Microstrip Line Characteristic Impedance and Effective Permittivity

Characteristic impedance, effective permittivity, phase velocity and guided wavelength of a microstrip PCB trace from its width, substrate height and permittivity.

Method: Quasi-static microstrip formulas (Hammerstad)

Input parameters

Unit system: SI

Parameter	Value	Unit
Trace width	1.9000	mm
Substrate thickness (trace to ground plane)	1.0000	mm
Substrate relative permittivity (FR-4 ≈ 4.3)	4.3000	
Frequency (for the guided wavelength)	1,000.0	MHz

Calculated results

Parameter	Value	Unit
Effective permittivity	3.2600	
Characteristic impedance	50.948	Ω
Phase velocity	1.6604e+08	m/s
Guided wavelength	166.04	mm
Width-to-height ratio	1.9000	

Notes for this case

- Quasi-static closed-form fits (Hammerstad, as given by Pozar) for a zero-thickness strip: about 1 % accuracy. Copper thickness, solder mask and dispersion at high frequency change the impedance slightly.

Formula and method

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12h/w}}$$

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[w/h + 1.393 + 0.667\ln(w/h + 1.444)\right]} \quad (w/h \geq 1), \qquad Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln\left(\frac{8h}{w} + \frac{w}{4h}\right) \quad (w/h < 1)$$

Variables

w	Trace width	m
h	Substrate thickness (trace to ground plane)	m
ε_r	Substrate relative permittivity (FR-4 ≈ 4.3)	-
f	Frequency (for the guided wavelength)	1/s
ε_{eff}	Effective permittivity	-
Z_0	Characteristic impedance	Ω
v_p	Phase velocity	m/s
λ_g	Guided wavelength	m
w/h	Width-to-height ratio	-

Method and standards

Quasi-static microstrip analysis.

Assumptions and limits

- Zero-thickness strip, quasi-static (TEM-like) mode.

References

Quasi-static microstrip formulas (Hammerstad)

Report details

Report reference	FCC-1JGE-3K4N (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/microstrip-impedance

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.