PWM to Analogue: RC Filter Ripple and Settling Time

Average output, exact peak-to-peak ripple and settling time of a single-pole RC filter turning a PWM signal into an analogue voltage.

Method: First-order RC response to a rectangular wave

Input parameters

Unit system: SI

Parameter	Value	Unit
PWM high level	3.3000	V
Duty cycle	50.000	%
PWM frequency	20.000	kHz
Filter resistance	10.000	kΩ
Filter capacitance	1.0000	µF
Settling band as a share of the step	0.40000	%

Calculated results

Parameter	Value	Unit
Filter corner frequency	15.915	Hz
Average output	1.6500	V
Peak-to-peak ripple	4.1250	mV
Settling time to the band	55.215	ms

Notes for this case

• The capacitor charges towards V_H while the PWM is high and discharges while it is low. In steady state the swing is exactly ΔV = V_H(1 − a)(1 − b)/(1 − ab) with a = e^(−DT/τ) and b = e^(−(1−D)T/τ); it is largest at 50 % duty and, for τ ⍰ T, close to V_H D(1 − D)T/τ. Lowering the ripple by raising τ slows the response: a step settles to within ε after τ ln(1/ε). A second RC stage or an active filter breaks this trade-off.

Formula and method

$$\Delta V = V_H \frac{(1-a)(1-b)}{1-ab}, \quad a = e^{-DT/\tau}, \quad b = e^{-(1-D)T/\tau}, \quad t_s = \tau \ln \frac{1}{\epsilon}$$

Variables

V_H	PWM high level	V
D	Duty cycle	-
f	PWM frequency	1/s
R	Filter resistance	Ω
C	Filter capacitance	F
ϵ	Settling band as a share of the step	-
f_c	Filter corner frequency	1/s
$\bar{V}$	Average output	V
ΔV	Peak-to-peak ripple	V
t_s	Settling time to the band	s

Method and standards

PWM filter.

Assumptions and limits

- Ideal PWM source; unloaded filter.

References

First-order RC response to a rectangular wave

Report details

Report reference	FCC-ASBR-N77D (the same inputs always give the same reference)
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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/electrical/electronics/pwm-rc-filter-ripple

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.