- Metal lines on different layers can cross one another. Contacting two metal lines requires a via



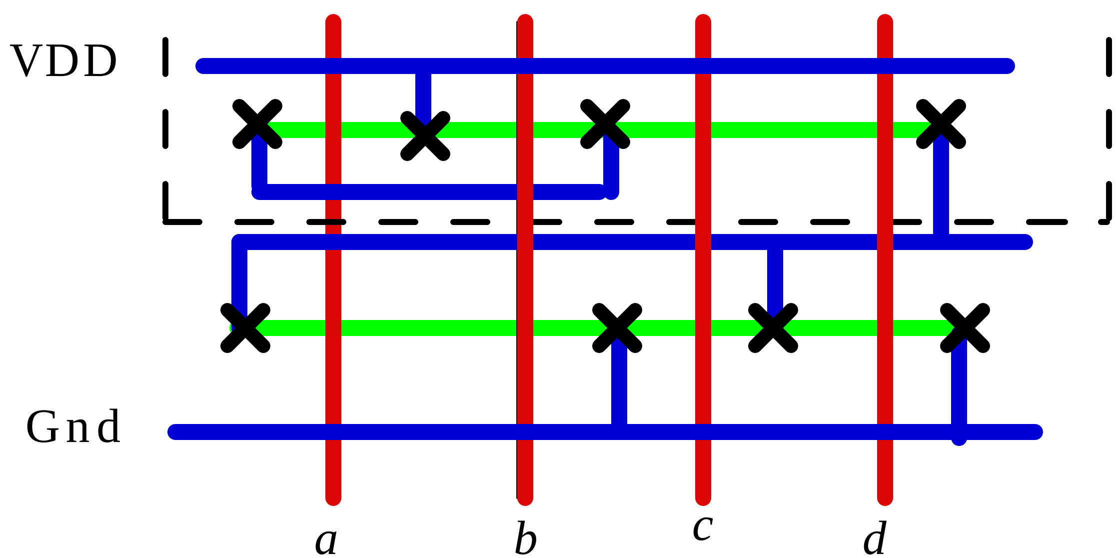


Usage

Stick diagrams can be drawn using a set of colored pencils to aid in wiring of basic gates, or in routing interconnect lines on the chip.

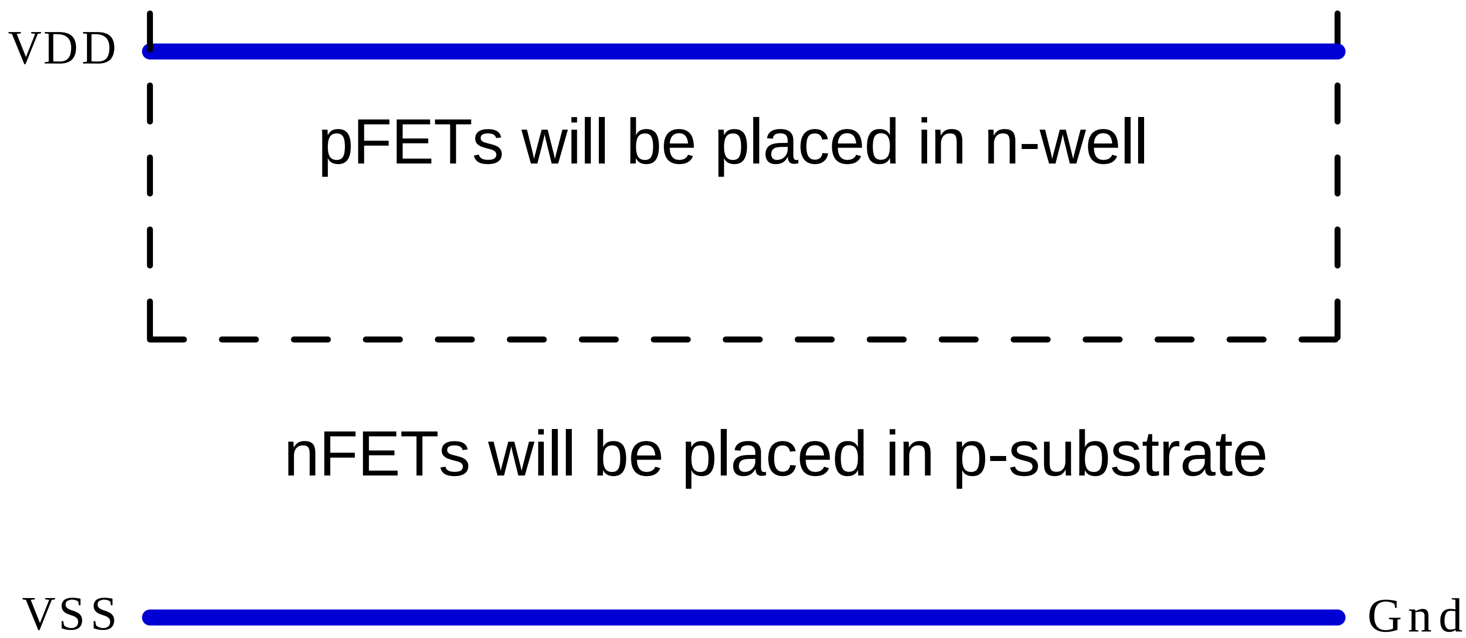
You will discover that VLSI layout can become complicated due to the large number of wires that need to be included. Since stick diagrams are easy to draw, they can be used to plan the wiring before you access a CAD tool. Many hours of frustration can be avoided by planning ahead!

The drawing below is the same as Figure 3.44 in the text



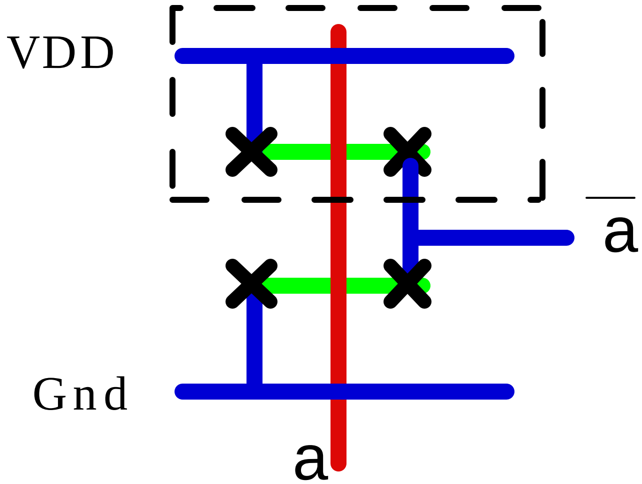
Logic Gate Design

To create CMOS logic gates, we start with the VDD and VSS (ground) lines. We will use a horizontal orientation for the lines. Remember that stick diagrams only deal with the routing. Widths and spacings are not important.

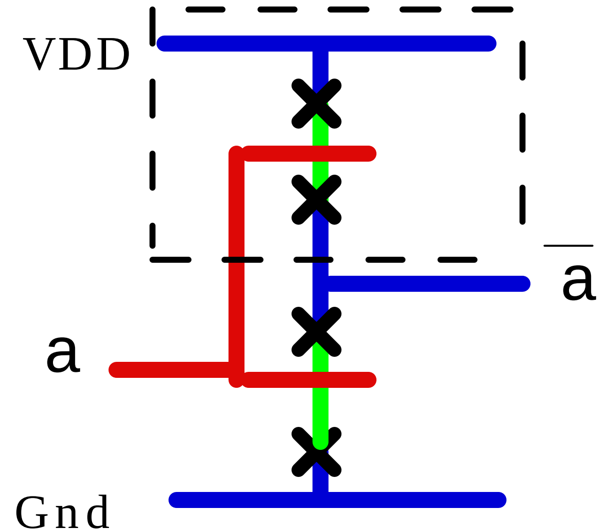


We have included an n-well region around VDD

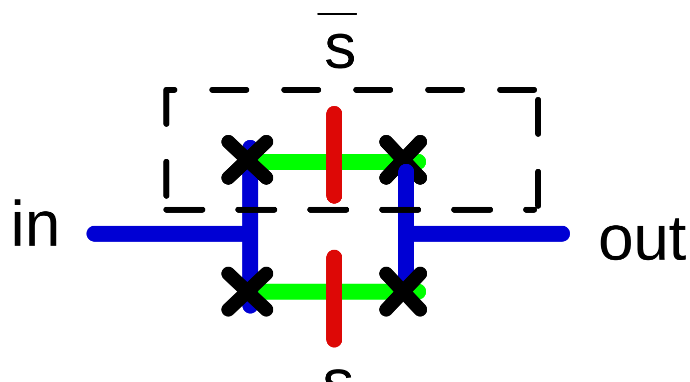
Examples



NOT

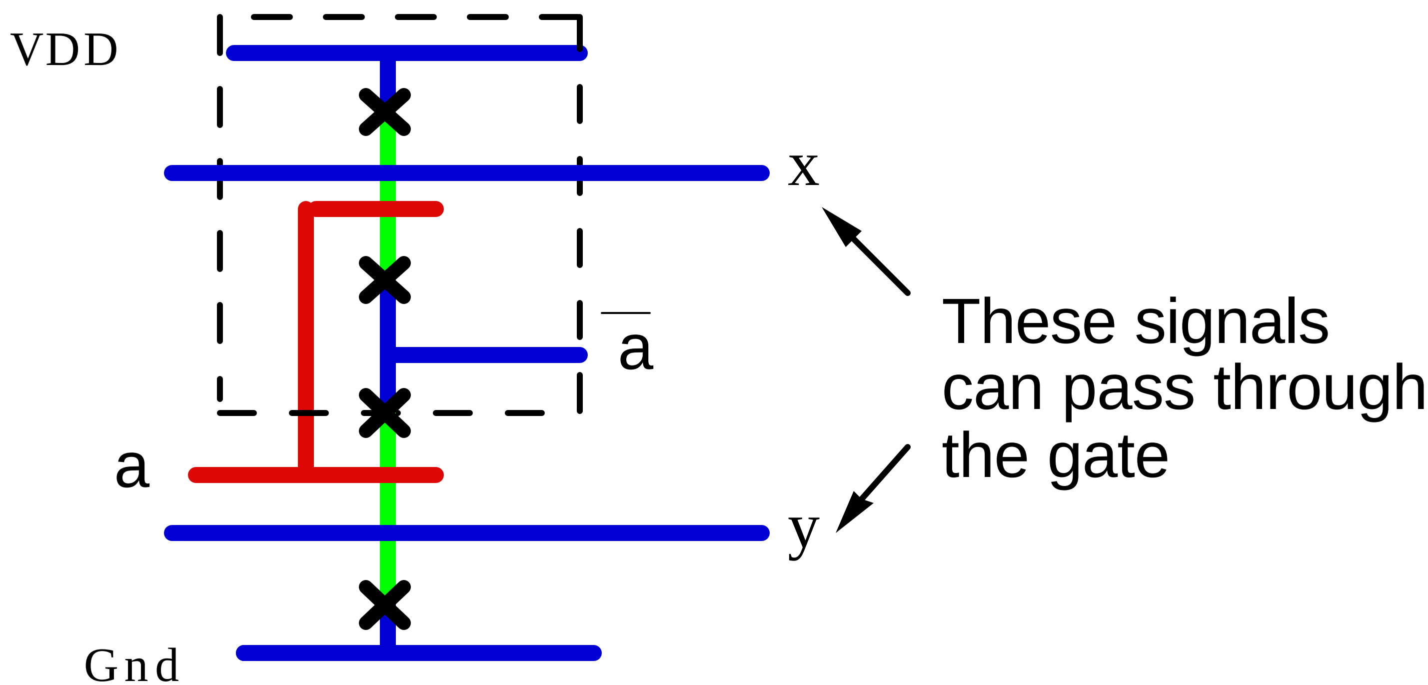


NOT



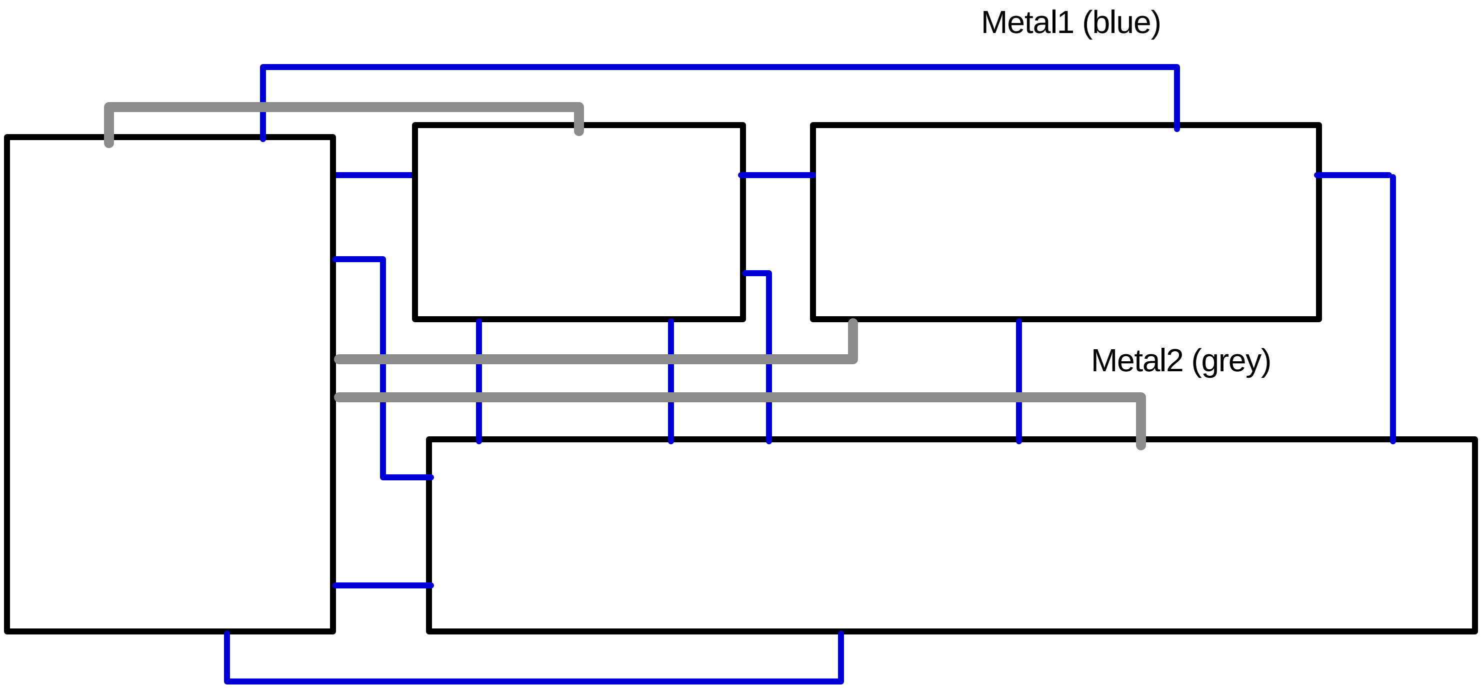
TG

Stick diagrams are often used to solve routing problems.



The routing scheme can be translated to the actual design

Complicated wiring of gates and cells is often easier to visualize using stick diagrams. This allows the designer to converge on a design using trial and error.

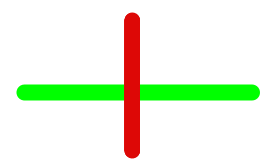


Crossovers (such as Metal2-Metal1) are easy to plan using stick drawings.

Conclusions

Stick diagrams provide an easy approach to performing simple CMOS circuit layouts. Planning a physical design using stick diagrams before going to a CAD tool can save a lot of time and energy.

Stick diagrams are also useful for learning the CMOS process flow. Rules like

Red over Green = FET 

tell you how a self-aligned transistor is made!

Many people use stick diagrams to visualize the signal flows in complex networks.

Learning to use stick diagrams will ease your introduction into the field of VLSI design.