

# Review of Stick Diagram in Design of Microelectronic Circuits

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**Abstract:** *Electronic industry's revolution has continued to hold a prime place in the technological development of the world. Industrial systems automation and electronic control has grown astronomically in the last three decades owing to the rapid advancement in electronic integration technologies, the Very large scale integration (VLSI), informed by the miniaturization of millions to billions of transistors unto a single chip or wafer. VLSI technology has led to the birth of very high performing computing, telecommunications and consumer electronics. Designing a VLSI layout is very strenuous and time consuming. Stick diagram is an intermediate step between the schematic and layout which shows the power/ground routing and interconnection visualization of the proposed design using different colours and geometrical shapes. This paper reviews the techniques of using stick diagram for effective design of microelectronic circuit, to troubleshoot circuits and as a guide to the implementation of the design layout.*

**Keywords:** *Integrated circuits, VSLI, Layout design, Stick diagram,*

## 1. INTRODUCTION

Microelectronic refers to the integrated circuit (I.C) technology which is the enabling technology for a wide range of innovative electronic devices and systems. The sophistication and miniaturization of electronic devices have grown steadily over the last three decades. This stems from the invention of the integrated circuit (I.C), to which credit goes to Jack Kilby and Robert Noyce. Advancement in the integrated circuit technology has led to the manufacture of a large number of small devices, of which the transistor is the core component. [1] described the driving force of technology, social change, productivity and economic growth, in which he predicted that there is an exponential growth in the number of transistors in an integrated circuit which double every two years. This

prediction gave birth to the Very Large Scale Integrated (VLSI) circuit which have transformed the electronic industry by introducing fast and reliable signal processing.

Integrated circuit (IC) layout or mask design is the representation of an integrated circuit in terms of planar geometric shapes which correspond to the patterns of metal oxide or semiconductor layers that form the components of the integrated circuit [2].

Designing an integrated circuit layout is very strenuous and time consuming. IC layouts are built to design rule specification which are specific to a particular manufacturing process. The manufacturability of an integrated circuit strictly depends on the layout meeting all the set design rules for the process. The more complex the integrated circuit design, the more the number of design rules to be met, which inevitably will introduce a number of violations in the design process.

To overcome these and other shortcomings in the implementation of the layout design process, the stick diagram was introduced which makes the designer's job easy.

The stick diagram is a means by which the design engineer visualizes the cell routing and transistor placement in a layout. With this system, the designer is not concerned with the precise sizes, spacing and interrelationships embodied in a set of design rules required for IC layout.

## 2. STICK DIAGRAM REVIEW

The physical mask layout of any circuit to be manufactured using particular process must obey a set of geometric constraints referred to as layout design rules. These rules specify the minimum allowable line widths, component dimensions and separation on-chip. The design rule objective is to achieve an overall high yield with reliability for any circuit manufactured with a particular process using the smallest possible silicon chip. However violation to any specified rule, which is imminent in a VSLI

layout design, due to its complexity, would mean a low yield and therefore un-manufacturability of the product.

In the early days of CMOS integrated circuit, it was observed that when a chip was illuminated with a source of white light, each conducting layer had a unique colour associated with it when viewed under the microscope.

This observation apparently provided the basis for the development of the stick diagram technique. Oxide layers appeared transparent (crystalline), hence not shown in a stick diagram.

A stick diagram is paper and pencil tool that is used to plan layout of a cell [3]. It resembles the actual layout but uses “sticks” or lines to represent the devices and components. It is a schematic representation of a circuit at the physical design level with each conducting component layer represented

by a line of distinct colour, used for planning the layout and routing of integrated circuit [4].

The stick diagram is an abstract representation of layout which can help us understand the circuit function and its geometrical location relative to other circuit block [5].

The stick diagram shows all components in their relative rather than exact positions. The sizes of the component (e.g. transistor) are not drawn to scale. The wires are drawn as stick figures with no width.

The VLSI is a 3-dimensional set of patterned material layers, whose designs aims at translating circuit concept onto silicon chip or wafer. The stick diagram provides a top view of the patterns. The colours allow us to trace signal flow paths through the conduction layers in a complex integrated circuit.

It is often advisable and faster to design layouts on paper using stick diagram before using layout CAD tools.

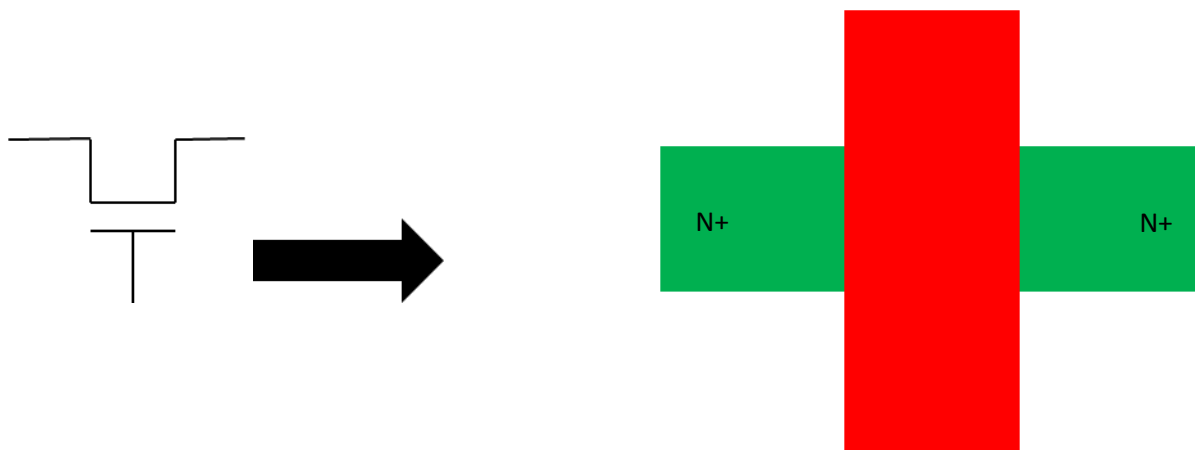









Figure 1: A stick diagram

Table 1: Stick diagram notations

Colour	Stick encoding	Layers
Blue		Metal 1
Purple or Grey		Metal 2
Red		Polysilicon
Green		N – diffusion
Brown		P – diffusion
Black		Contact
Black		Via

### STICK DIAGRAM DESIGN RULES

Some design rules that guide the drawing of a stick diagram are highlighted below;

**Rule 1:** An electrical contact is formed when two or more sticks of the same colour intersect.



Figure 2: Rule 1

**Rule 2:** An electrical contact is NOT formed when sticks of different colours intersect.

Note: If an electrical contact is desired, a contact is shown conspicuously at the intersection of the lines.



Figure 3: Rule 2

**Rule 3:** A transistor is formed when a polysilicon crosses N or P diffusion.



Figure 4: Rule 3

NOTE: If a contact is shown, then it is not a transistor.

- Polysilicon is drawn on top of diffusion (N or P).

- Diffusion must be drawn connecting the source and the drain.
- Gate is automatically self-aligned during fabrication.

**Rule 4:** In CMOS a demarcation line is drawn to avoid touching of P-diffusion with N-diffusion. All pMOS must lie on one side of the line and all nMOS will have to be on the other side.

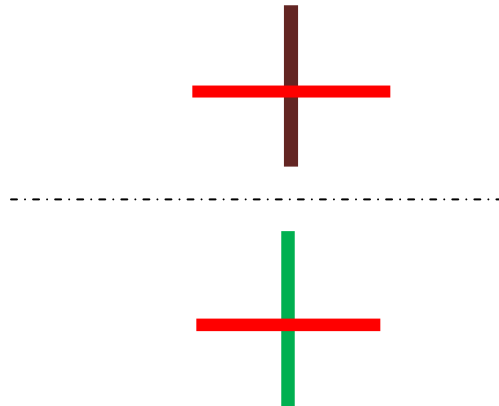


Figure 5: Rule 4

**Rule 5:** when a metal line needs to be connected to one of the other three conductors, a contact cut (Via) is required.

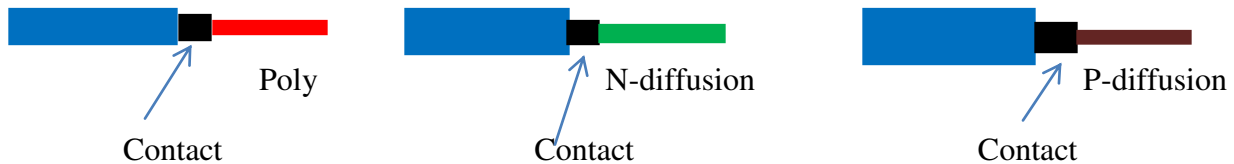


Figure 6: Rule 5

### 3. STICK DIAGRAM APPLICATION TO DESIGN AND BENEFITS

Manufacturing processes have inherent limitations in accuracy and repeatability. Design rules which are determined by experience specify

geometry of masks that provide reasonable yield. VLSI layout can be very complicated due to the large number of wires that need to be included. The stick diagram offers the designer the flexibility to plan the layout quickly. It saves a lot of time in transistor placement and device minimization.

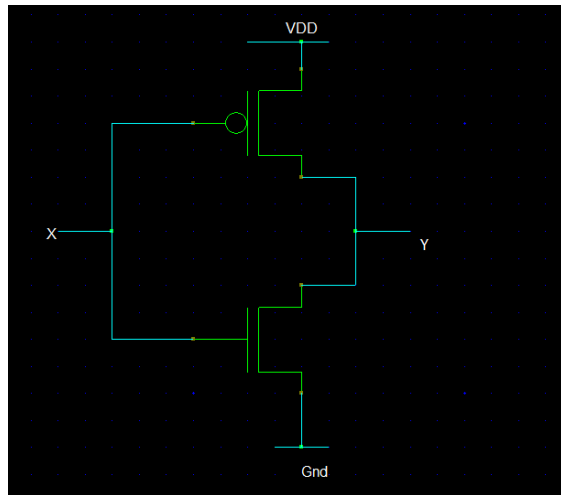


Figure 7: Schematic diagram of a CMOS inverter

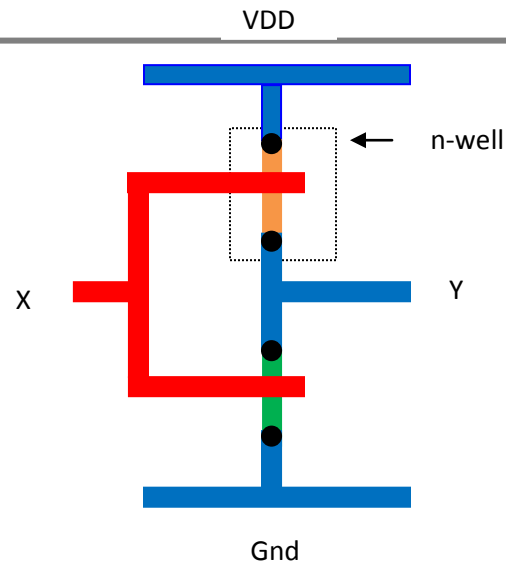


Figure 8: Stick diagram of a CMOS inverter

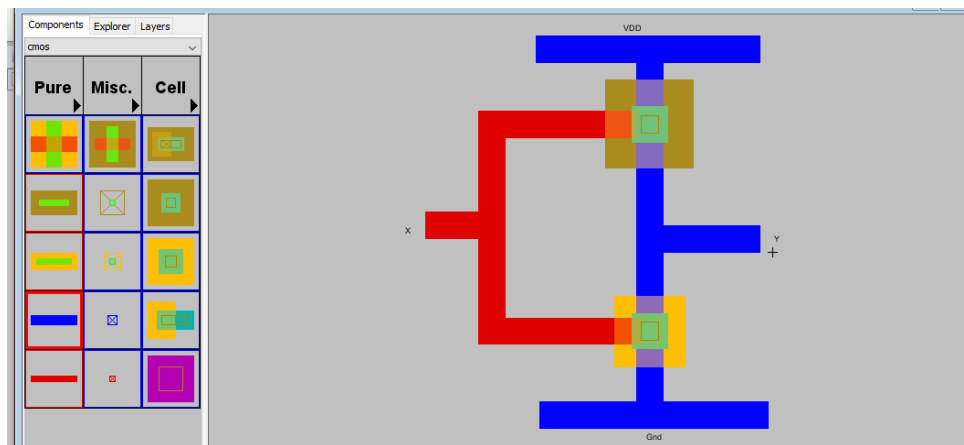


Figure 9: Layout diagram of a CMOS inverter

The stick diagram is a draft of real layout which serves as an abstract view between the schematic and layout. The design rules allow translation of circuit (usually in stick diagram or symbolic form) into actual geometry in silicon. The stick diagram is used to display transistors in a higher level abstract view for easier transistor manipulation. [6] Says that the designer's input to the STICK's system called a stick diagram, is a high level, schematic-like representation of the circuit. They can be used to plan the wiring before you access a CAD tool.

The stick diagram increases designer's efficiency and permit automatic translation to final layout. It produces longevity of designs that are simple, abstract and with minimal clutter. They are scalable, portable and durable making it easy of learning.

#### 4. ANALYSIS

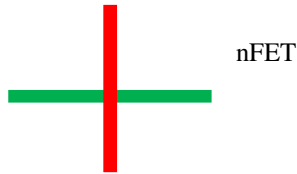
Two types of transistors are provided for by the CMOS technology. They are an n-type transistor (nMOS) and a p-type transistor (pMOS).

Stick diagrams are means of capturing topography and layer information. It conveys layer information through colour codes (or monochrome encoding). It helps in the quick planning of VLSI layouts.

Stick diagram will not show exact placement, transistor sizes, wire lengths and widths, boundaries or any other form of compliance with layout or design rules. It is useful for interconnection visualization, preliminary layout, layout compaction, power routing and ground routing.

In terms of stick diagrams, an nFET is formed whenever a Red (poly) crosses over a green (Active).

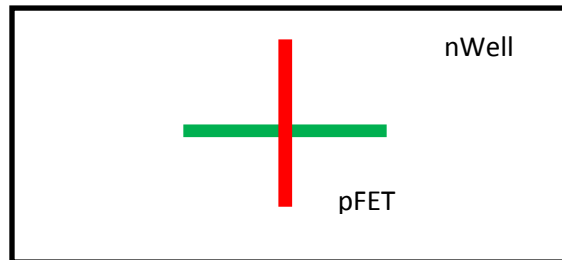
Figure 10: nFET



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 in a nWell boundary.

Figure 11: pFET



The stick diagram can be drawn by hand and is a handy form between the circuit diagram and the physical layout since it can easily be modified and corrected. It therefore can be used to anticipate and avoid any problems when laying-out the circuit. The colours used in stick diagrams, make visualization of the entire circuit easy, thus enabling easy tracing and correction of faults. Stick diagram can be drawn using a set of coloured pencils to aid in wiring of basic gates or in routing interconnect lines in chip.

## 5. CONCLUSIONS

Design of VLSI layout has been made much simpler and easier by the introduction of the stick diagram. Stick diagrams ensure an easy approach to performing simple CMOS circuit layout. The stick diagrams are used to solve routing problems. To do this it employs different lines, colours and geometrical shapes to represent circuit nodes, devices and their relative position. Planning a physical design using stick diagrams before going to CAD tool can save a lot of time and energy.

## 6. REFERENCES

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