Let's make some measurements using one of the simplest combinational devices: a buffer.

A buffer has a single input and a single output, where the output will be driven with the same digital value as the input after some small propagation delay.

This buffer obeys the static discipline - that's what it means to be combinational - and uses our revised signaling specification that includes both low and high noise margins.

The measurements will be made by setting the input voltage to a sequence of values ranging from 0V up to the power supply voltage.

After setting the input voltage to a particular value, we'll wait for the output voltage to become stable, i.e., we'll wait for the propagation delay of the buffer.

We'll plot the result on a graph with the input voltage on the horizontal axis and the measured output voltage on the vertical axis.

The resulting curve is called the voltage transfer characteristic of the buffer.

For convenience, we've marked our signal thresholds on the two axes.

Before we start plotting points, note that the static discipline constrains what the voltage transfer characteristic must look like for any combinational device.

If we wait for the propagation delay of the device, the measured output voltage must be a valid digital value if the input voltage is a valid digital value - "valid in, valid out".

We can show this graphically as shaded forbidden regions on our graph.

Points in these regions correspond to valid digital input voltages but invalid digital output voltages.

So if we're measuring a legal combinational device, none of the points in its voltage transfer characteristic will fall within these regions.

Okay, back to our buffer: setting the input voltage to a value less than the low input threshold V_IL, produces an output voltage less than V_OL, as expected.

A digital 0 input yields a digital 0 output.

Trying a slightly higher but still valid 0 input gives a similar result.

Note that these measurements don't tell us anything about the speed of the buffer, they are just measuring the static behavior of the device, not its dynamic behavior.

If we proceed to make all the additional measurements, we get the voltage transfer characteristic of the buffer, shown as the black curve on the graph.

Notice that the curve does not pass through the shaded regions, meeting the expectations we set out above for the behavior of a legal combinational device.

There are two interesting observations to be made about voltage transfer characteristics.

Let's look more carefully at the white region in the center of the graph, corresponding to input voltages in the range V_IL to V_IH.

First note that these input voltages are in the forbidden zone of our signaling specification and so a combinational device can produce any output voltage it likes and still obey the static discipline, which only constrains the device's behavior for *valid* inputs.

Second, note that the center white region bounded by the four voltage thresholds is taller than it is wide.

This is true because our signaling specification has positive noise margins, so V_OH - V_OL is strictly greater than V_IH - V_IL.

Any curve passing through this region - as the VTC must - has to have some portion where the magnitude of the slope of the curve is greater than 1.

At the point where the magnitude of the slope of the VTC is greater than one, note that a small change in the input voltage produces a larger change in the output voltage.

That's what it means when the magnitude of the slope is greater than 1.

In electrical terms, we would say the device as a gain greater than 1 or less than -1, where we define gain as the change in output voltage for a given change in input voltage.

If we're considering building larger circuits out of our combinational components, any output can potentially be wired to some other input.

This means the range on the horizontal axis (V_IN) has to be the same as the range on the vertical axis (V_OUT), i.e., the graph of VTC must be square and the VTC curve fits inside the square.

In order to fit within the square bounds, the VTC must change slope at some point since we know from above there must be regions where the magnitude of the slope is greater than 1 and it can't be greater than 1 across the whole input range.

Devices that exhibit a change in gain across their operating range are called nonlinear devices.

Together these observations tell us that we cannot only use linear devices such as resistors, capacitors and inductors, to build combinational devices.

We'll need nonlinear devices with gain greater than 1.

Finding such devices is the subject of the next chapter.