Date: October 27, 2004
To: T10 Technical Committee
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Subject: SAS 1.1 PHY common mode transient reference paper

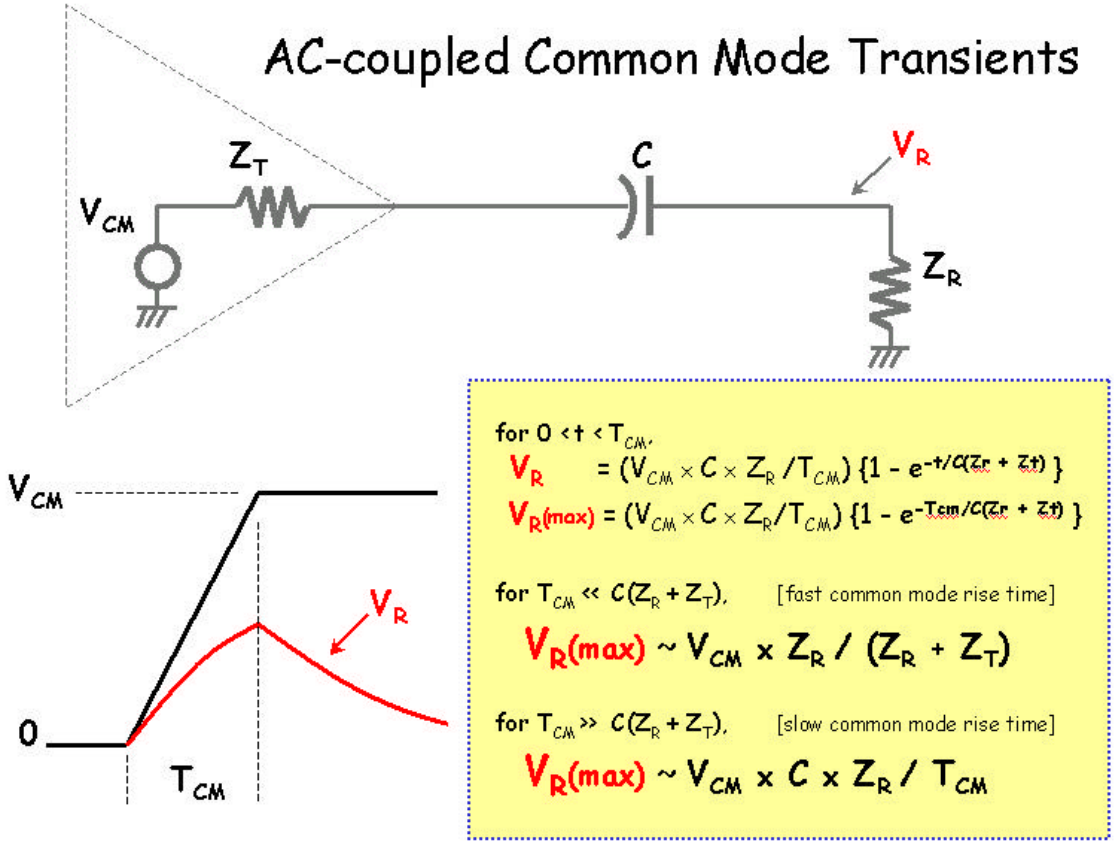
The attached reference material was used during the initial discussion of the common mode AC transient specification in 2002 that was included in proposal 02-349r4.

Techniques for Limiting AC-coupled Common Mode Transients

Problem: As gate oxide becomes thinner with each new technology, lower gate-to-drain and gate-to-source voltages can cause damage. Approximately at the 90 nm node, the clamping action of ESD diodes may no longer be adequate to protect some devices.

In AC-coupled nets, one end powering on or off can induce a transient on top of the normal bias voltage at the other end. This note will quantify this effect and suggest simple techniques for minimizing these transients, which might otherwise cause thin oxide damage.

The figure below shows a generalized circuit with near- and far-end termination separated by a DC-blocking capacitor. (For differential nets, these components represent the single-ended (i.e., *even mode*) values -- that is, one line of the differential pair.)



From the equation for V_R(max), useful approximations result in two limiting cases:

1. If the coupling capacitor time constant, $C(Z_R+Z_T)$, is much *larger* than the rise time of the common mode signal (that is, a *fast* common mode rise time), then the transient seen at V_R is smaller than the common mode voltage, V_{CM}, by the ratio, $Z_R/(Z_R+Z_T)$.
2. If the coupling capacitor time constant, $C(Z_R+Z_T)$, is much *smaller* than the rise time of the common mode signal (that is, a *slow* common mode rise time), then the transient seen at V_R is smaller than the common mode voltage, V_{CM}, by the ratio, $C*Z_R/T_{CM}$.

Some examples:

- If there is no effective far-end, common mode termination (Z_R is infinite), then V_R(max) equals V_{CM}, and the problem must be solved by further circuitry or restrictive specifications.
- If the maximum far-end termination is 80 ohms and the minimum near-end termination is 30 ohms, then V_R(max) is 80/110, or 73% of V_{CM} (assuming a fast rise in V_{CM}).
- If V_{CM} rises in 1 microsecond, C is 0.012 microfarads, and the terminators are as in the previous example, then V_R(max) is 51% of V_{CM}. (This uses the exact formula for V_R(max), since neither of the limiting cases apply.)
- If, in the previous example, V_{CM} rises in 50 microseconds or more, then V_R(max) is ***less than 2%*** of V_{CM}.

Considering the above, a specification limiting AC-coupled common mode transients induced by power on and power off could be met either by limiting the magnitude of the circuit's common mode voltage or (if maximum and minimum common mode termination has been specified) by limiting the speed of the power supply turn on and turn off.

Of course, the specification value for the maximum common mode transient also must be established. Beyond the technology limitations on gate-to-drain and gate-to-source voltage, how restrictive this limit must be is also a function of circuit topology and design, including judicious use of thicker gate oxide devices in I/O circuits.

Summary: For AC-coupled nets, a designer has considerable flexibility to meet a common mode transient specification either by:

a) limiting the bias voltages (i.e., common mode voltages) of the transmitter and receiver circuits or by
b) limiting the speed (dV/dt) at which that bias voltage turns on and off.

But these options are available only if min and max common mode termination values, as well as a maximum coupling capacitor value, are specified.