ROCHESTER INSTITUTE OF TECHNOLOGY
MICROELECTRONIC ENGINEERING

Introduction to Electronics

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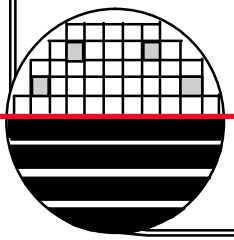
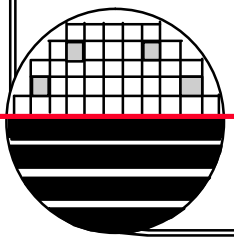


OUTLINE

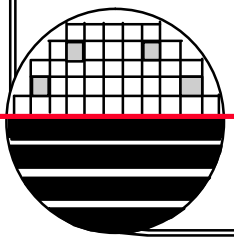
Introduction
Definition of Terms
Characterization of Electronic Devices
Electronic Device Classification
I-V Characteristics
Digital Logic
Laboratory Kit Parts
Laboratory Exercise
References
Review Questions



INTRODUCTION

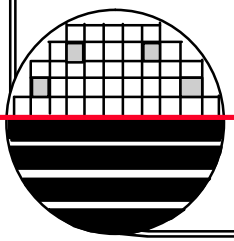
This is a laboratory guide that will introduce the reader to electronic components, ohms's Law, current and voltage measurements and characterization of electronic components.

In addition a brief introduction to digital logic realization is given through the building of simple logic gates and combining these gates to make more complex digital systems.



DEFINITION OF TERMS

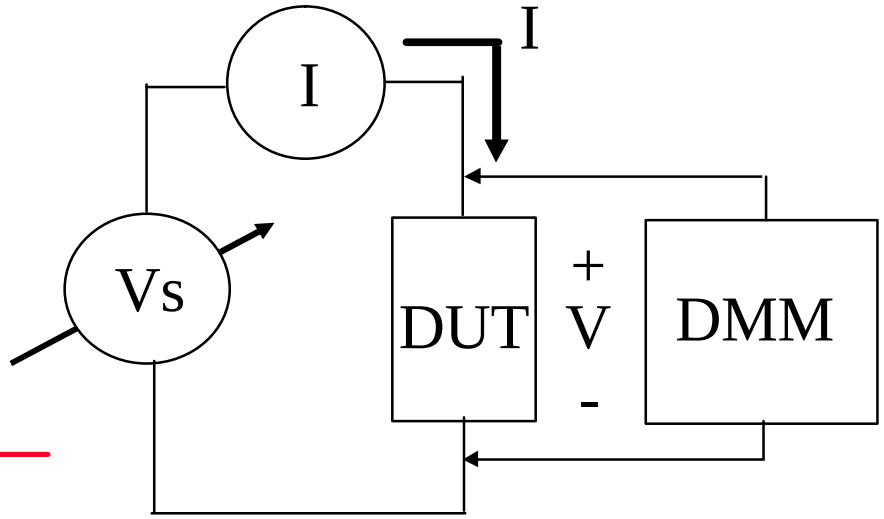
DUT - Device Under Test
Ohm's Law – Fundamental Relationship between current through and voltage across a resistor.
Charge – created by the presence or absence of electrons
Current – movement of charge
Voltage – potential to move charge
Resistor – opposition to the movement of charge
LED – Light Emitting Diode
Diode – device that allows current to flow in one direction only
BJT – Bipolar Junction Transistor



CHARACTERIZATION OF ELECTRONIC DEVICES

Electronic devices are classified by their current-voltage (I-V) characteristics. The I-V characteristics could be measured experimentally or derived theoretically. The experimental approach would involve applying several voltages and measuring the corresponding current. The current vs voltage is plotted and compared with known classifications. For example: a variable voltage supply Vs is used to apply different voltages to the Device Under Test (DUT) while a current meter (I) and Digital Multimeter (DMM) is used to measure I and V

Data is collected for I and V (shown on the next page)

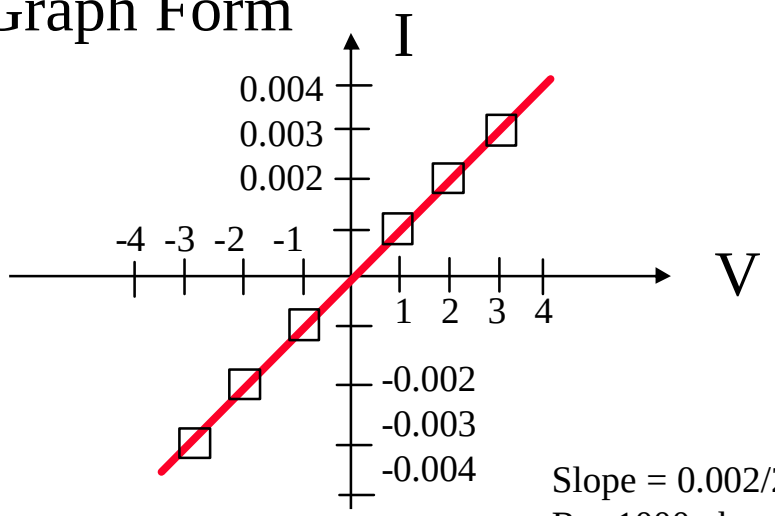


DATA

Data in Table Form

I (amps)	V (volts)
-0.003	-3
-0.002	-2
-0.001	-1
0	0
0.001	1
0.002	2
0.003	3

Data in Graph Form



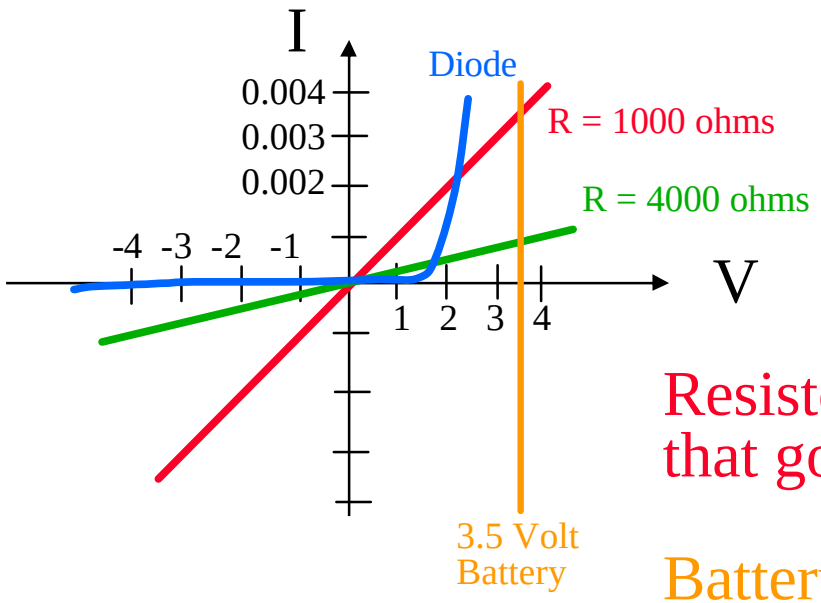
Slope = 0.002/2
R = 1000 ohms

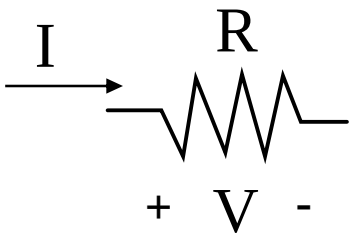
$Y = mX + \cancel{B}^{0}$

$I = \text{slope } V + 0$

$\boxed{I = (1/R)\,V}$ Ohm's Law

DEVICE CLASSIFICATIONS



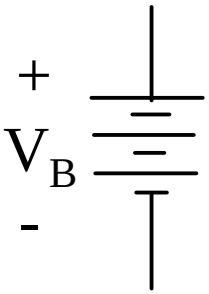


Resistor Symbol

Resistors have linear I-V characteristics that go through the origin.

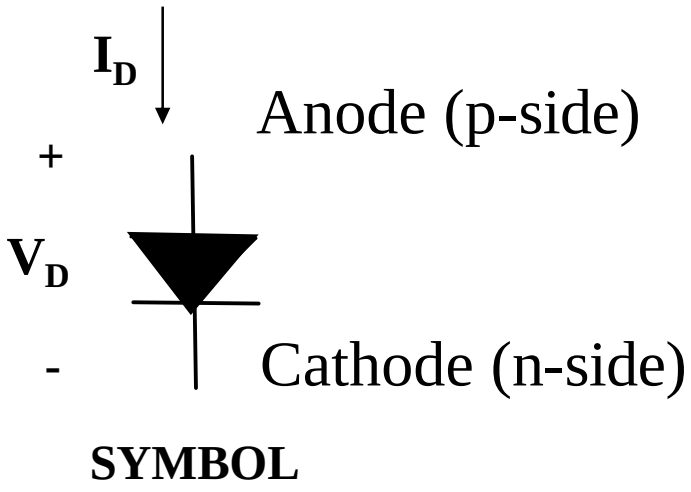
Battery has linear I-V characteristics with constant voltage at any current

Diode has exponentially increasing current in the first quadrant and ~ zero current in the third quadrant (until breakdown).

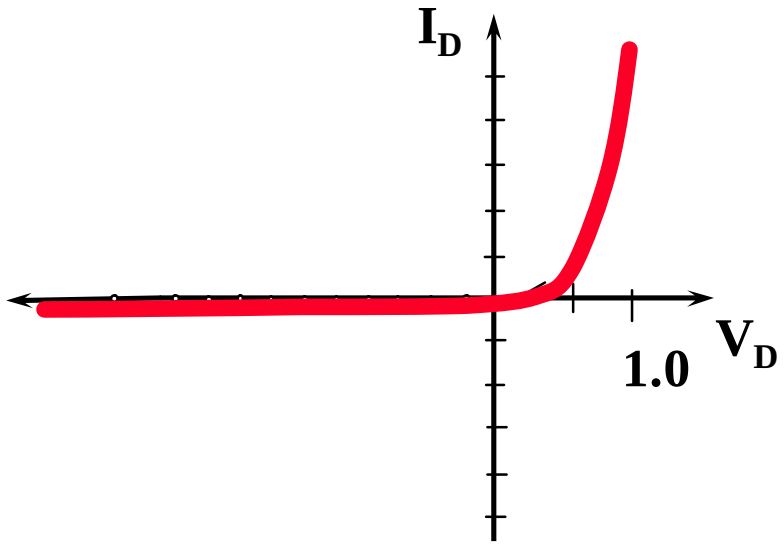


Battery Symbol

DIODES



SYMBOL



Diodes are like check valves. Current only flows in one direction (as shown by arrow in the symbol)

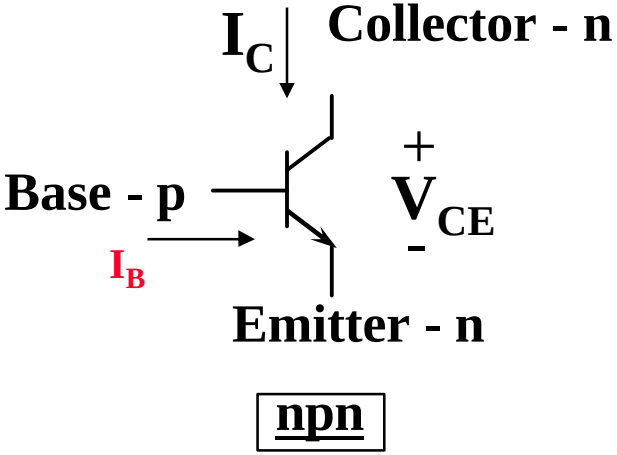
$$I_D = Io\,[EXP^{(-VD/Vth)} - 1]$$

Ideal Diode Equation

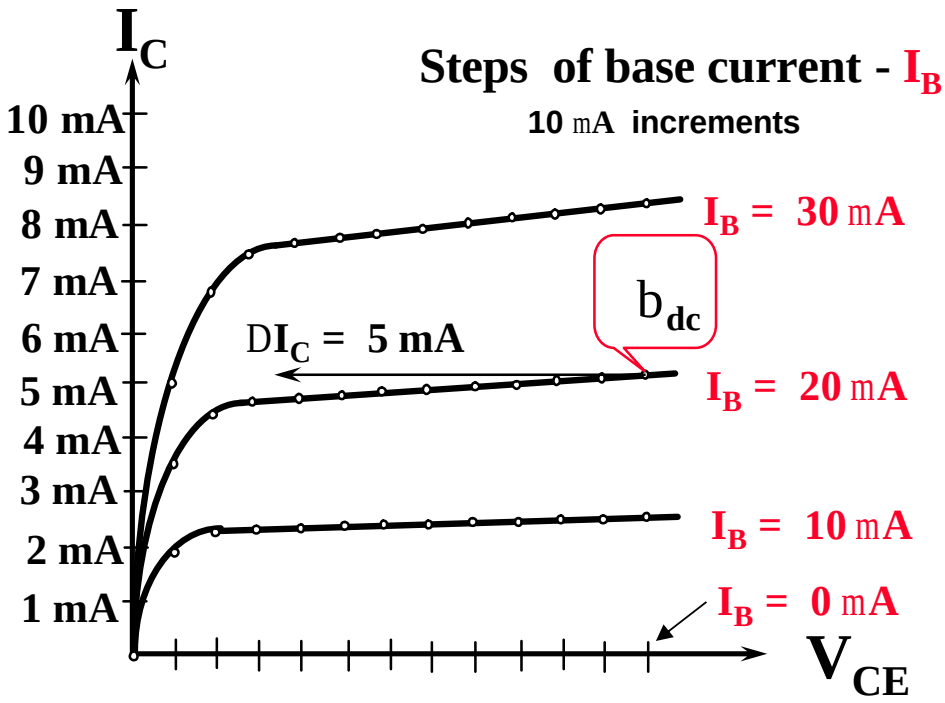
Io is a constant eg 1E-9 Amps
Vth is ~ 0.026 at room temperture

BIPOLAR JUNCTION TRANSISTOR

Schematic Symbol



npn



Current Gain (Beta)

$B_{dc} = I_C / I_B = 5\ mA / 20\ \mu A = 250$

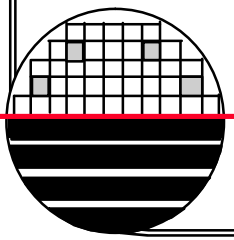
DIGITAL INTEGRATED CIRCUITS

BOOLEAN ALGEBRA IS BASED ON TWO DISCRETE LEVELS CALLED LOW OR HIGH (0 OR 1). (from George Boole)

BOOLEAN ALGEBRA USES FUNCTIONS SUCH AS "INVERT", "AND", "OR" TO EVALUATE INPUTS AND GENERATE "OUTPUTS".

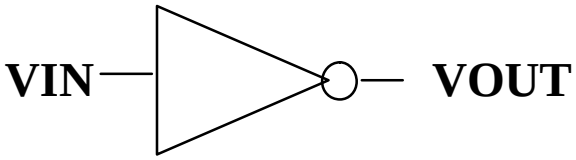
THE TERM "BINARY LOGIC" IS USED TO DESCRIBE DEVICES THAT FOLLOW THE RULES OF BOOLEAN ALGEBRA.

EACH SUB CIRCUIT OR "GATE" SHOULD HAVE ITS INPUTS AND OUTPUTS AT 0 OR 1 (Except Briefly During Switching)



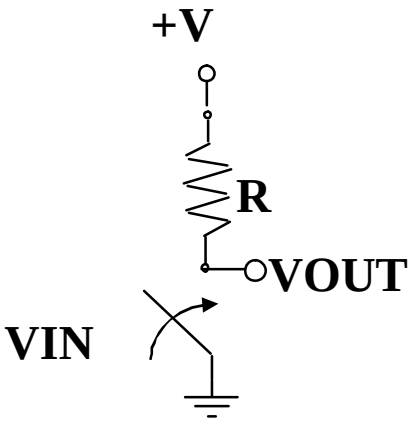
INVERTER

SYMBOL

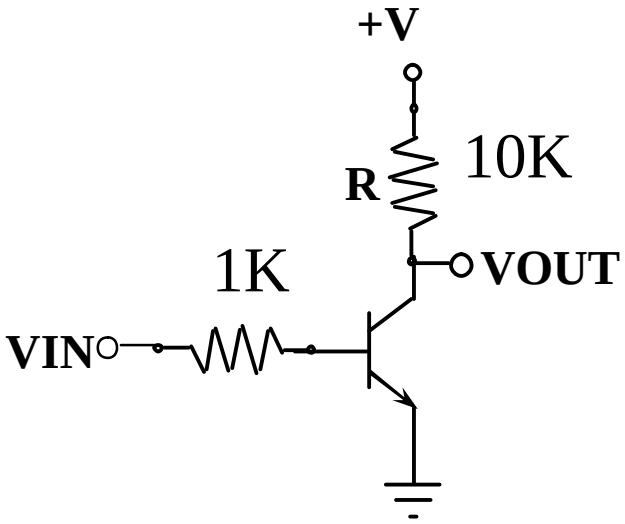


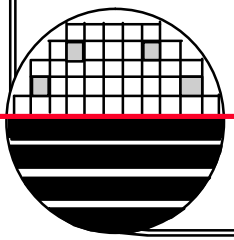
TRUTH TABLE

VIN	VOUT
0	1
1	0



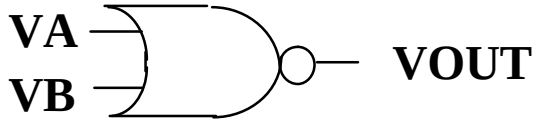
SWITCH





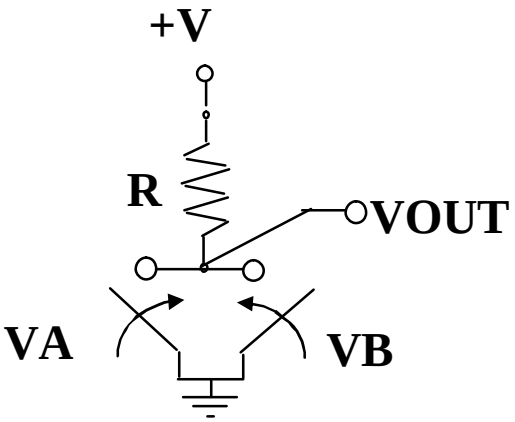
NOR GATE

SYMBOL

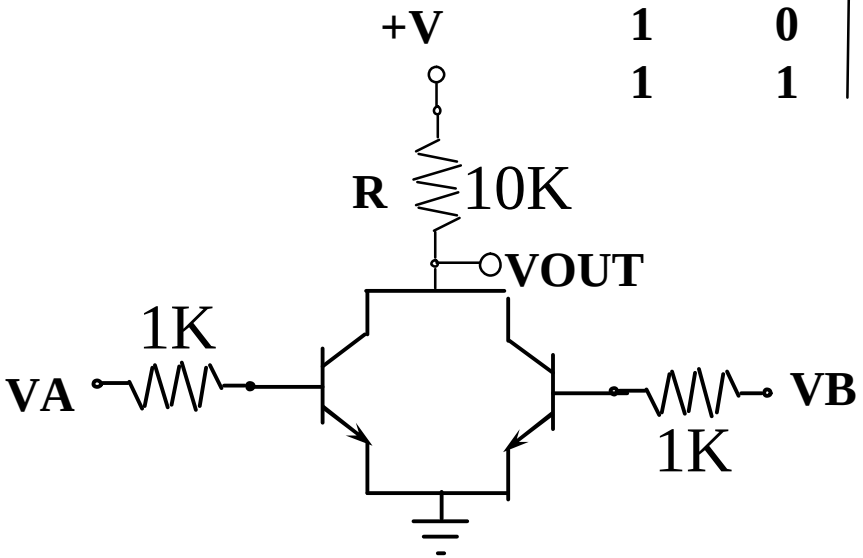


TRUTH TABLE

VA	VB	VOUT
0	0	1
0	1	0
1	0	0
1	1	0



SWITCH

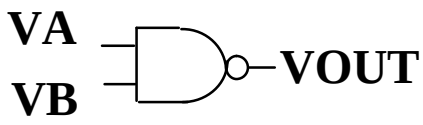


OTHER LOGIC GATES

SYMBOL

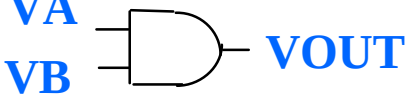
TRUTH TABLE

NAND



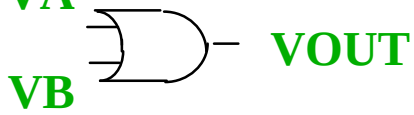
VA	VB	VOUT
0	0	1
0	1	1
1	0	1
1	1	0

AND

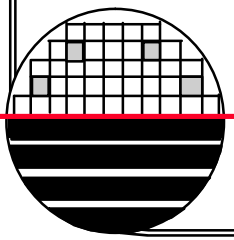


VA	VB	VOUT
0	0	0
0	1	0
1	0	0
1	1	1

OR

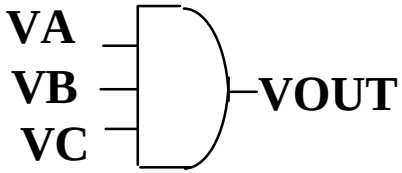


VA	VB	VOUT
0	0	0
0	1	1
1	0	1
1	1	1

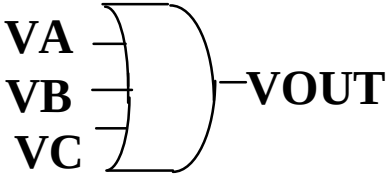


MORE LOGIC GATES

3 INPUT AND

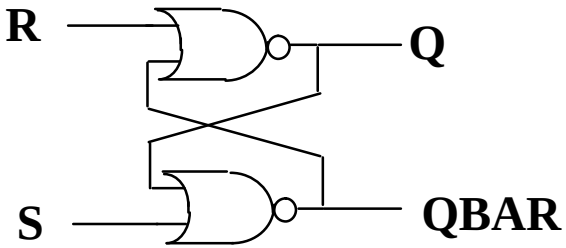


3 INPUT OR



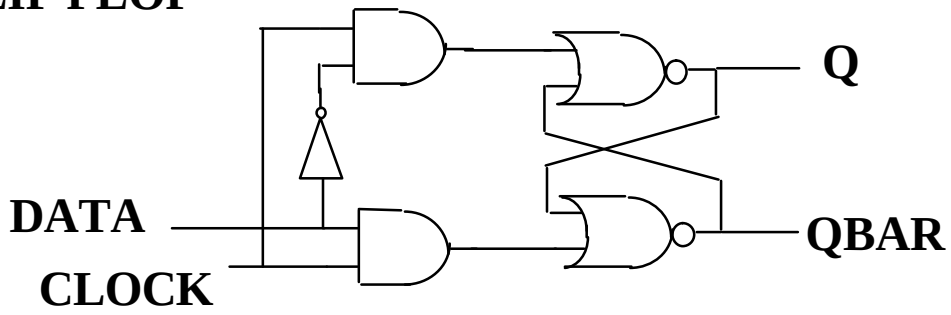
FILP-FLOPS (BASIC MEMORY STORAGE DEVICE)

RS FLIP FLOP



R	S	Q
0	0	Qn-1
0	1	1
1	0	0
1	1	INDETERMINATE

D FLIP FLOP



Q=DATA IF CLOCK IS HIGH
IF CLOCK IS LOW Q=PREVIOUS DATA VALUE

ADDITION IN BINARY

IN BASE 10

```
  7
 +2
 ___
  9
```

IN BINARY

```
11          CARRY
0111
0010
____
1001        SUM
```

0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

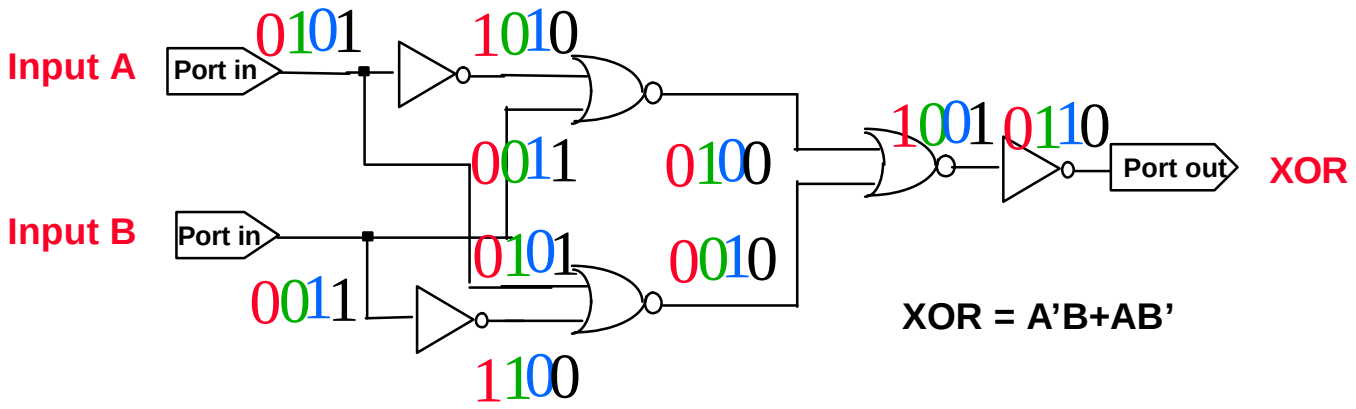
TRUTH TABLE FOR ADDITION RULES

A	B	CIN	SUM	COUT
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

HALF ADDER (EXCLUSIVE OR) XOR

B	A	NOR
0	0	1
0	1	0
1	0	0
1	1	0

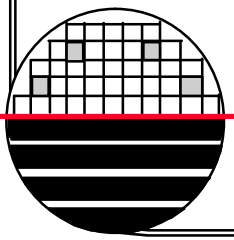
B	A	XOR
0	0	0
0	1	1
1	0	1
1	1	0



XOR = A'B+AB'

LIST OF LABORATORY MATERIALS

Hook – Up Wire (22 gauge, Solid, PVC colored insulation)
Assorted LED's (Qty 6)
Solderless Breadboard (2 ¼ " x 6 ½")
Digital Multimeter (AC and DC voltages up to 500V, current up to 200 mA, Resistance up to 2 M ohm)
Type 23A battery for Digital Multimeter
9 Volt Alkaline Battery
9 Volt Battery Snap Connectors (Heavy-Duty)
10 K ohm, 15 Turn Cermet Potentiometer (PCB-mount)
1K ohm ¼ watt Resistors (Qty 10)
10K ohm ¼ watt Resistors (Qty 6)
NPN BJT Switching Transistors (2N2222 or equivalent) (Qty 6)

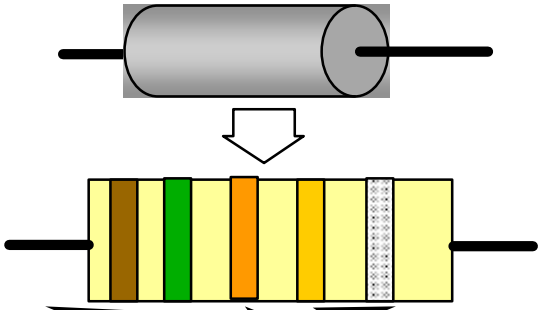


RESISTOR COLOR CODES

Example:

Brown 1
Green 5
Orange 1,000
Gold 5%

15x1,000 = 15kOhms, 5%



First Band 1st digit	
color	digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

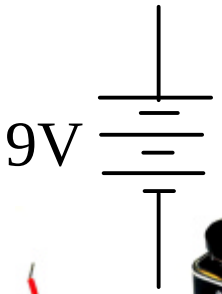
Second Band 2nd digit	
color	digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Third Band Multiplier	
color	Multiplier
Black	1
Brown	10
Red	100
Orange	1,000
Yellow	10,000
Green	100,000
Blue	1,000,000
Silver	0.01
Gold	0.1

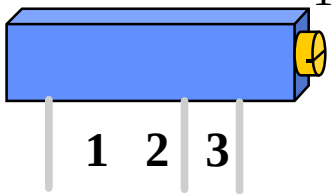
Fourth Band Resistance Tolerance	
color	Tolerance
Silver	+/- 10 %
Gold	+/- 5 %
No Band	+/- 20 %

Fifth Band
Reliability Level
(Used for Military Specifications)

COMPONENT DETAILS

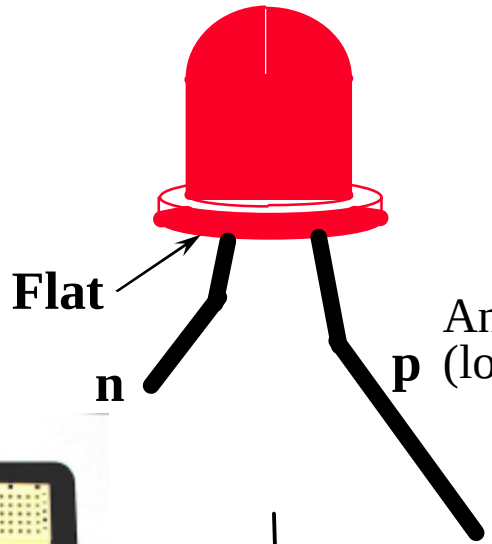


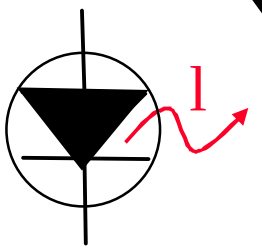
9V Battery



10K ohm
variable resistor
or potentiometer

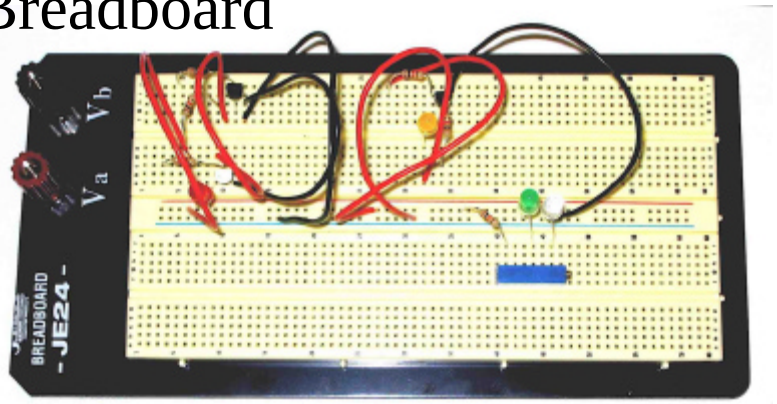
Light Emitting Diode -LED





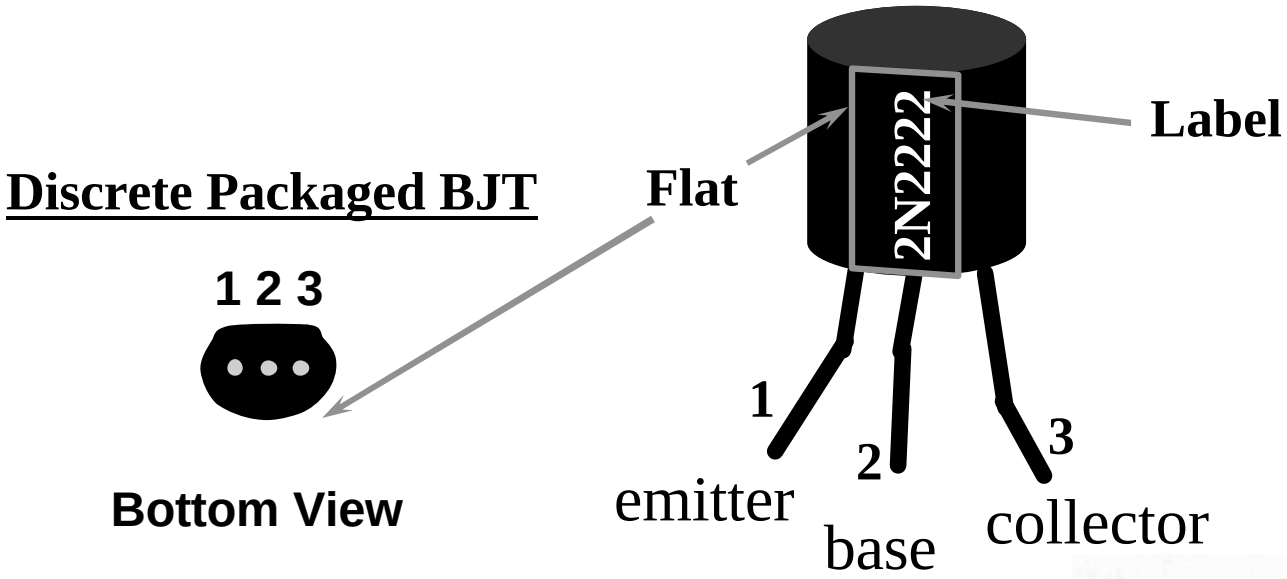
LED SYMBOL

Breadboard



Multimeter

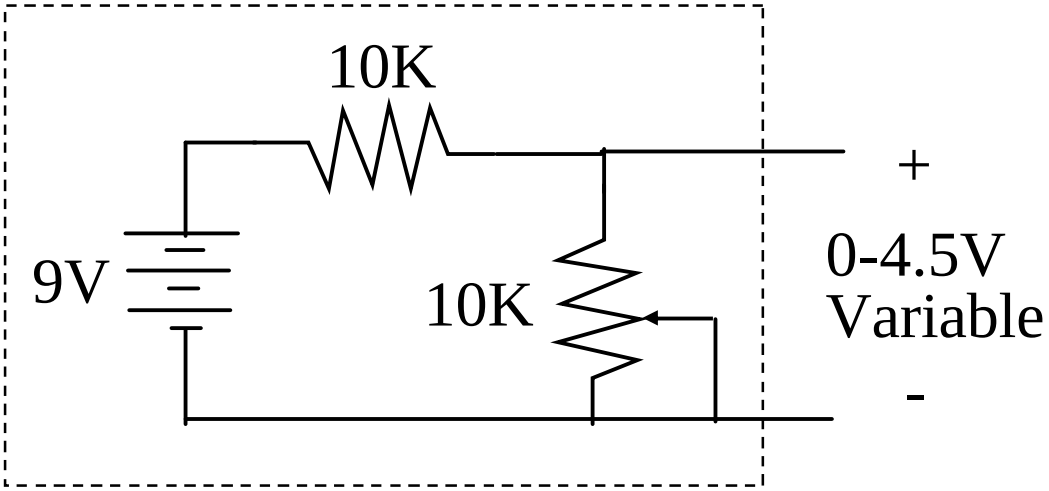
BIPOLAR JUNCTION TRANSISTORS



2N2222
NPN
Gain ~200
Maximum VCE = 30V
Maximum IC = 800mA
Maximum Power = 1.8watts

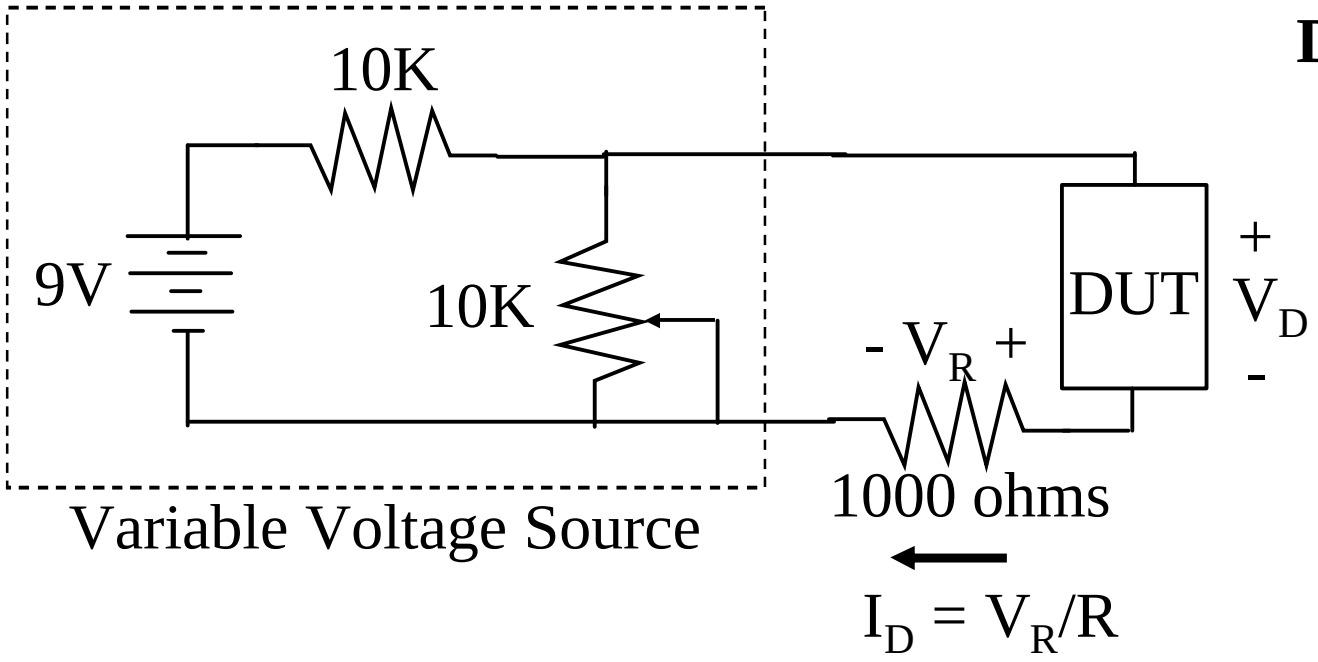
VARIABLE VOLTAGE SOURCE

Variable voltage sources (power supply) are commercially available in a wide range of maximum voltage and current values. For this laboratory we can approximate a variable voltage supply using the circuit below.



Flip the battery to get negative voltages

MEASURING CURRENT AND VOLTAGE FOR DUT



Device Under Test

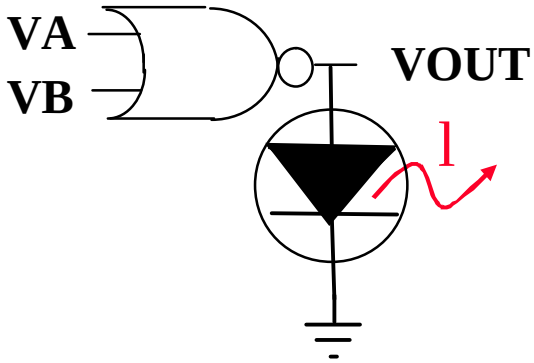
- **1K Resistor**
- **10K Resistor**
- **Red LED**
- **Yellow LED**
- **Green LED**
- **more**

For negative voltages, flip battery upside down
Measure and record V_D and V_R
Calculate I_D
Plot I_D versus V_D

BUILD AND TEST SIMPLE LOGIC GATES

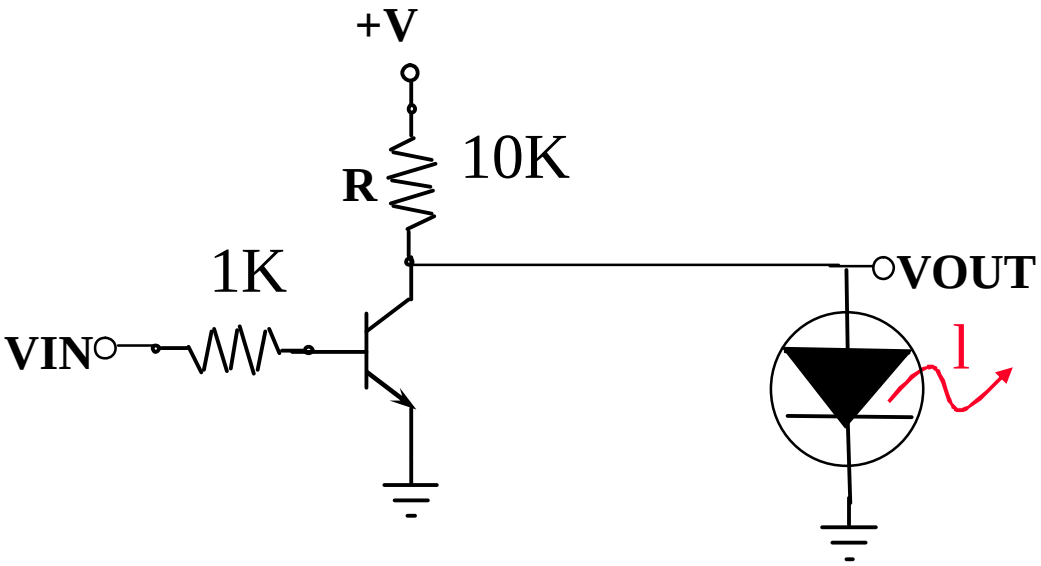
Build an inverter using resistors and a BJT
Build a two input nor gate using resistors and a BJT
Build a half adder (XOR)

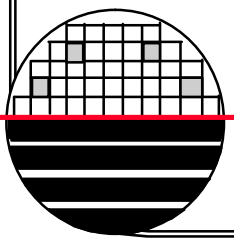
LED's can be used to test gate outputs



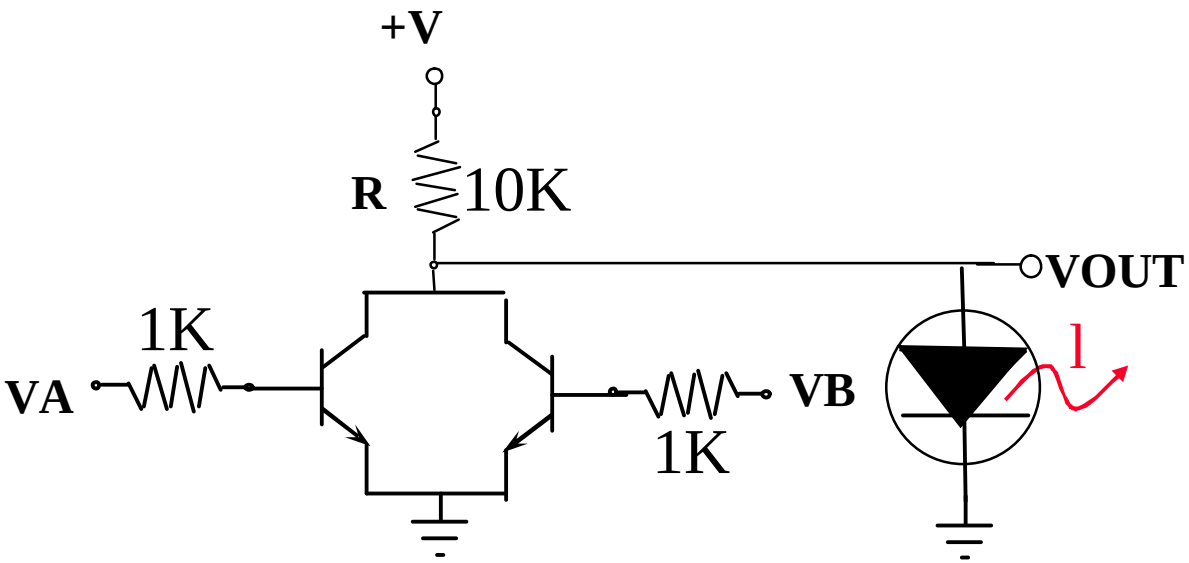
Output high LED on
low LED off

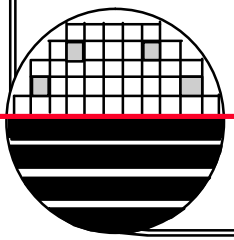
RESISTOR TRANSISTOR REALIZATION OF INVERTER



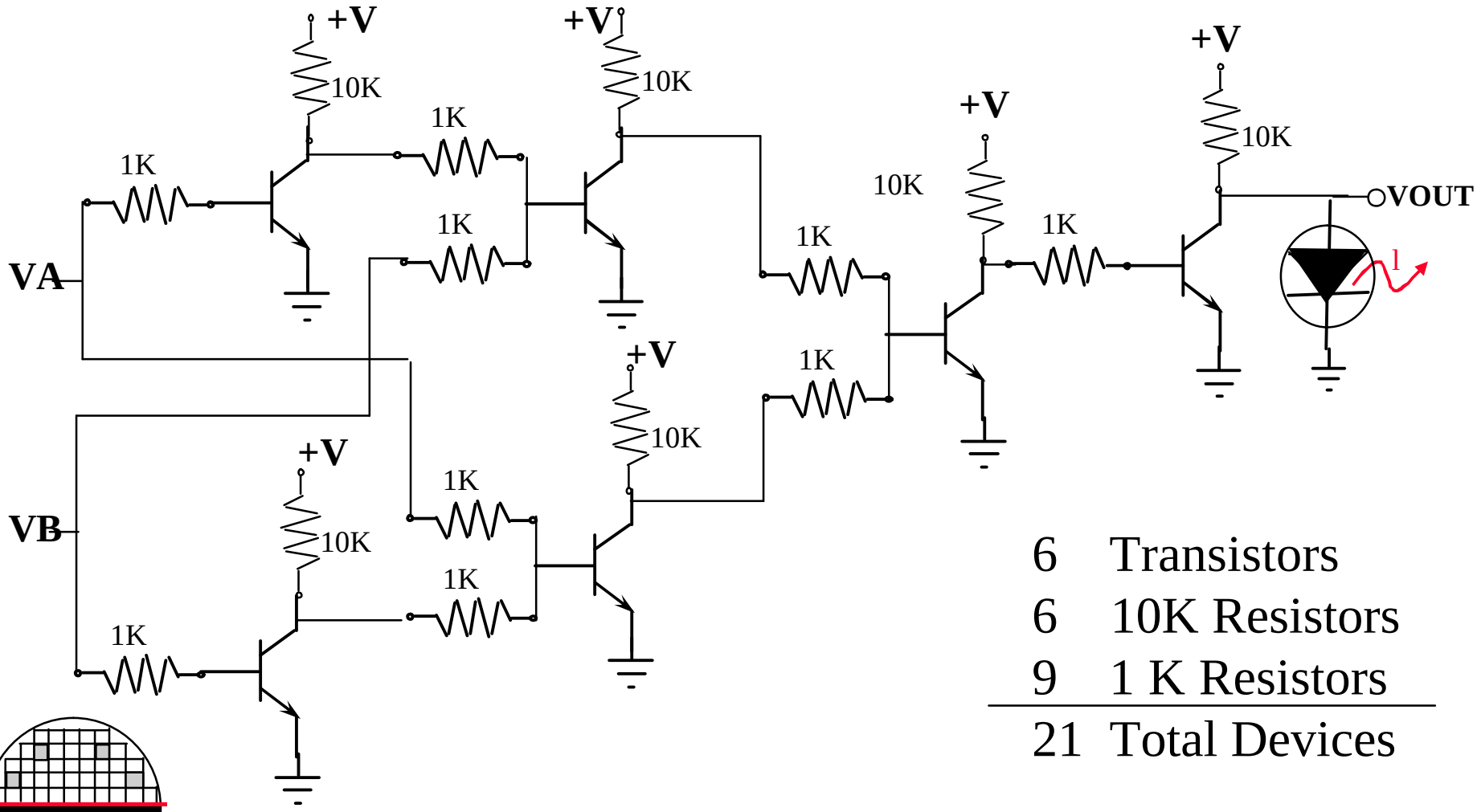


RESISTOR TRANSISTOR REALIZATION OF NOR GATE



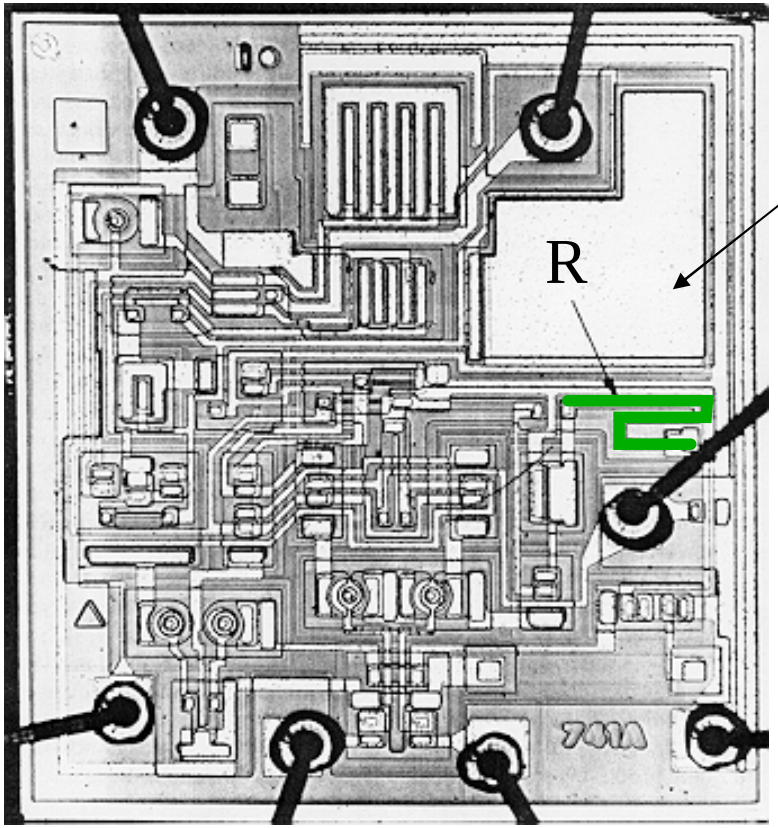


RESISTOR TRANSISTOR REALIZATION OF XOR

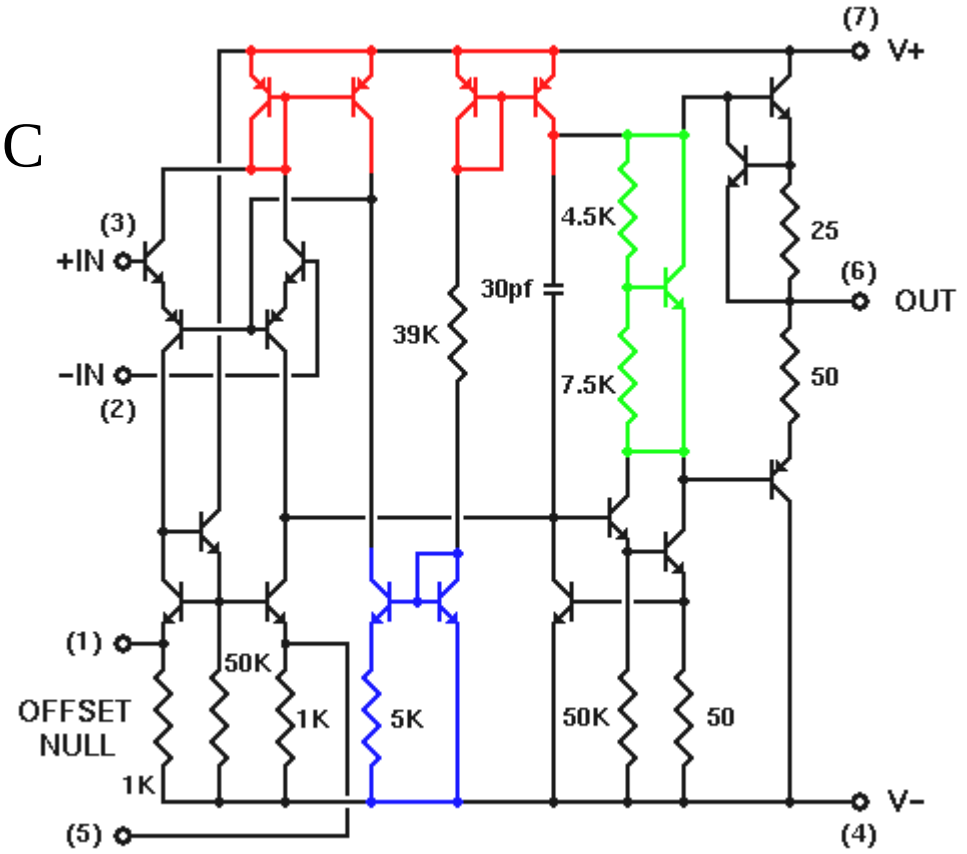


6 Transistors
6 10K Resistors
9 1 K Resistors
21 Total Devices

INTEGRATED CIRCUITS

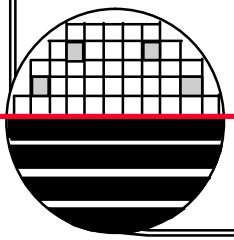


741 OpAmp



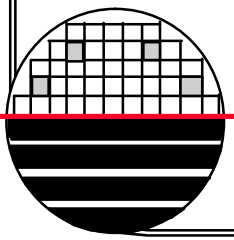
REFERENCES

1. Dr. Fuller's webpage http://www.rit.edu/~lffeee
2. more



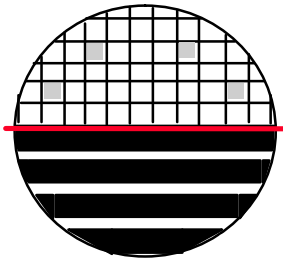
REVIEW QUESTIONS

1. A 220 ohm resistor has 1.5 volts across it. The current through the resistor is
   a)1.5 A b) 6.8 mA c) 147 A d)0.068 A
2. A diode has minus 1.5 volts across it. The current though the diode is
   a) infinite b) zero c) $1x10^{-9}$ A d) $-1x10^{-9}$ A
3. The I-V characteristics of a constant current source is a linear horizontal line.
   a) True b) False
4. The I-V characteristics of a BJT is a linear line in the first quadrant only
   a) True b) False
5. In resistor-transistor realization of logic gates the purpose of the BJT is to
   a) act as a voltage controlled switch b) limit the current drawn from the power supply c) provide voltage gain d) provide current gain e) all of the above.



Introduction to Electronics Laboratory

November 2, 2006



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Parts List:
Hook – Up Wire (22 gauge, Solid, PVC colored insulation)
Assorted LED's (Qty 6)
Solderless Breadboard (2 ¼ " x 6 ½")
Digital Multimeter (AC and DC voltages up to 500V,
current up to 200 mA, Resistance up to 2 M ohm)
Type 23A battery for Digital Multimeter
9 Volt Alkaline Battery
9 Volt Battery Snap Connectors (Heavy-Duty)
10 K ohm, 15 Turn Cermet Potentiometer (PCB-mount)
1K ohm ¼ watt Resistors (Qty 10)
10K ohm ¼ watt Resistors (Qty 6)
NPN BJT Switching Transistors (2N2222 or equivalent) (Qty 6)
Wire Cutters/Strippers
Small Screw Driver