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level shifter

It is often necessary, particularly when experimenting with circuits, to make connection between the output of one circuit and the input of another which is at a different DC level. If the signals involved in the circuit are AC signals this is no problem, a capacitor can be used to isolate the DC levels while allowing AC signals to pass. However, when dealing with DC or very low frequency AC signals the solution is not so easy, and it is in these cases that this little gimmick will prove useful.

The circuit consists simply of an op-amp connected as a voltage follower whose quiescent output voltage can be set to any desired level within the output range of the op-amp.

Input A is connected to the output of the circuit in question while the output is connected to the input of the circuit which it is feeding. Input C is grounded, while input B is connected to a DC voltage equal to the difference between the input voltage of the second circuit and the output voltage of the first.

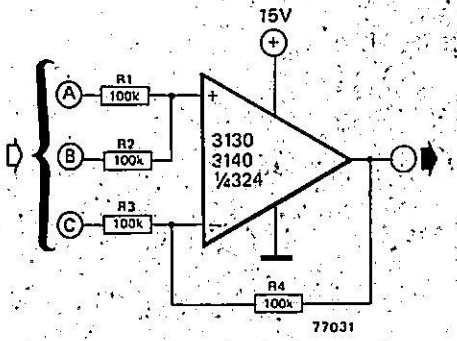
It can easily be proved that this works! Firstly, voltages appearing at the non-inverting input of the op-amp are amplified

by a factor $\frac{R_3 + R_4}{R_3} = 2$.

Secondly, suppose the output voltage of the first circuit is V_A and the input voltage of the second circuit is V_1. The voltage V_B applied to input B is thus $V_1 - V_A$. The voltage appearing at the junction of R1 and R2 is thus $V_A + \frac{V_B - V_A}{2}$.

The voltage appearing at the op-amp output is twice this, i.e. $V_A + V_B$.

But since $V_B = V_1 - V_A$ this equals V_1, the input voltage of the second circuit. Obviously, if V_1 is less than V_A then V_B will be a negative voltage.



Despite the difference in input and output levels the circuit functions as a voltage follower in that any change in the voltage at input A will produce the same voltage change at the output.

The circuit can also be used as an inverter. In this case the signal is fed to input C, B is grounded and A is fed with a DC reference voltage. To see what voltage must be applied to A it is simplest to treat the circuit as a unity gain differential amplifier. The output voltage V_O is equal to the difference between the voltages at the non-inverting and inverting inputs i.e. $V_O = V_A - V_C$ so $V_A = V_O + V_C$, i.e. input A must be fed with a voltage that is the sum of the voltage at C and the required output voltage. Any change in the input voltage at C will produce the same change at the output, but of opposite polarity.

Two points must be noted when using this circuit. Firstly, care must be taken not to exceed the common-mode input rating of the op-amp used, especially with a single-ended (asymmetric) supply. Secondly, the values of R1 to R4 should be at least ten times the output resistance of the circuit feeding the level shifter to avoid excessive loading of the output.