Wilkinson Power Divider Design Notes, v2

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9/12/2025

1. Determine the required center frequency F0 and bandwidth BW. Here, the bandwidth spans the full frequency range required. This bandwidth is the starting point for simulating the Wilkinson power divider.

2. Using the Wilkinson101\_Rev1.3 spreadsheet calculator, optimize the performance by adjusting both the number of rings and the bandwidth. The goal is to minimize the input reflection (S11), the output reflection (S22, S33) and the output isolation (S23). We want to achieve < - 20 dB for each of these quantities.

3. Record the ideal Wilkinson parameters: F0, BW, Z1, R1, Z2, R2.

4. Determine which microwave resistors will be used in place of the ideal resistances R1 and R2. These will be 0402 sized resistors. For frequencies up to 2 GHz, you can use the very inexpensive RR0510 series of metal thin film chip resistors. For most of our Wilkinsons, however, we will use the Vishay flip-chip (FC) resistors which can operate up to 40 GHz. For resistances of 250 Ohm or less, these work good up to roughly 12 GHz. These are available at 50, 75, 100, 132, 200, 250, 330 and 500 Ohm.



Internal impedance curve for FC0402 size flip-chip.

For very high frequencies, the CH series resistors work even better but at almost twice the price per resistor. Performance is very good for 50-100 Ohm resistances. These are available at 50, 100, 150, 180, 200, 250, 330 and 500 Ohm.



Internal impedance curve for CH0402 size (F and P terminations).



Internal imedance curve for CH0402 size (N and G terminations).

5. Use the AppCAD program to calculate the trace widths corresponding to the various center frequencies F0 and line impedances Z1 and Z2. We will be using 20-mil RO4350B laminates with a metal thickness of 1 ounce or 1.3-mil. Also calculate the electrical length (in mils) that is required to achieve 90 degrees at frequency F0 for each line impedance.

Examples: 50 Ohm = 44-mil, 60 Ohm = 32-mil, 70 Ohm = 24-mil, 86 Ohm = 15-mil.

6. All Wilkinson power dividers will use the same schematic symbol, which needs to be drawn up and inserted into the PDG.kicad\_sym symbol library. Here, I am assuming a 2-ring Wilkinson. This should have 7 pins: 1=IN, 2= OUT1, 3=OUT2, 4=R1A, 5=R1B, 6=R2A and 7=R2B. The resistors R1 and R2 will be placed between pins 4 and 5 and between pins 6 and 7 respectively. A 3-ring Wilkinson would have 9 pins, adding R3A and R3B. Each Wilkinson footprint will need to have the same number of pads (7 for a 2-ring and 9 for a 3-ring).

7. The resistors have a finite length and width which needs to be taken into account when generating the Wilkinson footprint. The KiCad 0402 resistor footprint (KiCad library Resistor\_SMD, footprint R\_0402\_1005Metric) has pads with centers that are 20.08 mil apart with dimensions of 21.26 mil and 25.2 mil. The gap between the two pads is 40.16 – 21.26 = 18.9 mil, which needs to be maintained (no metal between y= -9.45 and +9.45 mil).

8. For the footprint, I would begin by placing the 6 pads in the footprint, before laying any of the traces. The input pad (rectangular) should be centered on y=0 (x-value to be determined). The 0402 resistor pads R1 (rectangular with rounded corners) should be placed at x =0.00 mil, y= +/-20.08 mil). The 0402 resistor pads R2 (rectangular with rounded corners) should be placed somewhere to the right with y= +/-20.08 mil. The output pads (circular) should be centered around y=0 (x- and y-values to be determined).

Calculate the width W1 of arc 2 based on transmission line impedance Z1, and the length of the arc L1 (corresponding to 90 degree or lambda/4). Create an arc on front-metal with width W1 and initial radius of L1/ ϖ. If W1 > 25.2 mil, line up the right side of the arc with the center of the R1 pad. If W1 < 25.2 mil, place the end of the arc in the center of the R1 pads (x=0). Write down the y-center of the arc Y1, corresponding to having the bottom of the arc line up with the bottom of the pad. Adjust the radius of arc 1 to (L1 – 2×Y1)/ϖ, keeping the right end of the arc fixed (both x,y).

Line up the right-side of the input pad to the right edge of the left end of arc 1.

Calculate the width W2 of arc 1 based on transmission line impedance Z2, and the length of the arc L2 (corresponding to 90 degree or lambda/4). Create a 180 degree arc on front-metal with width W2 and initial radius = L2/ ϖ, and place it to the right of the R2 pad. Place a horizontal trace of width W1 from the R2 pad to arc 2, lining up the bottom of the trace with the bottom of the R2 pad.

Move arc 2 horizontally until you have a 6.0 mil gap between the right edge of arc 1 and the left edge of arc 2. Adjust the left edge of the trace until it just touches the traces formed by arc 1 and the R2 pad. Adjust the right edge of the trace so that it ends on arc 2 (i.e. on the end point of the arc). The trace should then have a length of X2. Adjust the radius of arc 2 to (L2 – 2×Y2 – X2) / ϖ, keeping the left end of the arc fixed (both x,y).

Create 50 Ohm traces which line up on the R2 resistors, taking care that none of the trace falls in the gap between the resistor pads or inside the arc. The other end of the trace should extend to Y= ±36 mil, adjusting the X-point (integer value please!) so that you have a roughly 90 degree angle between this trace and the arc. Place the output pads on the end of these traces.