



**PCB Calculator**

**November 4, 2021**

# Contents

|          |                               |          |
|----------|-------------------------------|----------|
| <b>1</b> | <b>Introduction</b>           | <b>1</b> |
| <b>2</b> | <b>Calculators</b>            | <b>1</b> |
| 2.1      | Regulators . . . . .          | 1        |
| 2.2      | Track-Width . . . . .         | 2        |
| 2.3      | Electrical-Spacing . . . . .  | 3        |
| 2.4      | TransLine . . . . .           | 3        |
| 2.5      | RF-Attenuators . . . . .      | 5        |
| 2.6      | Color-Code . . . . .          | 6        |
| 2.7      | Board-Classes . . . . .       | 6        |
| 2.7.1    | Performance Classes . . . . . | 6        |
| 2.7.2    | PCB Types . . . . .           | 7        |

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*Reference manual*

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## Contributors

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## Feedback

Please direct any bug reports, suggestions or new versions to here:

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## Publication date and software version

March 05 2020

# 1 Introduction

The KiCad PCB Calculator is a set of utilities to help you find the values of components or other parameters of a layout. The Calculator has the following tools:

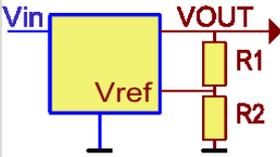
- Regulators
- Track Width
- Electrical Spacing
- Trans Line
- RF Attenuators
- Color Code
- Board Classes

## 2 Calculators

### 2.1 Regulators

This calculator helps with the task of finding the values of the resistors needed for linear and low-dropout voltage regulators.

---

| Regulators  | Track Width | Electrical Spacing | TransLine | RF Attenuators | Color Code | Board Classes |
|---|-------------|--------------------|-----------|----------------|------------|---------------|
| <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;">  </div> <div style="width: 65%;"> <input checked="" type="radio"/> R1: <input type="text" value="10"/> kΩ<br/> <input type="radio"/> R2: <input type="text" value="10"/> kΩ<br/> <input type="radio"/> Vout: <input type="text" value="12"/> V<br/>           Vref: <input type="text" value="3"/> V<br/>           Iadj: <input type="text"/> μA<br/>           Type: <input type="text" value="Standard Type"/> </div> </div> |             |                    |           |                |            |               |
| <input type="button" value="Calculate"/>  |             |                    |           |                |            |               |
| Regulator: <input type="text"/>   |             |                    |           |                |            |               |
| Regulators data file: <input type="text"/> <input type="button" value="Browse"/>  |             |                    |           |                |            |               |
| <input type="button" value="Edit Regulator"/> <input type="button" value="Add Regulator"/> <input type="button" value="Remove Regulator"/>  |             |                    |           |                |            |               |
| Message   |             |                    |           |                |            |               |
| Formula: <b><math>V_{out} = V_{ref} * (R1 + R2) / R2</math></b>   |             |                    |           |                |            |               |

For the *Standard Type*, the output voltage  $V_{out}$  as a function of the reference voltage  $V_{ref}$  and resistors  $R1$  and  $R2$  is given by:

$$V_{out} = V_{ref} \cdot \left( \frac{R1 + R2}{R1} \right)$$

For the *3 terminal type*, there is a correction factor due to the quiescent current  $I_{adj}$  flowing from the adjust pin:

$$V_{out} = V_{ref} \cdot \left( \frac{R1 + R2}{R1} \right) + I_{adj} \cdot R2$$

This current is typically below 100  $\mu\text{A}$  and can be neglected with caution.

To use this calculator, enter the parameters of the regulator *Type*, *Vref* and, if needed, *Iadj*, select the field you want to calculate (one of the resistors or the output voltage) and enter the other two values.

## 2.2 Track-Width

The Track Width tool calculates the trace width for printed circuit board conductors for a given current and temperature rise. It uses formulas from IPC-2221 (formerly IPC-D-275).

|  |                                       |                    |           |                |            |               |
|--|---------------------------------------|--------------------|-----------|----------------|------------|---------------|
| Regulators   | Track Width                           | Electrical Spacing | TransLine | RF Attenuators | Color Code | Board Classes |
| Parameters:  |                                       |                    |           |                |            |               |
| Current:   | <input type="text" value="0.744609"/> | A                  |           |                |            |               |
| Temperature rise:  | <input type="text" value="10.0"/>     | deg C              |           |                |            |               |
| Conductor length:  | <input type="text" value="20"/>       | mm                 |           |                |            |               |
| Resistivity:   | <input type="text" value="1.72e-8"/>  | Ohm-meter          |           |                |            |               |
| <p>If you specify the maximum current, then the trace widths will be calculated to suit.<br/>                 If you specify one of the trace widths, the maximum current it can handle will be calculated. The width for the other trace to also handle this current will then be calculated.<br/>                 The controlling value is shown in bold.</p> <p>The calculations are valid for currents up to 35A (external) or 17.5A (internal), temperature rises up to 100 deg C, and widths of up to 400mil (10mm).<br/>                 The formula, from IPC 2221, is</p> $I = K * dT^{0.44} * (W*H)^{0.725}$ <p>where:<br/> <b>I</b> = maximum current in amps<br/> <b>dT</b> = temperature rise above ambient in deg C<br/> <b>W,H</b> = width and thickness in mils<br/> <b>K</b> = 0.024 for internal traces or 0.048 for external traces</p> |                                       |                    |           |                |            |               |
| External layer traces:   |                                       |                    |           |                |            |               |
| Trace width:   | <input type="text" value="0.2"/>      | mm                 |           |                |            |               |
| Trace thickness:   | <input type="text" value="0.035"/>    | mm                 |           |                |            |               |
| Cross-section area:  | 0.007                                 | mm x mm            |           |                |            |               |
| Resistance:  | 0.0491429                             | Ω                  |           |                |            |               |
| Voltage drop:  | 0.0365922                             | Volt               |           |                |            |               |
| Power loss:  | 0.0272469                             | Watt               |           |                |            |               |
| Internal layer traces:   |                                       |                    |           |                |            |               |
| Trace width:   | <input type="text" value="0.520288"/> | mm                 |           |                |            |               |
| Trace thickness:   | <input type="text" value="0.035"/>    | mm                 |           |                |            |               |
| Cross-section area:  | 0.0182101                             | mm x mm            |           |                |            |               |
| Resistance:  | 0.0188906                             | Ω                  |           |                |            |               |
| Voltage drop:  | 0.0140661                             | Volt               |           |                |            |               |
| Power loss:  | 0.0104738                             | Watt               |           |                |            |               |

### 2.3 Electrical-Spacing

This table helps finding the minimum clearance between conductors.

Each line of the table has a minimum recommended distance between conductors for a given voltage (DC or AC peaks) range. If you need the values for voltages higher than 500V, enter the value in the box in the left corner and press *Update Values*.

| Regulators  | Track Width | Electrical Spacing | TransLine | RF Attenuators | Color Code | Board Classes |      |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
|---|-------------|--------------------|-----------|----------------|------------|---------------|------|----|----|----|----|----|----|----|--------------|------|-----|-----|------|------|------|------|---------------|------|-----|-----|------|------|------|------|---------------|-----|-----|-----|------|------|-----|------|----------------|-----|-----|-----|------|------|-----|------|-----------------|-----|-----|-----|-----|-----|-----|-----|-----------------|-----|------|-----|-----|-----|-----|-----|-----------------|-----|------|-----|-----|-----|-----|-----|-----------------|-----|------|------|-----|-----|-----|-----|-----------------|------|-----|------|-----|-----|-----|-----|------------------|------|-----|------|-----|-----|-----|-----|
| <div style="display: flex; align-items: center;"> <div style="margin-right: 10px;">mm</div> <div style="flex-grow: 1;"> <p style="text-align: center;"><b>Note: Values are minimal values (from IPC 2221)</b></p> <table border="1"> <thead> <tr> <th></th> <th>B1</th> <th>B2</th> <th>B3</th> <th>B4</th> <th>A5</th> <th>A6</th> <th>A7</th> </tr> </thead> <tbody> <tr> <td><b>0-15V</b></td> <td>0.05</td> <td>0.1</td> <td>0.1</td> <td>0.05</td> <td>0.13</td> <td>0.13</td> <td>0.13</td> </tr> <tr> <td><b>16-30V</b></td> <td>0.05</td> <td>0.1</td> <td>0.1</td> <td>0.05</td> <td>0.13</td> <td>0.25</td> <td>0.13</td> </tr> <tr> <td><b>31-50V</b></td> <td>0.1</td> <td>0.6</td> <td>0.6</td> <td>0.13</td> <td>0.13</td> <td>0.4</td> <td>0.13</td> </tr> <tr> <td><b>51-100V</b></td> <td>0.1</td> <td>0.6</td> <td>1.5</td> <td>0.13</td> <td>0.13</td> <td>0.5</td> <td>0.13</td> </tr> <tr> <td><b>101-150V</b></td> <td>0.2</td> <td>0.6</td> <td>3.2</td> <td>0.4</td> <td>0.4</td> <td>0.8</td> <td>0.4</td> </tr> <tr> <td><b>151-170V</b></td> <td>0.2</td> <td>1.25</td> <td>3.2</td> <td>0.4</td> <td>0.4</td> <td>0.8</td> <td>0.4</td> </tr> <tr> <td><b>171-250V</b></td> <td>0.2</td> <td>1.25</td> <td>6.4</td> <td>0.4</td> <td>0.4</td> <td>0.8</td> <td>0.4</td> </tr> <tr> <td><b>251-300V</b></td> <td>0.2</td> <td>1.25</td> <td>12.5</td> <td>0.4</td> <td>0.4</td> <td>0.8</td> <td>0.8</td> </tr> <tr> <td><b>301-500V</b></td> <td>0.25</td> <td>2.5</td> <td>12.5</td> <td>0.8</td> <td>0.8</td> <td>1.5</td> <td>0.8</td> </tr> <tr> <td><b>&gt; 500V</b></td> <td>0.25</td> <td>2.5</td> <td>12.5</td> <td>0.8</td> <td>0.8</td> <td>1.5</td> <td>0.8</td> </tr> </tbody> </table> </div> </div> |             |                    |           |                |            |               |      | B1 | B2 | B3 | B4 | A5 | A6 | A7 | <b>0-15V</b> | 0.05 | 0.1 | 0.1 | 0.05 | 0.13 | 0.13 | 0.13 | <b>16-30V</b> | 0.05 | 0.1 | 0.1 | 0.05 | 0.13 | 0.25 | 0.13 | <b>31-50V</b> | 0.1 | 0.6 | 0.6 | 0.13 | 0.13 | 0.4 | 0.13 | <b>51-100V</b> | 0.1 | 0.6 | 1.5 | 0.13 | 0.13 | 0.5 | 0.13 | <b>101-150V</b> | 0.2 | 0.6 | 3.2 | 0.4 | 0.4 | 0.8 | 0.4 | <b>151-170V</b> | 0.2 | 1.25 | 3.2 | 0.4 | 0.4 | 0.8 | 0.4 | <b>171-250V</b> | 0.2 | 1.25 | 6.4 | 0.4 | 0.4 | 0.8 | 0.4 | <b>251-300V</b> | 0.2 | 1.25 | 12.5 | 0.4 | 0.4 | 0.8 | 0.8 | <b>301-500V</b> | 0.25 | 2.5 | 12.5 | 0.8 | 0.8 | 1.5 | 0.8 | <b>&gt; 500V</b> | 0.25 | 2.5 | 12.5 | 0.8 | 0.8 | 1.5 | 0.8 |
|   | B1          | B2                 | B3        | B4             | A5         | A6            | A7   |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>0-15V</b>  | 0.05        | 0.1                | 0.1       | 0.05           | 0.13       | 0.13          | 0.13 |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>16-30V</b>   | 0.05        | 0.1                | 0.1       | 0.05           | 0.13       | 0.25          | 0.13 |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>31-50V</b>   | 0.1         | 0.6                | 0.6       | 0.13           | 0.13       | 0.4           | 0.13 |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>51-100V</b>  | 0.1         | 0.6                | 1.5       | 0.13           | 0.13       | 0.5           | 0.13 |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>101-150V</b>   | 0.2         | 0.6                | 3.2       | 0.4            | 0.4        | 0.8           | 0.4  |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>151-170V</b>   | 0.2         | 1.25               | 3.2       | 0.4            | 0.4        | 0.8           | 0.4  |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>171-250V</b>   | 0.2         | 1.25               | 6.4       | 0.4            | 0.4        | 0.8           | 0.4  |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>251-300V</b>   | 0.2         | 1.25               | 12.5      | 0.4            | 0.4        | 0.8           | 0.8  |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>301-500V</b>   | 0.25        | 2.5                | 12.5      | 0.8            | 0.8        | 1.5           | 0.8  |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <b>&gt; 500V</b>  | 0.25        | 2.5                | 12.5      | 0.8            | 0.8        | 1.5           | 0.8  |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |
| <p>* B1 - Internal Conductors<br/>                 * B2 - External Conductors, uncoated, sea level to 3050 m<br/>                 * B3 - External Conductors, uncoated, over 3050 m<br/>                 * B4 - External Conductors, with permanent polymer coating (any elevation)<br/>                 * A5 - External Conductors, with conformal coating over assembly (any elevation)<br/>                 * A6 - External Component lead/termination, uncoated<br/>                 * A7 - External Component lead termination, with conformal coating (any elevation)</p>   |             |                    |           |                |            |               |      |    |    |    |    |    |    |    |              |      |     |     |      |      |      |      |               |      |     |     |      |      |      |      |               |     |     |     |      |      |     |      |                |     |     |     |      |      |     |      |                 |     |     |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |     |     |     |     |     |                 |     |      |      |     |     |     |     |                 |      |     |      |     |     |     |     |                  |      |     |      |     |     |     |     |

### 2.4 TransLine

Transmission line theory is a cornerstone in the teaching of RF and microwave engineering.

In the calculator you can choose different sorts of Line Types and their special parameters. The models implemented are frequency-dependent, so they disagree with simpler models at high *enough* frequencies.

This calculator is heavily based on [Transcalc](#).

The transmission line types and the reference of their mathematical models are listed below:

- Microstrip line:
    - H. A. Atwater, “Simplified Design Equations for Microstrip Line Parameters” , Microwave Journal, pp. 109-115, November 1989.
  - Coplanar wave guide.
  - Coplanar wave guide with ground plane.
  - Rectangular waveguide:
    - S. Ramo, J. R. Whinnery and T. van Duzer, ”Fields and Waves in Communication Electronics”, Wiley-India, 2008, ISBN: 9788126515257.
  - Coaxial line.
  - Coupled microstrip line:
    - H. A. Atwater, “Simplified Design Equations for Microstrip Line Parameters” , Microwave Journal, pp. 109-115, November 1989.
    - M. Kirschning and R. H. Jansen, ”Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristic of Parallel Coupled Microstrip Lines,” in IEEE Transactions on Microwave Theory and Techniques, vol. 32, no. 1, pp. 83-90, Jan. 1984. doi: 10.1109/TMTT.1984.1132616.
    - Rolf Jansen, ”High-Speed Computation of Single and Coupled Microstrip Parameters Including Dispersion, High-Order Modes, Loss and Finite Strip Thickness”, IEEE Trans. MTT, vol. 26, no. 2, pp. 75-82, Feb. 1978.
    - S. March, ”Microstrip Packaging: Watch the Last Step”, Microwaves, vol. 20, no. 13, pp. 83-94, Dec. 1981.
  - Stripline.
  - Twisted pair.
-

## 2.5 RF-Attenuators

With the RF Attenuator utility you can calculate the values of the resistors needed for different types of attenuators:

- PI
- Tee
- Bridged Tee
- Resistive Splitter

To use this tool, first select the type of attenuator you need, then enter the desired attenuation (in dB) and input/output impedances (in Ohms).

## 2.6 Color-Code

This calculator helps translating the color bars from the resistor to its value. To use it, first select the *tolerance* of the resistor: 10%, 5% or equal or smaller than 2%. For example:

- Yellow Violet Red Gold:  $47 \times 100 \pm 5\% = 4700 \text{ Ohm}$ , 5% tolerance
- 1kOhm, 1% tolerance: Brown Black Black Brown Brown

| Regulators | Track Width | Electrical Spacing | TransLine | RF Attenuators | Color Code    | Board Classes |
|------------|-------------|--------------------|-----------|----------------|---------------|---------------|
|            | 1st Band    | 2nd Band           | 3rd Band  | 4th Band       | Multiplier    | Tolerance     |
|            | Black 0     | 0                  | 0         | 0              | $\times 1$    |               |
|            | Brown 1     | 1                  | 1         | 1              | $\times 10$   | $\pm 1\%$     |
|            | Red 2       | 2                  | 2         | 2              | $\times 100$  | $\pm 2\%$     |
|            | Orange 3    | 3                  | 3         | 3              | $\times 1k$   |               |
|            | Yellow 4    | 4                  | 4         | 4              | $\times 10k$  |               |
|            | Green 5     | 5                  | 5         | 5              | $\times 100k$ | $\pm 0.5\%$   |
|            | Blue 6      | 6                  | 6         | 6              | $\times 1M$   | $\pm 0.25\%$  |
|            | Violet 7    | 7                  | 7         | 7              | $\times 10M$  | $\pm 0.10\%$  |
|            | Grey 8      | 8                  | 8         | 8              | $\times 100M$ | $\pm 0.05\%$  |
|            | White 9     | 9                  | 9         | 9              | $\times 1G$   |               |
|            | Gold        |                    |           |                | $\times 0.1$  | $\pm 5\%$     |
|            | Silver      |                    |           |                | $\times 0.01$ | $\pm 10\%$    |

Tolerance  
 10% / 5%  
  $\leq 2\%$

## 2.7 Board-Classes

### 2.7.1 Performance Classes

In IPC-6011 have been three performance classes established

- Class 1 General Electronic Products Includes consumer products, some computer and computer peripherals suitable for applications where cosmetic imperfections are not important and the major requirement is function of the completed printed board.
- Class 2 Dedicated Service Electronic Products Includes communications equipment, sophisticated business machines, instruments where high performance and extended life is required and for which uninterrupted service is desired but not critical. Certain cosmetic imperfections are allowed.
- Class 3 High Reliability Electronic Products Includes the equipment and products where continued performance or performance on demand is critical. Equipment downtime cannot be tolerated and must function when required such as in life support items or flight control systems. Printed boards in this class are suitable for applications where high levels of assurance are required and service is essential.

### 2.7.2 PCB Types

In IPC-6012B there are also 6 Types of PCB defined:

- Printed Boards without plated through holes (1)
  - 1 Single-Sided Board
- And Boards with plated through holes (2-6)
  - 2 Double-Sided Board
  - 3 Multilayer board without blind or buried vias
  - 4 Multilayer board with blind and/or buried vias
  - 5 Multilayer metal core board without blind or buried vias
  - 6 Multilayer metal core board with blind and/or buried vias

| Regulators                             | Track Width    | Electrical Spacing | TransLine      | RF Attenuators | Color Code     | Board Classes  |
|--|----------------|--------------------|----------------|----------------|----------------|----------------|
| <b>Note: Values are minimal values</b> |                |                    |                |                |                |                |
| mm ▼                                   |                |                    |                |                |                |                |
|  | <b>Class 1</b> | <b>Class 2</b>     | <b>Class 3</b> | <b>Class 4</b> | <b>Class 5</b> | <b>Class 6</b> |
| <b>Lines width</b>                     | 0.8            | 0.5                | 0.31           | 0.21           | 0.15           | 0.12           |
| <b>Min clearance</b>                   | 0.68           | 0.5                | 0.31           | 0.21           | 0.15           | 0.12           |
| <b>Via: (diam - drill)</b>             | --             | --                 | 0.45           | 0.34           | 0.24           | 0.2            |
| <b>Plated Pad: (diam - drill)</b>      | 1.19           | 0.78               | 0.6            | 0.49           | 0.39           | 0.35           |
| <b>NP Pad: (diam - drill)</b>          | 1.57           | 1.13               | 0.9            | --             | --             | --             |