Section 1 - Overview

Electronic Systems

Electronic systems consist of three main parts: **input**, **process** and **output**. This can be represented in a block diagram:

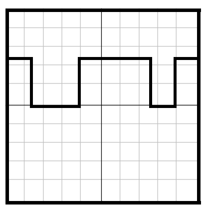
Digital and Analogue Outputs

The output of an electronic system can either be analogue or digital.

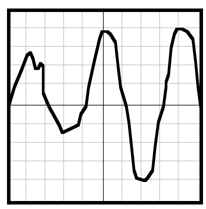
Digital outputs can only have certain values (usually this is either ON or OFF).

Analogue outputs have a continuously varying value.

Analogue and digital signals can be identified from the waveforms produced on an oscilloscope.



digital



analogue

Section 2 - Output Devices

Digital Output Devices

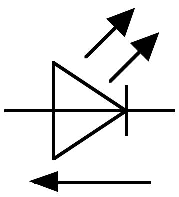
Solenoid	electrical to kinetic (in a line)
Buzzer	electrical to sound
LED	electrical to light
Relay	electrical to kinetic
7-Segment Display	electrical to light

Analogue Output Devices

Motor	electrical to kinetic (rotation)
Loudspeaker	electrical to sound
Bulb	electrical to light

The LED

An **LED (Light Emitting Diode)** converts electrical energy into light, but it will only do so when is connected the correct way round.



electron flow

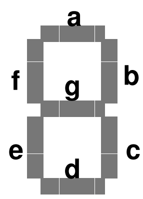
A resistor is always placed in series with an LED *to prevent it being damaged by too large a current passing through it.*

Choosing Output Devices

Output devices should be chosen for a particular situation according to what form on energy is required and whether the output needs to be digital or analogue.

7- Segment Display

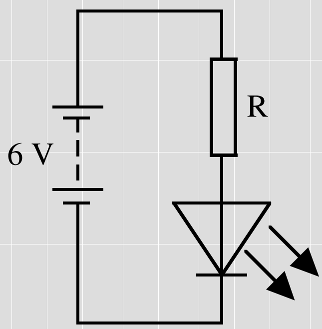
A **7-segment display** consists of seven LED bars. Different numbers can be produced by lighting the appropriate segments:



Digit	Segments lit
0	abcdef
1	bc
2	abged
etc.	etc.

Calculating the Series resistance for an LED

The following circuit would allow an LED to light:



LED Data

$I_{LED} = 10$ mA

$V_{LED} = 1.8$ V

The value of the series resistance that must be used can be calculated as follows:

Firstly $V_R = V_s - V_{LED}$
$= 6 - 1.8$
$= 4.2$ V

Then $I_R = I_{LED} = 10$ mA $= 0.01$ A

So $R = V_{LED} / I_{LED}$
$= 4.2 / 0.01$
$= 420\ \Omega$

Binary Numbers

In many electronic systems numbers are expressed in **binary** form. Binary numbers are expressed in terms of the digital values ‘1’ and ‘0’. The positions of the digits give their relative value with each digit worth twice the digit to it’s right.

Binary Number				Decimal
8s	4s	2s	1s	Number
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

Section 3 - Input Devices

Energy Changers

Many input devices are energy changers; they convert some form of energy into an electrical signal. (Note: These are all analogue devices.)

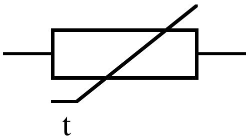
Microphone	sound to electrical
Thermocouple	heat to electrical
Solar cell	light to electrical

Resistance Changers

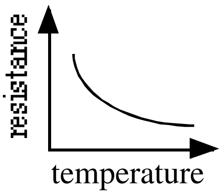
Some input devices are resistance changers; their resistance depends on some external factor. These include **thermistors**, **LDRs** and **variable resistors**. (Note: These are also all analogue devices.)

The Thermistor

A **thermistor** has the following symbol:



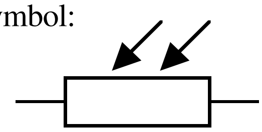
The resistance of a thermistor depends on temperature. As temperature increases resistance decreases.



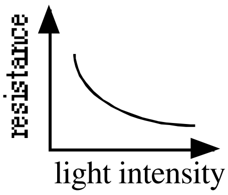
Temperature
Up
Resistance
Down

The LDR

An **LDR (Light Dependent Resistor)** has the following symbol:



The resistance of an LDR depends on light intensity. As light intensity increases resistance decreases.



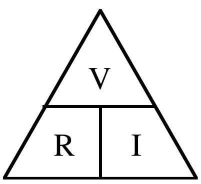
Light
Up
Resistance
Down

Resistance, Current and Voltage
(Ohm's Law)

V

$$\text{resistance} = \frac{\text{voltage}}{\text{current}}$$

Ω A



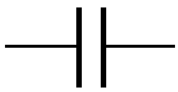
$V = IR$

$R = \frac{V}{I}$

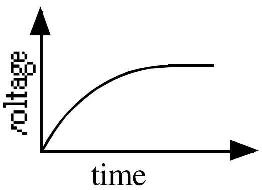
$I = \frac{V}{R}$

Capacitors

A **capacitor** has the following symbol:

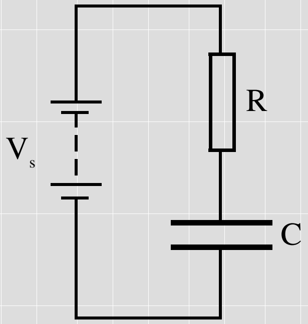


The voltage across a capacitor increases with time.



Charging Capacitors

When used as an input for electronic systems capacitors are usually connected in series with a resistor. This allows the time taken for the capacitor to charge up to the supply voltage to be controlled.



Increasing the capacitance, C, of the capacitor increases the time it takes to charge.

Increasing the resistance, R, of the resistor increases the time taken for the capacitor to charge.

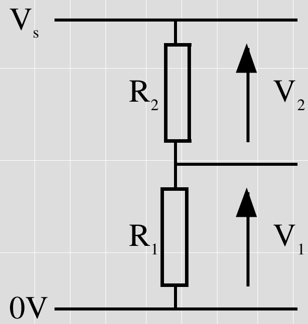
Choosing Input Devices

Input devices should be chosen for a particular situation according to what form of energy is providing the information.

For any system requiring a time delay chose a capacitor and resistor.

Voltage Divider Circuits

A **voltage divider** circuit consists of two or more resistors placed in series and is used to split the supply voltage between the resistors.



In a voltage divider circuit the ratio of the voltages is equal to the ratio of the resistances. i.e.

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

To calculate the voltage across each resistor the following equations should be used:

$$V_1 = \frac{R_1}{R_1 + R_2} \times V_s$$

or $$V_2 = \frac{R_2}{R_1 + R_2} \times V_s$$

Note also that $V_s = V_1 + V_2$

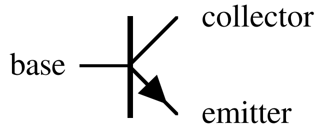
Section 4 - Digital Processes

Transistors

A **transistor** can be used as an electronic switch.

A transistor can either be conducting (ON) or non-conducting (OFF).

An NPN transistor has the following symbol:

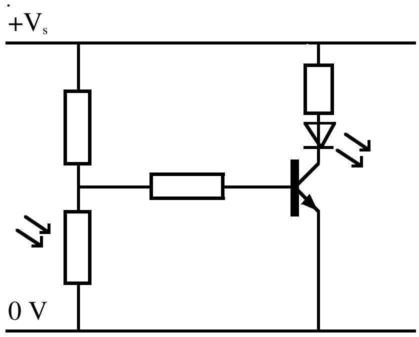


If the voltage across the base-emitter is less than 0.7 V the transistor will not allow current to pass between the collector and emitter (the transistor is OFF).

If the voltage across the base-emitter increases above 0.7 V the transistor will allow current to pass between the collector and emitter (the transistor is ON)

Low Light Level Sensor

The following circuit will switch on the LED when the light level decreases.

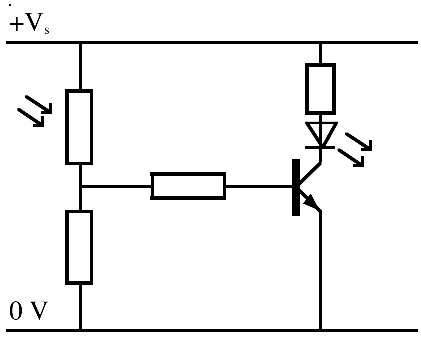


Explanation:

- Light level decreases.
- Resistance of LDR increases.
- Voltage across LDR increases.
- Voltage at base of transistor increases above 0.7 V.
- Transistor switches ON.
- LED lights.

High Light Level Sensor

The following circuit will switch on the LED when the light level increases.

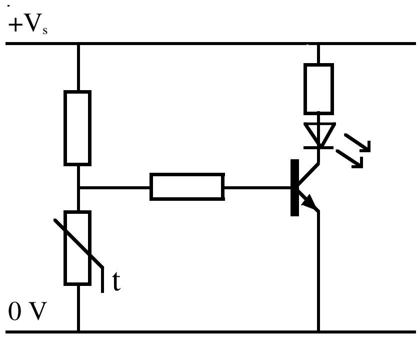


Explanation:

- Light level increases
- Resistance of LDR decreases
- Voltage across LDR decreases.
- Voltage across resistor decreases.
- Voltage at base of transistor increases above 0.7 V.
- Transistor switches ON.
- LED lights

Low Temperature Sensor

The following circuit will switch on the LED when the temperature decreases.

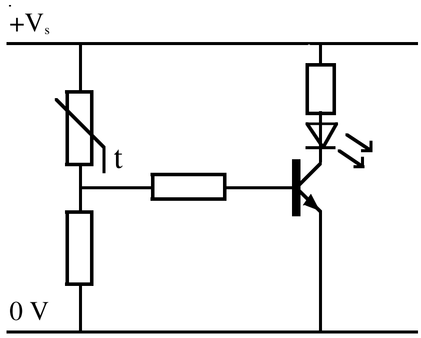


Explanation:

- Temperature decreases.
- Resistance of thermistor increases.
- Voltage across thermistor increases.
- Voltage at base of transistor increases above 0.7 V.
- Transistor switches ON.
- LED lights.

High Temperature Sensor Sensor

The following circuit will switch on the LED when the temperature increases.

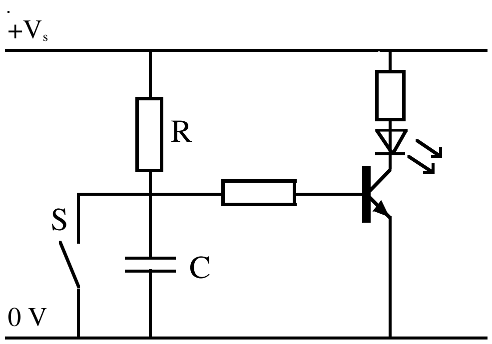


Explanation:

- Temperature increases
- Resistance of thermistor decreases
- Voltage across thermistor decreases.
- Voltage across resistor decreases.
- Voltage at base of transistor increases above 0.7 V.
- Transistor switches ON.
- LED lights

Time Delay Circuit

In the following circuit when the switch is released the LED will come on after a time delay.



Explanation:

Switch closed:

- Voltage across capacitor is 0 V.
- Voltage at base of transistor is 0 V.
- Transistor is OFF.
- LED is OFF.

Switch opened:

- Voltage across capacitor slowly increases.
- Voltage at base of transistor increases above 0.7 V.
- Transistor switches ON.
- LED lights.

Since the capacitor takes time to charge there is a delay between the switch being opened and the LED lighting

Logic Gates

Logic gates are digital electronic devices that have one or more inputs.

Logic gates have only two possible values (logic levels) for their inputs and outputs:

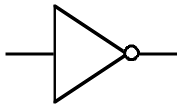
logic '1' - a high voltage
logic '0' - a low voltage

A **truth table** shows the output for all the possible input combinations of a logic gate.

Each logic gate has it's own unique symbol.

NOT Gate (Inverter)

Symbol:



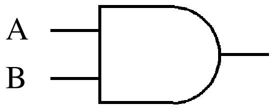
Truth table:

input	output
0	1
1	0

Function: The output is the inverse of the input

AND Gate

Symbol:



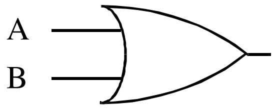
Truth table:

input A	input B	output
0	0	0
0	1	0
1	0	0
1	1	1

Function: The output is only 1 with both inputs A and B are 1.

OR Gate

Symbol:



Truth table:

input A	input B	output
0	0	0
0	1	1
1	0	1
1	1	1

Function: The output is 1 if either input A or input B is 1 (or both).

Combining Logic Gates

Logic gates can be combined together to perform simple logic circuits. The design of such circuits will depend on the inputs available and the output required.

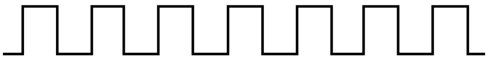
e.g. A circuit that will switch on when it is cold (NOT hot) AND light

Truth tables can be drawn for these simple logic gates.

These truth tables should show all the possible input combinations, the logic levels at important points in the circuit and the output logic level.

Clock and Counting Circuits

Digital electronic circuits can be designed to produce a series of **clock pulses**:

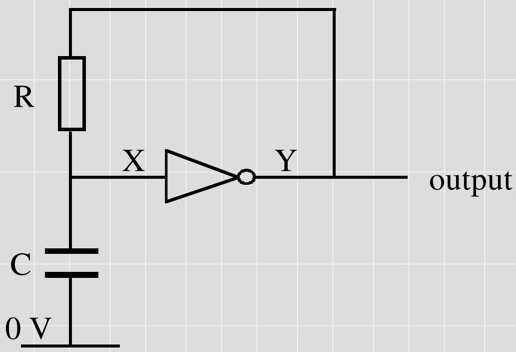


These clock pulses can be counted by a **counting circuit** which produces a binary output. Calculators and digital watches contain counting circuits.

With additional circuitry this binary signal can be turned into a **decimal display**.

Oscillator

An **oscillator** (or clock pulse generator) can produce a series of clock pulses.



Explanation:

- Capacitor initially uncharged.
- Voltage at X is 0 V
- Logic level at X is 0.
- Logic level at Y is 1.
- Voltage at Y is high.
- Capacitor charges through resistor.
- Voltage across capacitor increases.
- Logic level at X becomes 1.
- Logic level at Y becomes 0.
- Voltage at Y is 0 V.
- Capacitor discharges through resistor.
- Voltage across capacitor decreases.
- Logic level at X becomes 0.
- This process repeats to generate a series of high and low pulses.

The frequency of the clock pulses can be changed by altering the values of the capacitor and resistor:

To increase the frequency decrease C or R.
To decrease the frequency increases C or R.

Section 5 - Analogue Processes

Amplifiers

Amplifiers increase the strength of electronic signals. The output signal of an amplifier has the same frequency but a greater amplitude than the input signal.

Amplifiers are found in many devices such as radios, televisions, music systems and walkie talkies.

Voltage Gain

The **voltage gain** of an amplifier is given by:

$$\text{voltage gain} = \frac{\text{output voltage}}{\text{input voltage}}$$

The voltage gain of an amplifier can be measured by:

1) Connecting the input of the amplifier to an oscilloscope and measuring the input voltage.
2) Connecting the output of the amplifier to an oscilloscope and measuring the output voltage.
3) Use the formula:

$$\text{voltage gain} = \frac{\text{output voltage}}{\text{input voltage}}$$

Power Gain

The **power gain** of an amplifier is given by:

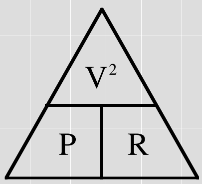
$$\text{power gain} = \frac{\text{output power}}{\text{input power}}$$

Power, Voltage and Resistance

V

$$\text{power} = \frac{\text{voltage}^2}{\text{resistance}}$$

Ω Ω



$V^2 = PR$

$P = \frac{V^2}{R}$

$R = \frac{V^2}{P}$