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Issues with Implementing Transmitter Pre-Compensation

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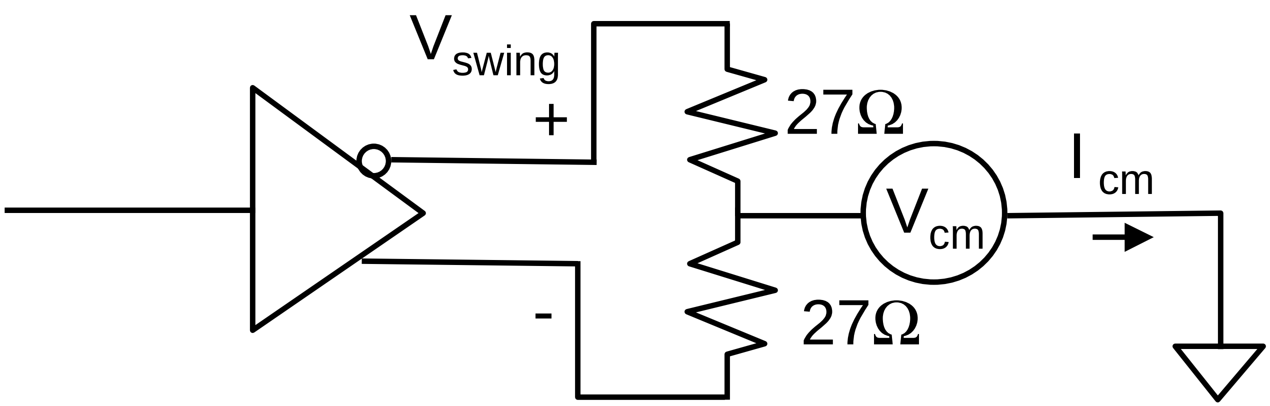
Tx Pre-comp Design Issues

- Amplitude sensitivity to common-mode voltage.
- Effects on driver Z_{out} and common-mode operating point.
- Feasibility of driving output stages harder.
- Feasibility of larger output stages.
- Slew rate issues.
- Effects on NEXT and FEXT.
- Power dissipation concerns.
- Power efficiency of a boost driver strategy.

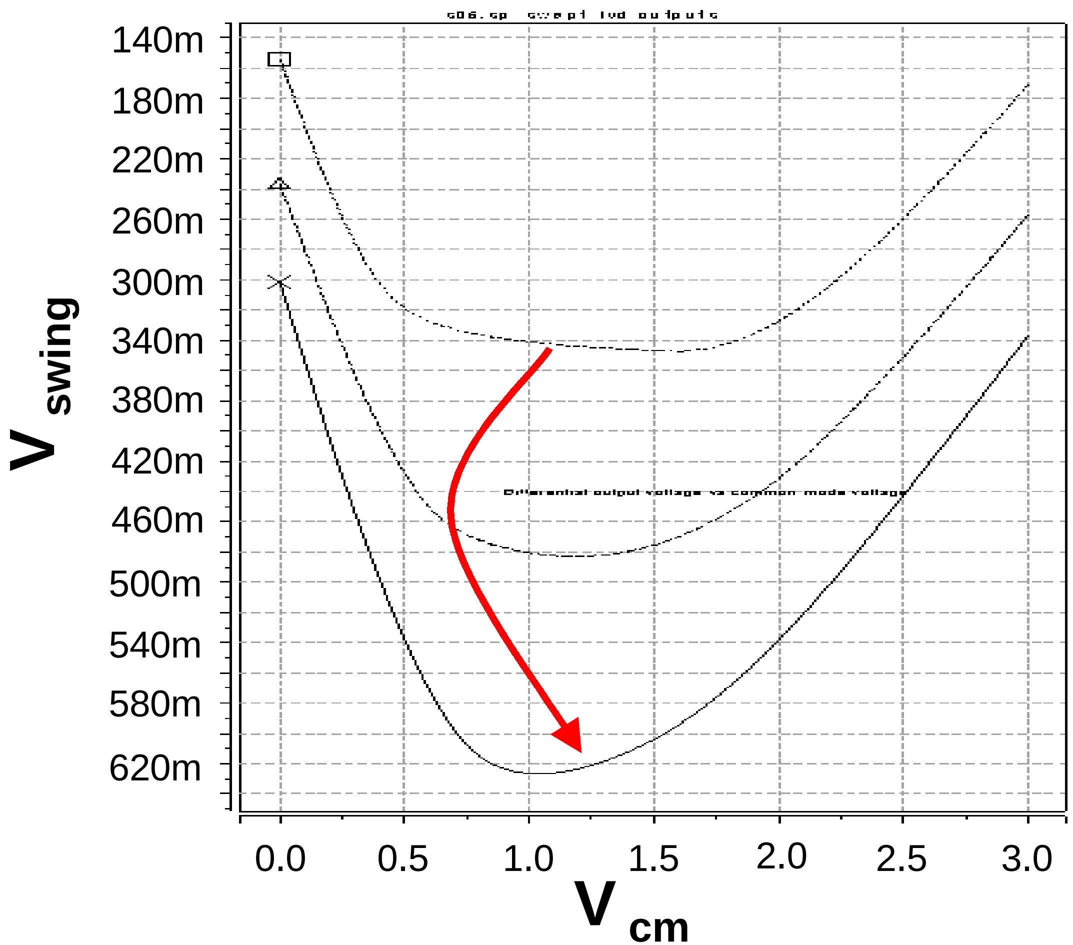
V_{swing} and I_{cm}

- It's difficult to drive more current with existing current-mode drivers
- Simulation circuit for observing differential V_{swing} and I_{cm}
  - Without terminator, negation swings smaller by 115mV



V_{swing} versus swept V_{cm}

- LVD V_{swing} for V_{cm} swept from 0V to 3.0V
- Currents are highly variable outside of the allowed common-mode range.



Increased driver amplitude

I_{cm} versus swept V_{cm}

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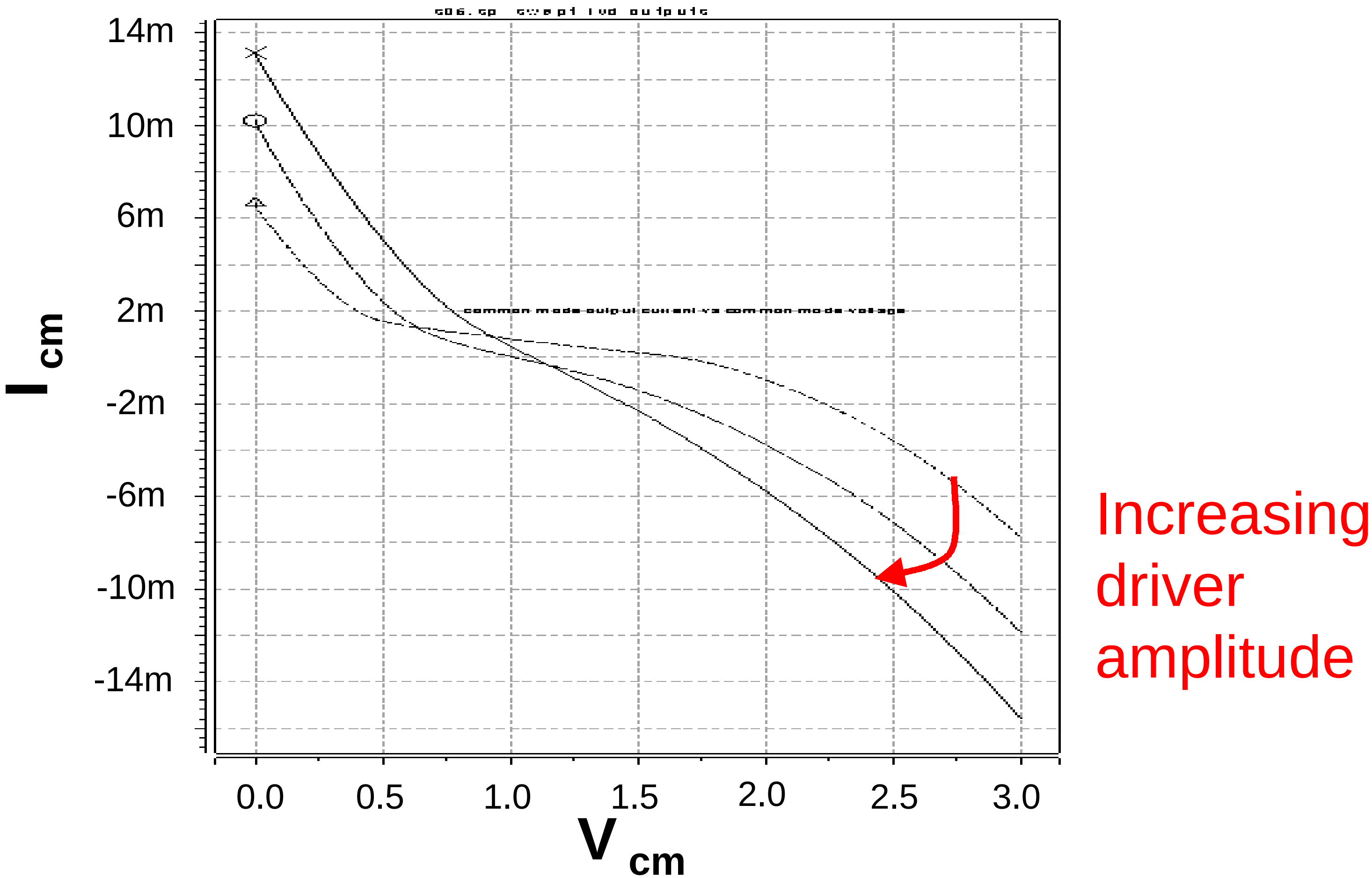
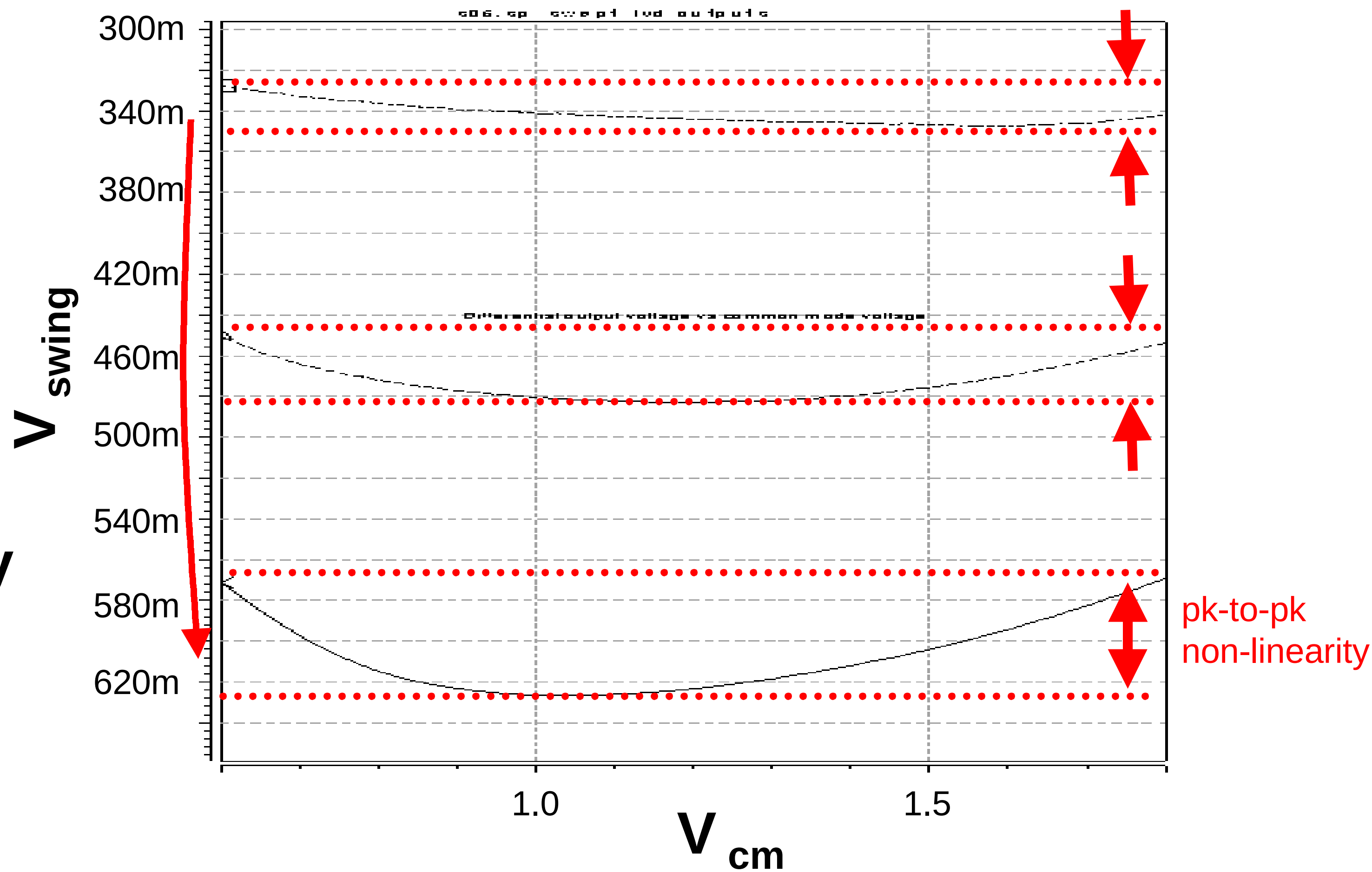


V_{swing} across common mode range

- Usable range (0.855V - 1.645V) V_{swing} versus V_{cm}
- Linearity degrades with increasing signal amplitude

Increasing driver amplitude
⇒
increases non-linearity



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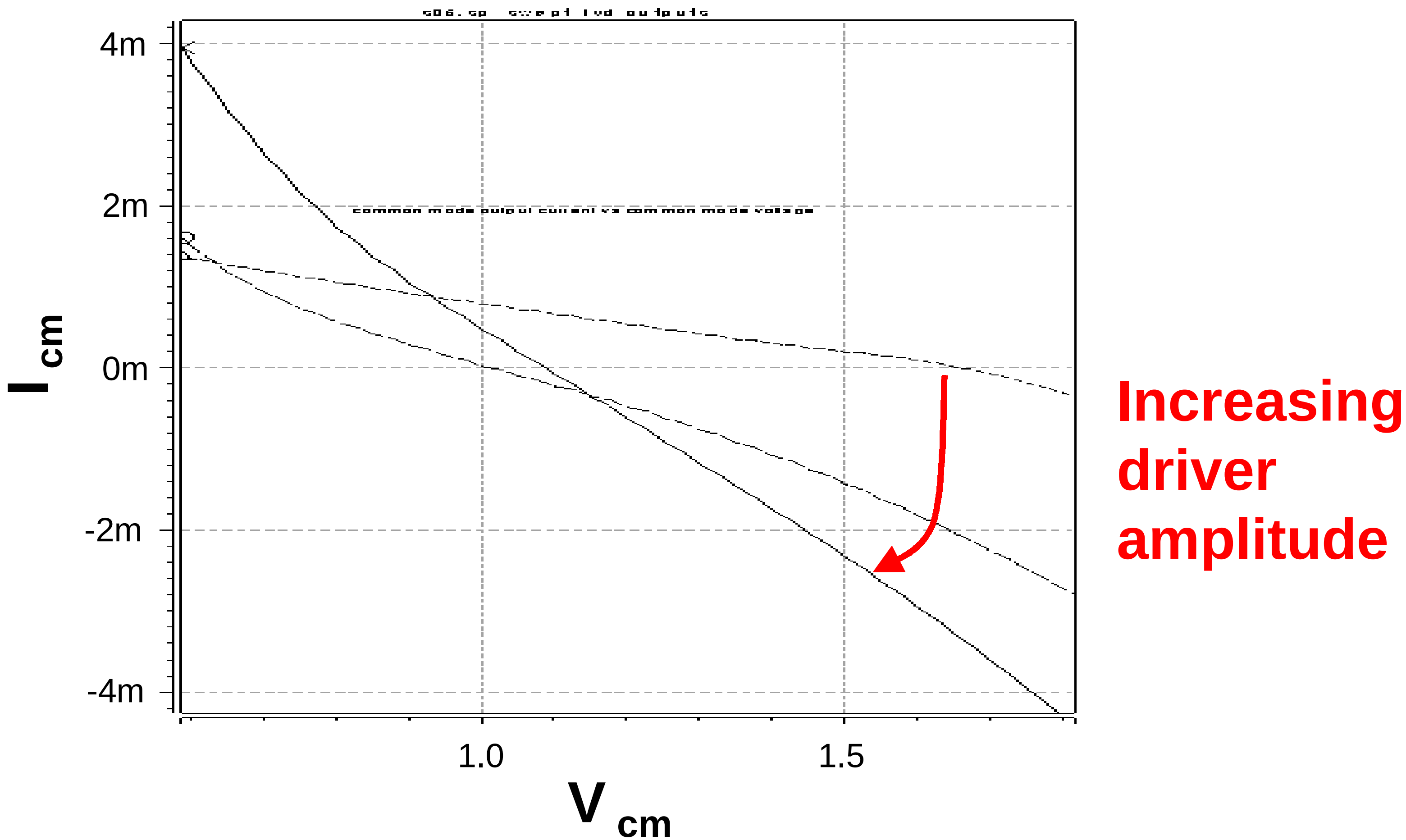


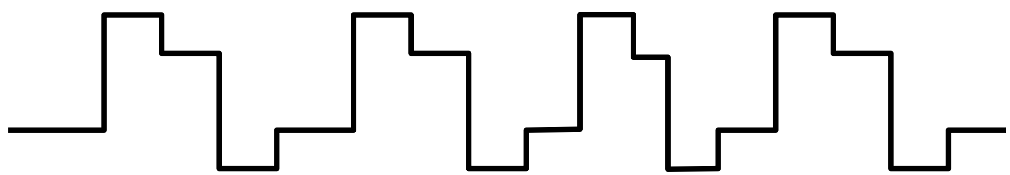
Issues Using Existing Structures

- Differential V_{swing} becomes a strong function of V_{cm}.
- D.C. common-mode current increases (lower Z_{out} for LVD current mode driver).
- Current sources are more problematic.
- Common-mode noise from 3.3V supply increases.
- Turning on and off a “boost driver” will result in common-mode glitches during driver enable and disable.
- Turning on and off a “boost driver” will result in a high frequency common-mode pulses on the bus.

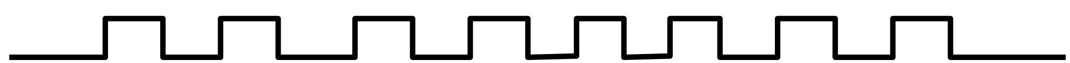
Issues Using Existing Structures

- **Consider a 11001100 data pattern, on a driver with 1.0mA of common-mode mismatch.**
- **An 80Mhz common-mode signal will be present on the bus, with levels 1.0mA and 1.8mA.**
- **Common-mode voltage waveform depends on the local common-mode line impedance and on common-mode reflections off of the terminator.**

110011001100
differential waveform



110011001100
Common mode
waveform



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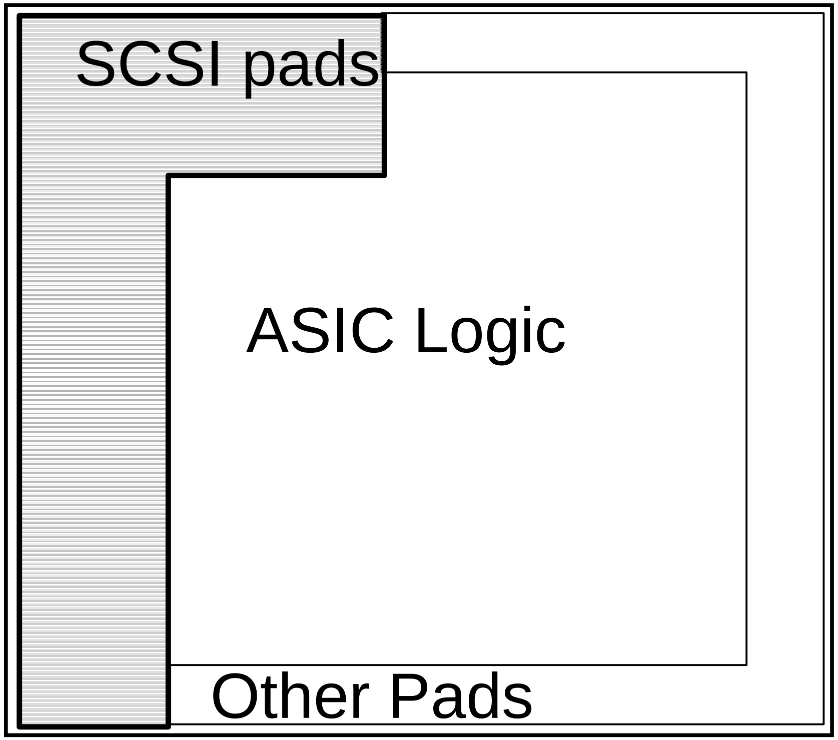
Issues Using Existing Structures

- A 68 wire cable can have up to 32 wires with identical common mode waveforms.
- Common-mode cross-talk is not helped by twisting wires.
- EM Radiation is a concern.
- At 80MHz a 2 meter cable is an efficient antenna.

Issues With Larger Structures

- **Die area increases**
- **SCSI pads already a large fraction of ASIC die area**



Issues With Larger Structures

- **Capacitance would increase for an "off" driver**
  - **Estimate an increase of 1.2 to 2.5pF to ground on bus- and bus+.**
  - **Possible problem with 15pF limit in standard for some vendors.**
  - **Very likely problem with the tighter capacitance limits in some customer purchase specs for most vendors.**
  - **Backward compatibility problem (Fast-40 or Fast-80) for back-planes which were marginal with current generation drives.**
  - **More capacitance would invalidate all eye-diagram data taken to date.**
- **Some back-plane impedance would drop below 85 Ω with added capacitance.**

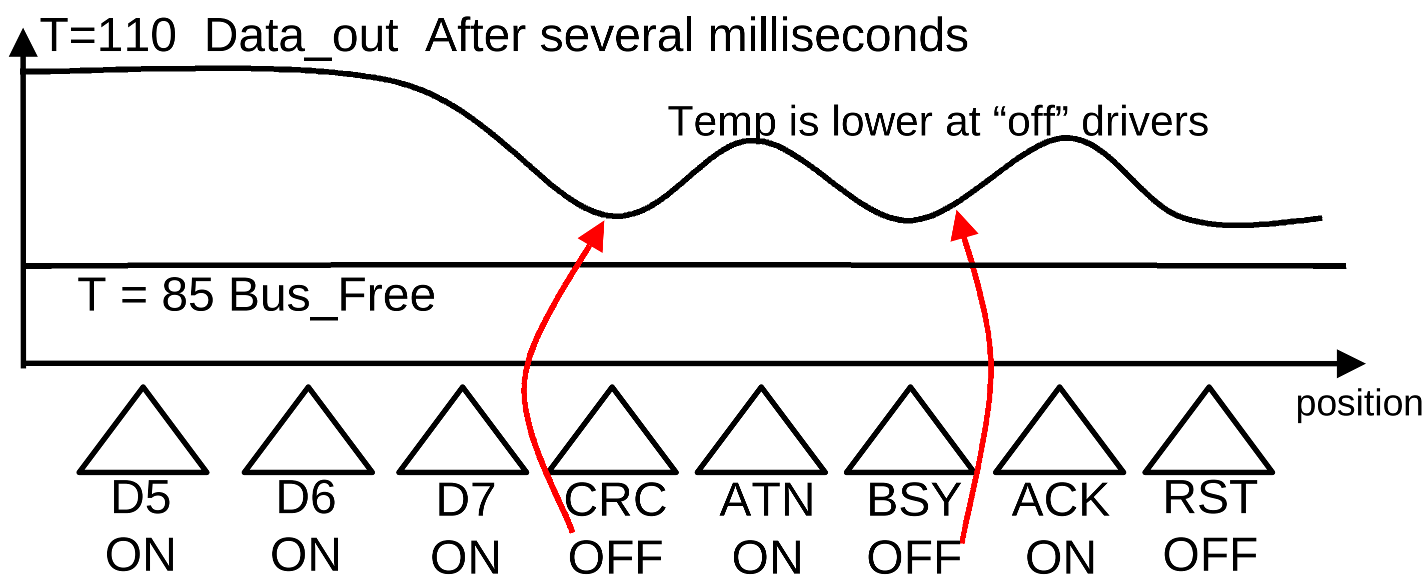
Thermal Issues

- **Chip heating will be greater as average drive power is increased.**
- **Power delivered to bus increases by the product of the boost factor (1.5, 1.8, …) and the transition density (100% for a 101010 pattern).**
- **Larger thermal gradients across die, making line to line timing de-skew less accurate.**
- **Larger delta temperature between first bits in data transfer and those driven after thermal equilibrium is reached.**
- **In SCSI targets, LVD power already over half of die power.**
- **More elaborate thermal management on target PCBs?**
- **Added power in the pad ring will undermine the chip’s timing performance.**

Thermal Issues

- **When LVD drivers are enabled on the bus, it takes over a millisecond to reach thermal equilibrium.**
- **Driver temperature also depends on adjacent heat sources (other enabled drivers).**
- **The temperature difference between REQ/ACK and Data will change over time.**

Thermal profile of driver output stages parallel to die edge



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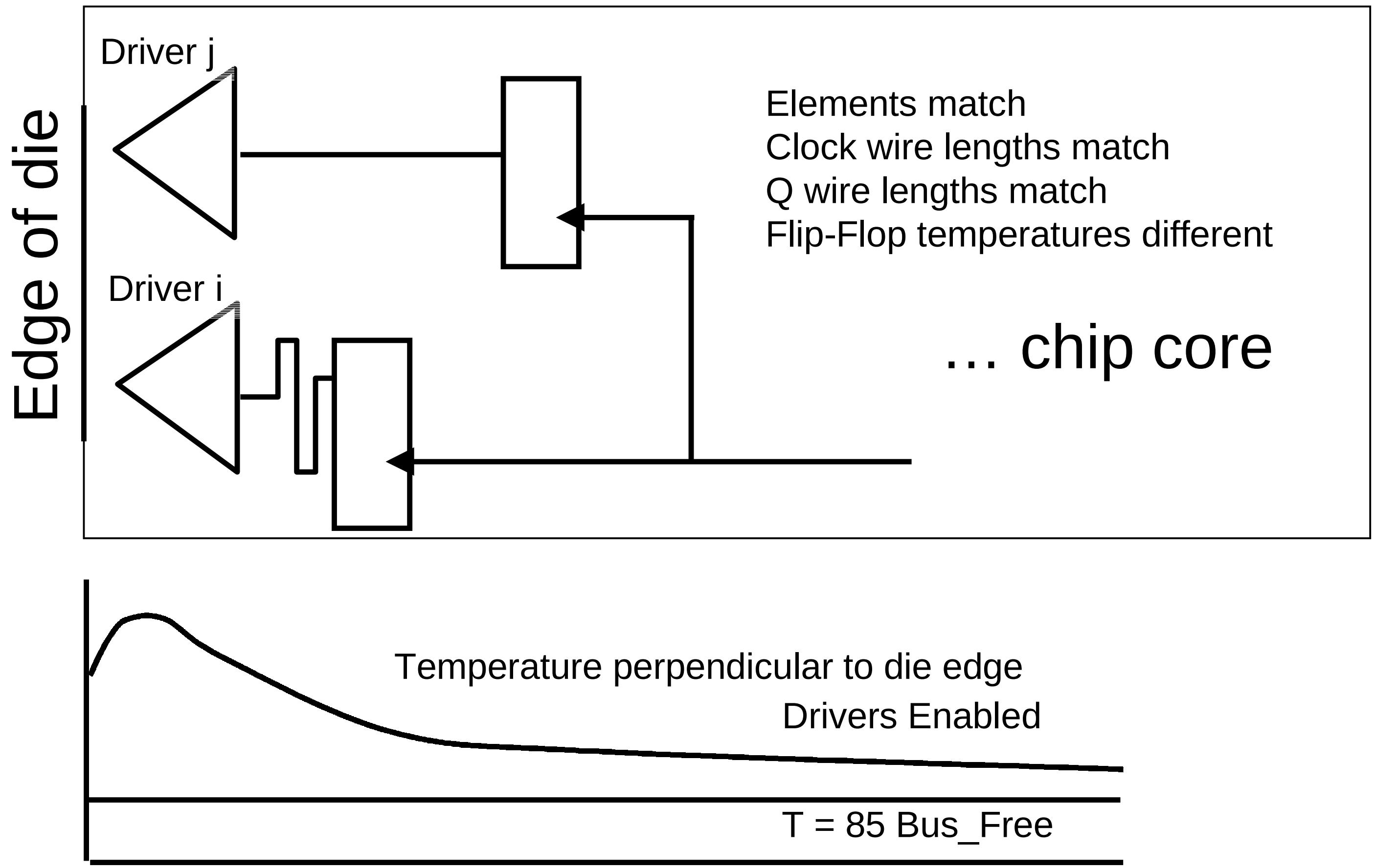
Thermal Issues

- **CAD tools cannot cope with elements at different temperatures.**
- **Adding more heat to the pad ring makes timing optimization harder.**



Slew Rate Issues

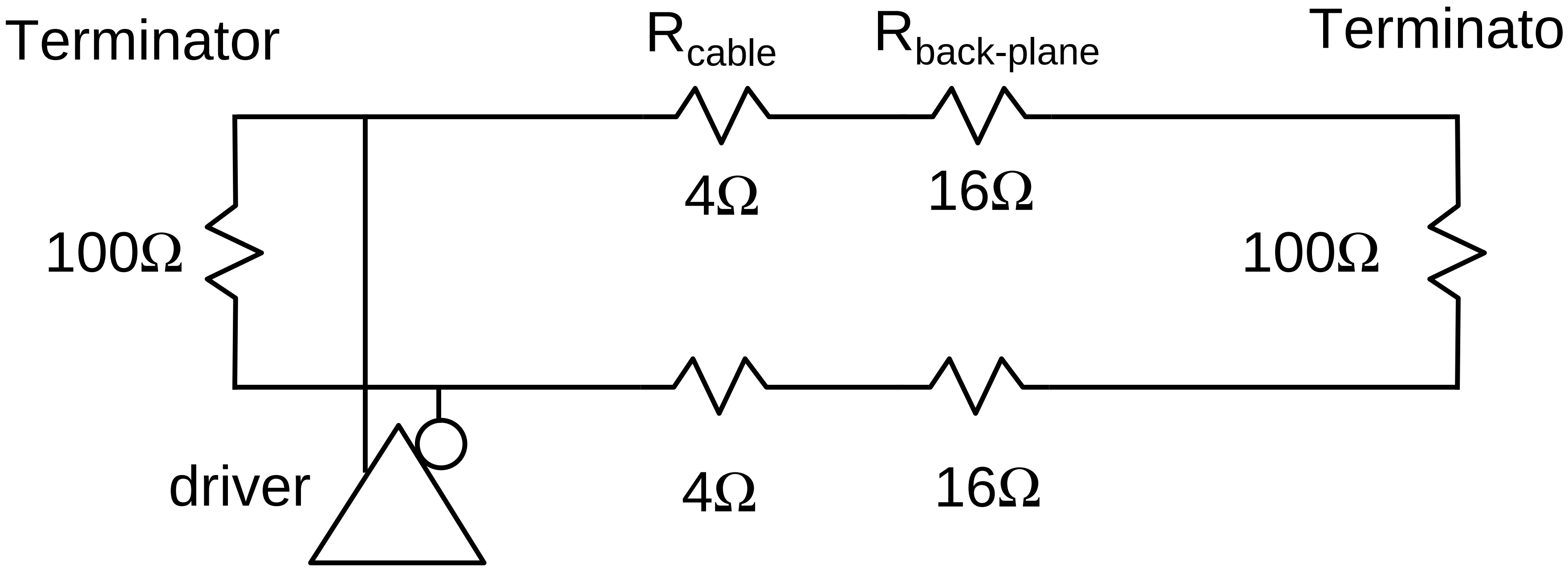
- The higher swings must be obtained with the same rise and fall times as in U160 products.
- Higher slew rates result, and will result in increased ringing at the transmitter.
- Higher slew rates will increase the number of stubs which cause problem reflections.
- Currently, any misalignment of pull-up and pull-down pre-drivers leads to a common-mode glitch during a data transition. With a “boost driver”, there are 4 pre-drivers to align instead of the current 2 pre-drivers.
- Sensitivity of common mode transition noise to the ASIC chip package and board mismatches (between bus+ and bus-) will increase.

Cross-Talk Issues

- **Near End Cross-Talk (NEXT) will increase due to the greater ∂i / ∂t on the driven wire pairs.**
- **Far End Cross-Talk (FEXT) will increase due to the larger voltage swings being driven.**
- **Ratio of coupled cross talk signal to quiescent signal will increase by the boost ratio.**
- **Increased intra-chip coupling through power and ground rails from non-constant current driver.**

Boost Drivers are Inefficient

- **Worst case buses have substantial series resistance.**
- **Net load R is 58 Ω.**
- **Adding 1.0mA to driver, adds 58mV to driver (cross-talk source)**
- **Adding 1.0mA to driver adds only 41mV at far terminator.**
- **Adding energy at the transmitter is inefficient.**



Summary of Circuit Design Issues

- ❶ Current source non-linearity versus drive current.
- ❷ Added common mode signals and noise.
- ❸ EM radiation issues.
- ❹ Limits for cables with substantial in-phase common mode signal.
- ❺ Additional capacitance needed.
- ❻ Power increases resulting in increases in local junction temperatures.
- ❼ Temperature profile issues relative to timing budget.
- ❽ Optimal transmitter pre-comp drive levels not yet determined.
- ❾ No proposals yet for transmitter pre-comp algorithms.

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Conclusions

❶ A transmitter pre-comp design which helps ISI without causing significant new problems is not trivial.

❷ The high multipliers (1.5x - 1.8x) are a major departure from existing LVD technology, and add a lot of risk to U320.

❸ Side effects of high ratio transmitter pre-comp will cause problems with backward compatibility and multi-vendor interoperability.

❹ We should consider other alternatives.