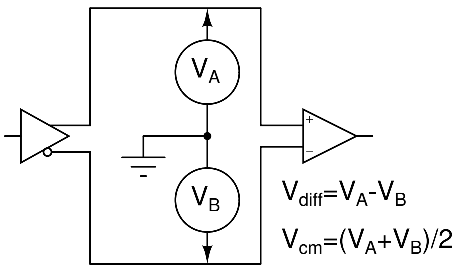
Differential Signalling

This lecture covers differential signalling.
After this lecture you should be able to: compute common-mode and differential voltages.

Differential Signalling

The voltage difference between two wires is the differential voltage. The average of the two voltages (each referred to ground) is called the common-mode voltage:



A differential transmitter encodes data as the voltage difference between its two outputs. For example, $V_A = +5$ V and $V_B = 0$ V for a logical '1' and $V_A = 0$ V and $V_B = +5$ V for a logical '0'. The differential receiver finds the differential volatage by subtracting the two voltages (resulting in differential volages of +5 V and -5 V for this example).

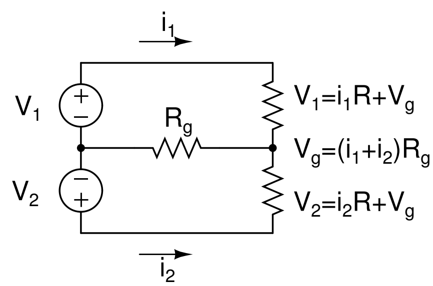
Data transmitted using the differential voltage (or current) is called differential signalling. Differential signalling is commonly used at higher speeds and longer distances where the use of a shared ("common") ground path can add noise as described below.

Noise From Shared Grounds

Some communication channels transmit over one conductor and use a return path that is shared with other circuits. These other circuits could be other communication links or could be used for power distribution.

One problem with common grounds is that the apparent "ground" voltage will be affected by all the return currents multiplied by the resistance of the return path. This results in a noise signal at the receiver that is proportional to the product of the sum of the currents on the return path and and the resistance of the return path. Therefore the common-ground approach is only practical where the product of the shared ground resistance and the shared current are small relative to the signal levels.

For example, in the figure below the current on one circuit (i_1) affects the "ground" voltage (V_g) and thus the voltage seen on the second circuit (V_2):

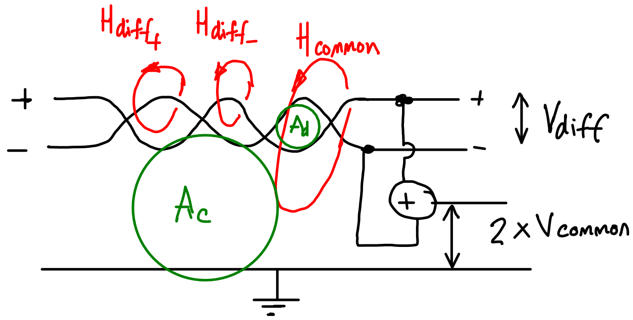


These effects can be particularly severe when the shared ground circuit is used as the return path for a power supply.

Differential signalling avoids this problem because the receiver only measures the voltage difference between the two conductors and ignores the ground voltage. Of course, the drawback is that each signal circuit requires two conductors.

Inductive Noise

The following diagram shows a twisted-pair transmission line running next to a ground return path. The differential and common-mode voltages are shown. Also shown are the two magnetic field loops which could cause differential and common-mode noise to be induced on the conductors (imagine the magnetic field direction perpendicular to the page):



The two conductors of the twisted pair are next to each other and the area between the wires (A_d) is much smaller than the area between the wires and ground (A_c). This will result in a smaller voltage being induced on the differential signal. In addition, the voltages induced on the twisted pair by the magnetic field (the parts of the field H_{diff+} and H_{diff-}) will cancel out due to the twisting.

Thus the use of differential signalling over twisted pair reduces induced noise both compared to common-mode signalling and compared to differntial signalling without twisted pair.

Shielding and Grounding

Some communication cables have a braided shield (similar to co-ax) to limit radiation from the signals carried by the cable. To avoid inducing noise on these signals and radiation from the shield, the shield should not act as a return path for other circuits.

In some cases the shield can be left disconnected at one end. Other techniques to prevent current flow along the shield are connecting the shield through a capacitor to block low-frequency currents and/or placing a ferrite cylinder around the shield to block high-frequency currents.