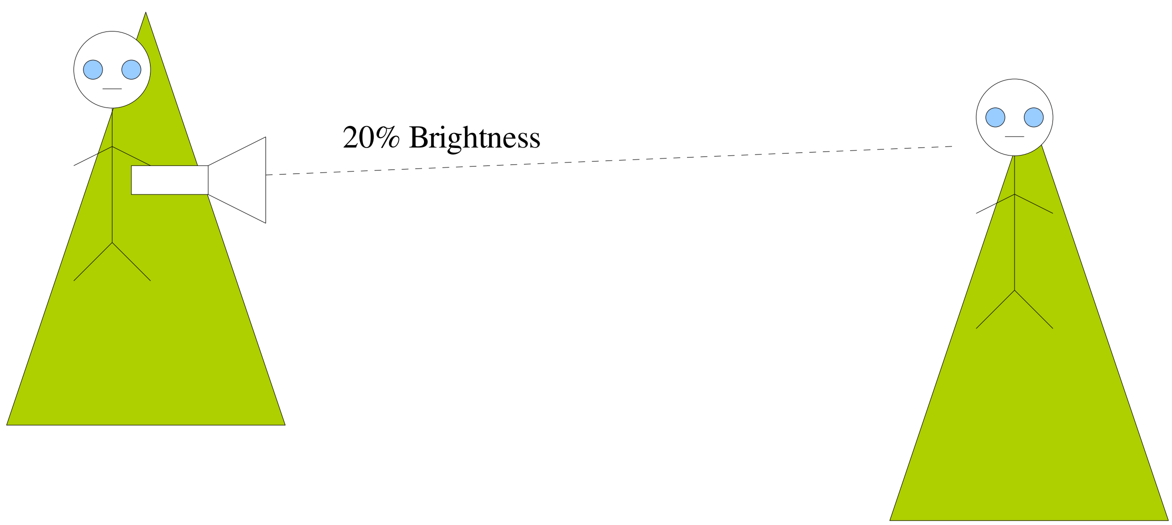
Analogue and Digital systems

Fundamentals of analogue and digital systems.

All of our senses are analogue sensors. We can hear the loudness of music, we can feel the pressure of a touch or how hot a cup of tea is. Our senses register not only the presence of something but its magnitude also. The output of our senses in some sense represents an *analogue* (or is analogous to) the size of whatever it is we are in contact with.

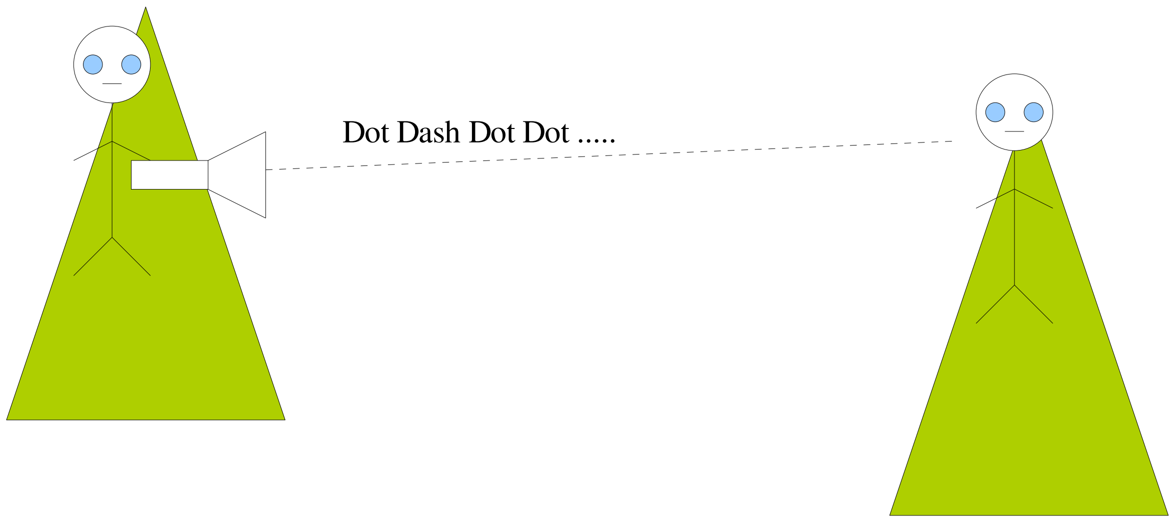
Digital systems operate very differently to analogue ones. In their simplest form, digital systems simply register the presence or absence of a signal – not its magnitude. How then can digital systems record music, video and other signals that are fundamentally analogue in nature? They do it by encoding magnitude in a set of digital signals. This might seem to be a complicated way of doing things however there are definite benefits to this approach. An example might help to clarify this.

A climber on a mountain needs to convey the temperature to another climber on a different mountain. He does this by partially blocking the front of his flash lamp so that its brightness is an analogue of temperature (20% brightness corresponds to 20 degrees and so on).



While this system seems to have the merit of simplicity it does in fact suffer from some serious problems. How well is receiver able to identify 20% brightness as compared with 25% brightness? What happens if there is fog? These problems can lead to a serious breakdown in communications in reality.

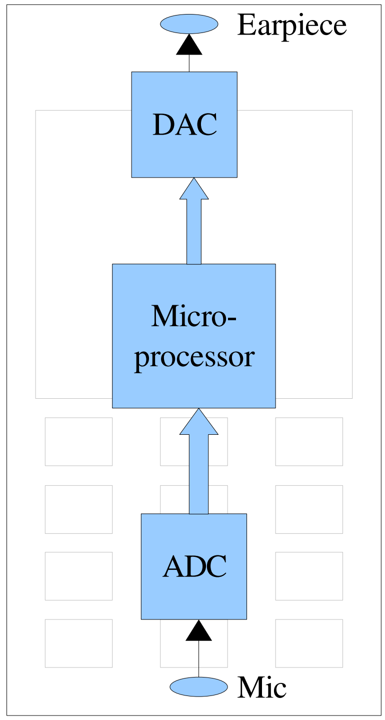
A digital version of this example might run like this:



Frustrated by the lack of certainty in their communications, the climbers decide to adopt Morse code to convey their data. Now the receiver simply needs to discriminate between Dots and Dashes to successfully decode the message. This system transmits a set of binary data (binary implies only two signals are possible: Dot or Dash) one piece or bit at a time. This sort of transmission is also serial in nature as only one bit of information is “in flight” at one time.
A modification of this scheme could involve the sender using a number of flash lamps to convey information. By turning some on and some off the sender can transmit a particular pattern of lights that can have some agreed meaning. The receiver can then read all of the data in one glance. This is parallel data transmission as it involves the sending of multiple bits of data in one go.

In the electronic world of microprocessors we don't use lights to send and store data (though optical computers are being developed). We use voltage levels instead. Generally speaking microprocessors interpret a 0 Volt signal as the number zero and a higher voltage as the number 1. The actual voltage used for '1' depends on the microprocessor system. Many earlier microprocessors used 5V though this has drifted steadily downwards over the years in an effort to save power.

Analogue to digital and back again.
Digital systems regularly need to interact with analogue ones. For example, our mp3 players are digital devices internally however they communicate with our analogue ears. In order to send or receive information with analogue systems some sort of converter device is required. An *Analogue to Digital converter* converts an analogue signal into a digital one. A *digital to analogue converter* converts a digital signal to an analogue one. Your mobile phone contains one of each of these. The user speaks into the microphone and listens to the earpiece. Internally, the phone converts the speech from the microphone using an analogue to digital converter (ADC). These digital numbers are used in the phone's digital electronics/microprocessor. Incoming voice data from the phone network is converted back into an analogue signal using a digital to analogue converter (DAC).



So what is an ADC? An ADC is a semiconductor device that takes an analogue signal and converts it to a set of digital 1's and 0's. These 1's and 0's are taken together to represent a binary number the magnitude of which is related to the magnitude of the analogue signal. DAC's work in reverse. They receive a binary (digital) number and convert it to a voltage the size of which is related to the digital number.

ADC's and DAC's have input and output numeric and voltage ranges. A 3V 8 bit ADC will typically produce the maximum 8 bit output of 1111 1111 when its input is 3V. When the input is 1.5V, the binary output will be 0111 1111 (half as much). When the input is 0V the output will be zero. DAC's operate in a similar manner.