Application Bulletin AB-8

Power Supply Bypass Capacitor Selection

Capacitor Selection

Most of the energy in digital pulses lies in the area below F_{knee}, where:

$$F_{knee} = \frac{0.5}{t_r}$$

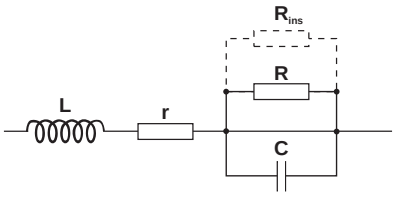
and t_r is signal rise-time.

For *IsoLoop* Isolators:

$$F_{knee} = \frac{0.5}{3 \times 10^{-9}} = 167\text{MHz}$$

This frequency may be considered the analog "bandwidth" of the device.

At higher frequencies (fast-rising edges), capacitors do not act as pure capacitors. Capacitors have parasitic lead inductance and parasitic series resistance called equivalent series resistance ("ESR"). These effects tend to reduce decoupling effectiveness at higher frequencies. A capacitor equivalent circuit is shown in Figure 1:



R = dielectric losses.
R_{ins} = insulation resistance.
r = transfer resistance between electrodes and terminating wires.
L = self inductance.

Figure 1. Equivalent circuit of a capacitor at high frequency.

Capacitor inductance is the component with the largest effect on ESR. A typical electrolytic capacitor has an inductance of around 10 nH – 20 nH, while a typical surface-mount ceramic capacitor has an inductance of around 500 pH. If we then look at the impedance of these capacitors, we can see the effect this inductance has on decoupling:

For an electrolytic capacitor:

Inductive Impedance = Z_L

$$Z_L = 2 \pi f L$$
$$= 2 \times 3.142 \times 1.67 \times 10^{8} \times 20 \times 10^{-9}$$
$$= 21\ \Omega$$

For a ceramic capacitor:

Inductive Impedance = Z_L

$$Z_L = 2 \pi f L$$
$$= 2 \times 3.142 \times 1.67 \times 10^{8} \times 500 \times 10^{-12}$$
$$= 0.5\ \Omega$$

The peak current in IsoLoop parts is approximately 40 mA per channel. Ohm's Law provides the instantaneous voltage drop at switching:

Electrolytic capacitor

$$V_{drop} = I \times Z_L$$
$$= (0.04\ A) \times (21\ \Omega)$$
$$= 0.84\ V$$

Ceramic capacitor

$$V_{drop} = I \times Z_L$$
$$= (0.04\ A) \times (0.5\ \Omega)$$
$$= 0.02\ V$$

It is apparent from this example that if more than one channel switches at the same time, the supply voltage could drop below the minimum operating voltage of the device. Therefore it is extremely important to use the correct capacitor type. ***Always use ceramic capacitors***. Use ceramic chip capacitors if possible since they have the lowest ESR. Polypropylene capacitors also have low ESRs, although they are more expensive.

Capacitor Placement

Decoupling capacitors as close as possible to the IsoLoop V_{dd} pins minimizes the resistive and inductive effects of printed circuit board traces, limiting the unwanted voltage drops discussed earlier. The importance of correct decoupling capacitor placement to ensure trouble-free operation cannot be overstressed. Arrows show correctly placed capacitors in Figure 2:

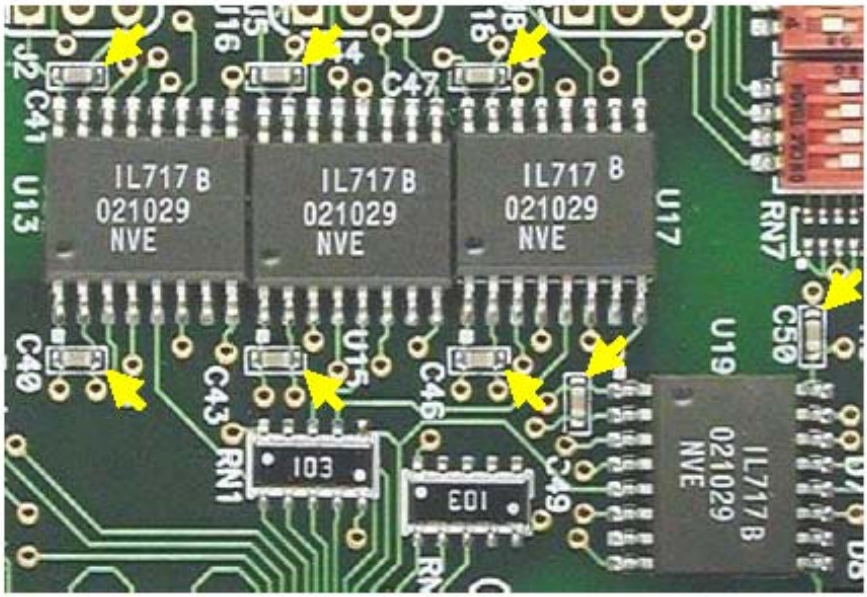


Figure 2. Correct placement of decoupling capacitors.