DC And AC Supplies

1 Earthing DC Circuits

In a DC circuit we call one of the supply terminals positive and the other negative. By convention we say that the positive terminal is at a higher electrical potential than the negative terminal, so that current flows from positive to negative. In fact electrons flow from negative to positive but for historical reasons current is considered to flow in the other direction. In the vast majority of cases it does not matter in which direction we consider current to flow, just so long as we keep it flowing in one direction only. Since the terminals are at different potentials there exists a potential difference between them and this difference is measure in volts. Note that when we measure voltage we measure the difference between two potentials and not absolute values of potential. Also note that if two points are at the same potential, there is no potential difference and no current flows.

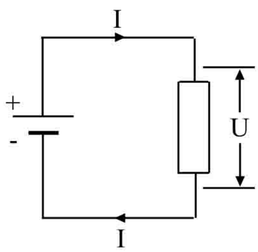

Figure 1: A simple DC circuit containing a battery and a resistor.

Consider a simple circuit as shown in figure 1. The battery has a fixed electromotive force (EMF) across its terminal (this is measured in volts and 1 volt is 1 joules per coulomb of charge). The battery can therefore only give each electron a finite energy, this energy is split between potential energy and kinetic energy. As the electrons flow through the resistor they lose potential energy therefore when they start out at the positive terminal they need enough potential energy to get around the circuit. However, the kinetic energy of the electrons must stay constant all the way around the circuit because their velocity must remain constant; if this were not so there would be different flow rates at different parts of the circuit, and electrons would become bunched up in slower moving sections. Current is a measure of how much charge (i.e. how many electrons) passes a given point in a circuit per second: one ampere is one coulomb of charge flowing past a reference point per second.

The circuit shown thus balances itself so that:

- if the circuit has a large resistance, the electrons need a lot of potential energy as they leave the positive terminal, therefore they have little kinetic energy and move slowly, so that few electrons pass any given point per second, which means a small current flows.
- if the circuit has a small resistance, the electrons need only a little potential energy as they leave the positive terminal, therefore they have a large kinetic energy and move quickly, so that many electrons pass any given point per second, which means a large current flows.

All this of course is summed up by the simple formula: $I = \frac{U}{R}$

It can be difficult to understand how an electron can 'know' the resistance of a circuit before it leaves the battery, however there are two points to remember. Firstly, the battery produces electrons in a chemical reaction that must be balanced by the reverse reaction consuming electrons at the negative terminal, therefore the battery does not only 'push' electrons round from the positive terminal but also 'sucks' them round from the negative terminal. Because of this simultaneous push and suck the circuit must be unbroken for electrons to flow. Secondly, since electrons repel each other we can imagine the electrons as an incompressible fluid, so that they push the electrons in front and are pushed by the electrons behind.

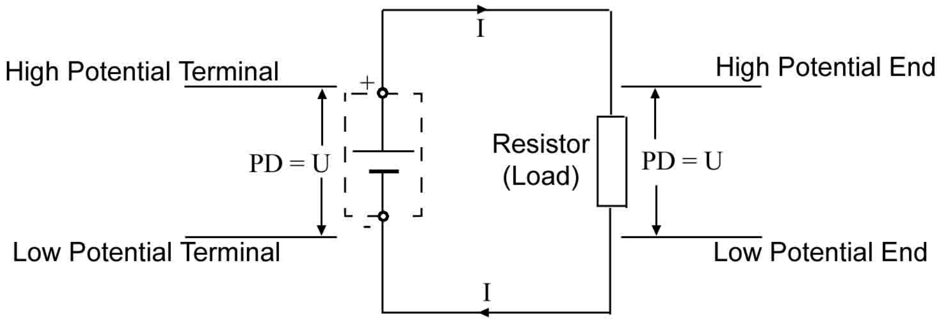

Figure 2: A simple AC circuit showing the potential difference (PD) across the battery terminals and the resistor.

As the electrons flow through the resistor in figure 2, they lose potential energy as heat. Therefore, the resistor has both a high and low potential end, which remain fixed so that the high potential end is connected to the positive terminal of the battery and the low potential end is connected to the negative terminal. There is therefore a potential difference across the resistor that is called a voltage drop. Since all of an electron's potential energy is used up flowing around the circuit the voltage drop across the circuit's resistance is equal to the EMF of the supply. This essentially splits out simple circuit in two; a high potential half and a low potential half. We can thus redraw the circuit to have a positive, high potential, line and a negative, low potential, line (figures 3a and b).

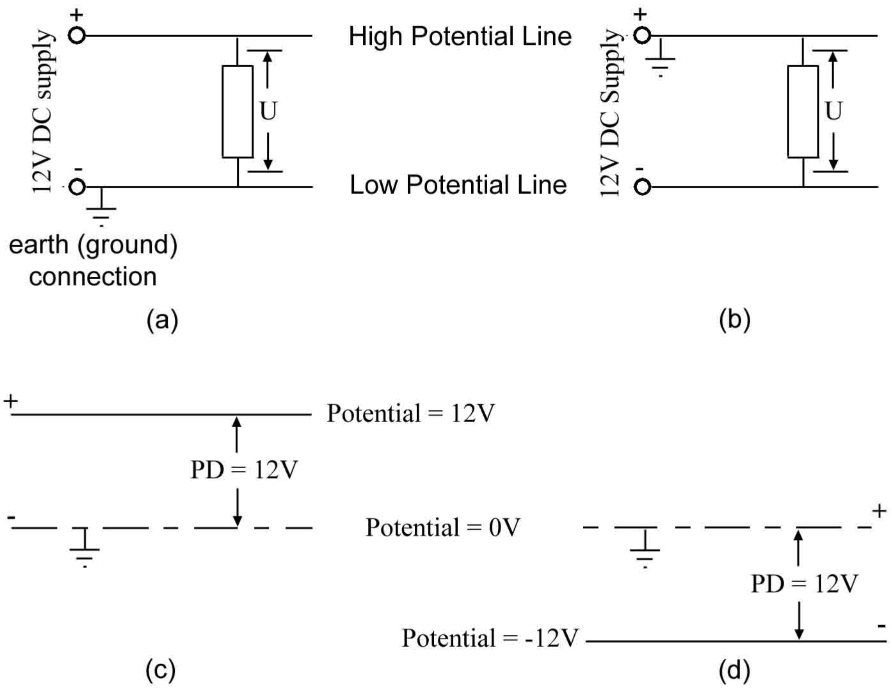

Figure 3: A simple DC circuit with: (a) negative line grounded; (b) positive line grounded; (c). Also the potential and potential differences with: (c) negative line grounded; (d) positive line grounded. Notice that in both instances the potential difference (PD) is 12V.

The Earth is considered to be an infinite source of electrons at zero potential, thus if a part of a circuit is connected to 'earth' will also be at a zero potential. In a DC circuit you can earth either the negative or the positive lines (although not both). Figure 3 shows these arrangements and illustrates that if the negative line of a 12V DC supply is connected to earth it is held at zero potential and therefore the positive line is at a potential 12V above this. When the positive line is earthed it is held at zero potential and the negative line is at a potential 12V below this. Note that the potential difference remains at 12V no matter which line is earthed. Also note that the potential of the negative line is always lower than that of the positive lines, so that the direction that the current flows in does not change, and that the potential difference remains at 12V for both cases. Under normal conditions current does not flow down the earth wire because it is at the same potential as the point in the circuit to which it is connected.

2 AC Circuits

The potential difference between terminals of an AC supply changes with time, normally sinusoidal (figure 4). Therefore, which terminal is at a high potential and which at a low potential constantly changes, in figure 4 the + and – signs indicate this change an show that consequently the potential difference 'changes direction'. This means that the polarity of the terminals also constantly changes

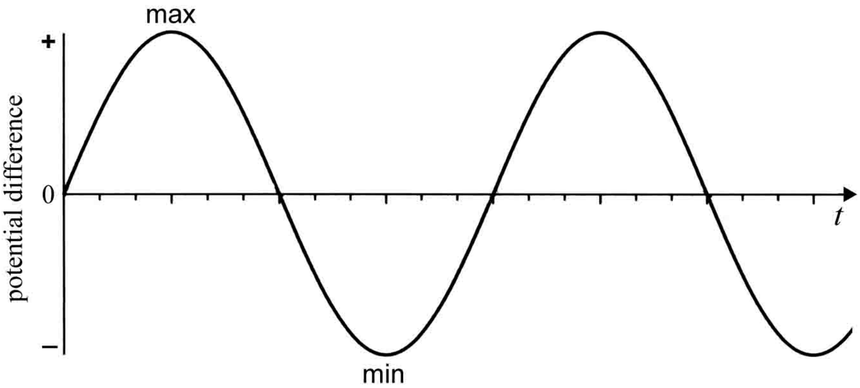

Figure 4: The potential difference between the terminals of a sinusoidal AC supply.

from + to – and therefore the electrons oscillate backwards and forwards over very short distances. Current is therefore also said to change direction, an this is also indicated by + and – signs.

In a simple AC circuit (figure 5) that is the equivalent to the DC circuit shown in figure 1, at first the polarity of terminal *a* is positive before becoming negative and so one. The polarity of terminal *b* changes so as to always be the opposite of *a*. As the polarity of the terminals changes so does their potential, and the terminal that is positive at a given time will be at a higher potential than the terminal that is negative. Consequently as the supply's terminals change potential, side *c* on the resistor changes from high to low potential, and side *d* also changes accordingly. Because of these constant changes we can not say that half of the circuit is at a high potential and half is at a low potential, as we did with the DC circuit. All these changes make AC circuits complex and so RMS values are used to calculate the heat dissipated in the resistor. The RMS values are defined so that the same heat is dissipated in a resistor when it is connected to 12V DC or 12V AC.

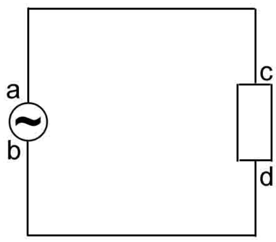

Figure 5: An simple AC circuit.

We can redraw the circuit (figure 6) so that we have two lines, one called the *phase* (or *line*) and the other called *neutral* (or *return*). Normally current flows in both lines and so both are *live*. Just like the DC circuit we can earth one side of the circuit so that the earthed line is always held at zero potential. Normally the neutral line is earthed and used as a common neutral and earth line.

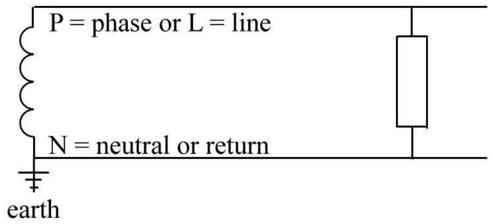

Figure 6: A simple AC circuit with the neutral earthed. The supply is shown as the output from the secondary coil of a transformer.

In a 240V AC supply the potential difference between the neutral and the phase terminals varies from +339V to -339V, since there is a potential difference between the terminals a current flows (constantly oscillating from on direction to the other). Even with the neutral earthed the potential difference across the supply's terminals still varies sinusoidal, therefore the electrons in the neutral wire still oscillate backwards and forwards, thus current does flows in an earthed neutral wire.

Figure 7 shows the shock hazards from an earthed neutral circuit. If you touch the neutral wire while it is carrying current you will not get a shock because you are earthed and the neutral wire is

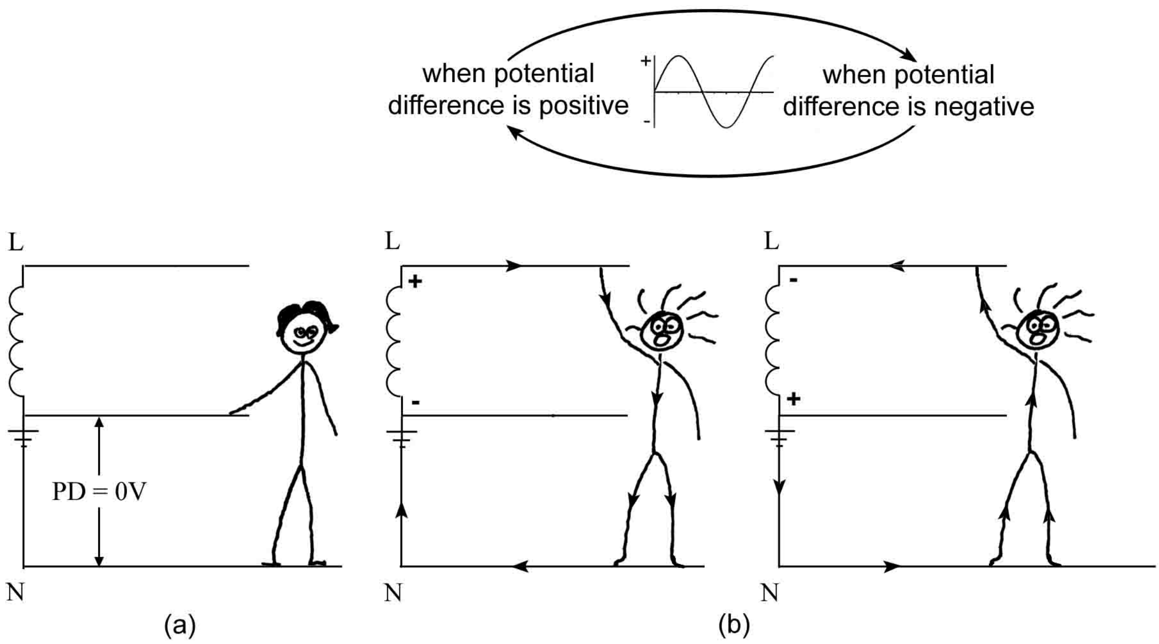

Figure 7: Shock hazards from an earthed neutral circuit: (a) touching the neutral wire; (b) touching the phase wire.

earthed, and therefore both are at the same potential. Touch the phase wire while it is carrying current and you will get a shock because you are earthed and at zero potential but the phase wire will be at a RMS potential of 240V, therefore a potential difference exists across your body. For these reasons the phase wire is often described as the *hot* wire.

To make circuit analysis easier, current is considered to flow from phase to neutral and RMS values are used. The phase terminal is sometimes given a + symbol and the neutral wire a – symbol so that a direct analogy is draw with DC circuits. However, be sure to realise that in AC circuits no net transfer of electrons occurs when current flows, the electrons just oscillate backwards and forwards.