ISCE

The Institute of Sound and Communications Engineers

Engineering Note 16.2

Rectifier filter capacitors

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Usually, the value of the filter capacitor has to be chosen to get no more than a certain amount of ripple voltage across it. The formula connecting the peak-to-peak ripple voltage with the d.c. load current I_{dc}, the input frequency and the capacitance value is:

$V_{ripple} = I_{dc}/2fC$

For a full-wave rectifier on 50 Hz mains, f is 100 Hz. A ripple voltage of 5% of the d.c. output voltage is a reasonable value for an unregulated supply, and for a regulated supply where there is not much voltage to spare across the regulator. And if you can accept 10%, you just halve the capacitance value result. We can modify the ripple formula this way:

$C = I_{dc}/(2fV_{ripple})$.

So $C \times V_{dc} = I_{dc}/\{2f(V_{ripple})V_{dc})\}$.

If I_{dc} =1 A and $V_{ripple}/V_{dc} = 0.05$, (= 5%)

$C \times V_{dc} = 10/f$ or, more conveniently,

$C = 10/fV_{dc}$ per amp of output current, and for 50 Hz mains, it's even simpler:

$C = 1/10V_{dc}$, per amp of output current, C in farads

For example, if V_{dc} = 20 V and I_{dc} = 1 A, C = 10/(100 x 20) = 0.005 F = 5000 μF.

Of course, for a 20 V supply at 20 mA, 100 μF is enough!

Well, that's the value settled, but what about the ripple current rating, which you ignore at your peril?

The ripple voltage waveform is a sawtooth, so the r.m.s. voltage at the fundamental frequency is V_{ripple}/π. This voltage is across the capacitive reactance and the Equivalent Series Resistance (ESR) of the capacitor in series. Unless the I_{dc} is many amps, we can err on the safe (high) side and assume the ESR is zero, otherwise it adds in quadrature (root-sum of squares) to the capacitive reactance. But the sawtooth waveform contains the fundamental frequency and a (theoretically infinite) series of harmonics. For each harmonic, the capacitive reactance is smaller than for the fundamental by a factor equal to the harmonic order n, but the harmonic amplitude is smaller by a factor n^2 (in a simplified theory; in practice, some of the amplitudes are even smaller). So the harmonic ripple current is smaller by a factor n, and the heating effect (which is what matters) is smaller by a factor n^2 and can largely be neglected. We are left with:

$I_{ripple} = V_{ripple}/\pi \times 2\pi fC$

But $C = I_{dc}/2fV_{ripple}$

So $I_{ripple} = V_{ripple}/\pi \times 2\pi f\, I_{dc}/2fV_{ripple}$

$= I_{dc}$

It's difficult to get simpler results than that!

If the effect of the harmonic currents is of concern, simply add 10% to 15% to the ripple current rating calculated as above, to allow for the factor (1/9 + 1/25 + 1/49 +…) for the additional power dissipation in the ESR.