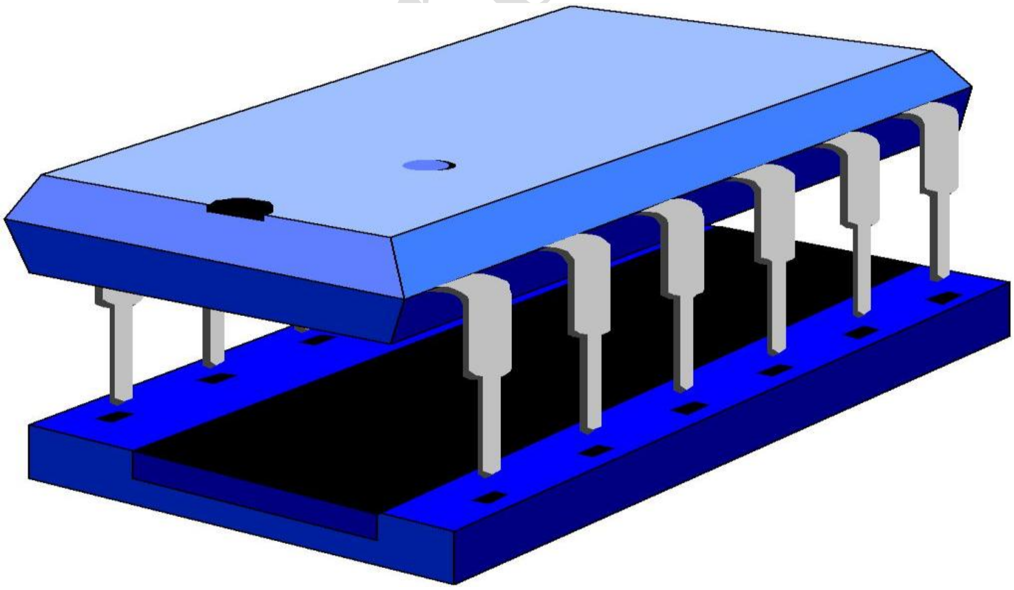
Digital Integreted Circuit



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Diode Logic Circuits

Diode Logic makes use of the fact that the electronic device known as a *diode* will conduct an electrical current in one direction, but not in the other. In this manner, the diode acts as an electronic switch.

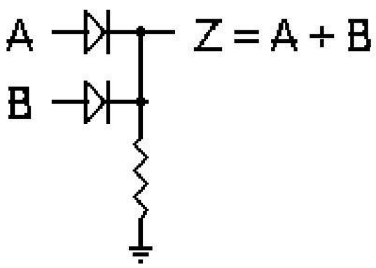

Fig1

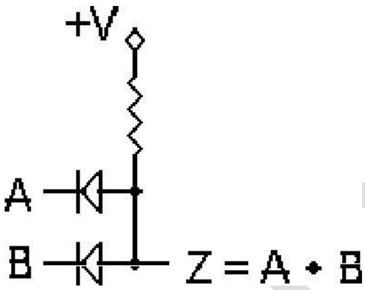

Fig2

To the left Fig1 you see a basic Diode Logic OR gate. We'll assume that a logic 1 is represented by +5 volts, and a logic 0 is represented by ground, or zero volts. In this figure, if both inputs are left unconnected or are both at logic 0, output Z will also be held at zero volts by the resistor, and will thus be a logic 0 as well. However, if either input is raised to +5 volts, its diode will become forward biased and will therefore conduct. This in turn will force the output up to logic 1. If both inputs are logic 1, the output will still be logic 1. Hence, this gate correctly performs a logical OR functions.

To the right Fig2 is the equivalent AND gate. We use the same logic levels, but the diodes are reversed and the resistor is set to pull the output voltage up to a logic 1 state. For this example, +V = +5 volts, although other voltages can just as easily be used. Now, if both inputs are unconnected or if they are both at logic 1, output Z will be at logic 1. If either input is grounded (logic 0), that diode will conduct and will pull the output down to logic 0 as well. Both inputs must be logic 1 in order for the output to be logic 1, so this circuit performs the logical AND function.

In both of these gates, we have made the assumption that the diodes do not introduce any errors or losses into the circuit. This is not really the case; a silicon diode will experience a forward voltage drop of about 0.65v to 0.7v while conducting. But we can get around this very nicely by specifying that any voltage above +3.5 volts shall be logic 1, and any voltage below +1.5 volts shall be logic 0. It is illegal in this system for an output voltage to be between +1.5 and +3.5 volts; this is the undefined voltage region.

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Logic Families, Circuit Analysis Part 1

Individual gates like the two above can be used to advantage in specific circumstances. However, when DL gates are cascaded, as shown in Fig3, some additional problems occur. Here, we have two AND gates, whose outputs are connected to the inputs of an OR gate. Very simple and apparently reasonable.

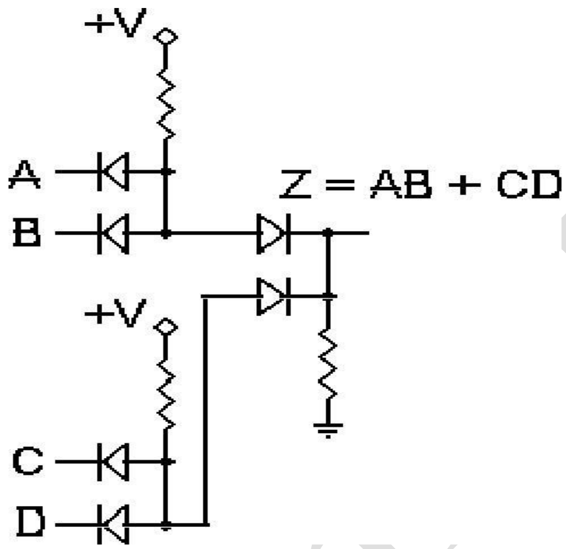

Fig3

But wait a minute! If we pull the inputs down to logic 0, sure enough the output will be held at logic 0. However, if both inputs of either AND gate are at +5 volts, what will the output voltage be? That diode in the OR gate will immediately be forward biased, and current will flow through the AND gate resistor, through the diode, and through the OR gate resistor.

If we assume that all resistors are of equal value (typically, they are), they will act as a voltage divider and equally share the +5 volt supply voltage. The OR gate diode will insert its small loss into the system, and the output voltage will be about 2.1 to 2.2 volts. If both AND gates have logic 1 inputs, the output voltage can rise to about 2.8 to 2.9 volts. Clearly, this is in the "forbidden zone," which is not supposed to be permitted.

If we go one step further and connect the outputs of two or more of these structures to another AND gate, we will have lost all control over the output voltage; there will always be a reverse-biased diode somewhere blocking the input signals and preventing the circuit from operating correctly. This is why Diode Logic is used only for single gates, and only in specific circumstances.

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Diode-Transistor Logic (DTL) Gates

Introduction

Circuits of the DTL family utilize diodes and BJTs in their design. As the name implies, the DTL family was introduced to improve the switching speed over the circuits of the RTL family. In 1964, a version of DTL was introduced and become the Standard digital IC family for nearly ten years.

In this experiment five circuits are introduced, the basic inverter, AND, OR, NAND, and NOR.

Theoretical background

- **The basic DTL inverter**

Figure 1 shows the DTL inverter, which could be built by replacing the resistor connected to the base of the transistor in the RTL inverter by a diodes. This allows faster switching action. As a result, gates built with diodes in place of most resistors can operate at higher frequencies. Because of this Diode-Transistor logic, DTL Rapidly replaced RTL in most digital applications.

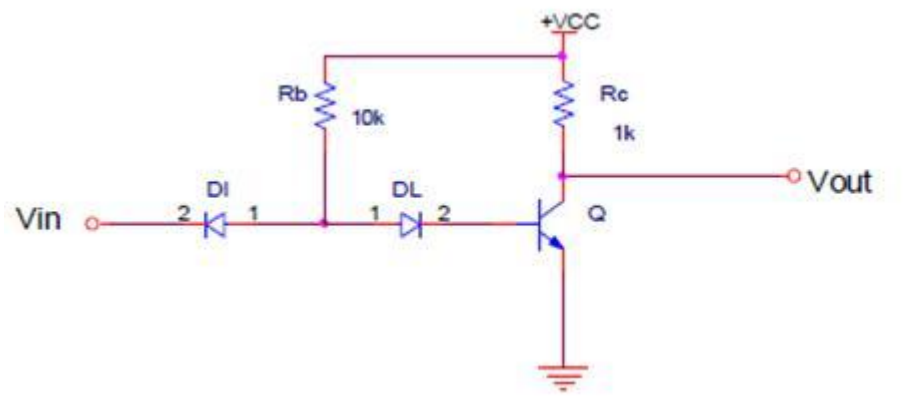

Figure 1. The DTL inverter

If the input is less than VIL=VBE (FA) then the BJT is cutoff. As a result, the output voltage is

$$VOH = VCC$$

If the input is greater than or equal to VBE(FA), the corresponding BJT conduct and if any input reaches VIH = VBE (SAT) the output drops to

$$VOL = VCE (SAT)$$

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❖ The NAND gate

The DTL NAND gate combines the DTL inverter with simple DL AND gate. Signal Degradation caused by DL is overcome by the transistor, which amplifies the signal While inverting it. **Figure 2** shows a two-input NAND gate.

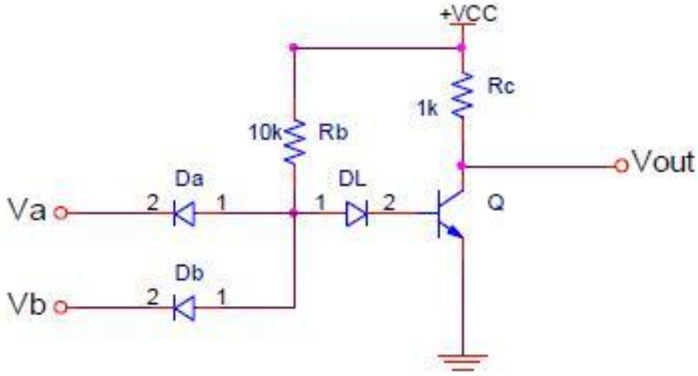

Figure 2. Two-input NAND Gate

If any input is less than VIL = VBE (FA), the transistor is cut off and the output is VOH=VCC

If all inputs are greater than or equal to VBE (FA), the BJT conducts and if they reach VIH=VBE(SAT) the output is

VOL=VCE(SAT)

❖ The AND gate

The DTL AND gate combines the DTL NAND inverter, **Figure 3** shows a two-input AND gate.

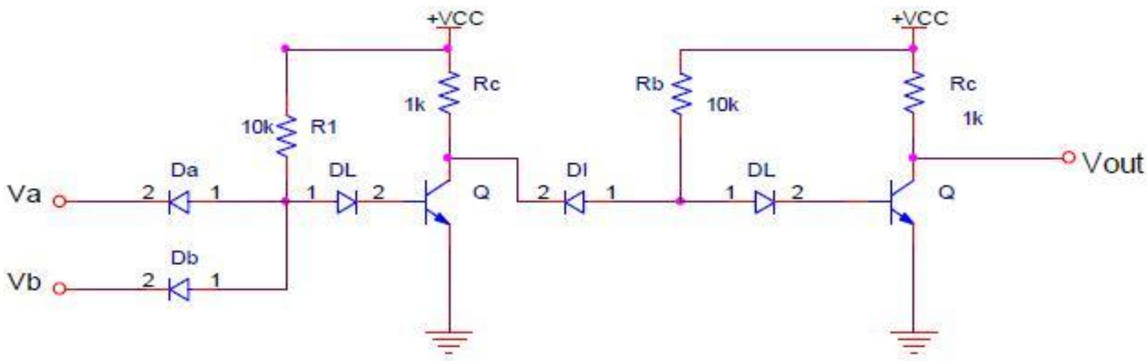

Figure 3. Two-input AND Gate

❖ The NOR gate

The DTL NOR gate combines multiple DTL inverters with a common output as shown in **Figure 4**. This is exactly the same as the method used to combine RTL inverters to form a NOR gate. Any number is inverters may be combined in this fashion to allow the required number of inputs to the NOR gate.

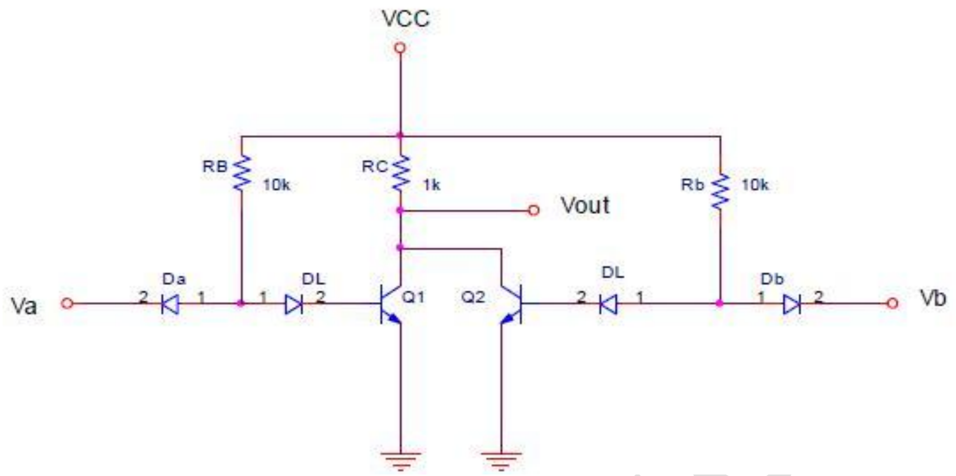

Figure 4. Two-input NOR Gate

If all inputs are less than VIL=VBE(FA) then all BJTs are cutoff. AS a result, the output voltage is

$$VOH=VCC$$

If any input is greater than or equal to VBE(FA), the corresponding BJT conduct and if any input reaches V_{IH}=VBE(SAT) the output drops to

$$V_{OL}=VCE(SAT)$$

❖ The OR gate

The DTL OR gate combines the DTL NOR gate with DTL inverter. **Figure 5** shows a two-input OR gate.

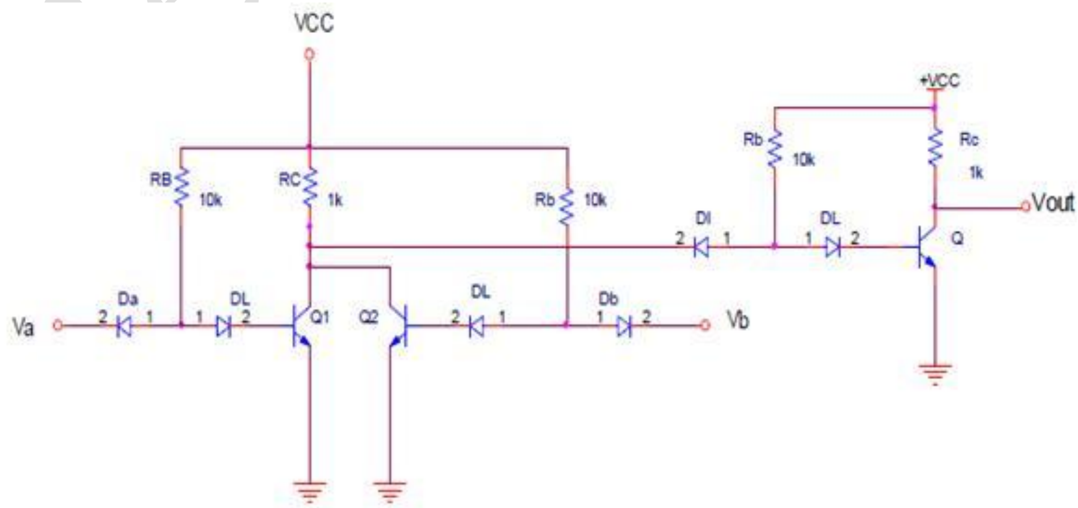

Figure 5. Two-input OR Gate

If all inputs are less than VIL=VBE(FA), the transistors are cutoff and the output is

VOL = VCE(SAT)

If any input is greater than or equal to V_{IL}=VBE(FA), the corresponding BJT conduct and if any input reaches VIH=VBE(SAT) the output

VOH = VCC

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