Single-to-differential Conversion in High-frequency Applications

Application Note

1. Introduction

The aim of this application note is to provide the user with different techniques for single-to-differential conversions in high frequency applications.

The first part of this document gives a few techniques to be used in applications where a single-to-differential conversion is needed.

The second part of the document applies the same techniques to e2v broadband data conversion devices, taking into account the configuration of the converters' input buffers.

This document does not give an exhaustive panel of techniques but should help most users find a convenient method to convert a single-ended signal source to a differential signal.

2. Single-to-differential Conversion Techniques

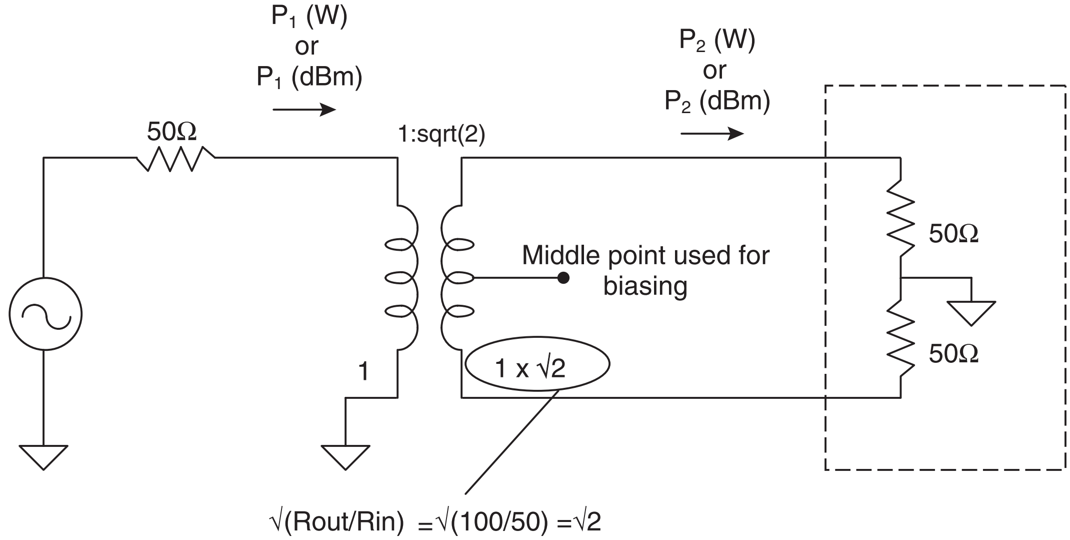
Note: All lines are 50Ω lines unless otherwise specified.

2.1 Technique 1: Direct Conversion Using a 1:$\sqrt{2}$ Balun

The following implementation is the simplest one in theory but not necessarily the easiest to implement in practice due to the limited availability of 1:$\sqrt{2}$ baluns.

The typical configuration of this technique is the following:

Figure 2-1. Single-to-differential Conversion Using a 1:√ 2 balun



The disadvantage of this method is that it can be difficult to find a 1:√ 2 balun on the market since the number of turns on the secondary has to be 2√ 2 times the number of turns on the primary.

For example, if the primary has 10 turns, then the secondary should have 2 x 7 turns, which could be of some difficulty (the total number of wires is 24 in this example, which is a huge number for an RF transformer). However, power hybrid junctions exist that have the same properties and may be found more easily.

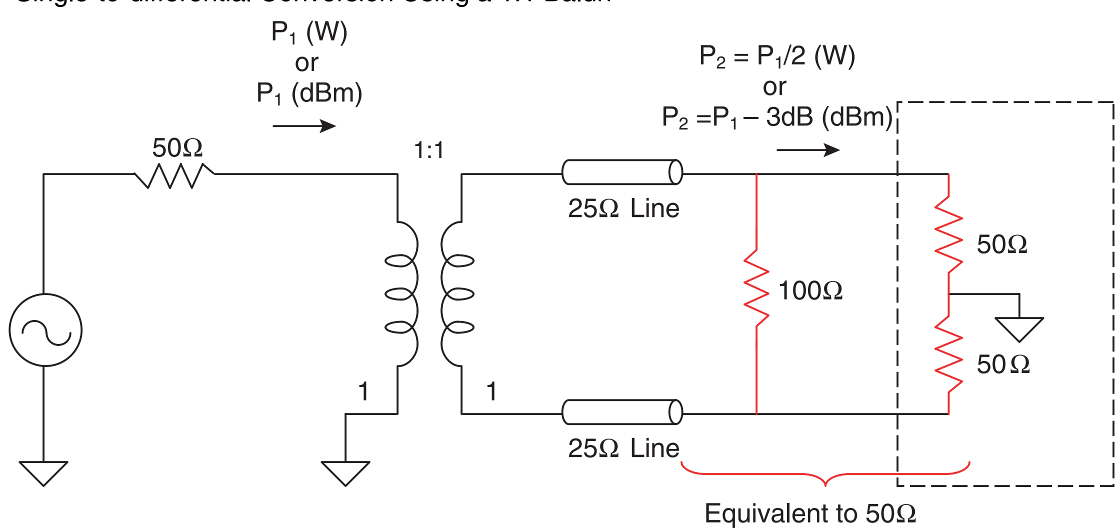
The advantage of this configuration is that there is no insertion loss during the transformation from single to differential (power from the primary to each secondary is conserved, $P_1 = P_2$ global power).

Furthermore, no additional discrete components are required for the matching between the source and the receiver.

2.2 Technique 2: Conversion Using a 1:1 Balun

In the following configuration, a standard 1:1 balun is used.

Figure 2-2. Single-to-differential Conversion Using a 1:1 Balun



The drawbacks of this solution is that a 100Ω (2 x 50Ω) resistor is required for the matching (50Ω at the source and 100Ω in parallel to 2 x 50Ω at the receiver input), and that while P_1 is supplied at the source, only half the power is transmitted to the receiver (the loss is due to the 100Ω resistor): $P_2 = P_1/2$ in W (or P_1 - 3dB in dBm). Extra components are also required to provide biasing.

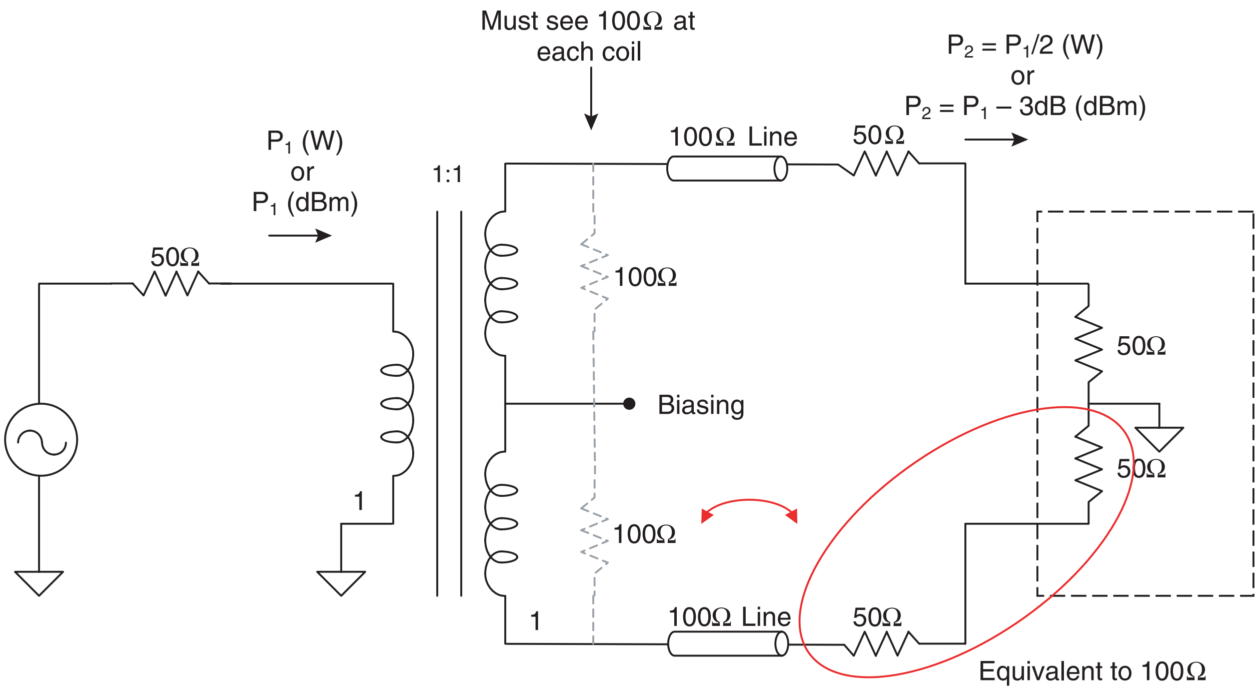
The advantage of this configuration is that it uses a standard 1:1 transformer that is easy to find on the market.

Notes: 1. The 100Ω resistor has to be placed as close as possible to the load (input buffer).
2. 25Ω lines have to be used at the output of the balun.

2.3 Technique 3: Conversion Using a 1:1 Balun with Double Secondary

In the following figure, a standard 1:1 double coil balun is used.

Figure 2-3. Single-to-differential Conversion Using a 1:1 Double Coil Balun



Again, this configuration has one main disadvantage, which is that two 50Ω resistors are required for the matching (50Ω at the source and 2 x 50Ω in parallel at the receiver input), and that as in the preceding technique, while P_1 is supplied at the source, only half the power is transmitted to the receiver (the loss is due to the 100Ω resistor): $P_2 = P_1/2$ in W (or P_1 - 3dB in dBm). In addition, 100Ω lines are required to keep the impedance matching.

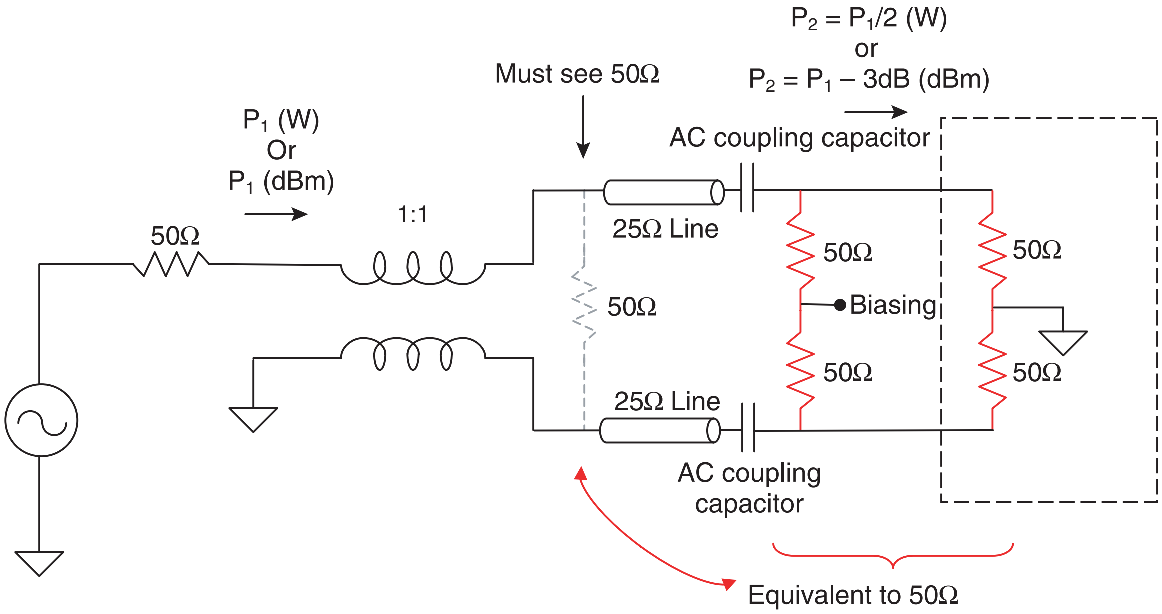
The advantage of this configuration is that the middle point can be easily used for biasing.

Notes: 1. The 50Ω resistors have to be placed as close as possible to the load (input buffer).
2. 25Ω lines have to be used at the output of the balun.

2.4 Technique 4: Conversion Using a 1:1 Balun with Twisted Cable

This last configuration uses a 1:1 balun but in a totally different way: it makes use of the fact that each coil has the same potential drop. In this configuration, however, the primary and secondary are well-isolated from one another.

Figure 2-4. Single-to-differential Conversion Using a 1:1 Twisted Pair Balun



The drawback of this configuration is that there is a dissymmetry at low frequencies (the threshold depends on the manufacturer's specifications): what is transmitted in BF on the primary branch is not on the secondary since the latter is grounded. A simple way to recover a symmetry at low frequency is to add a third whorl in parallel to the primary and connected to ground (see Figure 2-5 on page 5).

The other drawback is that only half the power is transmitted from the source to the receiver.

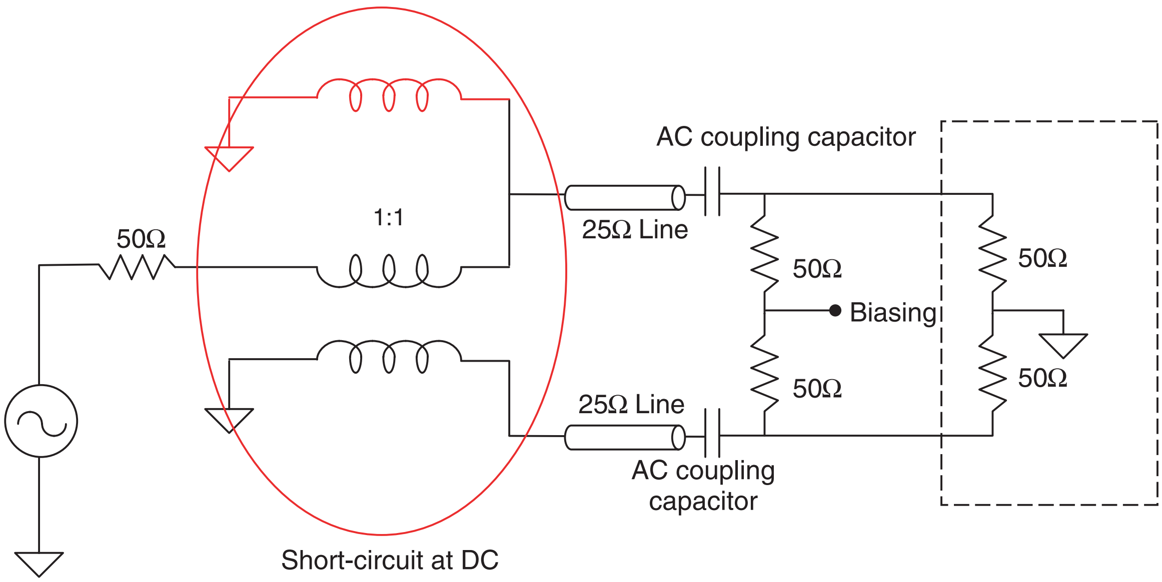
However, the advantage of this configuration is that the primary and secondary are well-isolated from one another.

When using this kind of transformer, special care has to be taken with regard to the specifications of the twisted pair, in particular for which impedance environment the transformer was built.

Notes:
1. The AC coupling capacitors may be removed if the common mode is ground.
2. The AC coupling capacitors have to be placed as close as possible to the load (input buffer).
3. The two 50Ω external resistors have to be placed as close as possible to the load (input buffer).
4. 25Ω lines have to be used at the output of the balun.

2.5 Technique 5

Figure 2-5. Single-to-differential Conversion Using a 1:1 Twisted Pair Balun



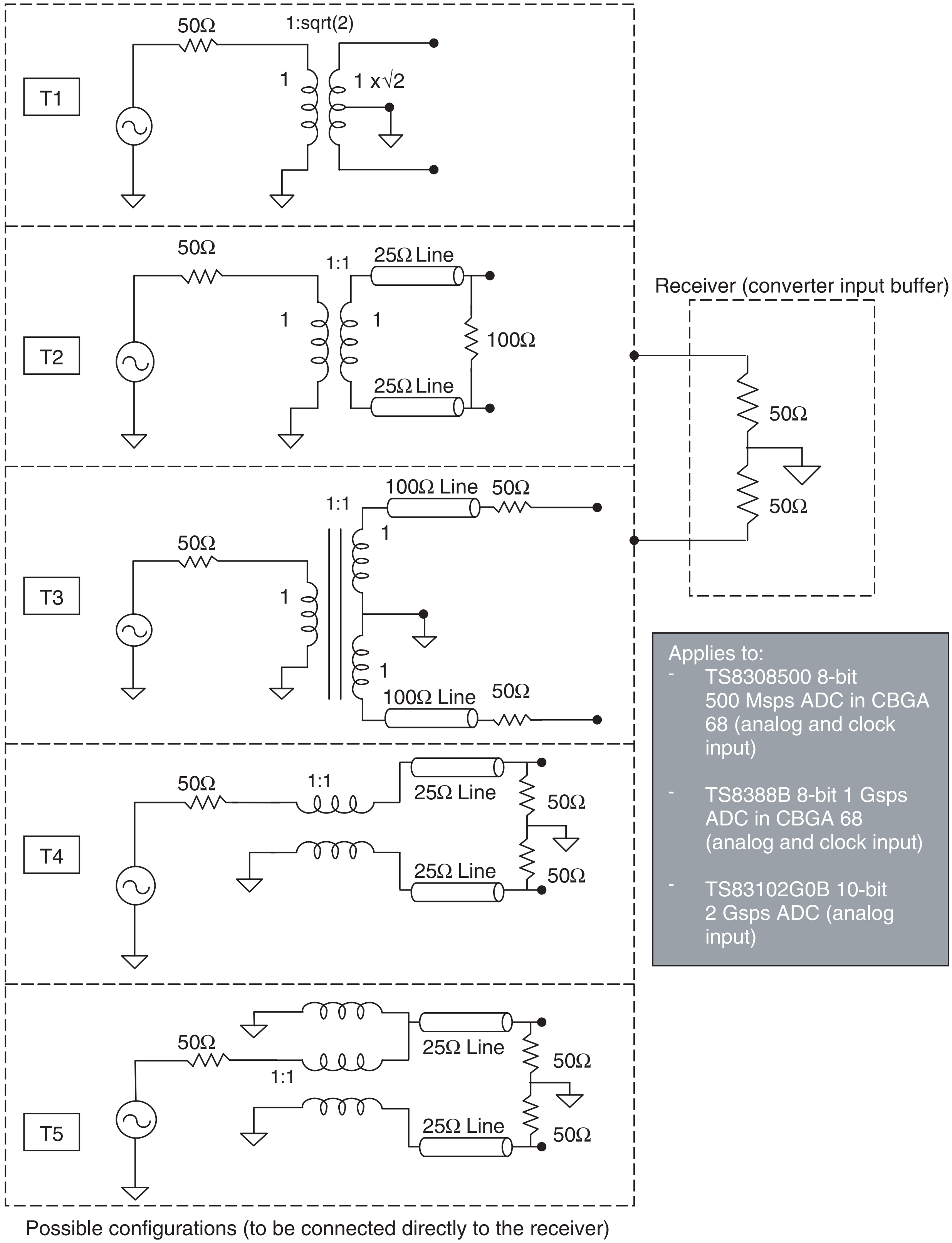
Like the previous configuration, the LF which is not transmitted by the secondary is not by the primary either.

Notes:
1. The AC coupling capacitors may be removed if the common mode is ground.
2. The AC coupling capacitors have to be placed as close as possible to the load (input buffer).
3. The two 50Ω external resistors have to be placed as close as possible to the load (input buffer).
4. 25Ω lines have to be used at the output of the balun.

3. Single-to-differential Conversion Applied to e2v Broadband Data Conversion Devices

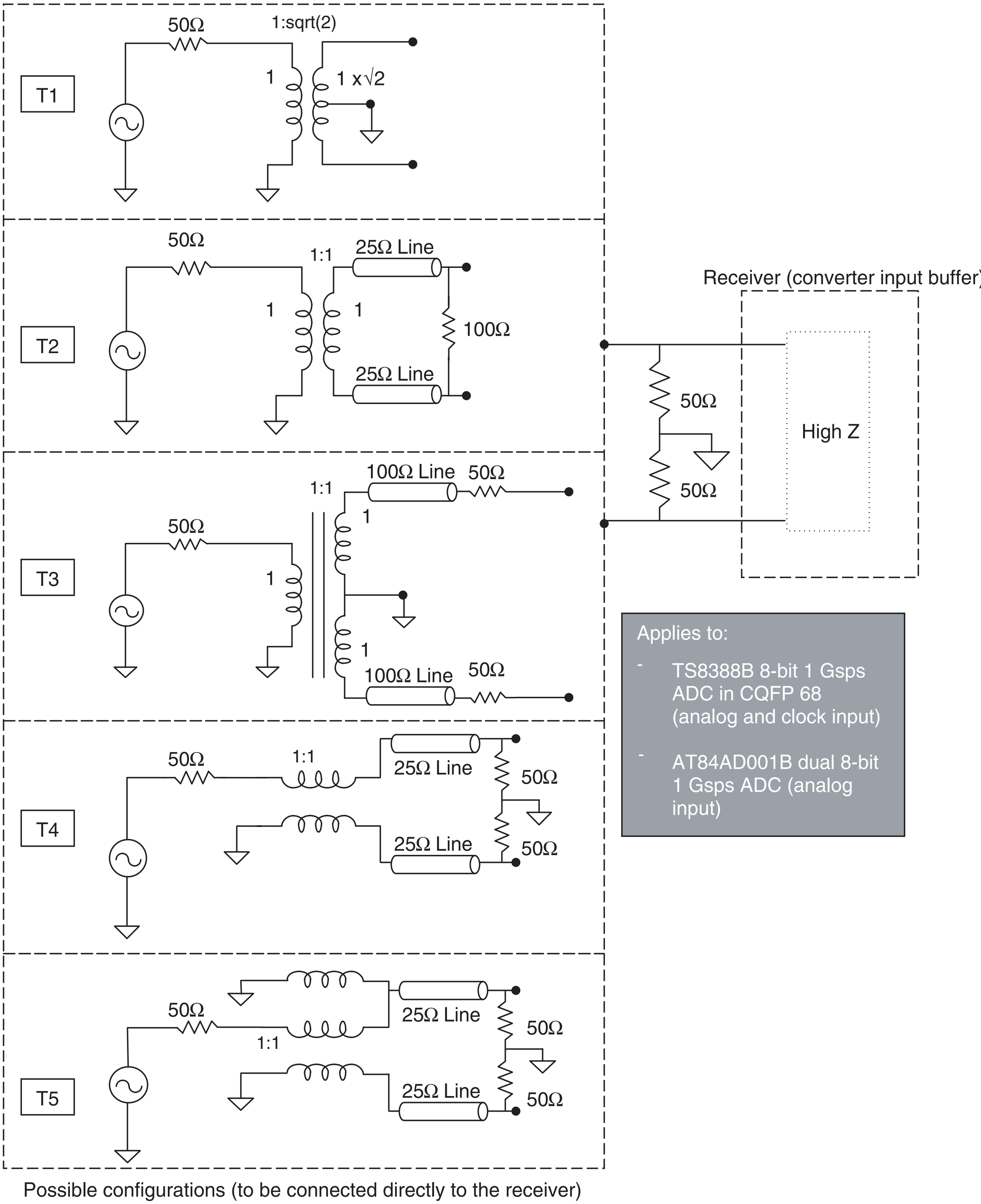
Notes:
1. All lines are 50Ω lines unless specified otherwise.
2. The external capacitors and resistors have to be placed as close as possible to the load.

Figure 3-1. 2 x 50Ω to Ground Internal Receiver Termination (Ground Common Mode)



Applies to:
- TS8308500 8-bit 500 Msps ADC in CBGA 68 (analog and clock input)
- TS8388B 8-bit 1 Gsps ADC in CBGA 68 (analog and clock input)
- TS83102G0B 10-bit 2 Gsps ADC (analog input)

Figure 3-2. 2 x 50Ω to Ground External Receiver Termination (Ground Common Mode)



Applies to:

- TS8388B 8-bit 1 Gsps ADC in CQFP 68 (analog and clock input)
- AT84AD001B dual 8-bit 1 Gsps ADC (analog input)

Figure 3-3. 2 x 50Ω to Ground via a Capacitor Receiver Termination

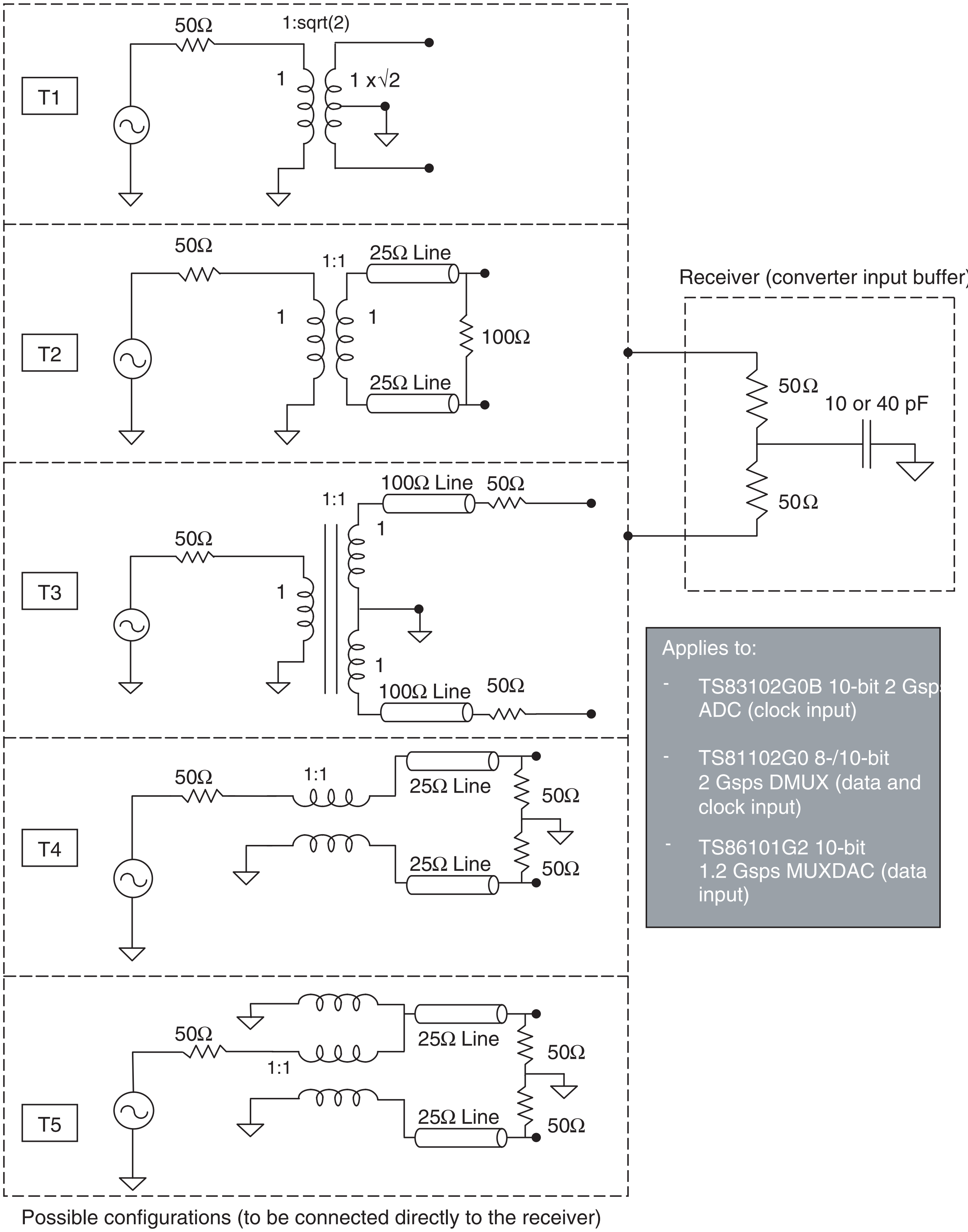
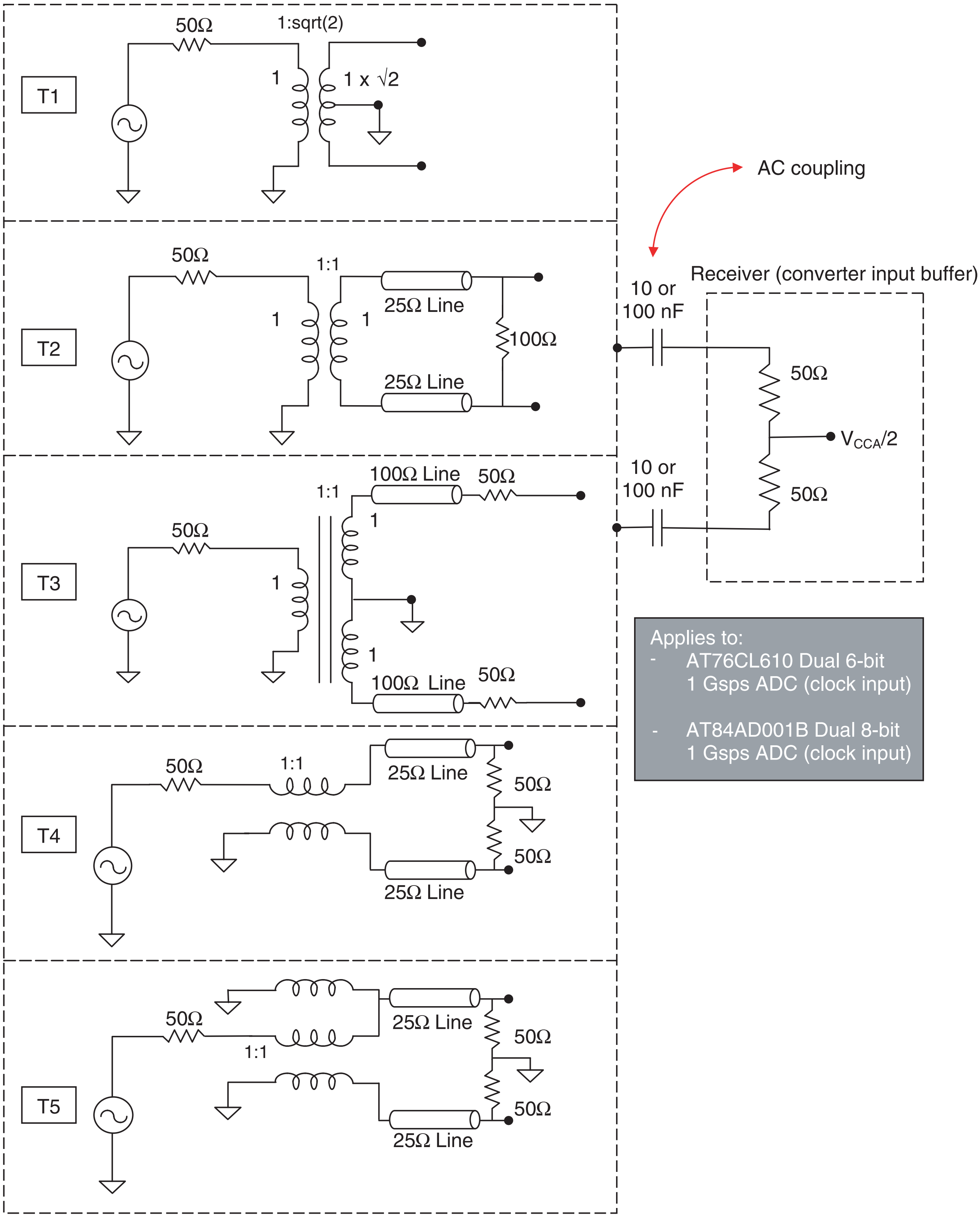
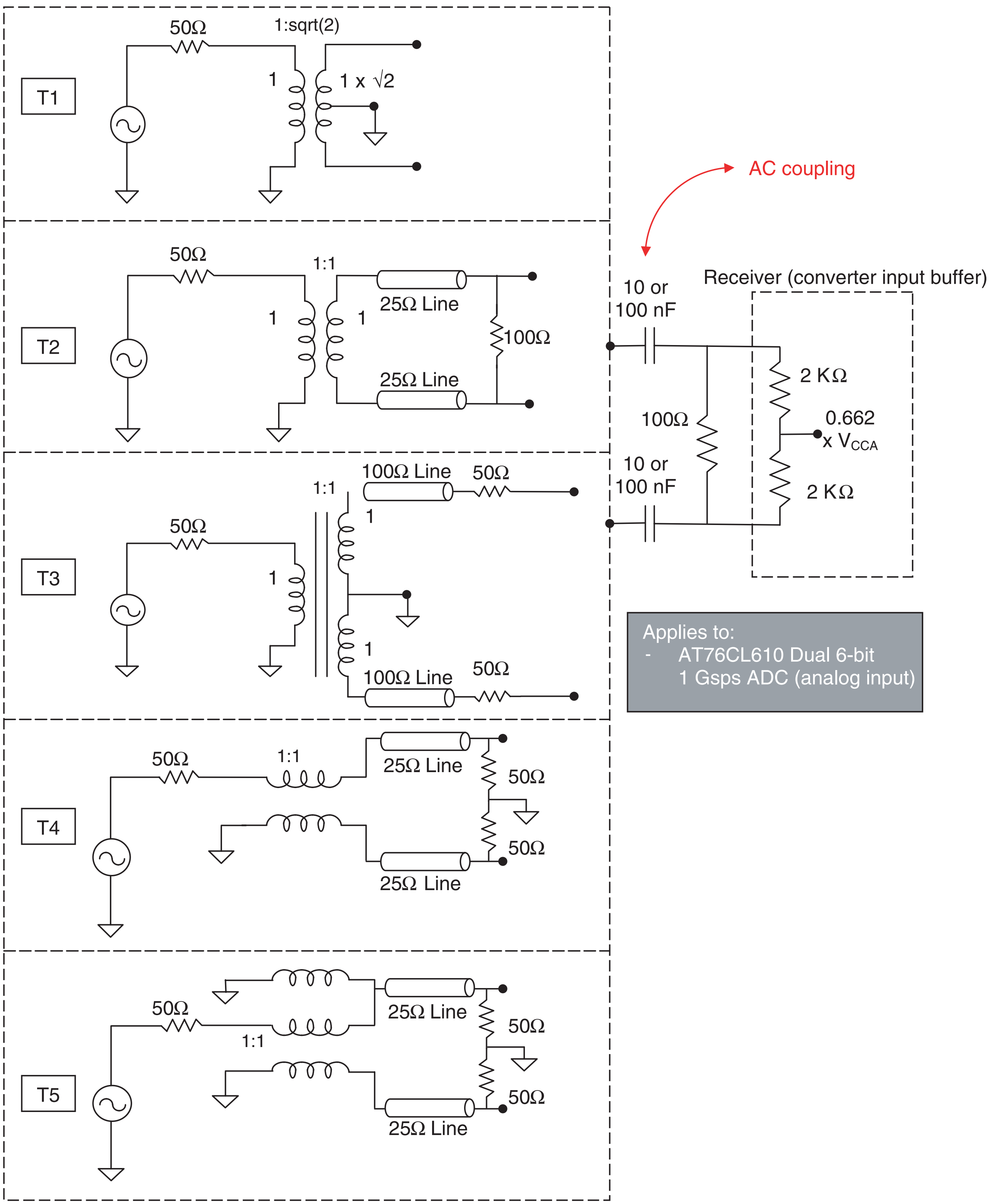


Figure 3-4. 2 x 50Ω to Ground with Biased Common Mode Receiver Termination



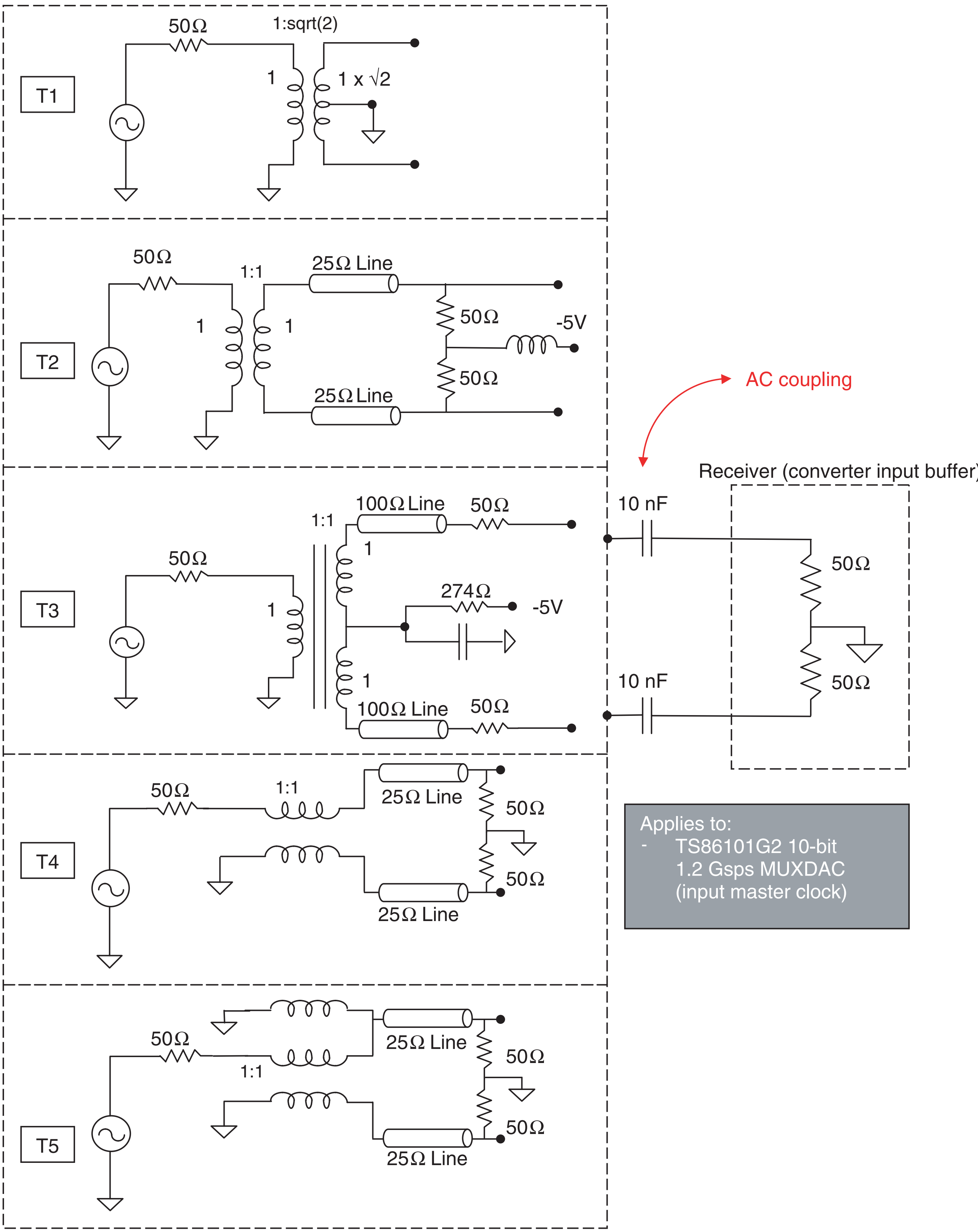
Possible configurations (to be connected directly to the receiver)

Figure 3-5. External 2 x 50Ω to Ground with Internally Biased Common Mode Receiver Termination



Possible configurations (to be connected directly to the receiver)

Figure 3-6. Internal 2 x 50Ω to Ground with Internal Bias Receiver Termination



4. Single-to-differential Transformers - References

This section gives some examples of transformers available on the market. They are provided for information only and are not exhaustive.

4.1 Wideband Transformer 4 to 2000 MHz GLSW4M202 from Sprague-Goodman

Table 4-1. GLSW4M202 Guaranteed Specification (from -40°C to 125°C)

Impedance (Ω)	Turns Ratio	3 dB Band Limits (MHz)	Loss at 20 MHz (dB) Max	Model Number
50:50	11	4-2000	0.5	GLSW4M202

Figure 4-1. GLSW4M202 Pin Configuration

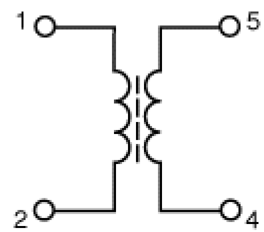
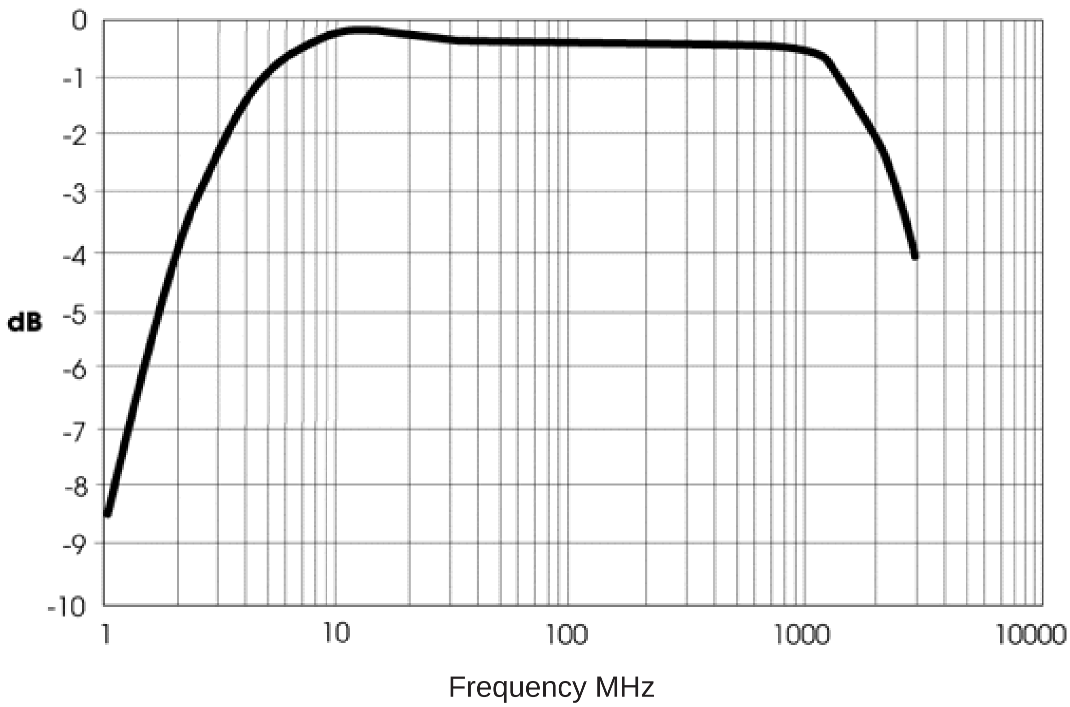


Figure 4-2. GLSW4M202 Typical Insertion Loss



4.2 Wideband Transformer 4.5 to 1000 MHz GLSB4R5M102 from Sprague-Goodman

Table 4-2. GLSB4R5M102 Guaranteed Specification (from -40°C to 125°C)

Turns Ratio	3 dB Band Limits (MHz)	Loss at 20 MHz (dB) Max	Model Number
1:1:1	4.5-1000	0.7	GLSB4R5M102

Figure 4-3. GLSB4R5M102 Pin Configuration

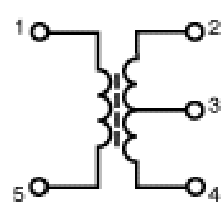
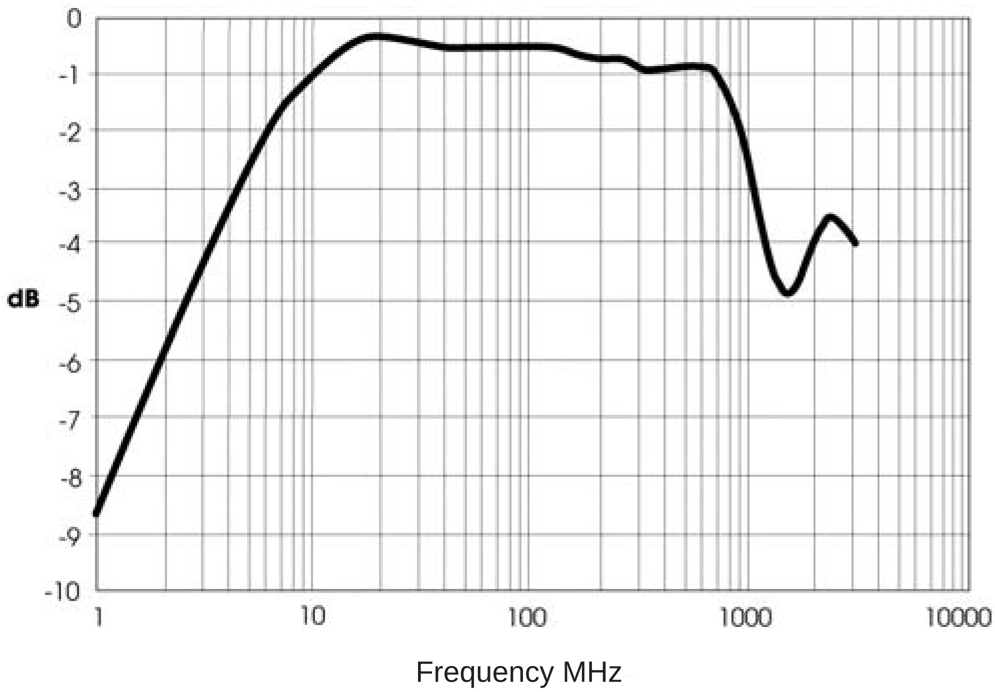


Figure 4-4. GLSB4R5M Typical Insertion Loss



4.3 RF Wideband Transformer 0.5 to 1500 MHz CX2039 from Pulse

Table 4-3. GLSW4M202 Guaranteed Specification (from -40°C to 85°C)

Impedance (Ω)	Turns Ratio	2 dB Band Limits (MHz)	Primary Pins	Model Number
50:50	11	Up to 1500	4-6	GCX2039

Figure 4-5. CX2039 Pin Configuration

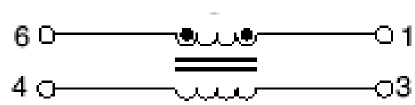
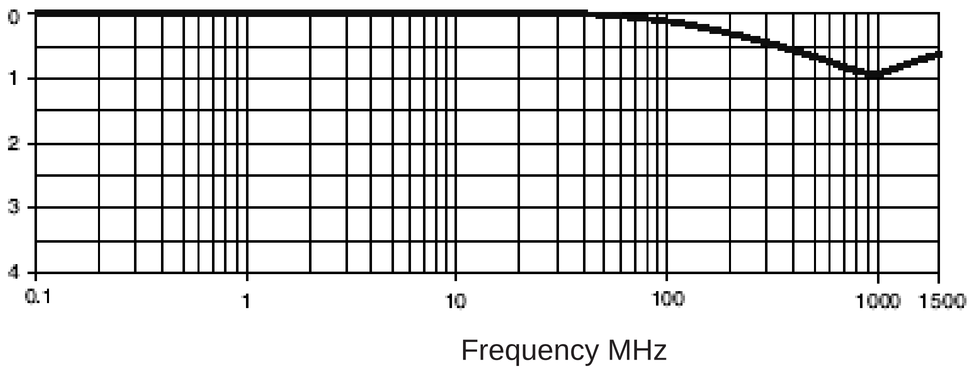


Figure 4-6. CX2039 Typical Insertion Loss



4.4 RF Pulse Transformer 500 kHZ/1.5 GHz TP-101 from Macom

The RF pulse transformer features 50Ω of either unbalanced or balanced impedance along with a fast rise time of 0.18 ns.

Additionally, it features a low insertion loss of 0.4 dB (typical) and the TP-101 pin model is available in a flatpack package.

Tables 4 and 5 provide the guaranteed specifications and operating characteristics.

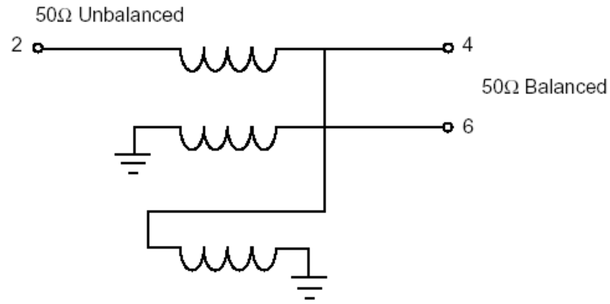
Table 4-4. TP101 Guaranteed Specification (from -55°C to 85°C)

Feature	Value
Frequency range (1 dB bandwidth)	500 kHZ/1.5 GHz
Input impedance	50Ω unbalanced
Output impedance	50Ω balanced
Insertion loss 10/50 MHz	0.5 dB maximum
VSWR 1 MHz/1 GHz	1.4:1 maximum
VSWR 750 kHZ/1.5 GHz	1.8:1 maximum

Table 4-5. TP101 Operating Characteristics

Feature		Value
Input power	750 kHz/1 MHz	1.0 watt maximum
	1 MHz/5 MHz	1.5 watts maximum
	5 MHz/1.5GHz	3.0 watts maximum
Rise time (10-90%)		0.18 ns typical
Droop (10%)		300 ns typical
Environmental		MIL-STD-202 screening available

Figure 4-7. RF Pulse Transformer TP-101 Pin Configuration



Note: Pins 1, 3 and 5 are grounded to case.

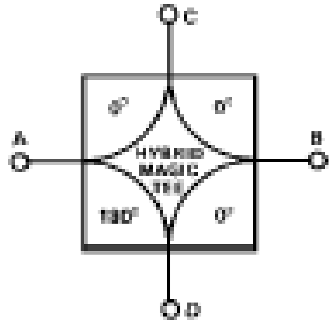
4.5 Hybrid Junction 2 MHz to 2 GHzH-9 from Macom

Table 4-6. H-9 Guaranteed Specification (from -55°C to 85°C)

Frequency Range		2-2000 MHz
Insertion Loss (Less Coupling)	2 - 5 MHz	1.7 dB Max.
	5 - 20 MHz	1.7 dB Max.
	20 - 300 MHz	0.7 dB Max.
	300 - 1000 MHz	1.4 dB Max.
	1000 - 1500 MHz	2.25 dB Max.
	1500 - 2000 MHz	2.5 dB Max.
Isolation	2 - 20 MHz	35 dB Min.
	20 - 300 MHz	40 dB Min.
	300 - 1000 MHz	30 dB Min.
	1000 - 2000 MHz	30 dB Min.
Amplitude Balance	2 - 2000 MHz	0.5 dB Max.
VSWR	2 - 5 MHz	3.5:1 Max.
	5 - 20 MHz	2.4:1 Max.
	20 - 300 MHz	1.4:1 Max.
	300 - 1000 MHz	1.7:1 Max.
	1000 - 2000 MHz	1.7:1 Max.
Phase Unbalance	2 - 300 MHz	2° Max.
	300 - 1000 MHz	3° Max.
	1000 - 2000 MHz	7° Max

* All specifications apply with 50 ohm source and load impedance.
This product contains elements protected by United States Patent Number 3,325,587.

Figure 4-8. Hybrid Junction H-9 Functional Diagram



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