[**The Number 1 Design Mistake**
I saved the very best and most common mistake for last. And it doesn't even involve an op amp. It involves support components: the decoupling capacitors!
In Chapter 1, I mentioned some part numbers that are etched in the memory of every design engineer, at least those involved in analog design. There is one other: 0.1 mF.
Need to decouple? OK, everybody knows you put a 0.1 mF capacitor on every power supply input and the job is done, right? I can disprove that truism very easily with two words: cell phone.
Put your cell phone near your prototype circuit, which is bypassed with 0.1 mF, and make a call while monitoring the output on a high bandwidth oscilloscope. You will see horrendous 2.4 GHz leakage!
An alternative version of this problem came from some cellular telephone base station installers who called in a panic, "We have 90 MHz noise running all over our system—and can't figure out where it is coming from." A suspicion on my part asked them to tell me the exact coordinates where they were installing the system, and they provided the exact latitude and longitude. A quick check of the FCC database revealed the problem. I asked them, "Are you anywhere near the tower for W____ 90.5 FM, a 100,000 W NPR station listed at those coordinates?" They told me on the phone that they could see the transmitter 5 ft away—they were colocating with the station!
The point of this is that their board was bypassed with 0.1 mF capacitors. While that worked fine for the digital portions of the board, the analog portions were being clobbered by radiation of the powerful 90.5 MHz FM station. Conventional thinking is that the lower the value of capacitance, the lower the frequencies it will filter.
So, 0.1uF should get rid of just about everything because it is a very large value (relatively speaking). This conventional wisdom is wrong! The actual case is the exact opposite.
Where did the value 0.1 mF come from, anyway? A high technology store near me used to have antiquated computer boards as a wall decoration. Backlit with white light, the translucent green boards made a pretty sight. But, they were also populated with 0.1 mF decoupling capacitors. A quick survey of the circuitry revealed that the clock rate of the old computer had been 1 MHz.
So, the 0.1 mF capacitor value seems to have come from bypassing TTL logic in the 1960s! Isn't it time to rethink the issue a bit, in light of op amps and other analog components that can operate to frequencies of 3 GHz, especially when almost every engineer carries a 2 W, 2.4 GHz transmitter into the lab (cell phone)?
The reality of the situation is that a good 0.1 mF capacitor with an X7R dielectric exhibits a resonance in the 10 MHz region. This is due to parasitic inductance creating an LC circuit. Below 10 MHz, its impedance is capacitive, decreasing almost linearly on a logarithmic plot until it reaches the resonant frequency. Above the resonant frequency, the impedance is inductive. Since inductor resists the flow of high frequencies and passes only low frequencies, the decoupling capacitor is useless above its resonant frequency.
Looking at representative plots from capacitor manufacturers, at 100 MHz, the venerable 0.1 mF bypass capacitor has become an inductor with an XL of at least 1 O. By 2.4 GHz, XL has risen to above 10 O.
A good rule of thumb for effective bypassing is to put several capacitors in parallel. The standard 0.1 mF capacitor does quite nicely for frequencies up to 10 MHz, a 1000 pF NPO dielectric does nicely up to 100 MHz, and 33 pF NPO eliminates frequencies in the 2.4 GHz region. Bulk decoupling of the power supply as it enters the board eliminates low frequency ripple.
Here is a truism to replace the older one: When poor decoupling is suspected, decrease (do not increase) the value of the capacitance.]