Using Decoupling Capacitors in 3.3-V Systems

A power supply decoupling structure is like a tree, starting at the supply and ending at the individual Vcc pin. At each level, you should not allow a voltage drop (delta V) of more than 30 mV.

General Formula: delta V = I • t / C

The following example shows how to calculate capacitor values in a typical application. These calculations ignore the series inductance in each capacitor, and make assumptions about power and frequency that may not fit every application.

There is a decupling capacitor at every Vcc pin. A dc current of 200 mA per pin is a reasonable assumption, but this current might come as a 1-Amp spike with 20% duty cycle at perhaps 40 MHz:

C= 1 A • 5 ns / 30 mV = 150 nF = 0.15 µF

This capacitor also must support the charging of load capacitors. Let's assume eight pins with 50 pF each = 400 pF total:

C= 3 V • 0.4 nF/ 30 mV = 40 nF = 0.04 µF

This means that a 0.1 µF decoupling capacitor is marginal for supplying the internal dynamic current (1 A•5 ns), but can easily supply eight full-swing outputs.

There is a larger capacitor, one per device, that evens out slower current changes. This capacitor might supply 5 Amps dc for a microsecond:

C = 5 A•1 µs / 30 mV = 150 µF.

At the output of the switching supply is a capacitor that supplies 50 Amps to the whole board, and covers the 100 kHz period of the switching supply:

C= 50 A • 10µs / 30 mV = 15,000 µF.

Vcc decoupling is important, and becomes more critical as chips get bigger, as clock frequencies and supply current increase, and as supply voltage decreases. ◆