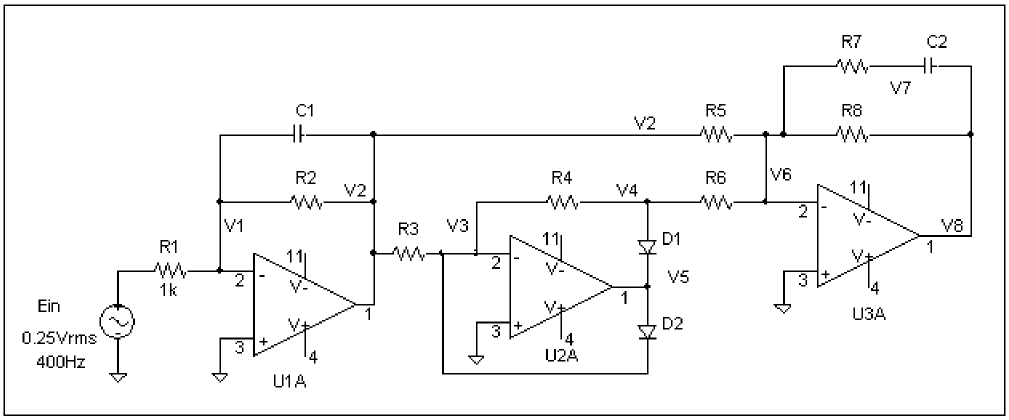
Tolerance Analysis of a 400 Hz Full-wave rectifier circuit

The transient analysis of a 400 Hz full-wave rectifier can be simplified by converting to an equivalent dc circuit. A RSS/EVA is then performed on the equivalent circuit.

This circuit is used in an aircraft AC power control system. The 0.25Vrms input in the circuit diagram below is from a step-down current transformer and represents 250Arms of ac bus load on the aircraft's electrical system. Hence this must be monitored for under and over-current conditions. The 0.25Vrms is rectified to +5Vdc at the output of U3A. Window comparators following this stage are tripped if the dc output exceeds specified levels.

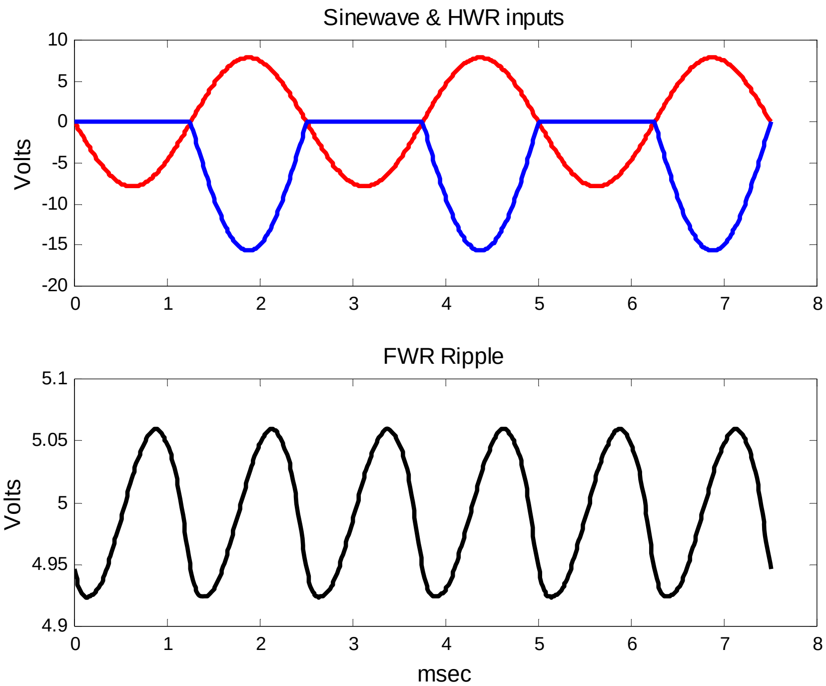


This analysis is facilitated by the fact that the output of U2A half-wave rectifier at the anode of diode D1, does not include the diode forward drop. Hence it can be modeled as ideal. Fourier coefficients of a halfwave rectified sine wave are used to simulate the output of U2A.

MATLAB M-files: hwrsine2.m; simp3a.m; hwr.m

The blue trace in the top plot represents the current in R6, while the red trace represents the current in R5. When these two currents are summed by U3A, the output is a full-wave rectifier before filtering by R7 & C2.

The lower FWR Ripple plot is an expanded view of the output after filtering. This is equivalent to putting a scope in the AC mode and observing the output.



Dc Equivalent Circuit Derivation

On the positive half-cycle of the 0.25Vrms 400 Hz ac input, the output of U3A is

$$\mathrm{Vo1} = \frac{\mathrm{Vin} \cdot \mathrm{R2} \cdot \mathrm{R8} \cdot \sqrt{2}}{\mathrm{R1} \cdot \mathrm{R5}} = +7.857 \text{ Vpk}$$

On the negative half-cycle of the input this will be –7.857 Vpk, which we will call Vn2

The output via U2A on the negative half-cycle of the input is

$$\mathrm{Vn3} = \frac{\mathrm{Vin} \cdot \mathrm{R2} \cdot \mathrm{R4} \cdot \mathrm{R8}\sqrt{2}}{\mathrm{R1} \cdot \mathrm{R3} \cdot \mathrm{R6}} = +15.713 \text{ Vpk}$$

The dc average over one complete cycle is then

$$\frac{\mathrm{Vo1} + \mathrm{Vn2} + \mathrm{Vn3}}{\pi} = \frac{\mathrm{Vin}\sqrt{2}}{\pi}\left(\frac{\mathrm{R2} \cdot \mathrm{R8}}{\mathrm{R1} \cdot \mathrm{R5}} - \frac{\mathrm{R2} \cdot \mathrm{R8}}{\mathrm{R1} \cdot \mathrm{R5}} + \frac{\mathrm{R2} \cdot \mathrm{R4} \cdot \mathrm{R8}}{\mathrm{R1} \cdot \mathrm{R3} \cdot \mathrm{R6}}\right)$$

(Note: The average over one cycle of a FWR sine wave is $2/\pi$; the average over one half cycle is $1/\pi$.)

The first two terms on the right hand side cancel giving

$$\mathrm{Vdc} = \frac{\mathrm{Vin} \cdot \mathrm{R2} \cdot \mathrm{R4} \cdot \mathrm{R8}\sqrt{2}}{\pi \cdot \mathrm{R1} \cdot \mathrm{R3} \cdot \mathrm{R6}} = +5.002\ \mathrm{Vdc}$$

Note that R5 drops out. If R5 were an incorrect value, the amplitude on alternate half-cycles of the full wave output (prior to filtering) would be unequal. The dc average (as measured by a dc DVM) would be unaffected. A scope measurement would reveal the excessive ripple.

Using the format given many times previously in the book, it is a simple task to write an RSS/EVA program on the above dc equation. With 1% tolerance resistors and a 2% tolerance on the 0.25 Vrms input, the RSS values are +4.844 and +5.160 Vdc. The EVA values are +4.616 and +5.417 Vdc.