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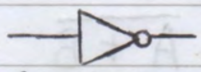
Truth Tables

- A truth table shows the logic state of the output for all possible inputs
- If a system has n inputs, they can be set in 2^n ways e.g. a 4-input gate can be set in $2^4 = 16$ ways
- The input state column is filled by counting from 0 to $(2^n - 1)$ in binary

NOT Gate



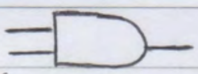
(symbol)

Input	Output
A	Q
0	1
1	0

$Q = \bar{A}$

(boolean equation)

AND Gate



(symbol)

Inputs		Output
B	A	Q
0	0	0
0	1	0
1	0	0
1	1	1

$Q = A.B$

(boolean equation)

NAND (NOT-AND) Gate

(symbol)

Inputs		Output
B	A	Q
0	0	1
0	1	1
1	0	1
1	1	0

$Q = \overline{A.B}$

(boolean equation)

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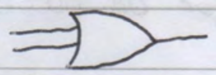
OR Gate



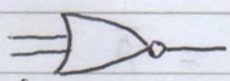
(symbol)

Inputs		Output
B	A	Q
0	0	0
0	1	1
1	0	1
1	1	1

$Q = A + B$

(boolean equation)

NOR (NOT-OR) Gate



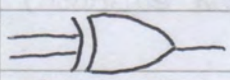
(symbol)

Inputs		Output
B	A	Q
0	0	1
0	1	0
1	0	0
1	1	0

$Q = \overline{A + B}$

(boolean equation)

EXOR Gate



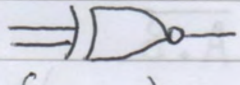
(symbol)

Inputs		Output
B	A	Q
0	0	0
0	1	1
1	0	1
1	1	0

$Q = A \oplus B$

(boolean equation)

EXNOR (NOT-EXOR) Gate



(symbol)

Inputs		Output
B	A	Q
0	0	1
0	1	0
1	0	0
1	1	1

$Q = \overline{A \oplus B}$

(boolean equation)

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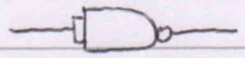
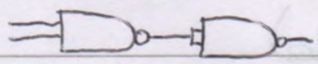
NAND Gates

- Other types of gates can be made from NAND gates

NOT Gate

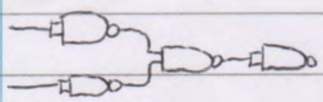


AND Gate

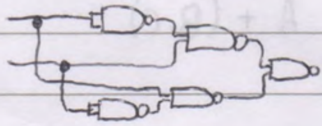


OR Gate

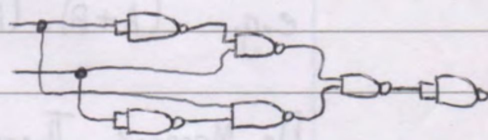
NOR Gate



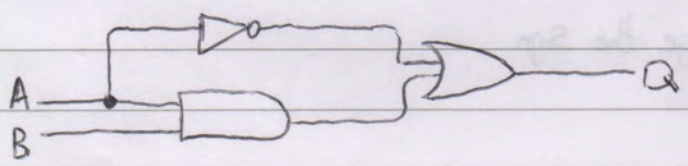
EXOR Gate



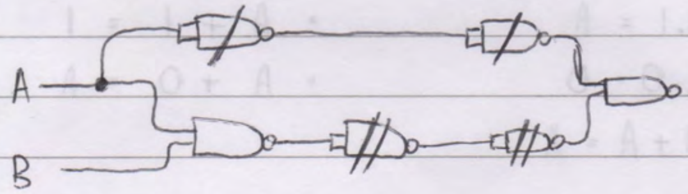
EXNOR Gate



Reducing a Circuit with NAND Gates



- Identify gates
- Replace with NAND equivalent
- Cancel double inversions



Why Use NAND Gate Circuits

- No wasted gates
- Only one type of IC needed
- NAND Gates are cheaper
- Less board space used

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Rules of Boolean Algebra

Commutative Rule

- The order of variables does not matter

e.g. $A.B = B.A$ and $A.B + C.D = D.C + A.B$

Brackets (Distributive Rules)

- If all terms in an equation contain the same variable, the variable can be taken out brackets

e.g. $A.B + A.C = A.(B+C)$

e.g. $(A+B).(A+C) = A + (B.C)$

De Morgan's Theorem

- Can be separated into two theorem parts
- a) Break a bar and change the sign

e.g. $\overline{A+B} = \bar{A}.\bar{B}$

- b) Make a bar and change the sign

e.g. $\bar{A} + \bar{B} = \overline{A.B}$

Single Variables

- $A.\bar{A} = 0$
- $A + \bar{A} = 1$
- $A.A = A$
- $A.1 = A$
- $A.0 = 0$
- $A + A = A$
- $A + 1 = 1$
- $A + 0 = A$

Example

$Q = \overline{(A+C)} + \bar{A}.(\bar{C} + B) + \overline{(A + \bar{B}.C)}$

$= \bar{A}.\bar{C} + \bar{A}.\bar{C} + \bar{A}.B + \bar{A}.\bar{\bar{B}}.\bar{\bar{C}}$

$= \bar{A}.C + \bar{A}.B + \bar{A}.(B + \bar{C})$

$= \bar{A}.C + \bar{A}.B + \bar{A}.B + \bar{A}.C$

$= \bar{A}.B + \bar{A}.C$

$= \bar{A}.(B+C)$

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Karnaugh Maps

- Karnaugh maps are a method of simplifying circuits

C \ B.A	00	01	11	10
0				
1				

3-input Karnaugh map

D.C \ B.A	00	01	11	10
00				
01				
11				
10				

4-input Karnaugh map

- When drawing a Karnaugh map the numbering only changes one digit at a time e.g. 00, 01, 11, 10
- The letters are also reverse-alphabetical e.g. B.A and D.C

Filling In A Karnaugh Map

e.g. $Q = \bar{A}.B.\bar{C} + A.B.\bar{C} + A.\bar{B} + \bar{B}.\bar{C}$

- Fill the Karnaugh map with each term e.g. $\bar{A}.B.\bar{C}$, $A.B.\bar{C}$, $A.\bar{B}$, $\bar{B}.\bar{C}$

$\bar{B}.\bar{C}$

C \ B.A	00	01	11	10
0	1	1	1	1
1		1		

$\bar{A}.B.\bar{C}$

$A.\bar{B}$ $A.B.\bar{C}$

- Regroup terms starting with eight covered squares, then four, then two, then one

$A.\bar{B}$

C \ B.A	00	01	11	10
0	1	1	1	1
1	0	1	0	0

$\bar{C}$

- Rewrite the equation with the new terms e.g. $Q = A.\bar{B} + \bar{C}$

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Karnaugh Maps - Things To Remember

- There can be groups of one

D.C \ B.A	00	01	11	10
00	1	0	0	0
01	0	0	1	1
11	0	0	1	1
10	0	0	0	0

$Q = B.C + \bar{A}.\bar{B}.\bar{C}.\bar{D}$

- Groups can overlap

D.C \ B.A	00	01	11	10
00	1	1	1	1
01	0	1	0	0
11	0	1	0	0
10	0	1	0	0

$Q = A.\bar{B} + \bar{C}.\bar{D}$

- There cannot be diagonal groups

D.C \ B.A	00	01	11	10
00	0	0	0	0
01	0	1	0	0
11	0	0	1	0
10	0	0	0	0

$Q = A.\bar{B}.C.\bar{D} + A.B.C.D$

- Groups can go round edges

D.C \ B.A	00	01	11	10
00	0	1	1	0
01	0	0	0	0
11	1	0	0	1
10	1	0	0	1

$Q = \bar{A}.D + A.\bar{C}.\bar{D}$

- There is also the corner group

D.C \ B.A	00	01	11	10
00	1			1
01				
11				
10	1			1

$Q = \bar{A}.\bar{C}$

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Multiplexers

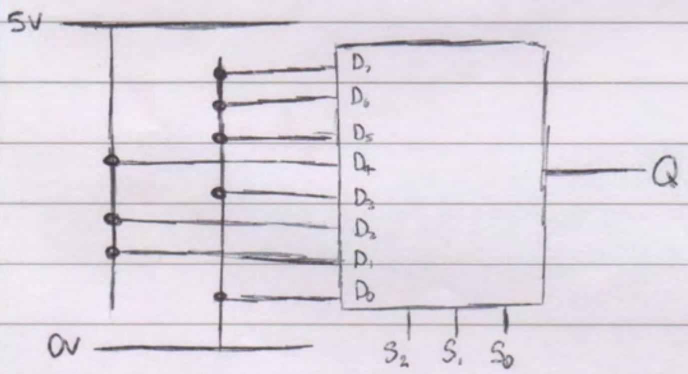
- A multiplexer is a device with multiple inputs and one output
- An x-to-1 multiplexer has x inputs
- 2-to-1, 4-to-1 and 8-to-1 are commonly used multiplexers

Data Transmission

- Multiplexers can be used with demultiplexers for data transmission
- Demultiplexers are the opposite of multiplexers
- The multiplexer accepts data in parallel form and transmits it in serial form
- The rate of transmission is called the baud rate

Logic Function

- Multiplexers can be reprogrammed to perform any logic function



S_2	S_1	S_0	Input	Output Q
0	0	0	D_0	0
0	0	1	D_1	1
0	1	0	D_2	1
0	1	1	D_3	0
1	0	0	D_4	1
1	0	1	D_5	0
1	1	0	D_6	0
1	1	1	D_7	0

- The multiplexer forms the truth table, above, of an EXOR function

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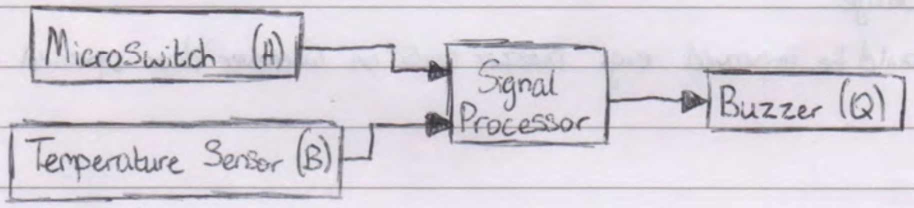
Systems and Devices

- There are five key stages to developing a system in electronics
- A system is a number of units linked together to form a useful circuit
- A complete system can accept inputs, carry out processes and produce outputs
- The example used is a system that provides an output when the door is open below a certain temperature

1) Selecting Transducers

- Transducers convert external signals into electrical signals or vice versa
- Input transducers could be a microswitch or temperature sensor
- Output transducer could be a buzzer



A simple block diagram for the System

2) Design Processing Unit

- Each transducer must have logic 0 and 1 under certain conditions

Temperature Sensor - logic 0 when cold
logic 1 when hot

Microswitch - logic 0 when door open
- logic 1 when door closed

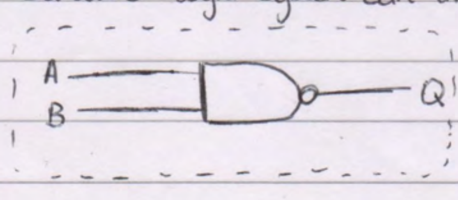
- The truth table and boolean expression can then be completed

B	A	Q
0	0	1
0	1	0
1	0	0
1	1	0

Buzzer on when door open ($A=0$) and temperature cold ($B=0$)

$Q = \bar{A} . \bar{B}$

- A suitable logic system can then be designed



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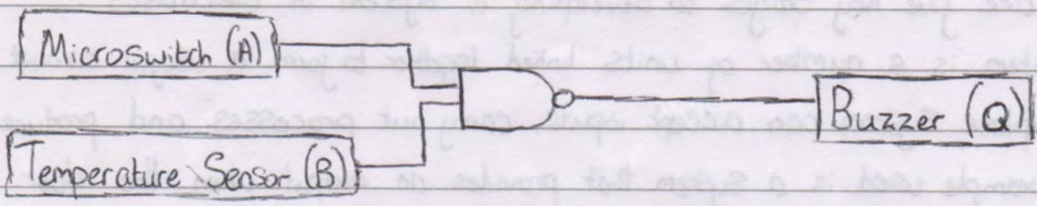
3) Drawing/Building System

- The logic processing system can now be combined with the transducers



4) Testing System

- The design may not completely solve the problem
- If the problem is not solved, maintenance or modification is needed

5) Modify System

- The optional stage
- The system could be improved e.g. buzzer goes on whenever door opened on cold day

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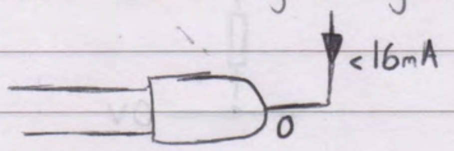
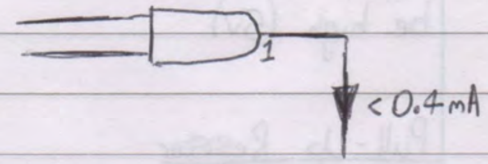
Systems and Devices

Sinking and Sourcing

- Standard TTL gates can Source (give out) and sink (take in) currents up to a certain value before they stop working

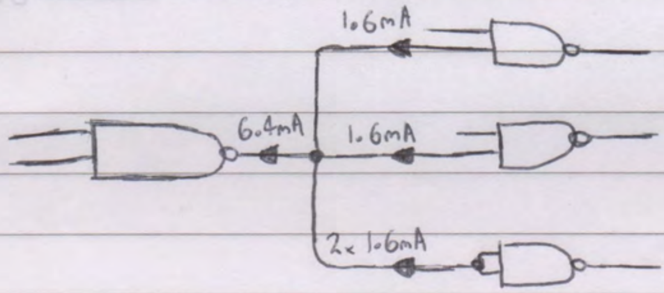




- Outputs can sink up to 16mA
- The current must be at least 1.6mA

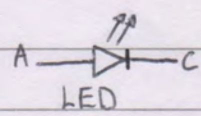
- Outputs can source up to 0.4mA
- The current must be at least 0.04mA

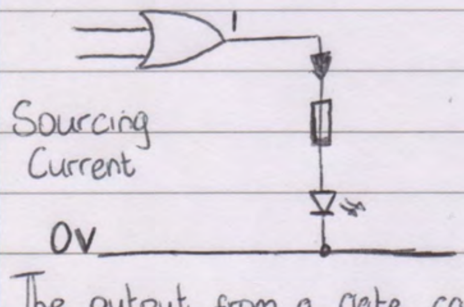
- Fan-out is the maximum number of inputs an output can feed
- The standard TTL fan-out is 10.

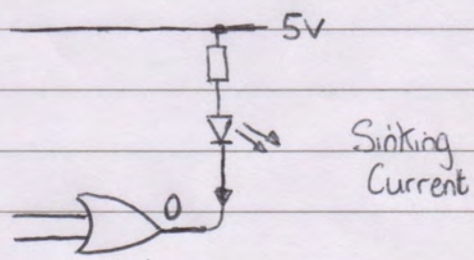


Light Emitting Diodes (LEDs)

- Current can only flow one direction through an LED
- The anode is always connected to the higher voltage







- The output from a gate can be used to light an LED
- The gate can Source current from a high output
- The gate can Sink current from a low output

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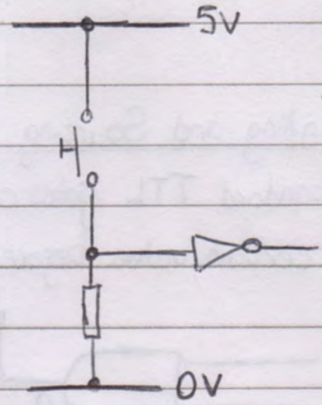
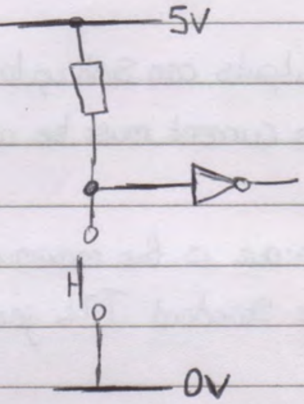
Pull-Down Resistor

- It is easier for current to flow through the switch than the resistor
- Therefore if the switch is not pressed the input will be low (0V)
- If the switch is pressed the input will be high (5V)



Pull-Up Resistor

- If the switch is not pressed the input will be high (5V)
- If the switch is pressed the input will be low (0V)
- The resistor's value should be greater than 1 KΩ



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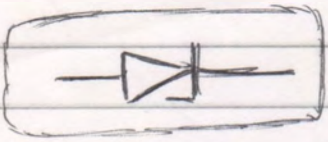
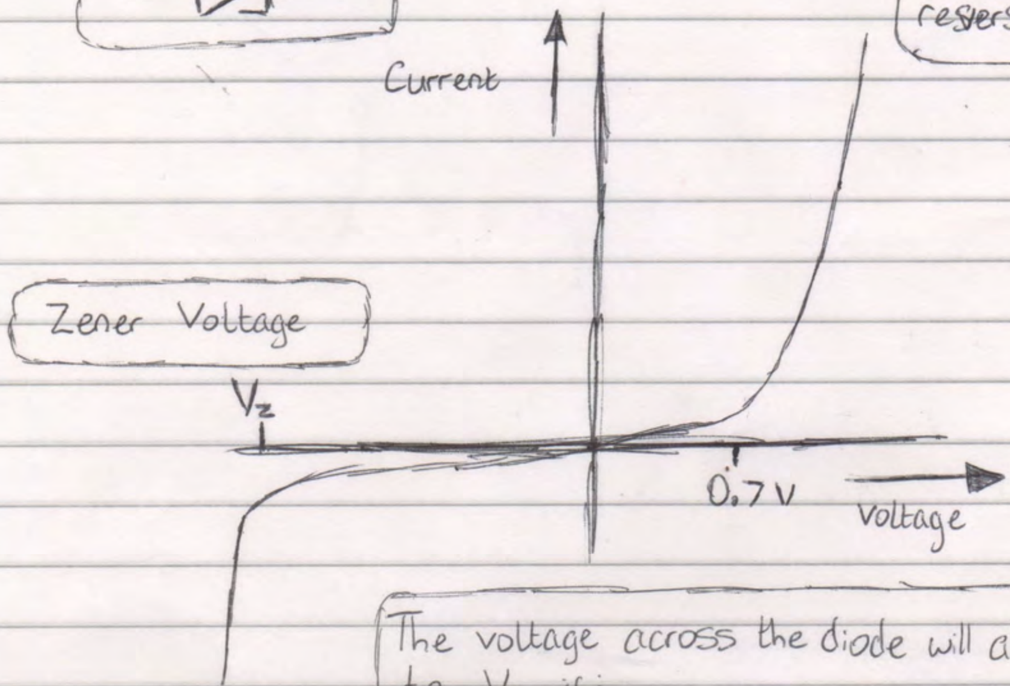
Zener Diodes

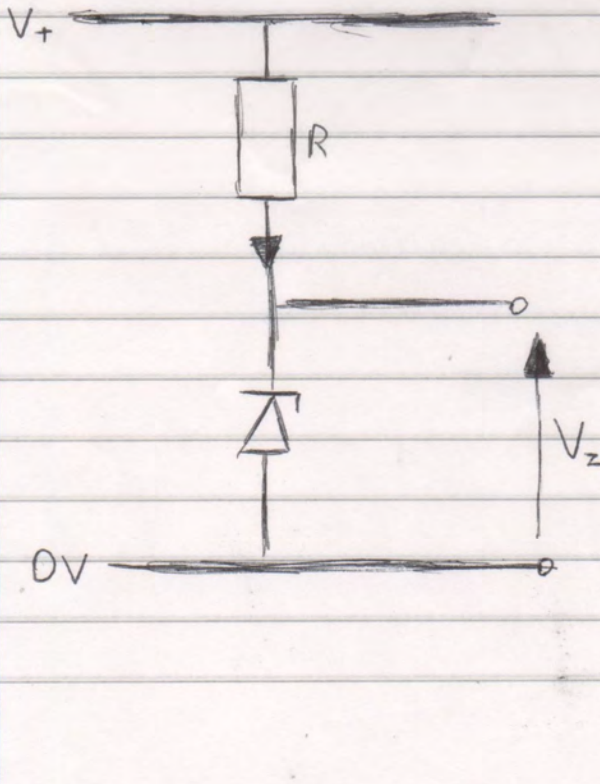


Zener diodes are always used in reserse bias mode



The voltage across the diode will always be equal to V_z if:

- Supply voltage larger than V_z
- Current above minimum value



A zener diode will produce a steady voltage of V_z, even if the supply voltage changes ustis Thompson

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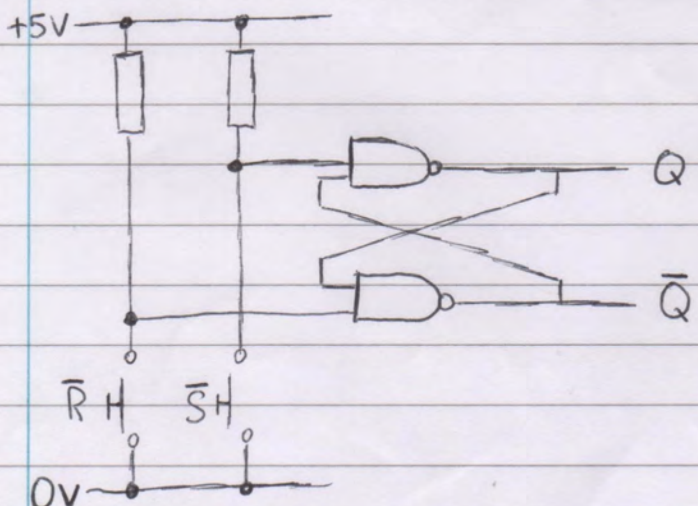
Flip Flops

- The output of a sequential logic circuit can only be worked out if we know the present and previous input states
- Flip-flop circuits are a basic element of these systems
- Feedback between outputs and inputs allows memory
- There are 3 important flip-flops for AS Electronics; $\bar{S}$-$\bar{R}$ flip-flop, clocked S-R flip-flop, D-type flip-flop

SET and RESET States

- Flip-flops can be in two stable states, SET and RESET
- SET is where $Q = 1$ and $\bar{Q} = 0$
- RESET is where $\bar{Q} = 1$ and $Q = 0$

$\bar{S}$-$\bar{R}$ Flip-Flop



- Inputs held at 1 with a pull-up resistor
- Closing switch changes input to 0

- $\bar{S}$ connects to Q
- $\bar{R}$ connects to $\bar{Q}$

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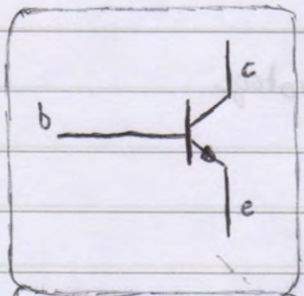
Transistors



Transistor Symbol

- Semiconductor device like a diode
- 3 terminals instead of 2

b = base

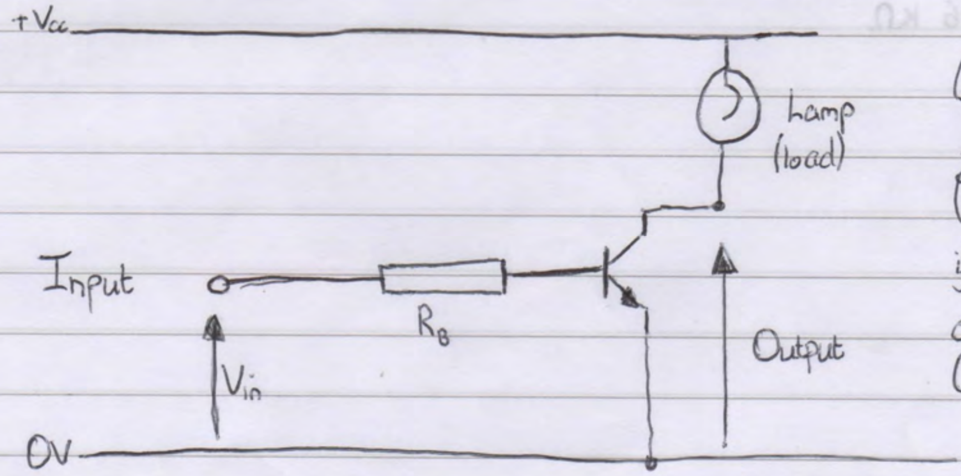
c = collector

e = emitter

- There are two types of transistors: npn type (used in AS) and pnp type
- Current always flows in the direction of the arrow
- Current can flow from base to emitter or collector to emitter
- The base-emitter current controls the collector-emitter current
- A small current into the base can control a large current from the collector

Uses:

- Amplify an analogue signal
- Allow a low power subsystem turn on or off a high power device



Current can only flow through the lamp (collector-emitter current) if a large enough current flows into the base (base-emitter current).

Three possible outcomes:

- Cut-off where no current flows through the lamp (output is equal to supply voltage)
- Linear where the load current varies with the base-emitter current
- Saturation where the load current is constant

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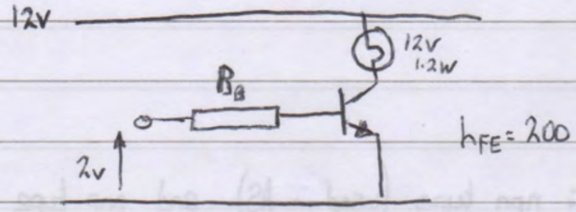
- $I_C = h_{FE} \times I_B$
- h_{FE} is gain of the transistor (usually 100-800)
- Output voltage is equal to supply votage minus load voltage

Example 1



What value of R_B is needed to ensure saturation?

$$I_c = P/V$$
$$= 1.2/12$$
$$= 0.1\ A$$

$$I_B = I_c / h_{FE}$$
$$= 0.1 / 200$$
$$= 0.5\ mA$$

$$R_B = \frac{2 - 0.7}{0.5}$$
$$= 2.6\ k\Omega$$