Interfacing Integrated Circuits of the same or different types

When connecting two integrated circuits of the same family (which means having the same input/output characteristics) it is usually OK simply to connect the output of one directly to the input of the other using a wire. However, it is often good engineering practice to introduce a current limiting resistor. Too much current flowing either into an input or out of an output can permanently damage an integrated circuit. Good engineering practice would need to consider the possibility of accidentally shorting an input or output to ground or to the supply voltage, or having some other error creep into the circuit. Good engineering practice would also consider that the actual supply voltage may vary by a certain percentage from its designated value.

The connection of one integrated circuit to another is even more complicated if the two circuits are of different families and designed to operate at different voltages. For example, some circuits are designed to operate at 5 Volts and others at 3.3 Volts. There are other families which operate at even higher and lower voltages. Interfacing different families of ICs can be more difficult than interfacing circuits of the same family.

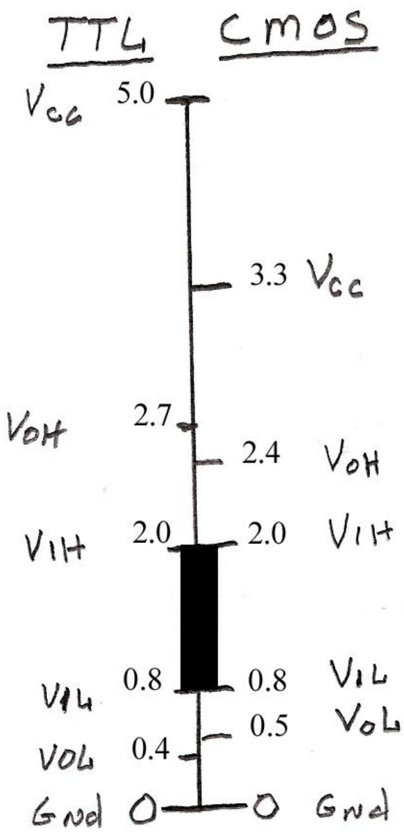
LEVEL SHIFTING:

Special integrated circuits exist which can convert logic levels between different families of ICs. However, the bulk of what we will be doing will be limited to single lines which need to connect between 3.3 V and 5 V devices. It would seem to be good engineering practice to reduce the parts count (and thus the cost and complexity) of the circuit.

Example 1:

We are using a Propeller microcontroller (a CMOS device which operates at 3.3 V). The Propeller's output pin is driving a TTL device which operates 5V. How do we get our 3.3 V output to drive a 5 V input?

The following diagram compares the specifications of CMOS and TTL devices:



Symbols:

VIH = minimum voltage on an input pin which is guaranteed to be interpreted as a high. Any voltage above this will be interpreted as high.

VIL = maximum voltage on an input pin which is guaranteed to be interpreted as low. Any voltage below this will be interpreted as low.

VOH = Minimum voltage on an output pin which is intended to be high.

VOL = maximum voltage on an output pin which is intended to be low.

Let's see how that works. Consider the TTL family. Any TTL device intending to send out a LOW will send a voltage of 0.4 V or lower. But since the receiving device interprets any voltage lower than 0.8 volts to be a low, all is well. In fact, there is a 0.4 volt margin of error.

Likewise if a TTL circuit intends to send out a HIGH it will send out 2.7 volts or more. However the receiving circuit will interpret any voltage over 2 volts to be high, there is a 0.7 volt margin of error.

How about voltages between 0.8 and 2.0? Since they are too high to be considered low and too low to be considered high, they are undefined. This is sometimes called the noise margin.

CMOS OUTPUT → TTL INPUT:
Now consider interfacing the OUTPUT of a CMOS device to the INPUT of a TTL device. Assuming they have identical grounds, you will see that the CMOS will send out 0.5 volts for a low. Since the TTL recognizes anything below 0.8 volts as a low, all is well. Similarly, if the CMOS is sending a high (2.4V) and the TTL recognizes anything above 2.0 V as high, again all is well. That leads us to the conclusion that it is OK to connect the output of a CMOS device directly to the input of a TTL device, assuming you are not drawing too much current from the CMOS device. However, introducing a 1K ohm resistor is a

good practice to avoid overloading the CMOS circuit due to an accidental short between the output pin and ground.

TTL OUTPUT → CMOS INPUT:

Since the TTL device can output voltages up to 5 volts and the absolute maximum voltage on an input pin of a CMOS device is 3.6 volts, there is a very real possibility that direct connection can cause permanent damage to the CMOS device. In this case there are several ways of shifting the signal levels. They include series resistors, transistors, optoisolators, solid state relays, and level translating integrated circuits.

The Propeller has been engineered in such a way that its I/O pins have protection diodes to drain current to the power supply or to ground, assuming there is enough series resistance to keep the current below the maximum permitted level. Because the Propeller is designed to be "5 V tolerant", all that is needed is a current limiting resistor. To connect TTL output to Propeller CMOS input you use a 10 K ohm resistor between the TTL output and CMOS input.