IALP 2011 – Digital Electronics

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MIEET 1º ano

The next step of electronics is non-linear electronics, a basic ingredient of digital electronics.

Non-linear electronics

The circuits of the lecture on analog electronics were all linear. Increasing the voltage by a factor *n* will increase the current by a factor *n*. The ratio of the two, voltage and current – the resistance – does not change. They follow Ohm's Law with a constant resistance *R*. Not all components and circuits are like that. In fact, with non-linearity it gets interesting from an electronics point of view. Then we can build amplifiers, logic circuits, computers, etc. Let's start with the diode.

The diode

The simplest and most familiar non-linear component is the diode. We can look at the diode in several ways (approximations that we will use in our electronics lectures)

- A diode lets through current only in one direction. Or, in other words, multiplying the bias with a factor $n = -1$ will cause the current to be multiplied by a factor $m = 0$. Hence non-linear. Or,

$$V < 0: R = \infty$$
$$V > 0: R = 0$$

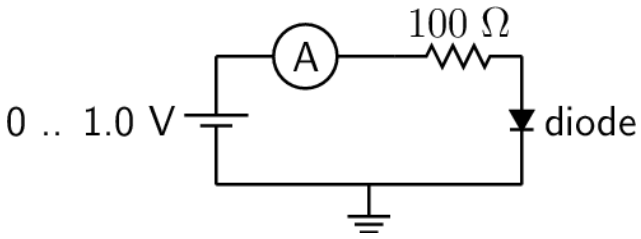
- A diode starts conducting at 0.7 V.

$$V < 0.7\ \text{V}: R = \infty$$
$$V > 0.7\ \text{V}: R = 0$$

- A diode conducts exponentially (Ebers-Moll):

$$R(V) = R_0\,[e^{-V/Vo} - 1]$$

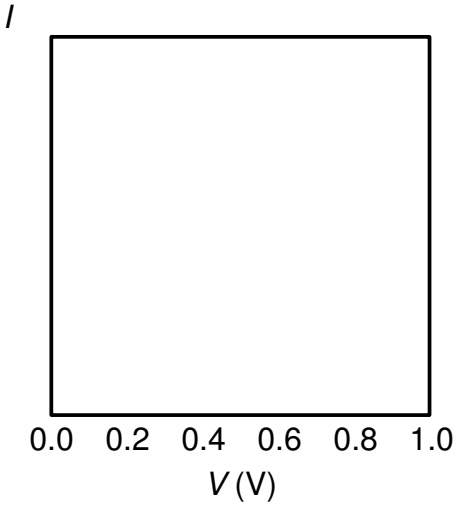
Exercise 1



1) Measure the relation between voltage and current of the circuit above. Write the results in the table and figure below
2) Repeat the same with the diode replaced by a 100 Ω resistor

V (V)	(1) diode *I* (mA)	(2) R *I* (mA)
0.0		
0.1		
0.2		
0.3		
0.4		
0.5		
0.6		
0.7		
0.8		
0.9		
1.0		

Draw the results here below



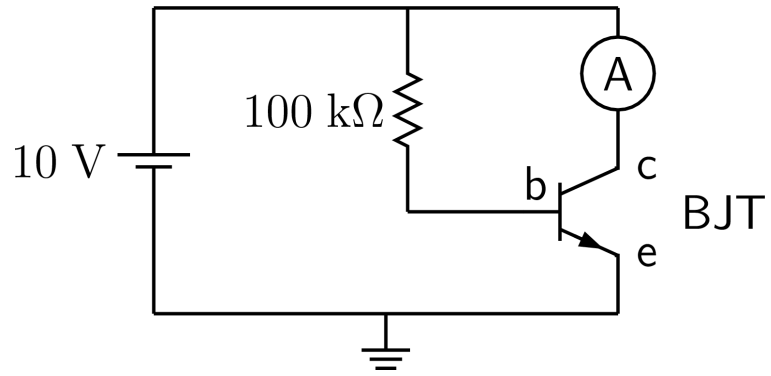
The transistor

A transistor is an abbreviation for trans-resistor. It is a resistor whose resistance value from one side to the other is controlled by an input signal 'on the side'. The two major types of transistors are bipolar-junction transistors (BJTs) and field-effect transistors (FETs). A BJT is effectively a current multiplier, or a resistance divider.

Exercise 2

3) Construct the circuit below bases on an npn BJT (for example BC549). Measure the current with the multimeter. Given the fact that the transistor has a voltage of 10 V applied, what is the effective resistance of the transistor?

■ $R_{BJT} = V/I$ = (10 V) / I =



PIN	DESCRIPTION
1	emitter
2	base
3	collector

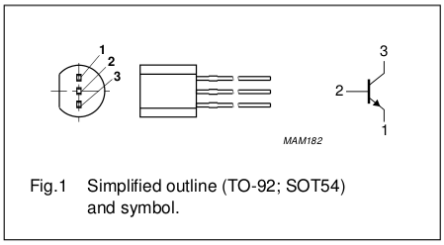


Fig.1 Simplified outline (TO-92; SOT54) and symbol.

← *seen from bottom*

4) What is the correlation of this resistance and the measured resistance of the transistor?

■ $\beta \approx R / R_{BJT}$ =

5) Measure the 'β' of the transistor with the multimeter (It is often called h_{FE}. Not all multimeters can measure this).

■ β =

(Don't worry if this mismatches)

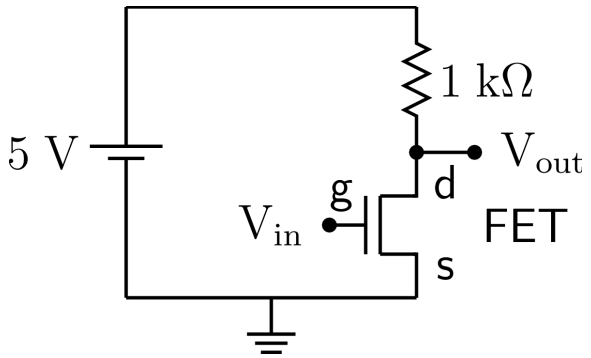
Digital electronics

When the non-linear electronics become highly non-linear such that they basically have only two states we speak of binary electronics, or digital electronics when in general we have a limited number of states. Where analog electronics has revolutionized the world, the digital electronics era has sped up the revolution.

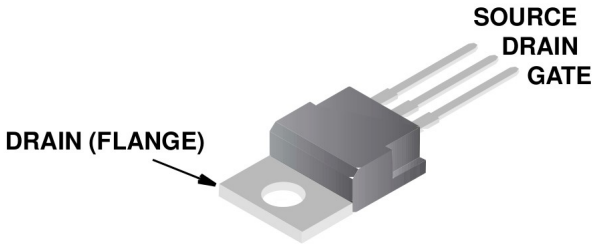
Why digital electronics is winning over analog electronics? The biggest advantage of digital formats is that signals can be copied, transmitted, retransmitted, processed, resent, etc., without signal degradation (information loss). You can make copies of CDs, copies of copies, copies of copies of copies, etc. The contents are still the same. With analog signals this is not the case. With every step the signal loses some information.

The digital inverter

The simplest digital circuit is the inverter. If we define a signal below 1.5 V as a logical '0' and a signal above 3.5 V as a logical '1' we can use the following circuit as an inverter:



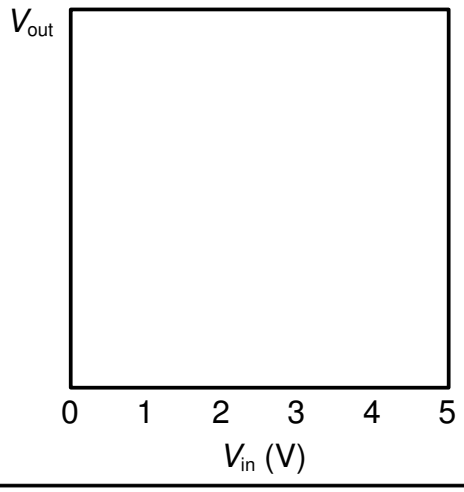
V_{in} and V_{out} are relative to ground (connections similar to the 5 V power supply). Use a power FET (for example the IRF530) for this purpose. Power FET transistors normally have the connections as shown below (taken from IRF530 datasheet):



The output state is the inverse of the input state. The FET transistor works as switch. When we press the 'button' (Logical '1'; apply 5 volts at the entrance V_{in}), the FET becomes a short circuit ($R = 0$) and a current flows through the resistance. This lowers the output voltage that goes to a logical '0'.

Exercise 3

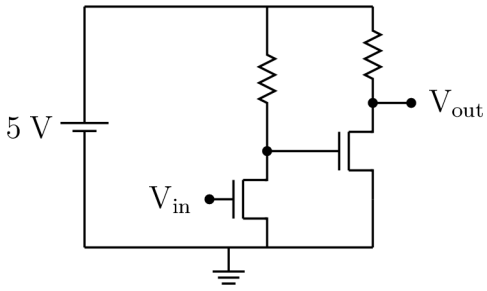
6) Measure the 'transfer function' of the circuit above. V_{out} as a function of V_{in}. From 0 V to 5 V.



We can put this in a logic table or 'truth table'. A logic '0' becomes a logic '1' and vice versa:

in	out
0	1
1	0

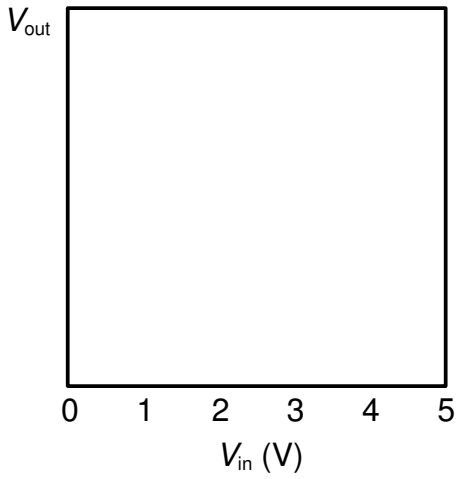
With this building block we can build logic circuits. Let's take a look at some examples:
If the above circuit is an inverter, than the inverter-inverter should be a copier. See the circuit below



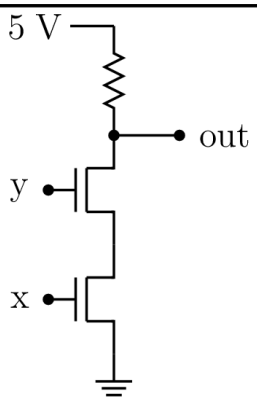
Exercise 4

7) What is the truth table and the transfer function of the above circuit?

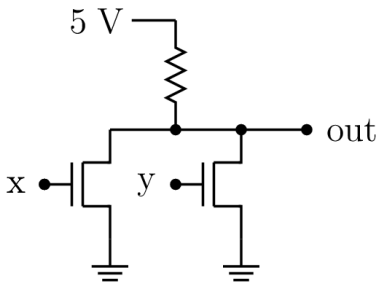
in	out
0	
1	



Exercise 5



NAND



NOR

8) Assuming the signals x and y work as switches, determine the truth tables of the digital circuits above

x	y	NAND	NOR
0	0		
0	1		
1	0		
1	1		