GCSE Electronics - Revision Notes 2015 Milo Noblet

ELECTRICAL SAFETY

- Whenever a voltage is present this can pose a danger
- voltage will cause a current to flow from higher voltage to a place with lower voltage (e.g. +V to 0V)
- Mains circuits feature very high voltages – students shouldn't work on any circuit with mains going straight into the board.

Low voltage (0-30V) DC circuits
Natural body resistance will allow us to handle up to 15V safely.
However, there may still be other dangers:

- BURNS – if excess current flows through components (e.g. due to fault or poor design) they can become hot and one may receive burns from them. NB ICs & resistors.
- EXPLOSIONS – can occur if excess voltage occurs across components such as LEDs and capacitors. Do not exceed voltage specified for the component

High voltage AC (230V mains) circuits
NEVER work on mains – energy available is sufficient to overcome body resistance and may result in fatal shock.
As well as low-voltage dangers, other dangers exist with mains:

- FIRE/EXPLOSIONS- if sparks from switches or wiring faults ignite gases/liquids/sprays/powder/dust in the air
- STORED CHARGE – high voltage can be left on capacitors even after circuits are switched off – can then create sparks or give an electric shock
- ELECTRIC SHOCK – when the body receives sufficient energy from high voltage sources to create a conductive path through the body. Current tries to get to ground.
    - Our general health, moisture & skin condition can affect how bad we will be affected
    - The MAIN FACTORS influencing the effect of electricity on the body are SIZE OF CURRENT and TIME IN CONTACT.
    - *"Electric shock is the effect on NERVES, ORGANS & TISSUE due to the passage of current through the body"*
    - *"FIBRILLATION is the stimulation of the heart muscles that overrides the natural rhythm"*

Current	Effect on the body
1mA	Maximum safe current
10mA	Muscle spasms – may be unable to let go
100mA	FIBRILLATION occurs – likely to be fatal. BURNS may be seen where current enters and exits the body

FIRST AID

Know the ENVIRONMENT – location of TELEPHONE, procedure for contacting emergency services, and how to describe your location
Know BASIC FIRST AID. Upon coming across an electric shock victim:

1. MAKE SCENE SAFE
    a. isolate mains and/or move body away from mains using an insulating aid e.g. wooden pole
2. SUMMON HELP
3. ASSESS CASUALTY using DR ABC
4. RESUSCITATE if casualty not breathing, but only if trained to do so

PREVENTION OF ACCIDENTS, & SAFETY DEVICES

Mains circuits

Transformers can be used to obtain safe stepped-down low voltages from the mains, which can then be used to power the circuits in many modern electronic devices.

Mains cabling

Due to higher energies in the mains, THREE-CORE cable is used – the additional wire is a safety feature.

- different thicknesses of wire are used for different currents. Must use the correct thickness of cable for the current to avoid fire hazard
- rubber grommets are used to feed mains cable through the metal cases of appliances to avoid cuts to the cable.

The mains plug

LIVE – BROWN: higher energy wire driving current back and forth
NEUTRAL – BLUE: completes the circuit back to source
EARTH – YELLOW/GREEN: safety wire. Current will travel through this to ground instead of through the user

PREVENTING ACCIDENTS

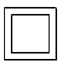
- RISK ASSESSMENTS allow us to identify dangers associated with an activity & then take action to reduce this risk
- PORTABLE APPLIANCE TESTING (PAT) is done by a qualified engineer on all power supplies for mains equipment to ensure they're safe to use
- VISUAL INSPECTION of plugs/cables/cases is your responsibility

- Industry & education have a responsibility for safety

MAINS SAFETY FEATURES

- FUSE – placed in live wire of supply. It will break the circuit if too much current flows. Fuse wire melts due to the excess heat generated by too much current flowing. P=IV gives fuse value – should just exceed calculated current.

- EARTH – provides a low resistance route from the metal casing to ground & will protect the user if any fault caused the case to be live.
    - earth of a mains plug is the first pin connected and last pin disconnected to maximise safety.

   means 'double insulated' – there is no exposed metal and so the appliance doesn't need a mains earth.
    - Live and neutral terminals of a power socket have safety shutters that are opened and closed by the earth pin
    - The switch on a socket or appliance is in the live lead so the appliance can be isolated from the high energy supply

- CIRCUIT BREAKERS are thermal or magnetic and can be reset once the fault is repaired.
    - RCCB & ELCB use electromagnets that break the circuit when too much current flows. They detect the difference between the live & neutral current e.g. when some current going to earth.
    - NB circuit breakers do not protect against all possible faults
    - when selecting the circuit breaker one must consider the response time, acceptable overload current & type of fault most likely to occur.

SYSTEM DESIGN

Electronic systems are composed of subsystems.

Any system has inputs, processes and outputs. An -> between subsystems represents the flow of information.

Inputs & outputs are usually quantities – heat, light, sound, force – and as circuits can only process electrical signals these have to be converted.

- A TRANSDUCER is a device that converts one type of energy/quantity to another e.g. a microphone, LDR, LED, loudspeaker.
- A signal is an electrical current or voltage representing information. A COMPARATOR compares two signals
- A TRANSDUCER DRIVER amplifies a signal so it can operate a transducer
- A MICROCONTROLLER is *'computers on a single IC complete with memory and all the circuits needed for input & output.*

System sequence – flowcharts

- Rounded rectangle – start or end (a.k.a "loop")
- Parallelogram – input or output
- Rectangle – process
- Diamond – compare/question

RESISTORS

- main function to control the flow of current
- common types are carbon film & metal film (better quality)
- unit for resistance is the Ohm.

E24 series are standard values – choose nearest value but ensure it will not allow too much current through.
BS1852 printed code: J=5%, K=10%, M=20% tolerance. R=x1, K=x1000, M=x1,000,000

Power rating

- When current passes through a resistor, heat is generated & the resistor must be able to withstand this so it is not damaged
- When selecting a resistor, power rating should exceed value calculated as being the power output from the resistor
- Common ratings: 1/8W, 1/4W, 1/2W, 1W, 2W, 5W
- In modern circuits the currents are so low that 1/8W can usually be used.

LIGHT EMITTING DIODES

Cathode is the –ve side: shorter leg or the flat side of the LED. It's the side with the | on the circuit symbol.
Longer leg on the rounded side is the +ve anode.

When voltage is applied across a diode to make it conduct, it is forward biased. If the diode will block the flow of current it is reverse biased.

Typical LED values: 2V forward voltage drop, 10mA typical current, 30mA max current.

- A simple silicon diode has a forward voltage drop of approx. 0.7V

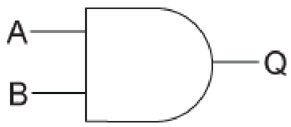
A protective current-limiting resistor must take the excess voltage (e.g. Vs-2V) & same current as the LED (~30mA)

SWITCHES are inputs in digital electronics. They have two values only.
Examples of switches are: push to make & push to break, toggle (SPST, SPDT etc), microswitch, (magnetic) reed switch, tilt switch.

LOGIC GATES

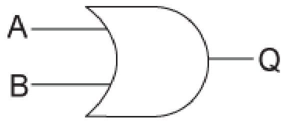
AND gate

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



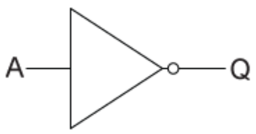
OR gate

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



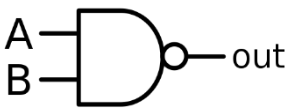
NOT gate

A	Q
0	1
1	0



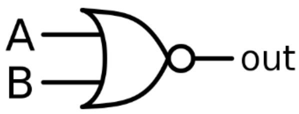
NAND gate (aka NOT AND)

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



NOR gate (aka NOT OR)

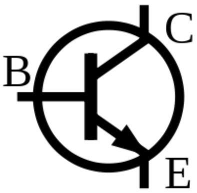
A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0



Identifying pins on an IC
A cutout or dot gives the left hand side of the IC. Pin 1 is bottom left, then count in an anticlockwise direction around the chip (so the highest pin is directly above pin 1)

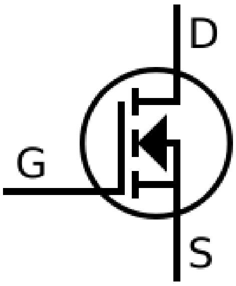
<u>TRANSISTORS</u>

1 – **BJT** – BIPOLAR JUNCTION TRANSISTOR



Made from semiconductor material w/ three different types sandwiched together. Small signal at base allows larger signal to flow from collector to emitter.
Transistors are triggered by CURRENT.
Larger the base current, the greater the output.
Base, **C**ollector, **E**mitter
A resistor is used to protect the base from too much current damaging it.

2 – **MOSFET**



The MOSFET is controlled by VOLTAGE.
The bigger the voltage at the gate, the more current that can flow through
Gate, **D**rain, **S**ource
MOSFET can tolerate high voltages at gate, so no base resistor needed

BJT or MOSFET?		
Characteristic	BJT	MOSFET
Input signal	Current + minimum 0.7V Current can be problematic e.g. when using with logic gates	2V voltage needed. As no current, will work fine with logic gates etc.
Peculiarities	None	Static-sensitive: some can be damaged by excessive handling, and all can behave erratically if input left floating (not tied up/down)
efficiency	High – doesn't waste much power	Low – wastes lots of power as gets hot when turning things on & off

RELAYS

The relay consists of an electromagnet (solenoid), an iron armature and contacts.
The relay can act as a transducer driver – the coil current can be as low as 50mA and the current the contacts are able to switch up to 16A.

The major advantage of the relay over the transistor is that the coil & contacts are electrically isolated, so they can be used to safely control higher voltages e.g. mains.

However, the relay needs much more current than a transistor – if a relay is needed, we can use a transistor to control current flowing to the coil.

NB a protective REVERSE BIAS diode is required around a relay (and a motor). When components with electromagnetics are switched off, "back e.m.f." can cause very high voltages to flow through the circuit 0 – without the diode this high voltage would cause damage.

<u>CAPACITORS</u>

Capacitors are made of two metal plates separated by an insulating layer.

- CAPACITANCE is the amount of charge a capacitor is able to hold – the unit of capacitance is the Farad, F.
- In addition to their capacitance, capacitors have a working voltage, above which the dielectric layer starts to break down.

- 1uF=1×10^{-6}F, 1nF=1×10^{-9}F, 1pF=1×10^{-12}F

ELECTROLYTIC capacitors have a chemical electrolyte as the dielectric layer. Most >1uF and all >100uF capacitors will be electrolytic. Electrolytic capacitors are POLARISED and if connected the wrong way round could explode.

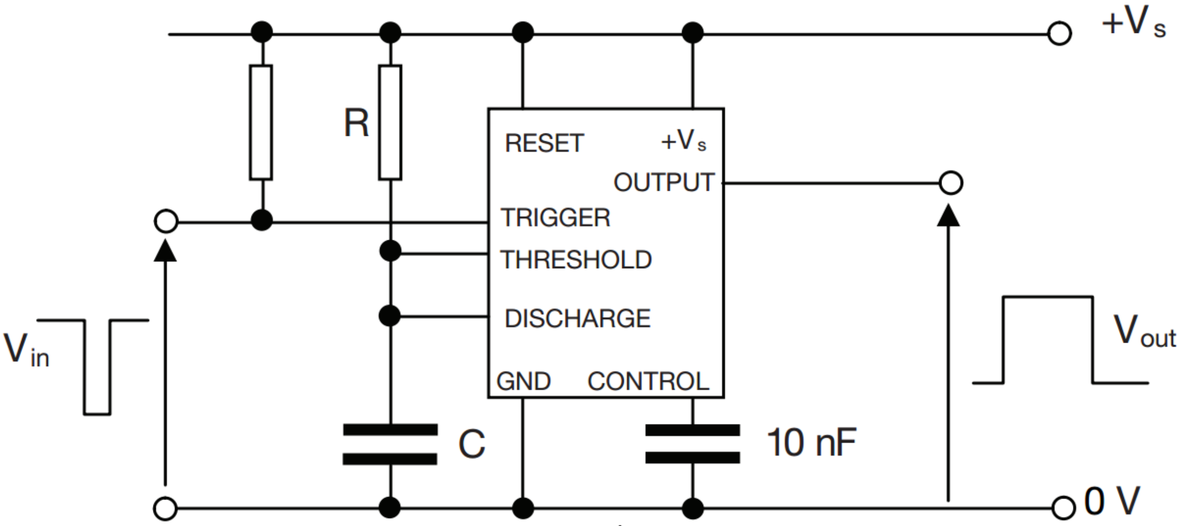
An <u>RC CIRCUIT</u> is a resistor & capacitor together to control the rate at which the capacitor charges.

$R \times C = T$ (in base units)

T, the time constant, is how long it will take for the capacitor to reach 63% capacity.

<u>555 TIMING CIRCUITS</u>

<u>1 – THE **MONOSTABLE**</u>

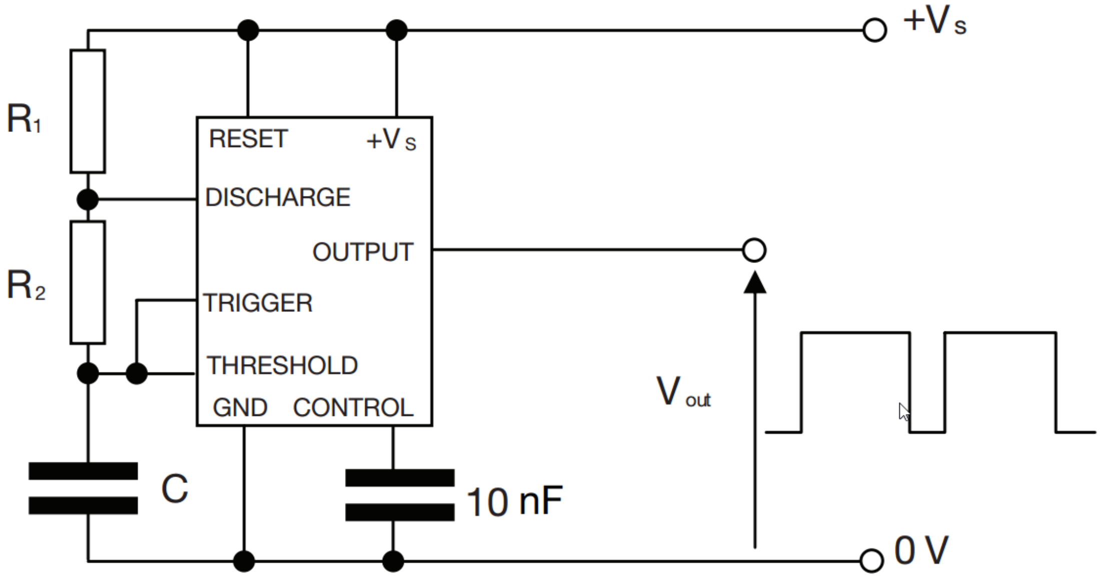


NB in MONOSTABLE, **THRES+DISCHG** are connected to each other.

The monostable is triggered by a FALLING EDGE input – the PTM & resistor allow trigger voltage to be momentarily taken to 0V. We are then given an output pulse, the duration of which is determined by the values of R & C. (T=1.1RC, base units)

- A monostable will give time periods of 1us up to ~5mins.
- R must be between 1K and 5.6M

2 – THE **ASTABLE**



NB IN ASTABLE, **TRIG+THRESH** are connected to each other.

- Output is high V followed by low V. Time taken for signal to repeat is the time period
- Rate at which pulse generated is frequency, measured in Hz. Number of time periods in one second.
  - f=1/T, and T=1/f.

$$T = \frac{(R_1 + 2R_2) \times C}{1.44}$$

(again, base units – R in Ohms, C in Farads, T in seconds)

Where might we use continuous pulses?
Flashing & buzzing, clocks & watches.

NB: 555 can't drive 8Ohm loudspeaker (standard) – 64Ohm best.
555 doesn't need transducer driver as has one built in.

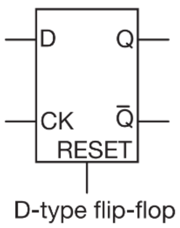
When pin 4 – RESET – is at Vs, the 555 operates normally. When at 0V, the 555 turns off.

COUNTING – THE **4017** DECADE COUNTER

4017 goes from 0-9 (hence 'decade counter'). It is triggered by a RISING EDGE input at the CLOCK, which causes it to advance one count. On the 10^{th} pulse the counter cycles to 0.

- EN & RST must both be LOW for the counter to function
- If want to count to <9, connect RST to one of the outputs.
  - E.g. for 0,1,2,3,0,1,2,3, connect RST to output 4.
- **NB** in timing diagrams for the 4017, changes only happen on the RISING EDGE.

LATCHES & FREQUENCY DIVIDERS



A DATA LATCH is simple electronic memory that remembers only one thing – a 1 or 0.

When RISING EDGE @ clock, the signal at D is copied to Q.

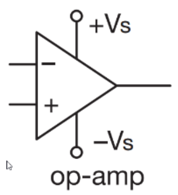
If S & R not being used, they must be at 0V. When R goes high, Q goes low.

FREQUENCY DIVIDERS turn a high frequency signal into a low frequency signal.

- connect D to not-$\bar{Q}$ to make a divide-by-2 frequency counter.

ADC, COMPARATORS & OP-AMPS

THE OP-AMP



The DIFFERENCE between the voltages at the non-inverting (+) input and the inverting (-) input is multiplied by the GAIN.

- If the non-inverting input is higher the output will be positive
- If the inverting input is higher, it will be negative

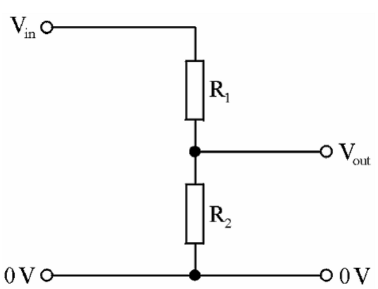
Saturation

Op-amps have massive gain (usually 100,000), so the difference between the two is multiplied so that it will be massively above or below the supply voltage. Thus, the op-amp saturates at the +Vs voltage for a positive output, and 0V/-Vs for a negative output.

- ideal op-amp has a gain of infinity.

The op-amp acts as a COMPARATOR, the output of which is a digital signal – it can only be 0V or +Vs. So the op-amp converts an analogue signal to a digital signal – ADC.

POTENTIAL DIVIDERS



These are *"a circuit which uses two resistors to divide a voltage into two smaller voltages".*

$$Vout = Vs \times \frac{R_2}{R_1 + R_2}$$

AUDIO SYSTEMS

We can get the whole circuit for an audio system on an IC, such as the **LM386.** The role of an audio amp is to make the input signal bigger so it can drive (for example) a loud speaker.

VOLTAGE GAIN

Audio amps increase the voltage of a signal – the voltage of the input signal is multiplied by the amplifier's gain.

$$G_V = \frac{V_{out}}{V_{in}}$$

BANDWIDTH

Amplifiers change the AMPLITUDE (*maximum displacement of a wave*) but NOT THE FREQUENCY. Hence, the frequency of the input signal is the same as the output signal.

Amplifiers are designed to work with signals of different frequencies. They will not work well if the frequency of the signal is too high or low.

- When the frequency of the input is too high the power gain is reduced.

BANDWIDTH is *"the range of frequencies where the power gain is at least half the maximum gain"*.

Electrical noise is an unwanted signal. It can be picked up by the connecting wires in electronic equipment. If electrical noise is picked u on the input wires to an amplifier, the noise will be amplified and can cause problems.

- Coaxial cable doesn't pick up as much noise but is more expensive than ordinary cable. It has a central conductor surrounded by a shield conductor and is used for connecting microphones & other devices to amplifiers to reduce electrical noise

POWER SUPPLIES

MAINS is $230V_{RMS}$ AC, with a frequency of 50Hz.

- Alternating current is "*made to constantly change direction and value by the applied alternating voltage"*
- Direct current is *"made to flow with a constant value in a fixed direction by an applied fixed value voltage"*

Peak value is the maximum positive or negative value than an a.c. apply achieves.

Root mean square (RMS) is the equivalent d.c. value that would provide the same power as the a.c. supply.

$$V_{peak} = V_{RMS} \times \sqrt{2}$$

$$V_{RMS} = \frac{V_{peak}}{\sqrt{2}}$$

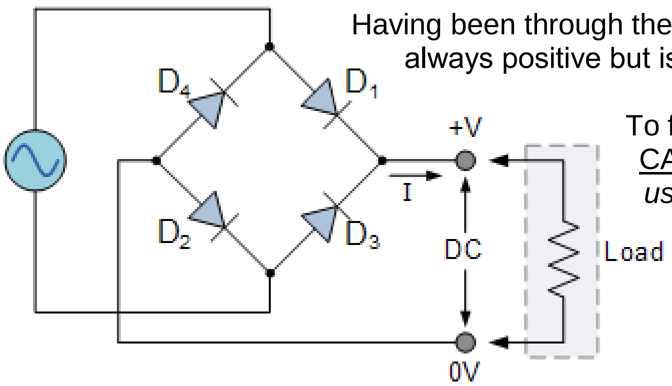
How can high voltage a.c. be turned into low voltage d.c.?

$230V_{AC}$ mains -> transformer -> rectifier -> smoothing -> regulator -> low voltage DC

A TRANSFORMER converts a.c. voltages up or down. Alternating currents in one coil generate an alternating magnetic field that is enhanced by the iron core. A voltage is then induced in the secondary coil by the moving field.

A HALF-WAVE RECTIFIER uses a silicon diode to block the negative part of the waveform. However, the output is 'lumpy'. Also, only half the power of the full wave is now available.

A FULL-WAVE RECTIFIER allows us to make use of both the positive & negative parts of the a.c. wave.



Having been through the full-wave rectifier, the voltage is now always positive but is still too "lumpy".

To fix this we use a SMOOTHING CAPACITOR – a *large value capacitor used as a storage reservoir that acts to reduce the fluctuation (ripple) of the rectified signal.*

A DC REGULATOR IC (e.g. 7805) helps to hold the voltage steady when "loading" occurs – as more current is demanded, the voltage might drop.

RADIO SYSTEMS

AUDIO FREQUENCY (AF) is *"the wave frequency associated with sound and lying in the range 20Hz-20kHz".*
AF is an analogue signal – one that *'can take up voltage values over a continuous range'*

RADIO FREQUENCY is *"that part of the EM spectrum used for radiocommunication"*. Radiocommunication is the means by which information is sent over a distance using radio waves.

The CARRIER WAVE is the radio wave used to transport the information.

MODULATION is the act of changing a property of the carrier to encode the information on to it.

AMPLITUDE MODULATION, AM, is achieved by changing the AMPLITUDE of the RF wave to encode the information so that the change mimics the RF wave.

- AM radio makes use of the medium-frequency RF range and provides a relatively cheap and uncomplicated means of mass communication.
- The RF is at a much higher frequency than the RF, an the resultant wave to be transmitted is gained by combining the two.
- When drawing an AM resultant wave, keep the frequency constant & vary the height of the wave to match the AF.

FREQUENCY MODULATION is the act of changing the frequency (number of waves produced per second) to encode the information – the frequency is increased as the amplitude of the AF increases, and decreased as the amplitude of the AF decreases.

- FM is more complex & used for local and national stereo transmissions.
- when drawing an FM resultant wave, draw guidelines to help keep amplitude constant, and alter the wave spacing so the frequency changes.

THE SIMPLE RADIO RECEIVER (AM)

Antenna -> **tuned circuit** -> **demodulator** -> **AF amp** -> **loudspeaker**

An AERIAL is a length of wire used as a transducer – it turns the EM radiation into electrical energy. The EM waves influence the electrons in the metal wire of the aerial & these electrons then move to create a current in time with the frequency of the incoming RF wave.

The RF TUNED CIRCUIT *[an inductor & capacitor]* helps to select the frequency we want.

The DEMODULATOR strips away the RF carrier to leave us with just the AF>

The AF AMP then boosts the AF signal so that it can be used to drive a loudspeaker. There may also be a potential divider to act as a volume control.

SENSITIVITY is *"the ability of a radio receiver to receive a weak signal from a distant location".*

- can be improved with an RF amp at the frontend.

SELECTIVITY is *"the ability of a radio receiver to distinguish between two radio stations that transmit on frequencies that are close together"*

- can be improved w/ filters or use of more complex circuits e.g. superheterodyne receiver.

- **AM**
  - medium wave 0.3MHz – 3MHz
  - simple circuitry for relatively cheap communication system
  - used for national sport, chat and pop music
  - subject to NOISE – electrical interference
  - due to use of lower frequencies, get some sky reflection, which leads to wider coverage but also makes it susceptible to atmospheric effects e.g. fading.

- **FM**
  - VHF – 30-300MHz
  - more complex & expensive circuitry needed
  - take up large band of frequency
  - used for radio requiring high quality music transmission
  - works on a shorter line-of-sight principle, hence use by local radio
  - immune to electrical noise & some atmospheric conditions, although signal strength can be affected by reflection from buildings & hills, creating dead spots.

MICROCONTROLLERS

Microcontrollers are computers on a single IC, complete with memory and all the circuits needed for input and output.

- they are controlled by a PROGRAM – a *sequence of instructions that a computer can interpret and carry out*.

Pros & cons

- program in the microcontroller can be altered so the way it operates can be changed.
  - This means manufacturers can easily change the way a circuit operates before it leaves the factory
  - equipment can be updated if a fault found or a new feature is needed & equipment is not wasted
  - users can sometimes update their own equipment at home by downloading new software & reprogramming the microcontroller in their electronics themselves
- program memory is usually flash memory so reprogramming is called 'flashing'. The software is usually called 'firmware'
- if a circuit needs to be very fast, it must be specifically designed to do the job – microcontrollers aren't as fast as specially designed circuits
- microcontrollers have made things smarter as it's easier to customise things with programs
- as it's fast and cheap to produce microcontroller-based systems, new electronics equipment is being produced all the time
  - this means equipment is soon out of date
  - some worry about the amount of waste produced by constantly buying new electronic goods & throwing away equipment that is not very old

CONVERTING BETWEEN ANALOGUE & DIGITAL

Sometimes an analogue signal e.g. from a microphone may need to be connected to a microcontroller. Microcontrollers can only handle digital information so ADC & DAC are needed.

- ANALOGUE is a signal that can have any value between a min & max
- DIGITAL can only have 2 states: high V for 1 & low V for 0
- simplest ADC is a comparator
- to give an analogue signal from a microcontroller a DAC must be used to convert 1s & 0s to voltage.